RECORD OF DECISION

COLORADO SCHOOL OF MINES RESEARCH INSTITUTE SITE:
FLOOD PLAIN AREA SOIL
GOLDEN, CO

December 2011

Prepared for:
Colorado School of Mines
Golden, CO 80401

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List of Acronyms/Definitions

AEC	U.S. Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	U.S. Code of Federal Regulations
COPC	Constituent of Possible Concern
CSMRI	Colorado School Mines Research Institute (the Site)
CSWP	Characterization Survey Work Plan (URS Corporation)
cy	cubic yard
DCGL	Derived Concentration Guideline Level
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GPS	Global Positioning System
HEAST	Health Effects Assessment Summary Tables
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Levels (EPA Drinking Water)
MCLG	Maximum Contaminant Level Goal
mg/kg	Milligram per Kilogram
mrem	Millirem – small unit of radiation dose (one thousandth of a rem)
msl	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRC	Nuclear Regulatory Commission
O&M	operation and maintenance
OU	operable unit
PbB	blood lead
pCi/g	Pico-Curies per Gram
pCi/L	Pico-Curies per Liter
ppm	parts per million
PRP	potentially responsible parties
RA	Remedial Action
RAIS	Risk Assessment Information System
RAOA	Removal Action Options Analysis
RCRA	Resource Conservation and Recovery Act
RESRAD	Pathway analysis computer code developed for implementing U.S. Department of Energy Residual Radioactive Material Guidelines
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
TEDE	Total Effective Dose Equivalent
UAO	Unilateral Administrative Order (from EPA)
ug/L	micrograms per liter
UMTRCA	Uranium Mill Tailings Radiation Control Act

US	United States
WL	Working Level: Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3 x 105 MeV of potential alpha energy.
yr	Year

PART 1: THE DECLARATION

A. Site Name and Location

The Colorado School Mines Research Institute (CSMRI) Site has historically included several areas that have undergone characterization and/or corrective actions and been subsequently closed. These sites include the former soil stockpile area located near the School's softball field where material from the settling pond action was stored, the upper terrace that now contains the soccer field, and the Clay Pits Area located south of the intersection of Birch and 12th Streets. For this document only, the "Site" refers to the flood plain area, which is defined as the currently fenced area west of the intersection of 11th and Maple that includes portions of the Clear Creek flood plain and the former settling pond area.

The Site covers an area of about two acres and is currently defined by the shaded area shown in Figure 1. In accordance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Parts 300.5 and 300.400(e), the term "on-site" refers to the areal extent of contamination and all suitable areas in proximity to the contamination. Consequently, the Site boundary may be modified or expanded to address the needs of the remedial action alternatives.

The Site is located on the south side of Clear Creek, east of U.S. Highway 6, in the northwest quarter of the northeast quarter of Section 33, Township 3 South, Range 70 West as shown in Figure 2. The main entrance to the Site is located at the western end of 11th Street in Golden, Colorado. A chain-link fence restricts access to the Site. A settling pond was previously located on the flood plain within the perimeter fence and within the bounds of this investigation. The pond was cleaned up and closed by the U.S. Environmental Protection Agency (EPA) in 1997 as part of an Emergency Removal Action under CERCLA and was considered closed until groundwater impacted with dissolved uranium was identified as part of the School's ongoing groundwater quality monitoring program. The EPA removal action is not considered part of the School's remedial action.

Groundwater at the Site will continue to be monitored on the existing quarterly schedule after the remedy is implemented to assess water quality, the impact of offsite disposal of the contaminated soils in improving groundwater quality, and the need for additional remedial work. The School wishes to return the Site to beneficial use and recognizes that groundwater monitoring is necessary for an unknown period after the soil remedy is implemented. With this end in mind, the Site has been divided into two operable units (OU): Soil Operable Unit (OU1) and Groundwater Operable Unit (OU2). This Record of Decision (ROD) is for OU1 only. OU2 will be addressed separately in the future.

B. Statement of Basis and Purpose

This ROD document presents the Selected Remedy for the CSMRI flood plain (Site), in Golden, Colorado, which was chosen in accordance with CERCLA, as amended by Superfund Amendments and Reauthorization Act and, to the extent practicable, the NCP. This decision is based on the Administrative Record file for this Site. The Colorado Department of Public Health and Environment (CDPHE) reviewed the CSMRI *Flood Plain Soil Remedial Investigation and Feasibility Study* (Stoller 2011) and concurs with the Selected Remedy.

The S.M. Stoller Corporation (Stoller) prepared a Remedial Investigation and Feasibility Study (RI/FS) in 2007. It provided the nature and extent of contamination, evaluated alternative remedies, and proposed an offsite disposal remedy for the upper terrace soil. After a ROD for the upper terrace soil was issued, the remedy was implemented and groundwater was monitored.

Groundwater monitoring following the remediation indicated a persisting uranium plume predominantly on the flood plain area of the CSMRI Site. The flood plain soil was not part of the 2007 RI/FS and ROD because the EPA had previously cleaned up the flood plain. Further characterization work was requested of the School by CDPHE to better define the source of the groundwater impacts in the flood plain.

In June 2010, eight test pits were dug on the flood plain and data were collected as part of a preliminary Site characterization. Results of this investigation were used to prepare for the work described herein and address concerns brought forth by the CDPHE and the potentially responsible parties (PRPs). The findings of the preliminary flood plain characterization are described in the *Preliminary Flood Plain Characterization* report, which is Appendix A to the characterization work plan (Stoller 2010a).

In the fall of 2010, further investigation of the soils, as guided by the results of the June 2010 work, led to the excavation of approximately 1,400 cubic yards (cy) of contaminated soils. The soil was stockpiled on the upper terrace for storage pending the evaluation of remedial options. The 2011 RI/FS for the Soil Operable Unit (OU1) proposed offsite disposal of the stockpiled soils to a local landfill.

This ROD addresses the flood plain soils (OU1) and the proposed plan from the 2011 RI/FS. The groundwater at the flood plain (OU2) will be addressed separately in the future.

C. Assessment of Site

The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment. The remedial investigation found soils with elevated radionuclide activities (uranium and radium-226). Elevated metals concentrations, primarily arsenic, lead, and uranium also were detected in Site soil. Uranium concentrations in excess of the maximum contaminant level (MCL) of 30 µg/L persist in groundwater monitoring wells. The contaminated soil contributed to the groundwater contamination.

D. Description of Selected Remedy

The selected remedy involves the excavation and transportation of the stockpiled soil to an approved landfill (Alternative 2 from the CSMRI Flood Plain RI/FS). An estimated 1,400 cy (2,200 tons) of material will be shipped offsite for disposal at the Allied Waste Services Inc., Foothills Landfill in Jefferson County, Colorado. The landfill and CDPHE previously approved acceptance for disposal of up to 30,000 cy of material from the 2007 Remedial Action and, because this ceiling is not exceeded, allows for additional material from the Site meeting waste acceptance criteria to be sent to the Foothills facility. To date, about 13,000 total cy of soil have been sent to the facility and 1,400 cy of material excavated during the flood plain investigation will not exceed the 30,000 cy ceiling.

Given the low volume of material anticipated (about 100 truck loads), traffic will be routed directly through the City of Golden. Alternative 2 includes loading the stockpiled material into trucks, transportation to the disposal facility, traffic control, re-grading of the stockpile staging area, and Site reclamation of disturbed areas. In the past, trucks had the option of using the temporary access lane just west of the softball field to access U.S. Highway 6. This route is no longer considered viable, as it would require truck traffic to use the newly constructed pedestrian/bike trail. In addition, the intersection where the bike path meets the highway access point lacks sufficient area for trucks to safely turn before entering the highway.

Offsite disposal was deemed to be the most likely corrective action to reduce the concentration of uranium in groundwater to levels acceptable to the CDPHE. Ongoing groundwater monitoring will be required to verify the effectiveness of the remedy by providing the data necessary to demonstrate that a reduction in the concentration of dissolved uranium occurred. Surface areas will be returned to beneficial use upon CDPHE approval. Groundwater will continue to be monitored and addressed in the future as to additional remedial work, if any.

Upon completion of offsite disposal, the Site would be available for any uses, with conditions for some uses. An environmental covenant will be implemented to require installation of a radon mitigation system for any residential structure built on the flood plain site to meet Applicable or Relevant and Appropriate Requirements (ARARs) and as a best management practice. The potential dose due to the radon emanation from post-excavation soils remaining on the flood plain into a future residence is 16.1 mrem/yr. This is less than the 100 mrem/yr limit allowing Alternative 2 to comply with ARARs but not less than the 15 mrem/yr CERCLA standard. An environmental covenant will also prohibit beneficial use of the shallow groundwater.

E. Statutory Determinations

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable. The remedy does not satisfy the statutory preference for treatment as a principal element of the remedy for the following reasons: treatment is not cost effective and there are concerns about the effectiveness of the technology to properly manage the risks at the Site. Because the baseline risk assessment presented in Section 6 of the 2011 RI/FS concluded that offsite disposal of the stockpile (Alternative 2) will result in soils remaining onsite posing no unacceptable risk to human health or the environment it will allow for all uses of the property with an environmental covenant requiring radon mitigation and no beneficial use of the groundwater. A five-year review for soils will not be required for this remedial action; however, continued monitoring of groundwater will occur and will be addressed separately in the future.

F. Data Certification Checklist

The following information is included in the Decision Summary section of this ROD. Additional information can be found in the Administrative Record file for this site:

- Chemicals of concern and their respective concentrations
- Baseline risk represented by the chemicals of concern
- Cleanup levels established for chemicals of concern and the basis for these levels
- How source materials constituting principal threats are addressed
- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the baseline risk assessment and ROD
- Potential land use that will be available at the Site as a result of the selected remedy
- Estimated capital, annual operation and maintenance (O&M), total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected
- Key factor(s) that led to selecting the remedy (i.e., how the selected remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision)

G. Authorizing Signatures

Formally authorized by Colorado School of Mines:

________________________ ________________________

Linn D. Havelick Date
Director, Environmental Projects

PART 2: THE DECISION SUMMARY

A. Site Name, Location, and Brief Description

The CSMRI Site has historically included several closed areas, including the EPA soil stockpile (material removed from the settling pond) formerly located near the School's softball field, the upper terrace that now contains the soccer field, and the Clay Pits Area located south of the intersection of Birch and 12th Streets. For use in this document only, the Site is defined as the Clear Creek flood plain and the former settling pond area, bounded by the currently fenced area west of the intersection of 11th and Maple. The upper terrace soil is not part of this ROD.

Following the 2007 upper terrace remedial action, a groundwater monitoring well was installed in the former pond area. The former building / soccer field area, where the upper terrace material was stockpiled, had been cleaned up when the new well was installed. The new well showed groundwater impacted with dissolved uranium. Contaminated soil in the flood plain was investigated and now is slated for offsite disposal.

The State of Colorado acting by and through the Board of Trustees of the Colorado School of Mines is the lead agency for the Site for this remedial action. Its remedial action and its work plans are being reviewed and approved by CDPHE. The School is the source of the cleanup monies for this remedial action. The remedial action is voluntary; it is not the subject of an enforcement action by EPA or CDPHE.

B. Site History and Enforcement Activities

The Site is a former metallurgical and mining research facility. Numerous mineral research projects (some of which involved the mineral extraction and beneficiation of materials that contained levels of radionuclides and/or metals above background) were conducted at the Site from 1912 until approximately 1987. The research projects used 17 buildings on the Site that were subsequently razed in the mid-1990s. An impoundment (settling pond) also was situated between the building complex and Clear Creek to store wastewater generated in the laboratories and research facilities. Wastewater discharged from the buildings was transferred to the settling pond through a system of sumps and floor drains in the buildings. Materials from the research projects had also been disposed of at the Site.

Research operations ceased at the Site in 1987. On January 25, 1992, a water main owned by the City of Golden broke on the Site and began discharging a large volume of water into the settling pond. EPA's Emergency Response Branch responded in February 1992. EPA cleaned up the pond and stored approximately 20,000 cy of materials at the Site, which were later disposed of at an offsite landfill. The EPA removal action was completed in 1997.

Following demolition of the buildings, existing pits and basements were backfilled to grade; building foundations and concrete footers were left in place. Concrete and asphalt were then characterized and disposed offsite to allow access to subsurface soils for investigation. Contaminated soils were excavated.

Two soil stockpiles were established for excavated materials: Stockpile A contained material over 100 pCi/g and contained approximately 200 cy of material. Stockpile B contained the majority of the excavated material (less than 100 pCi/g but greater than the tentative derived concentration guidelines [DCGLs]) and contained approximately 12,500 cy of material.

Stoller published the May 2007 RI/FS that included a proposed plan. The proposed plan included offsite disposal of the two stockpiles to two different landfills, an environmental covenant requiring radon mitigation systems in all residences onsite, and continued groundwater monitoring to evaluate the impact that soil excavation and offsite disposal had on improving water quality. Implementation of the selected remedial alternative was completed during August and September 2007.

After the remedy for the upper terrace soil was completed, a groundwater monitoring well (CSMRI-8) was installed. The well detected the presence of a dissolved uranium plume predominantly on the flood plain area of the Site. Further characterization work was requested of the School by the CDPHE to characterize flood plain soils as the most likely source of the groundwater impacts.

In June 2010, eight test pits were excavated on the flood plain and data were collected as part of a preliminary Site characterization. Results of this investigation were used to design a plan for more comprehensive flood plain characterization work.

The flood plain characterization work in September 2010 delineated elevated uranium concentrations suspected to be the sources of groundwater contamination. Characterization included excavation, sampling, and analysis. The characterization effort began near well CSMRI-8, an area known to contain CSMRI process contaminant fill material. The team excavated two former effluent outfall pipes still present on the hillside. Assessment and characterization of the soils above the groundwater table were completed in 1-foot lifts with the soil being segregated between clean soil (soil less than Site tentative cleanup goals, including uranium at 14 mg/kg [ppm]) and impacted soil above Site tentative cleanup goals. Characterization by segregation to bedrock was completed in strategic areas of the flood plain.

The excavated soils were transported to a lined staging area on the upper terrace in an area prepared for future use as a parking lot. The stockpile has approximately 1,400 cy of impacted soil and is being periodically inspected and maintained as needed until final remedy implementation.

Table 1 lists the constituents of potential concern (COPCs) and the DCGLs.

Table 1
COPCs and Tentative Site DCGLs

Constituent	Tentative DCGL
Metals	**mg/kg**
Arsenic	39
Lead	400
Mercury (total)	23

Table 1
COPCs and Tentative Site DCGLs

Constituent	Tentative DCGL
Molybdenum	390
Vanadium	550 (78)
Uranium	14
Radioisotopes	**picoCuries/gram**
Radium 226	4.14
Radium 228	4.6
Thorium 228	6.47
Thorium 230	11.53
Thorium 232	3.88
Uranium 234	254.9
Uranium 235	4.97
Uranium 238	21.8

The 2011 Flood Plain RI/FS Soil Operable Unit (OU1) presents the results of the investigation on the flood plain. Groundwater (OU2) findings will be reported in a separate RI/FS.

A number of historical investigations have been completed at both the Fenced Area and the Clay Pits area. Results from these investigations are included in the following reports:

- *Surface Gamma Ray Scanner Survey*, U.S. Environmental Protection Agency, 1982
- *CSMRI Environmental Assessment*, Jacobs Engineering Group Inc., October 1987
- *Claypits Report to CDPHE*, Robert MacPherson, October 20, 1988
- *Preliminary Assessment of Radiological Risks at CSMRI*, *Creekside*, L. Hersloff, Radiant Energy Management, September 1989
- *Tailings Pond, CSMRI, Creekside Sampling Report*, Industrial Compliance Inc., October 1989
- *Preliminary Assessment of the Potential for Water-Borne Migration of Contaminants in the Claypits*, J. Kunkel, Advanced Science, October 20, 1989
- *CSM Environmental Sampling & Analysis Program: Claypits Site & CSMRI Facility*, James L. Grant & Associates, August 9, 1990
- *Characterization Plan for Claypits & CSMRI Creekside and Table Mountain Research Center Sites*, James L. Grant & Associates, March 22,1991
- *Preliminary Remedial Alternative Evaluation for the CSM Creekside Stockpile*, SR & K, August 25, 1994
- *Removal Action Options Analysis* (RAOA), Multiple authors, June 12, 1995 (three volumes)
- *Concrete and Asphalt Characterization Report*, URS Corporation, May 18, 2002
- *CSMRI Characterization Summary*, New Horizons Environmental Consultants, Inc., August 21, 2003
- *Clay Pits Area Remedial Site Investigation Report*, *CSMRI Site*, April 2007, Stoller
- *Remedial Action Implementation Report, CSMRI Site, Golden*, *CO* (Stoller 2009)

- *Preliminary Flood Plain Characterization , Appendix A CSMRI Final Work Plan Environmental Assessment and Characterization, Flood Plain Area* (Stoller 2010a)
- CSMRI *Flood Plain Soil Remedial Investigation / Feasibility Study (*Stoller 2011*)*

Site Licensing History

The CSMRI Site licensing and permitting history shows that the regulatory programs that provided facility oversight determined which regulatory program(s) was most appropriate for the Site activities. Governmental regulators concluded that the facility regulation would be under the authority of the Solid Waste Disposal Sites and Facilities Act and associated regulations.

Prior to this governmental determination CSMRI applied for permits under RCRA, Subtitle C, which regulates hazardous waste management, including the permitting for treatment, storage, and disposal facilities of hazardous materials. Obtaining a RCRA hazardous waste permit requires a two-part application process. On November 17, 1980, CSMRI applied for and received a Part A permit. On August 24, 1984, EPA requested that CSMRI complete the permitting process by submitting a Part B permit. In undertaking the more detailed Part B application, it became apparent that CSMRI had filed the original Part A application in error and that the facility was not subject to RCRA, Subtitle C, hazardous waste regulations. CSMRI submitted a request for exemption from Subtitle C as provided in 40 CFR part 261.4(b)(7) (this point is discussed in more detail below). The Colorado Department of Health reviewed this information and determined the facility was exempt from Subtitle C of RCRA. RAOA Attachment 21 contains four letters that discuss the RCRA history at the Site.

Although most of the research at the Site was not related to the study of radioactive materials, CSMRI possessed, and continues to possess, a license for the storage, handling, and possession of NORM, source, and by-product material (Colorado Radioactive Materials License Number 617-01S).

Table 2 presents a chronological summary of the U.S. Atomic Energy Commission (AEC) licensing actions, and Table 3 presents a summary of the State of Colorado licensing actions at the Colorado School of Mines Research Institute site:

Table 2
Summary of U.S. AEC Licensing Actions at CSMRI

Time Period	License Details
Terminated 1948	Weinig had License No. R-120 from the U.S. AEC for source material, which terminated in 1948. V2731, V2732. Weinig's clients also may have had separate licenses from the U.S. AEC for research at the Site. V1436.
1958 -1967	The State of Colorado has records of U.S. AEC licensing actions dating from January 1958 through December 1967.
1958 - 1967	U.S. AEC By-product Material License Number: 5-4607-1 (including amendment #1 through amendment #23) dated from January 1958 through December 1967 Issued to: Colorado School of Mines Research Foundation, Inc. Authorized uses: laboratory research; teaching of industrial radioisotopic courses; as a component of a neutron generator for activation analysis; calibration of instruments; measurement of specific gravity of slurry in a pipeline; laboratory tracer studies; monitoring of solutions and slurries; metallurgical studies; neutron generator for activation analysis; experimental

Table 2
Summary of U.S. AEC Licensing Actions at CSMRI

	curing of thin plastic films deposited on ceramics; studies of molybdenum; geochemical research; to measure wear rate of experimental pipelines and machines and similar laboratory studies; and for the determination of solubility constants.
1966	U.S. AEC Special Nuclear Materials License Number: SNM-972 (for Plutonium), dated August 1966 Issued to: Colorado School of Mines Research Foundation, Inc. Authorized uses: for use in accordance with the procedures described in the licensee's application dated July 20, 1966. Storage only of soil samples.

Table 3
Summary of State of Colorado Licensing Actions at CSMRI

Date	License Details
October 24, 1968	Colorado Radioactive Materials License Number: Colo. 08 – 01 (F) Issued to: Colorado School of Mines Research Foundation, Inc. and Colorado School of Mines Authorized uses: Research, development, and teaching.
March 7, 1969	Amendment No. 2 to License Number: Colo. 08 – 01 (F).
May 25, 1971	Amendment No. 2 to License Number: Colo. 08 – 01 (F).
September 29, 1971	Amendment No. 3 to License Number: Colo. 08 – 01 (F).
February 25, 1972	Amendment No. 4 to License Number: Colo. 08 – 01 (F)
August 16, 1974	Amendment No. 5 to License Number: Colo. 08 – 01 (F)
October 31, 1975	Amendment No. 6 to License Number: Colo. 08 – 01 (F).
	Note: The State does not have record(s) of licensing actions between November 1975 and March 1985.
April 10, 1985	Colorado Radioactive Materials License Number: Colo. 617-01S Issued to: Colorado School of Mines Research Institute. Authorized uses: Possess, use, and store.
March 25, 1986	Amendment No. 1 to License Number: Colo. 617-01S
September 11, 1990	Amendment No. 2 to License Number: Colo. 617-01S. Issued to: Colorado School of Mines Research Institute Authorized uses: Possess, use, and store.
October 31, 1997	Amendment No. 3 to License No. 617-01
March 30, 2001	Amendment No. 4 to License No. 617-01
February 11, 2002	Amendment No. 5 to License No. 617-01. Issued to: Colorado School of Mines Research Institute Authorized uses: Possess and store naturally occurring, source and by-product.
May 19, 2005	Amendment No. 6 to License No. 617-01 (same authorized uses)
December 15, 2006	Amendment No. 7 to License No. 617-01 (same authorized uses)
Application Submitted January 2011 pending	Amendment No. 8 to License No. 617-01 (same authorized uses)

The Site was licensed by both the AEC and the State of Colorado for numerous types of radioactive materials over several decades. The current license includes NORM, source material, and by-product material. Previous licenses authorized possession and use of radioactive materials having atomic numbers 3 through 88 inclusive, americium, and plutonium. The scant available records related to plutonium materials indicate that disposal of certain plutonium materials occurred at Rocky Flats west of Denver (RAOA, Attachment 22). The licenses authorizing the use of americium state that the americium was for the calibration of instruments and for gauges. The amounts of americium for these instruments must have been minute. There are no records related to the disposal of americium.

C. Community Participation

Community participation activities for this Site began after the water main break in 1992 and upon issuance of the UAO in 1994. Many community meetings were held through 1995, including a public meeting and comment period for the RAOA that documented the proposed offsite disposal alternative for the stockpiled soils in 1995. The community participation activities for the 2004 RI/FS, 2007 Revised RI/FS, and 2011 Flood Plain RI/FS built upon those prior efforts.

A community open house was held at the School in 2003 prior to completion of the 2004 RI/FS to solicit input on the ongoing RI/FS activities. In addition, School representatives met with CPDHE and some PRPs to solicit input on the ongoing RI/FS activities. The 2004 RI/FS Report and Proposed Plan for the CSMRI Site in Golden, Colorado, were made available to the public in January 2004. They can be found in the Administrative Record file and the information repository maintained at the Golden and School public libraries. The notice of the availability of these two documents was published in the *Golden Transcript*, the *Denver Post*, and the *Rocky Mountain News*. A 30-day public comment period was held, including an extension of time to the public comment period requested by some parties. Moreover, additional comments were accepted from CDPHE after the close of the public comment period but before publication of the ROD. In addition, a public meeting was held in February 2004 to present the Proposed Plan to a community audience. At this meeting, representatives from CDPHE and the School answered questions about problems at the Site and the remedial alternatives. The School's response to the comments received during this period is included in the Responsiveness Summary, which is part of this ROD.

After the 2007 revised RI/FS was published on May 15, 2007, notice of its availability was published in local and major newspapers, and letters and e-mails were also sent to stakeholders regarding the availability of the RI/FS and Proposed Plan, and the opportunity for public comment. A 30-day public comment period was held, including a public meeting on May 30, 2007 to present the Proposed Plan and RI/FS results, at which some local residents and CDPHE and PRP attended. Written comments were received from CDPHE and some PRPs within the 30-day comment period. The School's response to comments received during the public comment period is included in the Responsiveness Summary, which is a part of this ROD.

In September 2010, notice of the Flood Plain Characterization Work Plan availability was published in local and major newspapers, and letters and e-mails were also sent to stakeholders regarding the public meeting/open house at the School and the opportunity for public comment on planned activities.

In November 2011, notice about the availability of the Flood Plain RI/FS, the proposed plan, and the public comment period were published in the *Denver Post* and the *Golden Transcript*. Oral comments were received during the Flood Plain Public Meeting held on November 29, 2011. Generally, they supported the proposed plan and the schedule to dispose of the soil in December

2011. Written comments were also received at the end of the 30-day public comment period. They too supported the proposed plan. Golden and CDPHE also support the proposed plan.

D. Scope and Role of Operable Unit or Response Action

As noted above in Part II.A, numerous Site investigation and cleanup activities have been occurred. The scope of this ROD addresses the Clear Creek Flood Plain Soil Operable Unit (OU1), which provided a source of dissolved uranium in groundwater (OU2). OU2 is the last remaining area that requires continued investigation at the Site. The results of ongoing groundwater monitoring of OU2 will provide data to help determine whether additional remedial action is necessary. The former settling pond area (located within the flood plain), the softball/soccer field area, Clay Pits, and upper terrace have already been addressed in prior efforts. The flood plain soil remedial action is being performed under the authority of CERCLA and State laws that authorize the School to take action and expend money on the remediation.

After the stockpile has been transported from the Site during the course of the remedial action, the remaining surface areas will be stabilized, including the use of backfill as necessary, and used for beneficial purposes again, such as recreation. While the recreation is ongoing, the School will continue to monitor the groundwater (OU2). Groundwater will be addressed separately in the future.

E. Site Characteristics

In general, the approximately 2-acre Site slopes steeply to the north from the upper terrace to the flood plain. Once on the flood plain, the slope becomes almost negligible toward the creek or a large depression in the eastern portion of the flood plain referred to as the wetlands. By contrast the western portion of the terrace slope dips steeply until it intersects the bank of Clear Creek. No buildings or structures are located on the flood plain or the top of the terrace. Buildings on the terrace were razed. After the 2007 remedial remedy was implemented, the area was re-graded and is currently the site of a soccer field. The area between the soccer field and the terrace of the flood plain has been graded to accommodate a future parking lot, bike path, and ticketing booth planned for that location.

Utilities remaining on the Site at the start of the RI included City of Golden water mains (12-inch raw water, 24-, 20-, and 8-inch potable water) and a municipal sewer line. School utilities included stormwater drainage and irrigation lines for the Schools's sprinkler system. All other utilities had been disconnected prior to the investigation activities.

No significant historical or archeological resources are known in the immediate vicinity of the Site.

In the vicinity of the Site, the 100-year flood elevation is at an estimated 5,682 ft mean sea level (msl). The 500-year flood level is about 5 feet higher than this (about 5,687 ft msl). The Site is comprised of the flood plain proper with elevations ranging from the lowest point approximately 5,670 ft (former settling pond area next to Clear Creek) to about 5,680 ft at the toe of the terrace slope. The flood plain is from 2 ft to 7 ft below the 100-year and 500-year flood elevations, respectively. The terrace ranges in elevation from 5,680 ft at the toe of the slope to about 5,700 ft at the top with the majority of the terrace above the 100-year and 500-year flood elevations.

Chimney Gulch is a small drainage that passes about 100 feet west of the western gate of the Site. Chimney Gulch is a tributary of Clear Creek with a drainage basin of approximately 482 acres. This tributary's headwaters begin on Lookout Mountain and its confluence with Clear Creek is about 200 feet northwest of the Site. During most of the year, Chimney Gulch is dry. However, when the Welch Ditch is being used, excess water in the ditch routinely drains into Chimney Gulch and back into Clear Creek.

Clear Creek passes through a historic mining region of the Colorado Mineral Belt. Several reaches of Clear Creek upstream of the Site have been designated EPA Superfund Sites because of the extensive mining operations. Numerous mine adits along the Clear Creek watershed contribute to seasonally elevated concentrations of metals, primarily manganese and zinc.

The Site is located along the eastern edge of the Rocky Mountain Front Range foothills. The foothills include the areas where older deposits were folded and pushed aside as the younger Rocky Mountains uplifted. The foothills rock types range from unconsolidated sediment deposits (25 thousand to 1 million years old) to sedimentary rocks (primarily sandstone and shale - 300 million to 63 million years old) to igneous and metamorphic rocks (over 1 billion years old). These formations remain as horizontal layers beneath Denver and the eastern plains. The Clay Pits area is a surface expression of the unconsolidated sediment deposits (Laramie - Fox Hills Sandstone - these deposits have been tilted almost vertical) and the bedrock underlying the Site is a sedimentary rock (Pierre Shale). The Golden fault, a high-angle reverse fault, is present along the eastern edge of the foothills west of the Site (Figure 3).

Weimer's cross section (Figure 4) shows that the geologic strata are overturned and steeply dipping. Measurements of the strike of the beds in the Clay Pits area show a North 37° West trend with dips ranging from about 70° to 80° to the west (James L. Grant & Associates, Inc., April 1990). Farther east the beds become vertical and then east dipping. The Site is located in an area of surficial deposits overlying the Pierre Shale. Van Horn (1976) characterizes the Golden fault as a moderately to steeply west-dipping reverse fault of large displacement.

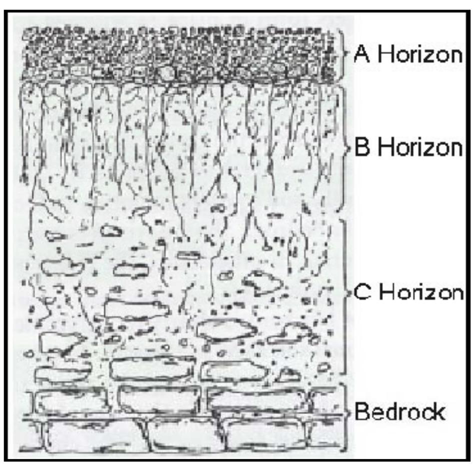

Figure 4 Schematic Representation of Hypothetical Soil Profile with Underlying Parent Rock (Weimer)

Small areas of Pierre Shale are evident along the western end of the former settling pond, exposed by the erosion action of Clear Creek. Weimer (1976) characterized the unit as consisting of dark gray shale with minor, thin laminae of tan-weathered limonitic siltstone and silty, very fine-grained sandstone. Pierre Shale underlies much of the Site, including part of the parking area. The Pierre Shale is estimated to be at least 2,000 feet thick beneath the Site.

In the immediate vicinity, exposures of the Fox Hills are limited because of localized faulting. Where exposed, the sandstone is tan to yellow, fine-grained, subrounded, friable, calcareous sandstone with thin beds or laminae of siltstone and gray montmorillonitic claystone. The exposed thickness of the Fox Hills near 12th Street (Figure 4) is about 40 feet; however, the exact thickness is questionable because of faulting and could be as much as 75 feet (Weimer 1976). The Fox Hills underlies a part of the eastern-most flood plain and was identified in several of the test pits dug during preliminary characterization work. The outcrop of this formation is visible to the west of the c1ay pits site.

The surficial deposits that overlie the bedrock in the vicinity of the Site (Figure 5) include the following (the order presented below does not show the age relationship):

- Louviers Alluvium
- Younger Alluvial Fan Colluvium
- Post-Piney Creek Alluvium
- Artificial Fill

The Louviers deposit is present on the upper terrace and is typically a coarse cobbly sand and gravel that is poorly sorted. Generally, there is less than 10 percent silt and clay present. Boulders as large as one-foot across are present, but the common large size is 6 inches. Based on the subsurface work performed on the upper terrace, this unit is about 10 feet thick and extends south under the baseball and practice fields to the approximate location shown where it pinches out against the bedrock. The Louviers is overlain by younger alluvial fan, colluvium, and artificial fill deposits. Locally, the flood plain consists of post-Piney Creek Alluvium. On the western portion of the flood plain where the 2010 RI was conducted it the post-Piney Creek Alluvium is deposited directly on the Pierre Shale.

In large part, the flood plain consisted of fill encountered during the 2011 RI that did not appear to be placed to enhance the useable area on the flood plain or to extend the footprint of the upper terrace for development. Fill material was heterogeneous, non-compacted, and contained a wide variety of debris with no evidence of building foundations or infrastructure. In short, fill on the terrace slope and flood plain appeared to be dumped directly onto the flood plain or from the top of the terrace rather than placed. The fill included debris (i.e., large timbers, crucibles, concrete, drum carcasses, metal, pipes, ore, etc.) in a poorly sorted matrix ranging from clay to large boulders. In places the fill appeared to be native alluvial material; however, the presence of manmade objects within this matrix clearly permitted soils to be classified as imported fill.

The following additional artificial fill was identified during the RI:

- Sandy, silty cobbles mixed with debris assumed to be excavated soil from building foundations and infrastructure from the upper terrace and dumped over the slope
- Imported uniform sand used as bedding material around drainage lines

- Ore from offsite mining operations
- Imported heterogeneous fill mixed with waste from historic laboratory operations
- Bricks and miscellaneous building debris mixed with varying mixtures of clay, sand and cobbles
- A variety of bricks, large hand hewn timbers, metal, and miscellaneous debris that may in some instances pre-date CSMRI activities

Because of the extensive construction activities on the Site, very little “A” horizon material remained. Small areas of an “A” horizon were encountered along the northern side of the eastern and western access road. A treed area is located along Clear Creek in the northeastern corner of the Site has a shallow “A” horizon underlain by sandy, silty sub-soils. No additional subsurface investigation was completed in this area for the RI. The majority of the Site is covered with “B” or “C” horizon subsoils that were exposed as the buildings and roads were constructed.

Groundwater is present in the following bedrock units: the Laramie/Fox Hills units, the Arapahoe, and some of the Denver. Groundwater is also present in the Louviers Alluvium and post-Piney Creek Alluvium. The Laramie/Fox Hills and the Arapahoe are important aquifers of regional significance and the Louviers Alluvium, post-Piney Creek Alluvium, and the Denver Formation can be locally significant. Regional studies by Robson (1983 and 1984) and Robson, e*t al.*, (1981a; 1981b) indicate that the outcrop areas for these units in the area are part of the recharge area. Recharge is primarily expected to occur from direct rainfall and snowmelt infiltration and by percolation from Clear Creek directly through the alluvium. However, RI observations suggest the reach of Clear Creek along the northern Site border may be a gaining reach because of the artesian nature of Laramie Fox Hills aquifer in this area (several seeps are visible in the area). Several seeps were visible in the western portion of the Site during the investigation. This portion of the Site is underlain by Pierre Shale bedrock and it is believed that groundwater from the upper terrace migrates along the weathered/competent Pierre Shale interface and surfaces at Clear Creek.

The most relevant water-bearing unit on the western side of the Site is the alluvial deposit above the weathered Pierre Shale. The Pierre Shale acts as an aquitard, allowing water from infiltration and nearby stream losses to move downgradient to Clear Creek. The Pierre Shale was encountered during the RI and depth to the unit varied from about 2 ft below ground surface (bgs) at the westernmost portion of the Site to about 9 ft bgs in the eastern portion of the Site (near the former settling pond). The groundwater zone on the flood plain is within the alluvial deposits on the eastern portion of the Site and migrates along the alluvium/bedrock (Pierre Shale) interface.

A complex groundwater system underlies the Site because of the area geology. Bedrock in the vicinity is a complicated system of nearly vertical sediment deposits overlying Precambrian, crystalline bedrock. Sediment layers that once were located deep under the Denver Basin were pushed up as a result of the uplift of the Rocky Mountains. The Site is located at the western edge of the Denver Basin aquifer system, which includes the following four aquifers: Dawson, Denver, Arapahoe, and Laramie/Fox Hills. These aquifers are unconfined along these uplifted beds and the potentiometric surface (water table) associated with each aquifer is typically closer to the surface than the majority of the aquifer. The aquifers are confined in the deeper portions of the basin, providing the pressure required to raise the groundwater closer to the surface. This artesian effect appears to be occurring in the portion of the Laramie/Fox Hills aquifer that underlies the Site.

A groundwater monitoring well was installed in the Laramie/Fox Hills formation during the characterization to evaluate water quality. Based on the difference in the potentiometric surface elevations measured in both the Laramie/Fox Hills well and a nearby monitoring well installed in the alluvial aquifer there appears to be an upward flow gradient and no communication between these aquifers on the Site.

The groundwater direction is governed by the underlying weathered Pierre Shale and appears to be flowing northeasterly toward Clear Creek. The surface expression of the Laramie/Fox Hills Sandstone may influence groundwater movement in the vicinity of the Clay Pits causing a northwestern movement. Weathering has removed any surface expression of the sandstone along Clear Creek so it is difficult to determine if the northwest movement is actually happening.

It appears that the majority of the western Site groundwater comes from surface infiltration from the surrounding foothills, surface irrigation of the soccer and baseball/softball fields, and the seasonal influence of the nearby Welch ditch. The eastern Site groundwater appears to be a mixture of the infiltration water and the Laramie/Fox Hills aquifer.

To date, buildings, foundations, and infrastructure have been demolished and taken offsite, and the upper terrace soil along with some flood plain soil have been remediated at the Site. Additionally, the Clay Pits Area, the former EPA stockpile location, and the upper terrace have been investigated, and cleaned up if necessary. The original operations that generated the affected material on the flood plain no longer exist on the Site. Because buildings and equipment were removed prior to the RI, only the residual affected material (primarily soil) remained on the Site.

As part of the flood plain characterization the soil around groundwater monitoring well CSMRI-8 was excavated exposing the opening of a 4 foot wide by 6 foot high concrete water supply tunnel. A hydrovac unit was used to vacuum as much of the soil and debris as possible from within the tunnel and a 3/8-inch-thick steel plate was placed in front of the entrance of the tunnel, and bentonite chips were placed inside the tunnel to seal it off from the surrounding environment. A subsequent search of historic documents from the School's library found the following reference in the *Quarterly of the School of Mines* vol. 7, July 1912.

> "A concrete-lined well, 5 ft in diameter and 25 ft deep, has been sunk near the bank of Clear Creek. A 4 by 6-ft tunnel, 120 ft long, extends from the bottom of the well to a stratum of gravel under the bed of the creek. The well and tunnel have a storage capacity of 20,000 gal. The pumping outfit consists of an automatic motor-driven, submerged-type, two-stage centrifugal pump. This has a capacity of 100 gal per minute against 50-lb pressure, pumping into pressure storage tanks of 2,500-gal capacity. An ample supply of clear water is thus assured for all operations."

After the upper terrace soil was remediated in 2007, groundwater monitoring results showed an isolated dissolved uranium groundwater plume located beneath the lower terrace where the former pond was located. This pond area had been the subject of an EPA removal action between 1992 and 1997. The EPA cleanup of the former pond was based on Ra-226 in soils, not uranium; and the cleanup standard for Ra-226 was higher in 1992 than the cleanup standard used for the upper terrace area in 2007. The eastern pond area had been subject to ongoing groundwater monitoring. New wells installed in the western pond area showed the uranium contamination was significantly more extensive than previously demonstrated by the eastern wells.

Five existing wells and the two new monitoring wells were sampled as part of the 2007 investigation to determine current groundwater conditions in and near the Site (Figure 6). The existing wells included three wells located along Clear Creek (CSMRI-1, -4, and -5) and one background well located south of the Clay Pits (CSMRI-2).

Two groundwater-monitoring wells were installed in 2004 (CSMRI-6 and CSMRI-7) and seven additional wells (CSMRI-1B, CSMRI-6B, CSMRI-7B, CSMRI-8, CSMRI-9, CSMRI-10, CSMRI-11) were installed in 2007. These wells were used in conjunction with existing monitoring wells to determine groundwater quality and to estimate groundwater flow directions.

Monitor wells CSMRI-6B and CSMRI-11 were abandoned in July 2008 to accommodate construction of the soccer fields. These two wells were replaced by CSMRI-6C and CSMRI-11B, respectively, in December 2008.

Monitor wells CSMRI-7B and CSMRI-8 were abandoned in October 2010 due to soil characterization activities associated with the flood plain area and the hillside to the west. These two wells were replaced by CSMRI-7C and CSMRI-8B, respectively. In January 2011, two new flood plain monitor wells (CSMRI-12, -13) were installed in the flood plain alluvial aquifer, and CSMRI-14 was installed into the deep underlying Foxhills Sandstone within the flood plain.

In the letter received September 18, 2009 from CDPHE, the School was notified of the following: “Specific actions should be proposed to bring the groundwater contamination noted in wells CSMRI-4, CSMRI-8 and CSMRI-9 into compliance. Groundwater contamination remains un-resolved at the Site. A specific remediation plan and schedule, which can include ground-water monitoring, is needed. An environmental covenant is not an appropriate remedial action at the Site unless future studies determine that it remains the only option.” The School had sufficient well monitoring data to confirm the presence of a uranium plume as identified by the CDPHE and agree that a better understanding of the geology, hydrology, and contaminant distribution on the flood was necessary.

On June 2 and 3, 2010, eight test pits were excavated on the flood plain and data were collected as part of a preliminary Site characterization. Results of this investigation were used to prepare for the work described herein and address concerns brought forth by the CDPHE and the PRPs. The findings of the preliminary flood plain characterization are described in the *Preliminary Flood Plain Characterization* report, which is Appendix A to the characterization work plan (Stoller 2010a). The preliminary investigation results delineated several metals that exceeded site cleanup goals in soil in two test pits on the western portion of the flood plain, specifically around monitoring well CSMRI-8. The presence of these contaminants above tentative cleanup goals further supports the rejection of the no-action alternative.

The flood plain soil investigation completed in 2010 used the data generated during the previous EPA and Stoller work to guide further data collection while progressing the Site toward final closure. This was accomplished only after detailed planning and analysis. A re-examination of Site data along with mechanisms of contaminant placement and regulatory framework were completed to evaluate the possible investigation options. Due to the heterogeneous nature of Site contaminants generated by the numerous research projects conducted at this Site, which is unlike many other sites contaminated with radionuclides and metals, additional data were required to accurately determine the nature and extent of contamination within a confidence range. The additional data were necessary to enable remedial cost estimates to be developed within the +50 percent to -30 percent range in the RI/FS stage and +15 percent to -10 percent range for the remedial design and implementation stage of the remedial action. Estimating a volume of impacted soil based on the data in the EPA Closure report, prior investigation work, and the test pit characterization was not possible with the requisite degree of confidence.

Therefore, to attempt to determine the volume of impacted material onsite using traditional methods of Site investigation would have been comparable in cost to the technique selected but would have provided less certainty in volume estimates. The investigative method selected was to excavate the impacted soil and stockpile it onsite to determine the nature and extent of contamination. This excavation method is analogous to the method used by EPA to address the former settling pond at the Site and used successfully by Stoller in 2007 to characterize the upper terrace.

Although EPA had excavated the former settling pond down to the Uranium Mill Tailings Remedial Action (UMTRA) cleanup goals for Ra-226 of 5 pCi/g for soil from surface to 0.5 ft. bgs and 15 pCi/g below 0.5ft bgs, data was not collected for metals COCs by EPA. Further rationale that characterization by excavation implemented on the flood plain was appropriate and that the no-action alternative could be rejected based on the following reasoning.

The preliminary characterization results found exceedances of site cleanup goals for several metals in soil in two test pits on the western portion of the flood plain, specifically around monitoring well CSMRI-8. In addition the entire vertical section of the test pit excavated closest to CSMRI-8 contained fill, which past Site experience has shown may contain isolated COCs that can easily be missed in discreet laboratory samples. The presence of these metal exceedances further supports the rejection of the no-action alternative.

The final evidence that validated the need for further action was data recovered from the soil excavated from the flood plain and stockpiled on the upper terrace for eventual disposal. Samples from this soil contained levels of Ra-226 far exceeding the cleanup goals as described in Section 4 of this document. In addition As, Pb, V, and U were detected in some soil samples above their tentative cleanup goals.

Furthermore, the estimated cost of using this excavation investigative method was comparable to the cost for using the traditional method of borehole site investigation to complete the subsurface site investigation. The excavation method simultaneously performed the likely inevitable task of soil excavation and guarantees the requisite degree of confidence to determine the nature and extent of the contamination to reliably estimate remediation costs, unlike the traditional investigation method of boreholes. This method was as cost effective as the traditional method, but it was expected to produce more reliable results than the traditional method.

To maintain fiscal responsibility and attain the requisite degree of confidence to estimate nature and extent of contamination, the Site characterization technique of excavating and stockpiling impacted material successfully used earlier was chosen. Field screening tools were used to guide excavation. Laboratory analyses were used to confirm that tentative cleanup goals were met and to determine the lateral and vertical extent of contamination.

F. Current and Potential Future Land and Water Uses

There is no current beneficial land use for the flood plain site. The Site had been used for mining and metallurgical research from 1912 until 1987, when Site research operations ceased. A new soccer field was constructed on the upper terrace portion of the Site.

The current Site is surrounded with a chain-link fence and posted. Access is limited to maintenance activities and the periodic sporting events. There are no drinking water supply wells in the immediate vicinity of the Site. Although the groundwater is not currently used as a drinking water source, it eventually enters the Clear Creek alluvial system. The City of Golden uses Clear Creek as the primary drinking water source however the surface-water diversion is located about 0.9 mile upstream of the Site. Miller Coors uses alluvial wells located about 0.4 mile downstream from the Site. Additional downstream diversions that currently supply drinking water include the Agricultural Ditch (0.6 mile) and the Farmer’s Ditch (0.7 mile).

Golden’s historic residential district is located near the Site to the east, while Golden public facilities such as a recreation and community center are located just north of the Site across from Clear Creek. The School’s football field is located to the east and School athletic fields are located to the west and southwest. The Clay Pits are located to the south of the Site. Clear Creek bounds the Site to the north.

Near-term land use scenarios could include improvements to the recreational areas, such as a parking lot and ticketing booth near the new soccer field for recreational users and spectators. A pedestrian/bike path is planned by the City of Golden for land on top of the terrace adjacent to the flood plain site. Foreseeable land use could include construction of student housing or academic buildings; given the flood plain of the Site is within the 100-year flood plain development is unlikely in the flood plain. Development of the upper terrace is likely – the contaminated soil is on the upper terrace. The requirements of 40 CFR §192.02 require that remedies for sites with similar radionuclide contaminants provide up to 1,000 years of protection to human health and the environment (at least 200 years). For a CERCLA NCP baseline risk assessment, the conservative subsistence farmer scenario was used as the baseline but was adjusted to the urban resident at CDPHE’s suggestion. To provide an overall picture of relative risk, urban residential and recreational scenarios were also provided in the 2004 RI/FS for comparison.

Alternative 2 in the 2011 RI/FS used four approaches to model the onsite receptor; the most conservative approach modeled being the urban resident. The urban resident assumed a 2,000 square-foot house similar to neighborhood housing, but drinking water would come from city water mains and minimal consumption of fruits and vegetables raised in a backyard garden. The recreational receptor assumed regular use by a nearby resident who would use the area to picnic during summer months. The student athlete also assumed regular use of the land for athletic endeavors such as running or playing Frisbee. The groundskeeper assumed a worker who is actively involved in landscaping and thus working in the soil. The results of the baseline risk modeling for the four scenarios are summarized in Table 4.

Table 4
Doses and Risks Associated with Radionuclides

Area	Scenario	Concentration Values[a]	Dose (mrem/y)				Risk (lifetime risk per million)			
			RESRAD	Microshield	Drinking water	Total	RESRAD	External[b]	Drinking water[c]	Total
Flood Plain (Post-characterization)	Residence (radon)	Maximum	16.1	NE[d]	NE	16.1	1.35	Included in the RESRAD calculation	NE	1.35
	Recreational (picnic)	Maximum	0.000893	0.000850	NE	0.00174	0.0882	0.00168	NE	0.0899
	Student athlete	Median	0.00193	0.0225	NE	0.0244	0.00511	0.000806	NE	0.00592
	Groundskeeper	Median	0.0226	0.00802	NE	0.0315	5.65	0.00232E-09	NE	5.65
Flood Plain (Pre-characterization)	Residence (radon)	Maximum	133	NE	NE	133	97.7	Included in the RESRAD calculation	NE	97.7
	Recreational (picnic)	Maximum	0.003	0.00701	NE	0.010	0.839	0.0143	NE	0.853
	Student athlete	Median	0.0194	0.0224	NE	0.666	3.38	0.0238	NE	3.41
	Groundskeeper	Median	0.657	0.00880	NE	0.661	5.65	0.0685	NE	5.72
Stockpile	Residence (radon)	Maximum	133	NE	NE	133	97.3	Included in the RESRAD calculation	NE	97.3
	Recreational (picnic)	Maximum	0.00288	0.00702	NE	0.00991	97.3	0.0143	NE	0.113
	Student athlete	Median	0.0185	0.0221	NE	0.0406	0.446	0.0238	NE	0.470
	Groundskeeper	Median	3.14	0.00876	NE	3.15	4.30	0.0685	NE	4.37

a. Concentrations minus background concentrations.
b. Based on the FGR 13 slope factor used in RESRAD of 2.29E-08 (risk/yr per pCi/g) for Ra-226.
c. Based on the FGR 13 slope factor used in RESRAD of 6.4E-11 (risk per pCi ingested) for U-238 in water.
d. NE = Not evaluated. Drinking water assumed to be from City, not groundwater wells.

G. Summary of Site Risks

The baseline risk assessment estimates what risks the Site poses if no action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the ROD summarizes the results of the baseline risk assessment for this Site.

The baseline risk assessment modeled four exposure scenarios that included an urban resident, a recreational user, a student athlete, and a groundskeeper for each of the three possible Site scenarios: the pre-excavation flood plain area (Site Condition 1) and the Site as it exists today, which includes both the post-characterization flood plain soil (Site Condition 2) and the impacted soil excavated during the characterization that is currently managed in a stockpile on the upper terrace (Site Condition 3). The post-characterization flood plain soil and stockpile although evaluated for human health risk as separate scenarios in Section 6 are discussed as Site Condition 2 when evaluating the no action alternative because together they represent the current Site configuration. The baseline risk assessment provides the basis of determining whether further action for these Site conditions is warranted or whether the no-action alternative considered in the FS is viable. The results of the baseline risk assessment confirmed the validity of eliminating the no further action alternative for the pre- and post-characterization Site conditions discussed below.

Site Condition 1 (pre-characterization flood plain soil)
The risk assessment evaluated the flood plain soils prior to characterization to determine if they posed an acceptable risk to human health if no further actions were undertaken and the soils remained in place. The preliminary characterization results from soil samples collected from exploratory test pits in June 2010 detected metals (As, Pb, V, and U) and Ra-226 above the tentative cleanup goals, which are based on either human health risk standards or background concentrations. When the characterization began, it was known that environmental impacts existed as evidenced by elevated concentrations of dissolved uranium in the groundwater. No further action is unacceptable, and further action is warranted because Site Condition 1 is neither protective of human health as described in Section 6 of the 2011 RI/FS nor is it protective of the environment.

Site Condition 2 and Site Condition 3 together represent the current Site status
The risk assessment evaluated the entire Site in its current configuration, which consists of the soils remaining post-characterization on the flood plain and the stockpile managed on the upper terrace to determine if they posed an acceptable risk to human health.

The risk assessment determined that soil remaining post-characterization on the flood plain no longer presents a human health risk. Two sample locations with elevated Ra-226, one of which detected uranium and lead above the tentative cleanup goals, could not be excavated due to their close proximity to municipal water lines. No further action is a viable alternative for the post-characterization flood plain, and further action is not warranted for the soil. However, it is important to note that this RI/FS deals only with soil. Quarterly compliance monitoring of groundwater wells since impacted soils were excavated has determined that although there is a decreasing trend, elevated concentrations of dissolved uranium persist. Groundwater (OU1) will be addressed in a separate RI/FS and ROD.

Soil was excavated from the flood plain during characterization work and transported to the upper terrace where it is currently managed in a lined stockpile. This stockpile contains soil determined to exceed tentative cleanup goals, based on field screening instruments and supported by laboratory data from soil samples from the flood plain. This stockpile was evaluated to determine if it poses an acceptable risk to human health. The risk analysis presented in Section 6 determined this soil presents a significant human health risk for the urban residence scenario. In addition, although measures have been taken to stabilized the stockpile while alternatives are evaluated, over the long-term without further action these measures will not be protective of the environment. Therefore, no further action is unacceptable, and further action is warranted because the stockpile is not protective of human health or the environment.

In conclusion, the pre-characterization flood plain soils presented an unacceptable risk to human health and the environment and further actions were warranted. Although, soils remaining on the post-excavation flood plain pose no human health risk, the FS alternatives analysis evaluated the current Site conditions as a whole which includes the stockpile thereby eliminating the no further action alternative. For the Site in its current condition to be protective of human health and the environment further action will be necessary with respect to the stockpile.

Radionuclides

Numerous tools were used for this risk assessment. Radionuclide doses and risks were estimated using the RESRAD (version 6.5) model developed by the Environmental Assessment Division of Argonne National Laboratory for the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC) (Yu *et al.* 2001). RESRAD used the current slope factors referenced in the Health Effects Assessment Summary Tables (HEAST). RESRAD calculations were supplemented, in most cases, with calculations of external exposure using MicroShield 7.0(Grove Software 2005). MicroShield was used for external gamma dose calculations, because it more accurately models the geometry of the source, shields, and location of the receptor and uses an extensive library of data (radionuclides, attenuation, buildup, and dose conversion), which reflect standard data from the Radiation Safety Information Computational Center, American Nuclear Society, and International Commission on Radiological Protection (ICRP).

The two primary exposure pathways considered by the RESRAD model for this assessment include:

- Internal dose from inhalation of airborne radionuclides, including radon progeny, and
- Internal dose from ingestion of radionuclides, which includes ingestion of:
- Plant foods grown in the contaminated soil irrigated with contaminated water,
- Meat and milk from livestock fed with contaminated fodder and water,
- Drinking water from a contaminated well or pond,
- Fish from a contaminated pond, and
- Contaminated soil.

RESRAD has been widely accepted and has a large user base. According to the RESRAD website (http://web.ead.anl.gov/resrad/home2/), it has been applied to over 300 sites in the U.S. and other countries. It is the only code designated by DOE for the evaluation of radioactively contaminated sites. NRC has approved the use of RESRAD for dose evaluation by licensees involved in decommissioning, NRC staff evaluation of waste disposal requests, and dose evaluation of sites being reviewed by NRC staff. The EPA Science Advisory Board reviewed the RESRAD model. EPA used RESRAD in its rulemaking on radiation site cleanup regulations. RESRAD code has been verified, has undergone several benchmarking analyses, and has been included in the IAEA's VAMP and BIOMOVS II projects to compare environmental transport models. In addition, the software has been verified and validated (Yu 1999; NRC 1998).

- Microshield (http://www.radiationsoftware.com/mshield.html) is a comprehensive photon/ gamma ray shielding and dose assessment program that is widely used for evaluating radiation designing shields estimating source strength from radiation measurements.

Metals

Health hazards were evaluated using the Risk Assessment Information System (RAIS) developed by Bechtel Jacobs Company LLC and the University of Tennessee for the DOE, Office of Environmental Management (http://rais.ornl.gov/). The RAIS (http://rais.ornl.gov/) was consulted to evaluate the metals. Typically risks are expressed in terms of carcinogenicity. Only arsenic is listed as a human carcinogen. The potential risk to an individual who accesses arsenic in the stockpile is assessed in Section 6.4.1 of the 2011 RI/FS. The potential consequences of a human being exposed to the other metals are discussed following the arsenic assessment.

Arsenic Assessment

Arsenic risk was determined for both the soil stockpile and the flood plain after soil excavation. The most conservative exposure scenario for an individual who intrudes into the stockpile would ingestion of arsenic contaminated soil. A groundskeeper who gardens during spring and summer months on the stockpiled material could be exposed to arsenic via ingestion of soil. Also evaluated is the urban resident scenario. The risk (linear, low-dose cancer) from this exposure pathway was calculated using the formula from EPA (1989b):

$$\textbf{Risk = CDI x SF}$$

where:

Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer;

CDI = chronic daily intake averaged over 70 years (mg/kg-day);

And SF = slope factor, expressed in $(\text{mg/kg-day})^{-1}$.

The following assumptions were used to calculate the risk to a groundskeeper/gardener:

- The groundskeeper gardens 5 days/week, 26 weeks of year (May-October)
- He or she spends 5 years as a gardener (entry-level position)

- An adult gardener consumes soil at a rate of 2 mg/day (EPA 1997)
- Body weight is 70 kg (EPA 2005)
- Averaging time is 70 years (EPA 2005)
- The approved cleanup level for arsenic is 39 mg/kg
- The concentration of arsenic in the stockpile is 780 mg/kg of soil
- The highest concentration of arsenic on the flood plain is 24 mg/kg
- The background concentration of arsenic is 38 mg/kg of soil
- The flood plain average concentration after soil removal is 10 mg/kg
- From the above information, the chronic daily intake is 5.7 × 10-6 mg/kg/da
- The slope factor for inorganic arsenic is 1.5 (mg/kg/da)-1 [(EPA Integrated Risk Information System (IRIS)]

The assumptions used for the residential scenario are the same, except for the following (from EPA 1996):

- The resident lives at the same location for 70 years (from childhood through adulthood).
- He or she is exposed to the contaminated soil 350 days/year.
- The weighted soil consumption rate from childhood through adulthood is 114 mg/day.

The calculation spreadsheet for the resident scenario was validated by comparing the soil screening level estimated by EPA (2011) that is estimated to approximate a risk of $1E^{-6}$. They estimated that a soil concentration of 0.43 ppm is equivalent to this risk. The calculations used for the CSMRI estimated a risk of $1\ E^{-06}$ for this soil concentration, thus confirming that the calculation is correctly applied. Table 5 contains the results for the stockpile, and Table 6 contains the results for the flood plain for the concentrations listed and referenced above.

Table 5
Soil Consumption Arsenic Risk: Gardener/Groundskeeper

COC	$Conc_{soil}$ [a]	Consumption Rate [b]	Expos freq [c]	Expos dur [d]	Body wt [e]	Averaging time [f]	Slope factor [g]	Chronic Daily Intake [h]	Lifetime Risk [i] (per million)
As	mg/kg	kg/da	days/yr	years	kg	days	$mg/kg/da^{-1}$	mg/kg/da	(cancer)
Stockpile Maximum Concentrations									
	780	0.00002	130	5	70	25550	1.5	0.0000056695	8.5
Flood Plain Maximum Concentration (post-excavation)									
	24	0.00002	130	5	70	25550	1.5	0.00000017445	0.262
Flood Plain Average Concentration (post-excavation)									
	10	0.00002	130	5	70	25550	1.5	0.000000072687	0.11
Background Levels									
	38	0.00002	130	5	70	25550	1.5	0.00000027621	0.41
Reference Levels									
	1	0.00002	130	5	70	25550	1.5	0.000000007268	0.011
	0.43	0.00002	130	5	70	25550	1.5	0.000000003125	0.0047

a. Measured value for As in metals data. The remaining are action levels.
b. Adult gardening. EPA, 1997. Exposure Factors Handbook, Vol. 1, EPA/600/P-95/002Fa, August 1997. p 4-16
c. Assume gardens 5 days/week, 26 weeks of year (May-October)
d. Assume he spends 5 years as a gardener (entry level position).
e. Adult. EPA, 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. EPA530-R-05-006, Sept. 2005.
f. 70 years. EPA 2005.
g. EPA Integrated Risk Information System (IRIS). http://www.epa.gov/iris. Arsenic, inorganic (CASRN 7440-38-2)
h. 70 years (EPA 2005)
i. Risk = CDI * SF. EPA, 1989

Table 6
Soil Consumption Arsenic Risk: Residential

COC	$Conc_{soil}$	Consumption Rate[a]	Expos freq[b]	Expos dur[b]	Body wt[b]	Averaging time	Slope factor[c]	Chronic Daily Intake	Lifetime Risk[d](per million)
As	mg/kg	kg/da	days/yr	years	kg	days	mg/kg/da^{-1}	mg/kg/da	(cancer)
Stockpile Maximum Measurement									
	780	0.000114	350	70	70	24500	1.5	0.00127	1910
Flood Plain Maximum Level (post-excavation)									
	24	0.000114	350	70	70	24500	1.5	0.0000391	58.6
Flood Plain Average Level (post-excavation)									
	10*	0.000114	350	70	70	24500	1.5	0.0000163	24.4
Background Levels									
	38*	0.000114	350	70	70	24500	1.5	0.0000619	92.8
Reference Levels									
e	1	0.00 0114	350	70	70	24500	1.5	0.00000163	10.5
f	0.43	0.000114	350	70	70	24500	1.5	0.0000007	2.44

* Post-investigation Flood Plain arsenic levels were reduced to 74% below the Site-approved background level.
a. Age-adjusted soil ingestion factor from EPA Risk Assessment Guidance for Superfund, Vol 1(Publication 540/1-89/002, December 1989)
http:// www.**epa.gov**/oswer/riskassessment/ragsa/index.htm
b. Factors from EPA Risk Assessment Guidance for Superfund, Vol. 1, Human Health Evaluation Manual, interim final, December 1989
c. EPA Integrated Risk Information System (IRIS). http://www.epa.gov/iris. Arsenic, inorganic (CASRN 7440-38-2)
d. Risk = CDI * SF.
e. DCGL
f. The Arsenic soil concentration estimated to be equivalent to 1E-06.From the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" website.
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/

Lead

RAIS does not provide a reference dose or slope factor for lead. Although there is a strong correlation between exposure to lead-contaminated soils and blood lead concentration, numerous factors make a direct prediction of blood lead concentrations difficult. Soil particle size, lead species, bioavailability, and health of the exposed individual affect the uptake of lead. Alternative exposure paths such as lead paint and lead pipes in older buildings also influence blood lead concentrations. According to the IRIS website,

> "It appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. The Agency's RfD Work Group discussed inorganic lead (and lead compounds) at two meetings (07/08/1985 and 07/22/1985) and considered it inappropriate to develop an RfD for inorganic lead."

Often lead is regulated by the use of the soil standards; however, there is significant disagreement about the appropriate concentration. A paper published by the Agency for Toxic Substances and Disease Registry (ATSDR) lists recommended lead soil standards ranging from <100 mg/kg to 1,000 mg/kg (HHS 1992). The current proposed Tier 2 soil standard listed by CDPHE is 400 mg/kg. The Tier 2 table value for lead is based on current EPA guidance (EPA 1994).

The highest measured lead concentration in the stockpile is 7,100 mg/kg (Table 7). The concentration is well above the proposed CDPHE soil cleanup standards of 400 mg/kg for unrestricted land use and 2,920 mg/kg for commercial use (CDHPE 1997), as well as the ATSDR recommended range of soil standards. This indicates the need to closely restrict access to the stockpile or dispose of it so that an individual does not ingest the contaminated soil.

Table 7
Summary of Metal Results (mg/kg) Above Action Levels and Background

Sample ID	Lead	Molybdenum	Arsenic	Mercury	Vanadium
Action Level[a]	400	39	39	23	78
Background[b]	86	6.1	38	0.63	44
116	<[e]	<	65	<	<
185[c]	7100	210	780	420	120
195[c]	520	<	150	290	<
196[c]	<	<	<	230	<
200[c]	<	<	<	76	<
268[d]	890	<	<	<	<
336	650	<	<	<	<
352	440	<	<	<	<

a. Tentative site cleanup goals agreed upon with the State of Colorado.
b. Data from New Horizons 2004 RI/FS, with the exception of arsenic.
c. Sample collected from the stockpile
d. Sample collected within characterization area
e. < = result is less than the action level and background

The maximum concentration of lead measured in confirmatory samples collected from the excavated flood plain is 170 mg/kg with an average concentration of 68 mg/kg. If this concentration is corrected for background (86 mg/kg) the resulting maximum concentration above background is 84 mg/kg. Using the EPA IEUBK model (EPA 1994) (www.epa.gov.gov/superfund/lead/products.htm) the estimated maximum blood lead contamination that could be received by an infant (1-2 years old) consuming soil containing these values is well below the values summarized in Table 8. The CDC has identified a blood lead concentration level of 10 mg/dL as the level of concern above which significant health risks occur.

Table 8
Lead Risk Urban Residential (Child)

Scenario	Soil Value	Blood Pb Concentration
Flood Plain Maximum Concentration.	170 ppm	4.1 µg/dL
Background Concentration	BKG = 86 ppm	2.1 µg/dL
Above Background Concentration	170 ppm – BKG (86 ppm) = 84 ppm	2.0 µg/dL
Flood Plain Average Concentration	68 ppm	1.8 µg/dL

Molybdenum
Molybdenum is considered an essential trace element. Molybdenum is placed in EPA Group D, not classifiable as to carcinogenicity in humans, and calculation of slope factors is not possible.

Data documenting molybdenum toxicity to humans are limited. Factors such as the physical and chemical state, route of exposure, and dietary deficiencies of copper and sulfur may affect toxicity. There is, however, no information available on the acute or subchronic oral toxicity of molybdenum in humans.

The provisional recommended dietary intake is 75 to 250 g/day for adults and older children (NRC 1989). Molybdenum in excess of the action level and background was determined in one sample in the stockpile (210 mg/kg, as shown in Table 7). Assuming that an individual accessing the stockpile (like the groundskeeper in Section 6.4.3 of the 2011 RI/FS) consumes 2 mg/da of soil, he or she could ingest approximately 420 mg (0.42 g) of the metal per day. This is well below the NRC provisional recommendation.

Mercury
Mercury is a naturally occurring element that exists in multiple forms and various oxidation states. Exposure to mercury in the natural environment typically involves dietary intake (ATSDR 1989). Absorption, distribution, metabolism, and excretion of the element depends on its form and oxidation states (ATSDR 1989). Ingestion of mercury metal is usually without effect (RAIS). Ingestion of inorganic salts may cause severe gastrointestinal irritation, renal failure, and death with acute lethal doses in humans ranging from 1 to 4 g (ATSDR 1989).Organic mercury, especially methyl mercury, rapidly enters the central nervous system resulting in behavioral and

neuromotor disorders (ASDTR 1989). An oral RfD_c of 1E-4 mg/kg/da has been established for methyl mercury (EPA 1996).

No data are available regarding carcinogenicity of mercury in humans or animals. Measurements of mercury in the stockpile exceeded background and the action limit in four samples. The highest result was 420 mg/kg. These results also exceed the maximum CDPHE soil cleanup standard for commercial land use (176.53 mg/kg). A groundskeeper could potentially ingest up to 840 µg of mercury a day through ingestion of soil while working. The consequence of consuming this depends on the form of mercury in the soil, and past speciation of mercury has indicated the predominant form is in metal and not organic (Stoller 2007), indicating low risk.

Vanadium
Vanadium is a metallic element that occurs in six oxidation states and numerous inorganic compounds (RAIS). Vanadium compounds are poorly absorbed through the gastrointestinal system but slightly more readily absorbed through the lungs (ICRP 1960).

There is little evidence that vanadium or its compounds are carcinogenic. The toxicity of vanadium depends on its physic-chemical state. The elemental metallic form is considered to be non-toxic (RAIS).

Measurements of vanadium in the stockpile exceeded background and the action limit in one sample (120 mg/kg). A groundskeeper could potentially ingest up to 240 mg of vanadium a day through ingestion of soil while working. The health impact of consuming this depends on the form of vanadium in the stockpile. However, previous risk indicators had concluded that the stockpile is a health risk, so the exact nature of vanadium is purely academic. The vanadium on the flood plain is below cleanup standard, thus below the risk threshold.

In conclusion, the baseline risk assessment indicates that taking no future action and leaving the Site in its current condition is not protective of human health and the environment. The urban resident would be exposed to excessive risk with current site conditions. Although there are minimal direct risks to the recreational user, the Site would be a continuing problem for the underlying groundwater and Clear Creek. Long-term institutional controls would be necessary to protect neighborhood children from exposure. Erosion controls would need to be maintained to minimize the transport of affected sediment to surrounding areas and eventually into Clear Creek. Radionuclides such as Ra-226 and Th-230 are very persistent in the environment, with half-lives of $1.6x10^3$ and $7.5x10^4$, respectively. Environmental factors such as acid rain can affect metal mobility.

H. Remedial Action Objectives

Remedial action objectives for the Site are designed to prevent or mitigate further release of affected materials to the surrounding environment and to eliminate or minimize risk to human health and the environment. The affected material was the surface and subsurface soil located on the flood plain and western slope of the upper terrace prior to soil segregation activities. After soil segregation, most of the affected material is located in the lined stockpile managed on the upper terrace. Potential receptor pathways included direct radiation, inhalation, and ingestion of plants and soil. Another potential exposure pathway is the migration of the affected material to groundwater and subsequent ingestion. The following objectives, originally established for the Site prior to soil segregation activities, remain valid:

- Eliminate or minimize the pathway for dermal contact, inhalation, and ingestion of site-specific radionuclides to human receptors to achieve a level of protection in compliance with the NCP levels of acceptable cancer risk (10^{-4} to 10^{-6}).
- Develop receptor-specific DCGLs to limit unacceptable radiation doses (total effective dose equivalent [TEDE] to less than 25 mrem/yr and 15 mrem/yr, distinguishable from background; and less than 100 mrem/yr above background if institutional controls fail for onsite restricted-use remedies) for the radionuclides found in the affected material (i.e., soil). Ra-226, Th-228, Th-230, Th-232, and U-238 are present onsite at activities above tentative DCGLs. Additional radionuclides were identified during the characterization (Ra-228, U-234, and U-235) but at activities consistent with background.
- Prevent exposure to indoor air concentrations of radon gas and radon decay products greater than 4 picocuries per liter (pCi/L) and 0.02 working level (WL), respectively. Exposure to 4 pCi/L of air for radon corresponds to an approximate annual average exposure of 0.02 WL for radon decay products, when assuming residential land use.
- Prevent long-term dermal, inhalation, and ingestion exposures to trace metal-affected materials with concentrations greater than the CDPHE proposed Residential/Unrestricted Land-Use Standards. The primary trace metals of concern are arsenic, lead, mercury, molybdenum, vanadium and uranium.
- Address specific issues associated with the hazards of soil containing elevated concentrations of lead (possible access issues with neighborhood children).
- Implement remedial measures that limit groundwater and surface-water concentrations to the MCLs at the points of compliance and to non-zero maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act and under Colorado law. Although the affected groundwater is not a current drinking water supply, it eventually enters Clear Creek, which is used by downstream users for drinking water. Uranium and arsenic are the primary groundwater contaminants of concern.
- Prevent offsite migration of affected material that could result in the exposures described above. This includes the groundwater pathway.
- Implement remedial actions that reduce exposures from ionizing radiation to levels that are as low as reasonably achievable (ALARA).
- Comply with soil-, location- and action-specific ARARs. (Table 18)

Table 9 presents the Site action levels agreed to in the CDPHE-approved 2010 Site Characterization Work Plan.

Table 9
Site DCGLs and Cleanup Levels

Metal	DCGL (mg/kg)	Site Action Level (inclusive of ambient) (mg/kg)
Arsenic	1.0	39
Lead	NA	400*
Mercury (elemental)	1.1	1.1
Mercury (compounds)	NA	23
Molybdenum	NA	390
Uranium	NA	14
Vanadium	NA	78
Radioisotope	**DCGL (pCi/g)**	**Site Action Level (pCi/g)**
Gamma Activity	field screening action level	< 2x ambient
Radium 226	1.44	4.14
Radium 228	2.20	4.6
Thorium 228	3.77	6.47
Thorium 230	9.83	11.53
Thorium 232	1.48	3.88
Uranium 234	253	254.9
Uranium 235	4.88	4.97
Uranium 238	20.2	21.8

[1] NA – Not applicable
* DCGLs not calculated for some metals. Site action levels use ARARs for cleanup goals.

The persistence of the affected material would place receptors at risk for over 1,000 years, and land use could change significantly in that amount of time. Both the urban resident and the recreational user have been evaluated for each scenario because of the future land use uncertainty and because it is reasonably foreseeable that the Site would be used for urban residents by the School or other future owners of the Site. Additionally, exposures resulting from each alternative must comply with a 1997 NRC rule (10 CFR Part 20, Subpart E), which has been adopted by Colorado (6 CCR 1007-1 4.61.3), which establishes a dose criterion for decommissioning a site. This rule includes a provision that permits decommissioning under restricted release conditions. Under a restricted release (a release including an environmental covenant), the dose to the average member of the critical group must not exceed 25 mrem/yr with the restrictions in place, and, if the restrictions were to fail, the dose due to residual radioactivity must not exceed 100 mrem/yr. However a restricted release is not envisioned because once the stockpile is removed the dose from the soil remaining on the flood plain should not exceed 16.1 mrem/yr as discussed in Part G of this document.

Soil segregation activities completed in 2011 were implemented to characterize the nature and extent of impacted soils on the Site. These activities are consistent with previous activities in that leaving the impacted material in place was not an option. All viable options evaluated in prior activities required being able to accurately quantify the volume of impacted soil and required the impacted soil to be relocated. Therefore, the objectives of the remedial actions listed above remain valid.

I. Description of Alternatives

Five site-specific alternatives were developed in the 2011 RI/FS that use a combination of techniques to protect human health and the environment. Similar to the materials at issue in the 2007 RI/FS, the impacted Site soils reside in a lined stockpile. The basis for eliminating alternatives that were eliminated in previous FS efforts remains valid. There is very little difference in the current state of the impacted soils from the state during preparation of the earlier FS efforts. Like in the 2007 RI/FS, the groundwater pathway has been temporarily interrupted and the volume of impacted soils is known. Having the impacted soil in a lined stockpile reduces some costs associated with the above-discussed options. The reduced costs were not, however, sufficient reason to re-evaluate any of the above-discussed options that have been screened out.

The 2011 Site characterization activities were successful, and the impacted Site soils were placed in a lined/stabilized stockpile. Remedial action alternatives evaluated in the FS are summarized in Table 10.

Table 10
Remedial Action Alternatives

Alternative	Description	Is Excavation Included as Part of Remedy?	Are Institutional Controls Included as Part of Remedy?
1	No Action	No	No
2	Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Yes	No
3	Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository	Yes	Yes
4	Onsite Solidification and Placement into an Above-Grade Repository	Yes	Yes
5	Place Cap over Stockpile Soil	Yes	Yes

Alternatives 1 and 5 did not meet the RAOs, because they failed to provide sufficient reduction of risk from each medium and/or pathway of concern for the Site. Therefore, these alternatives were eliminated from further consideration.

One of the primary criteria for remedy selection under CERLCA is protection of human health and the environment. If this criterion is not met, the alternative(s) will not be retained for further consideration. In the description of the FS screening process in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), it says:

> "Information available at the time of screening should be used primarily to identify and distinguish any differences among the various alternatives and to evaluate each alternative with respect to its effectiveness, implementability, and cost. Only the alternatives judged as the best or most promising on the basis of these evaluation factors should be retained for further consideration and analysis."

Alternative 5 is essentially a variation on Alternative 1 offering only a minimal increase to protection of human health and the environment whereas Alternatives 2, 3, and 4 contain elements that satisfactorily address the protectiveness of human health and the environment. Although the no-action alternative does not meet the RAOs, it is carried through the detailed analysis of alternatives for comparative purposes. As stated above, Alternative 5 fails to meet RAOs and thus was eliminated from further consideration.

The following describes the remedy components for each remedy considered in detail.

Description of Remedy Components:

Alternative 1 - No Further Action
Treatment Components:
- None

Containment Components:
- None

Institutional Components:
- None

Alternative 2 - Offsite disposal at solid-waste landfill
Treatment Components:
- None

Consolidation Components:
- None

Institutional Control Components:
- After transportation and disposal no institutional controls will be required for flood plain soil. Groundwater monitoring will occur. Based on these groundwater findings further action may or may not be necessary.

Common Elements and Distinguishing Features of Each Alternative
Each alternative, except no action, requires work plans, mobilization to the site, dust control traffic control, and stormwater control measures.

Each alternative requires an environmental covenant requiring a radon mitigation system for each residence on site to be maintained by the owner/operator, with the School, CDPHE, and the City having the ability to enforce the covenant against any owner or operator. Residual concentrations of Ra-226 above background require the covenant.

The major distinction among remedies is that Alternative 2 takes the stockpiled material offsite to landfills whereas Alternative 3 and 4 leave the stockpiled material onsite.

Key ARARs will be met with each alternative, except no action. Radionuclide contamination affects both soil and groundwater. A key ARAR is the receptor-specific and site-specific DCGLs that limit unacceptable radiation doses (TEDE to less than 25 mrem/yr and 15 mrem/yr, distinguishable from background; and less than 100 mrem/yr above background if institutional controls fail for onsite restricted-use remedies) for the radionuclides found in the affected material (i.e., soil). These DCGLs for soil will be met for all alternatives, except no action. Exposures from the stockpile would be 133 mrem/yr for an urban resident, which exceeds the ARAR of 100 mrem/yr for institutional control failure.

The MCL for uranium is exceeded in groundwater wells on Site. Alternative 2 provides the best prospect of improving groundwater quality and restoring it to levels below the MCL. The onsite remedies of Alternatives 3 and 4 have the possibility of failure and contributing contaminants again to the groundwater. Over a 1,000-year time horizon, it is difficult to predict the likelihood of failure for the onsite remedies. The certainty with the offsite remedies is 100 percent certain because the contaminated soil will be taken to an offsite landfill. There is no chance of contributing contamination again to the groundwater at the Site with the offsite remedy.

Continued groundwater monitoring will be needed for all alternatives to see if the excavation and offsite disposal or containment of the contaminated material is successful in improving groundwater quality to acceptable conditions. It is not clear at this time if additional measures will be necessary to improve and protect groundwater quality. Groundwater will be addressed as a separate OU in a separate RI/FS in the future.

ARARs for metals will be met with all alternatives, except no action. There is no chance of contributing to groundwater problems at the Site for the offsite remedies but some unquantifiable chance for the onsite remedies.

The quantity of waste is the same for all alternatives. With Alternative 4, the quantity of the waste will increase due to the need for adding concrete and fly ash to stabilize the waste. The degree of hazard remaining on site will be less with 4 but the degree of hazard remaining onsite is the lowest with Alternative 2 because the stockpile will be taken offsite.

Two months will be needed to implement Alternative 2, while Alternatives 3 and 4 would require 6 to 8 months. Groundwater monitoring will continue on its existing quarterly schedule for two years for Alternative 2; however, Alternatives 3 and 4 would require compliance monitoring as long as the disposal cells remained onsite.

The remediation goals for soil will be attained upon completion of Alternatives 3 and 4. Attainment of groundwater goals is uncertain for all alternatives. Analysis of future groundwater monitoring results will determine the time needed to attain groundwater remediation goals.

The least expensive remedy is Alternative 2 with an estimated cost of $289,000. Alternative 3 will cost $1.9 million and Alternative 4 will cost $1.6 million. Groundwater monitoring cost is not considered here but will be addressed in the RI/FS for OU2. The net present value of monitoring and maintenance costs for Alternative 3 and 4 are substantially higher than Alternative 2. Assuming only annual and five year inspections for 100 years, the costs is $660 thousand. Groundwater compliance monitoring cost although not included in the Alternatives 3 and would be in the millions of dollars as both would require some frequency of monitoring over their entire life cycle.

Alternative 3 – Onsite Disposal Cell with Engineered Cap
Treatment Components:
- None

Containment Components:
- Onsite materials will need to be consolidated. Some crushing of cobbles may be required. An area at a high enough elevation to remain above groundwater fluctuations would be selected for the final placement of the compacted material.
- A cap would be constructed over the structure to limit leaching effects.
- Geotechnical testing would be required to verify proper placement of the cell and proper compaction of the clay material.
- A clay sub-liner and geosynthetic liner over the clay would be installed.
- The affected material would then be placed in the cell. Once the operation is complete, a clay cap (3-feet deep) would be installed over the material.

Institutional Control Components:
- The structure and cap footprint would require institutional controls on about 1 acres of land if one assumes 4:1 slope into the cell. Long-term cap maintenance, periodic inspections and groundwater monitoring in the vicinity of the cell would be required.
- Environmental covenant would prohibit structures on top of cell, and require radon mitigation systems in all residences onsite.

Alternative 4 – Onsite Solidification and Placement into a Disposal Cell
Treatment Components:
- Consolidation and stabilization of stockpiled soils onsite using Portland cement, cement kiln dust or fly ash.

Containment Components:
- Alternative 4 would require a bench test to determine the appropriate mixture of reagent and soil.
- Onsite materials would need to be consolidated and solidified. Some crushing of cobbles may be required. An area at a high enough elevation to remain above groundwater fluctuations would be selected for the final placement of the solidified material. Reagent would be stockpiled onsite, and a batch processor (e.g. pug mill, soil recycler, cement trucks etc.) would be brought in to mix the materials. A water supply also would be required. Batches of material will be placed in lifts and solidification would be verified with test cores.
- A cap would be constructed over the structure to limit leaching effects.
- Geotechnical testing would be required to verify proper placement of the cell.
- Laboratory analytical would be required to verify stabilization of contaminants
- The affected material would then be placed in the cell. Once the operation is complete, a clay cap (3-feet deep) would be installed over the material.

Institutional Control Components:
- The structure and cap footprint would require institutional controls on about 1 acre of land if one assumes 4:1 slope from the top of the cap. Long-term cap maintenance, periodic inspections and groundwater monitoring in the vicinity of the solidified matrix would be required.

- Environmental covenant would prohibit structures on top of cell, and require radon mitigation systems in all residences onsite.

Expected Outcomes of Each Alternative
Alternative 2 allows the surface to be used for all uses so long as the covenant is in place to restrict groundwater use. Alternatives 3 and 4 are the same, except that no structures or certain activities may occur on the cap to ensure the integrity of the cap. The No Action Alternative does not allow for unrestricted use of the site for beneficial purposes. There is a significant loss in property value for Alternatives 1, 3 and 4.

For all remedies, the use of groundwater is restricted until future groundwater monitoring and analysis occurs. Five wells currently exceed the MCL for dissolved uranium (September 2011). It is not clear how much time will be needed to satisfy the MCLs, nor if the source excavation during the RI has succeeded at reducing dissolved uranium concentrations.

Summary of Remedial Alternatives

Alternative 1 – No Further Action
Estimated Capital Cost: $0
Estimated Present Worth Cost: $0
Estimated Construction Timeframe: NA
Estimated Time to Achieve Remedial Action Objectives: Not achieved, until natural attenuation is achieved, 100 years used for comparison.

Under Alternative 1, the affected soils would remain in the lined stockpile. A major weakness in the no-further action alternative is the failure to provide adequate protection of human health and the environment. Contaminants would not be adequately controlled to limit migration.

Alternative 1 has an additional cost associated with the loss of property value. Appraisal information indicates that without site cleanup, the land "stigma") value decreases land value by up to 20%. The estimated present worth cost would be $367,000 if the land value loss were included.

Alternative 2 Offsite disposal at solid waste landfill
Estimated Capital Cost: $289,000;
Estimated Operation and Maintenance (Present Value) Cost: $0
Estimated Present Worth Cost: $0
Estimated Construction Timeframe: 2 months
Estimated Time to Achieve RAOs: Upon Completion (Soil only; groundwater is a separate OU)

Alternative 2 involves the load-out and transportation of the affected material in the stockpile to an approved solid waste landfill.

Estimated transport times were determined assuming the closest solid waste landfill for alternative 2. Allied Waste Foothills Landfill on Colorado Highway 93 is approximately 8 miles north of the Site. Transportation times will increase if another facility is selected.

Upon completion of the offsite disposal, all of the property would be available for residential and other use without an environmental covenant for soil. Backfill material would be required as needed to bring the Site to original grade and for storm-water control and safety.

Because all of the affected material would be disposed offsite, Alternative 2 would not experience the loss in property value associated with the other alternatives.

Alternative 3 – Onsite disposal cell with engineered cap
Estimated Capital Cost: $1,926,000
Estimated Operation and Maintenance (Present Value) Cost: $660,000
Estimated Present Worth Cost: $367,000
Estimated Construction Timeframe: 6-8 months
Estimated Time to Achieve RAOs: RAOs only partially achieved, monitoring required for at least 100 years

Alternative 3 requires the construction of an engineered disposal cell without solidification of impacted soil. An area above groundwater fluctuations would be selected for the construction of the cell. Allowing a material depth of 5 feet and a 4:1 slope into the cell to allow for equipment movement, the footprint of the cell would be about 1 acre. Geotechnical testing would be required to verify proper placement of the cell and a compaction of the clay sub-liner. A geosynthetic liner would be installed over the clay to ensure containment. The affected material would then be moved from the stockpile(s) and placed in the cell. When all material is relocated to the cell, a clay cap (3 feet deep) would be installed over the material.

Institutional controls would be required for the cell to ensure the integrity of the cap and to monitor groundwater in the vicinity of the cell. Limited groundwater monitoring would likely be required to monitor the natural attenuation of current metal concentrations and radionuclide activities. Backfill would be required to bring the Site to a useable elevation and to provide storm-water control.

Alternative 3 has the additional cost associated with the loss of property value. Although a remediation process is completed, the land “stigma” value may still decrease by up to 20%. The estimated present worth cost would be $367,000if the land value loss were included.

Alternative 4 – Onsite solidification with engineered cap
Estimated Capital Cost: $1,629,000
Estimated Operation and Maintenance (Present Value)
Cost: $660,000
Estimated Present Worth Cost: $367,000
Estimated Construction Timeframe: 6-8 months
Estimated Time to Achieve Remedial Action Objectives: RAOs only partially achieved, monitoring required for at least 100 years

Alternative 4 would require soil to be solidified and capped. Alternative 4 involves the consolidation and stabilization of onsite soils using a reagent such as Portland cement or cement kiln dust. Alternative 4 assumes that the affected onsite material (1,400 cy) would be solidified, placed onsite, and capped. Confirmation sampling has already confirmed all soil above DCGLs in the stockpile, and limited additional sampling would be performed to ensure both metal and radionuclide limits are achieved beneath the stockpile.

Alternative 4would require a laboratory bench test to determine the appropriate mixture of reagent and soil. After the proper mixture is determined, stockpiled materials would require segregation by soil type. Some crushing of cobbles may be required. An area at a high enough elevation to remain above groundwater fluctuations would be selected for the final placement of the solidified material. Operational reagent would be stockpiled onsite in a silo, and a batch processor would be brought in to mix the materials. A water supply also would be required. Batches of material would be placed in lifts, and solidification will be verified with test cores.

After the solidification of the structure has been confirmed, a clay cap (depth of 3 feet) would be constructed over the structure to limit leaching effects. The structure and cap footprint would require institutional controls on about 1 acre of land. Long-term cap maintenance in the vicinity of the solidified matrix would be required. The remaining property would be available for unrestricted use although a limited groundwater monitoring program currently ongoing would continue to monitor the current metal concentrations and radionuclide activities. Some backfill would be required to bring the Site to a useable elevation and to provide stormwater control.

Alternative 4 has the additional cost associated with the loss of property value. Although a remediation process would be completed, the land value may still decrease by up to $367,000.

J. Comparative Analysis of Alternatives

Nine criteria are used to evaluate the different remediation alternatives individually and against each other in order to select a remedy. The nine criteria fall into three groups. The first group, the threshold criteria, includes overall protection of human health and the environment and compliance with the ARARs. If an alternative does not meet these criteria, it is not eligible for future consideration. The second group, the balancing criteria, includes long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, short effectiveness, implementability, and cost. These criteria are weighed against each other to determine a preferred option. The last group, the modifying criteria, includes State and community acceptance. The modifying criteria are often used to make a final selection.

The following sections profile the relative performance of each of the alternatives against the other alternatives. The nine evaluation criteria are individually discussed in the following sections. Detailed discussion of the alternative evaluation can be found in Sections 7.0 and 8.0 of the 2011 RI/FS.

A brief summary of the alternatives and the nine evaluation criteria is presented in Table 11

Table 11
Evaluation of Alternatives

Alternative	Protective of Human Health & Environment	ARAR Compliance	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability (Feasibility)	Cost Ranking[1]	State Acceptance	Community Acceptance
1 - No Action	N	N	N	N	Y	L	1	N	N
2 - Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Y	Y	Y	Y	Y	H	2	Y	Y
3 - Leave Stockpile Material Onsite and Cap design/build a Below-Grade Repository	Y	N	U	N	Y	M	4	U	U
4 - Onsite solidification and Placement into an Above-Grade Repository	Y	N	U	N	Y	M	3	U	U

Notes: Y, addresses criteria; N, does not address criteria; U, uncertainty associated with this element; Implementability factors, highly feasible (H) through problematic (L); Rankings range lowest to highest cost

1 Costs account for loss of property value for onsite remedies.

Overall protection of human health and the environment

Alternative 1, the no-further action alternative does not provide adequate protection of human health and the environment because it does not adequately address the exposure pathways. The alternative does not address the migration of metals (especially uranium) and radionuclides to groundwater. Unauthorized Site access by neighborhood children is also is a possibility with this alternative. Trespassers have already breached the existing security fence on a number of occasions. With a 1,000-year time horizon, access to the Site is reasonably foreseeable.

Alternatives 2, 3, and 4 effectively address the direct exposure pathways by either preventing access to the material using caps and a variety of containment options or offsite disposal. In each case, institutional controls would be required to ensure that radon abatement systems are a requirement for any structure or building constructed on the Site. Groundwater fluctuations and the presence of a City of Golden water main provide potential mechanisms for migration of affected material left onsite. Table 12 summarizes some of the factors associated with the protection of human health and the environment criteria. Factors associated with the ARARs criteria also are included.

Table 12
Factors Associated with Protection of Human Health and the Environment Criteria and ARARs Criteria

Alternative	Risk <10^{-4}	Dose <15 mrem/yr	Dose <25 mrem/yr	Hazard Index <1	PbB<10 µg/dL	Soil Lead <400 mg/kg	Protective of Groundwater	Dose < 100 mrem/yr with institution control failure
1 - No Action	N	N	N	N	N	N	N	N
2 - Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Y	Y	Y	Y	Y	Y	Y	Y
3 - Leave Stockpile Material Onsite and cap design/build a Below-Grade Repository	Y	Y	Y	Y	Y	Y	Y	N
4 - Onsite solidification and Placement into an Above-Grade Repository	Y	Y	Y	Y	Y	Y	Y	N

Notes: Evaluation based on urban resident; Y, meets requirement; N, does not meet requirement; U, uncertainty associated with this element;

A short-term groundwater-monitoring program is currently ongoing and would continue if Alternatives 2, 3 and 4 are selected because of uranium remaining in the groundwater system. However, because the groundwater has been separated as an operable unit from the soil in the flood plain area, the groundwater issue will be addressed separately in the future. The solidified matrix or disposal cell associated with Alternatives 3 and 4 would require a long-term groundwater monitoring as well as a long-term operations and maintenance program to ensure the ongoing integrity of the repository. The long-term groundwater monitoring would be required due to the presence of the repository, which is a separate issue than the one being evaluated under the current short-term groundwater monitoring program.

In the absence of institutional controls, the potential dose due to radon emanation into a residential structure ranges from 16.1 mrem/yr on the flood plain after the stockpile is disposed(Alternative 2) to 133 mrem/yr if no action were taken. Alternative 2 would provide the most protection to human health and the environment as it takes the source away from the Site.

Compliance with ARARs

Alternative 1 does not meet the ARARs that have been identified for the Site. Alternatives 3 and 4 do not meet ARARs. With the failure of institutional controls, the dose to the urban resident exceeds 100 mrem/yr in each case. Alternative 2 is compliant with ARARs by offsite disposal of the affected material.

Alternative 2 has the least uncertainty associated with the site-specific ARARs.

Long-term effectiveness and permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

Alternatives 2 and 4 would sufficiently address residual risk although some uncertainty is associated with the groundwater pathway for Alternative 4. The alternatives that involve a cap would have a degree of uncertainty associated with long-term permanence. Cap breakdown could result in significant risks to human health and the environment. The solidification process used for Alternative 4 also could be a problem in the future (other solidification structures have failed over time). Alternative 2 meets the long-term effectiveness and permanence criteria because the material leaves the Site.

Reduction of toxicity, mobility, or volume through treatment
Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternatives 3 and 4 are the only alternatives that address the material through treatment. Toxicity and mobility are addressed because the matrix prevents material migration and reduces toxicity through reduced bioavailability. Properly maintained the solidified matrix would be expected to remain intact for an extended period of time. But as mentioned in Section 7.3 of the 2011 RI/FS, there is some question about the leaching of arsenic and mercury.

Alternatives 3 and 4 use caps to address toxicity and mobility by limiting contact and infiltration. Onsite volumes are not reduced in Alternative 3, increased in Alternative 4, and eliminated in Alternative 2.

Short-term effectiveness
Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved.

The short-term effects of alternatives are assessed below considering the following:

- Short-term risks that might be posed to the community during implementation of an alternative;
- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
- Time until protection is achieved.

Analysis of Alternatives
This section presents the results of the analysis of each alternative with respect to the nine evaluation criteria.

Alternative 1: No Action
Under Alternative 1, the affected soils would remain in the lined stockpile without any controls. Even though the rationale behind performing a characterization procedure that excavated the

impacted soil from the flood plain supported eliminating the no action alternative it is carried through this evaluation to validate that rationale and evaluate the action alternatives for the stockpiled soil.

Alternative 1 - Protection of Human Health and the Environment

Alternative 1, the no-further action alternative, does not provide adequate protection of human health and the environment. It does not address the risks associated with potential skin contact, inhalation, or ingestion of contaminants from the elevated material. With the 40 CFR §192.02(a) requirement of 1,000 years (or at least 200 years) of protection, the no-further action alternative is not appropriate. In that amount of time, land use could reasonably revert to the urban resident modeled in the baseline risk assessment as discussed in Section 6. The risk assessment evaluated four scenarios in addition to resident including, recreational user, student athlete, and groundskeeper.

The predicted dose of the impacted soil for the urban resident scenario on the flood plain prior to segregation and stockpiling was as high as 133 mrem/yr including radon. This dose is approximately 5 times higher than the 25 mrem/yr radiological criteria limit for unrestricted and restricted use. Total risk from radionuclides, prior to segregation and stockpiling was up to 9.77×10^{-5}

Windborne particles would migrate offsite from the stockpile. Metals and radionuclides would be absorbed by vegetation, which could then migrate offsite in the form of leaves and debris.

The major weakness in the no-further action alternative is the failure to provide adequate protection of human health and the environment.

Alternative 1 - Compliance with ARARs

Assuming the urban resident receptor, the no-further action alternative fails to meet the ARARs presented in Table 18. The groundwater, drinking water and surface water ARARs also are not met.

Alternative 1 - Long-term Effectiveness and Permanence

The alternative would provide no reduction in risk and does not reduce toxicity, mobility, or volume of Site contaminants. It would remain a long-term source of possible contamination to groundwater and surface water.

Alternative 1 - Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment is associated with no-further action, resulting in no reduction of toxicity, mobility, or volume.

Alternative 1 - Short-Term Effectiveness

The short-term effects of the no-further action alternative would be unchanged from the current risks posed by the elevated material. Because no excavation is required, there would be minimal risk to workers. No elevated short-term risks would result from implementation of this alternative.

Alternative 1 - Implementability

Alternative 1 is technically feasible; however, the administrative feasibility of this alternative is problematic because it would not likely meet the criteria for radioactive materials license decommissioning, and it will be problematic to get a solid waste disposal license.

Alternative 1 - Cost

Cost elements associated with the no-further action alternative. There is the cost of loss in property value for the 1 acre of land associated with the soil stockpile. This loss of property value is estimated to be $0.37 million. Cost breakdown data for each alternative are provided in Section 8.3.7.

Alternative 1 - State Acceptance

CDPHE acceptance is unlikely because of possible metals and radionuclide exposure and lack of groundwater protection. The School and CDPHE have indicated that some proactive remedial action at the Site is required.

Alternative 1 - Community Acceptance

Comments received during an open house conducted by the School in September 2010 indicated that local residents preferred offsite disposal, making community acceptance of no-further action unlikely. The City of Golden long-term development plans include construction of a pedestrian/bike path that would traverse the top of the flood plain terrace in close proximity to the existing stockpile location, and possibly have a segment that comes down to the flood plain area. In addition, the School plans an auxiliary parking lot for their athletic fields on the current site of the stockpile.

Alternative 2: Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility.

Alternative 2 is the excavation and offsite disposal of the radionuclide- and metal-affected soil in the existing stockpile.

The material has already been consolidated into a stockpile containing approximately 1,400 cy of material with a mean Ra-226 concentration of 20.5 pCi/g. The stockpile would be shipped to an offsite licensed disposal facility under Alternative 2.

Alternative 2 uses one landfill for the stockpile. Several possible landfill options were considered: the U.S. Ecology facility in Idaho; the Clean Harbors Deer Trail facility in Colorado; the Waste Management CSI facility in Bennett, Colorado; the Waste Management Denver Arapahoe Disposal Site; the Energy Solutions landfill in Utah; the Waste Control Specialist facility in Texas; and the Allied Waste Foothills Landfill in Jefferson County, Colorado. The transportation/disposal costs and administrative feasibility for each one vary considerably based on distance to the facility and actual tipping fees.

The assumption used for Alternative 2 is that the stockpile would be disposed of at one landfill because it meets the waste acceptance criteria for each landfill evaluated. An estimated 1,400 cy or about 2,100 tons (assuming a estimated weight of 1.5 tons per cy) of material would be shipped offsite for disposal.

Alternative 2 - Protection of Human Health and the Environment

Alternative 2 assumes offsite disposal of all affected material above action levels. In this RI/FS, RESRAD predicted a dose of 133 mrem/yr including radon and a risk of $9.73 \times 10^{-5}$for urban resident if the stockpile were to remain on site. The subsistence farmer scenario was not modeled as the stockpile did not represent enough arable land to farm. These dose and risk levels assumed no backfilling of the area where the stockpile is managed. In addition a soil sampling plan would be implemented after remediation to ensure impacted soils are not present under the area where the stockpile was managed.

The excavation of the majority of the Ra-226 significantly reduces potential radon emanation rate on the flood plain. In Section 6, RESRAD predicts a dose of 16.1 mrem/yr and a risk or 1.35×10^{-6} (urban resident) on the flood plain after the stockpile is taken to offsite disposal facilities. Alternative 2 is protective of human health and the environment for all four scenarios evaluated in the RA. The addition of an environmental covenant for the Site is warranted due to high background levels of radium-226 in the area. A covenant for the flood plain requiring radon mitigation systems for structures will reduce doses to well below 15 mrem/yr.

Alternative 2 - Compliance with ARARs

Alternative 2 complies with the ARARs listed on Table 18, with the possible exception of some requirements for ongoing groundwater monitoring to verify the effectiveness of the source excavation from the flood plain area. However, compliance with groundwater ARARs will be assessed when the Groundwater OU2 RI/FS is performed. As shown in Table 13, even with the failure of institutional controls, the potential dose due to radon emanation into a future residence is 16.1 mrem/yr in the flood plain area. This is less than the 100 mrem/yr limit for failure of institutional controls (radon mitigation systems) allowing Alternative 2 to comply with ARARs. It is less than the 25 mrem/yr ARAR but slightly above the 15 mrem/yr ARAR. The covenant of radon mitigation systems for residential structures will reduce the mrem/yr dose below 15. Landfill disposal criteria need to be addressed to determine which alternative would be appropriate for offsite disposal. Of all the alternatives considered, Alternative 2 appears to meet ARARs best and was the remedy also selected in the 2007 FS.

Table 13
Dose Predictions under Alternative 2 with Failure of Institutional Controls

Alternative/Receptor	Predicted Dose with Failure of Institutional Controls
Urban Resident	16.1 mrem/yr

Alternative 2 - Long-Term Effectiveness and Permanence

Disposal at a solid waste landfill successfully mitigates the potential long-term effects associated with the elevated metals and radionuclides in the soil on the flood plain area and stockpile. With inclusion of the covenants mentioned earlier, this alternative provides for use of the entire property.

Alternative 2 - Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not reduce the toxicity, mobility, or volume of affected material through treatment. All of the material is moved to an offsite landfill where it can be properly managed, but no treatment would be expected.

Alternative 2 – Short-Term Effectiveness

Excavation and transport activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. Table 14 summarizes RESRAD predicted worker doses and risks associated with excavation activities. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment. Area factors also must be considered for the worker exposure.

Table 14
RESRAD-Predicted Worker Doses for Excavation Activities under Alternative 2

Worker Exposure	Dose (mrem)	Risk
Stockpile Excavation- 6 weeks after Agency approval of RI/FS	22.7	8.38×10^{-7}

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.

A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and material (i.e., traffic accidents). Access to State Highway 6 which was used during the implementation of the 2007 remedy would limit the risk to the immediate neighborhood. This option may no longer be available, however, due to the expansion of School athletic facilities and the construction of a new pedestrian/bike path. A somewhat higher risk is associated with transportation of the material through the neighborhood. This risk is regarded as low due to the limited number of truckloads (less than 100) that would be required to transport the material to the landfill.

Based on worker risk assessment evaluations, there is a small incremental short-term risk of potential adverse health consequences during a transportation-related accident. Exposure times would result in a risk significantly lower than the 1×10^{-6} threshold (assumes cleanup operations are completed within 24 hours and the only receptors are emergency response personnel). Typically access to transportation-related spills is not allowed to members of the general public. An accident involving an overturned truckload of affected material would have a small environmental risk if the material were to enter a drainage channel. However, the environmental risk would be limited because of the nature of the material (soil versus liquid) and containment procedures followed by emergency response teams.

Access to U.S. Highway 6 would eliminate the need to transport material and equipment through nearby residential areas. In the event that access to U.S. Highway 6 is not available, truck traffic through the 12th Street Historic District will likely result in public annoyance due to short-term noise and vibration in a residential area. Some operational noise would be expected that could be noticed by nearby residents.

Alternative 2 - Implementability

The technical feasibility of offsite disposal at a commercial landfill relies on use of conventional excavation and transport technology. Necessary equipment is readily available for implementation of this alternative.

Factors involving the administrative feasibility of the alternative include obtaining approval from CDOT to access Highway 6 or working with the City of Golden to control traffic during transport of material through their community and meeting the landfill acceptance criteria requirements. Physical construction of an access lane on Highway 6 in 2004 under CDOT Access Permit No. 603100 was completed during earlier RI/FS work. Stoller used this access lane for disposal of the soil stockpiled during the 2007 RI/FS under CDOT Access Permit 605167. However; direct access to this route has since been blocked by construction of a soccer field, and Stoller would need to utilize the newly constructed pedestrian/bike path to access the Highway 6 access lane. It is likely that CDOT would issue another use permit to allow transport of additional soil using this access point. However, both the City of Golden and the School are in agreement that closure of the pedestrian/bike path would be a less favorable route option for transport of the stockpile.

The above-listed landfills in Section 8.2.2 are administratively feasible, except for the following landfills:

- The Waste Management Denver Arapahoe Disposal facility will not accept these materials.
- The Waste Management CSI facility in Bennett, Colorado is not currently accepting material due to an Adams County letter to CSI stating that the landfill should not accept this type of waste due to the litigation pending between Adams County and Clean Harbors related to the Clean Harbors facility's ability to accept NORM. Although settlement talks are underway the facility does not know when the issue will be resolved.
- The Clean Harbors Deer Trail facility is available to accept NORM and TNORM waste if waste acceptance is met.
- The Foothills Landfill (Allied Waste) accepted the waste generated during the 2007 RI/FS. Approval to dispose of up to a total of 30,000 cy of similar material was given by CDPHE at that time. The analytical results from stockpile samples show that the soil in the stockpile is similar to the material that was approved for up to 30,000 yards, and CDPHE concurred. The stockpile material meets the acceptance criteria for the Foothills facility and the School has remaining capacity on the basis of the approval letter from CDPHE dated July 28, 2007 to use this landfill for Site soils.

Alternative 2 - Cost

Cost elements associated with Alternative 2 include loading the stockpiled material into trucks, transportation to the selected landfill, and re-grading and site reclamation. After the offsite disposal is performed, the two years of groundwater monitoring will be continued to analyze groundwater quality and confirm the effectiveness of the excavation in the flood plain, which will be assessed during the OU2 Groundwater RI/FS at a later date. The total present value of these cost elements is estimated at $0.72 million. Property values are not significantly affected by this alternative because the land will be available for residential and other use with the environmental covenant. The estimated schedule for Alternative 2 is about six weeks from the time the CDPHE approves the selected remedy in the RI//FS.

Cost breakdown data for each alternative are provided in Tables 13 and 14.

Alternative 2 - State Acceptance

CDPHE has stated its preference for offsite disposal (Alternative 2) and this remedial alternative was chosen, with CDPHE approval, in 2007. The School also prefers offsite disposal.

Alternative 2 - Community Acceptance

Comments received during an open house conducted by the School in 2010 indicated that local residents preferred this alternative.

Alternative 3: Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository

Alternative 3 would begin with the stockpiled material staying on site and the engineering and construction of a disposal cell. A properly sized area would be excavated on the upper terrace to hold the cell. An engineered clay liner base would be installed followed by a geosynthetic liner and additional cover soil. The stockpiled material would be transferred into the cell. Once all of the material is in the disposal cell, a cushion layer and geosynthetic liner would be placed over the cell (encapsulating the material) and a clay cap would be installed using suitable material from an offsite location. Once the encapsulation has been completed, the area would be re-graded. Fill would need to be placed over the remaining Site to bring the area to a useable grade and to control stormwater.

Institutional controls for Alternative 3 would include deed restrictions for the flood plain and the upper terrace of the Site, requiring radon mitigation for all structures as well as maintenance requirements for approximately 1 acre of land affected by the footprint of the disposal cell. Deed restrictions associated with the disposal cell would include limiting construction activities and excavation and ensuring the integrity of the cap. While construction has been allowed for some capped sites, it makes cap maintenance problematic. In accordance with 40 CFR §192.02(a), a long-term maintenance plan would be required to maintain cap integrity along with long-term groundwater monitoring.

Alternative 3 - Protection of Human Health and the Environment

Ra-226 would be a continuing long-term source of radon gas generating a dose of 136 mrem/yr in the absence of institutional controls, which does not meet one of the ARARs. Institutional controls would be needed to ensure that radon abatement systems are a requirement for any structure built at the Site.

Institutional controls for the disposal area would be required to prevent the degradation of the cap or excavation into disposal cell as well as to ensure radon mitigation techniques are employed for future residential development. Failure to maintain the institutional controls could jeopardize future protection of human health and the environment. In the event of institutional control failure, RESRAD predicts a dose of 136 mrem/yr to a residential receptor due to radon emanation from Ra-226 below the cap.

Alternative 3 - Compliance with ARARs

Alternative 3 complies with the ARARs listed on Table 18, with the exception of groundwater requirements and the radon standard. If the institutional controls failed, the expected dose would exceed 100 mrem/yr. Groundwater radionuclide activities and metals concentrations would be expected to decrease with time because the source material is controlled. Short-term restrictions on groundwater use coupled with a limited groundwater-monitoring program would be needed to meet ARARs. Long-term groundwater monitoring would be required for the disposal area.

Alternative 3 - Long-term Effectiveness and Permanence

If the cap is maintained, the alternative(s) would be effective; however, permanence is more difficult to predict. Using the 1,000-year life recommended by 40 CFR §192.02, it would be difficult to anticipate the permanence of the remedy. Although cap designs are advertised as having life spans of this magnitude, there are no existing examples of this type of performance. A number of claims are made about caps providing a radon barrier but this is highly dependent on maintaining moisture content. Semiarid climates make prescribed moisture content difficult to maintain.

Alternative 3 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 addresses the toxicity (reduces bioavailability) and mobility of the material through encapsulation, but the volume is not reduced. Alternative 3 addresses the mobility and toxicity. There would be no volume reduction.

Alternative 3 – Short-Term Effectiveness

Soil relocation activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Alternative 3 potentially would generate additional air particulate because of mixing and grinding operations. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. RESRAD-predicted worker doses and risks associated with soil handling activities would essentially be the same as those predicted for alternative 2. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment.

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.
A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and supplies to the Site (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or counties). A small incremental increase in risk is associated with transportation of equipment and supplies through the neighborhood.

Alternative 3 - Implementability

The technical feasibility of material encapsulation and onsite disposal with an engineered cap relies on the use of conventional technology. Necessary equipment and supplies are readily available for implementation of this alternative. This technology has been used successfully on a number of sites.

The alternative is administratively feasible, but long-term institutional controls for the disposal area must be considered. Permits may be required for onsite disposal, although they would take considerable time to obtain.

Alternative 3 - Cost

Cost elements associated with Alternative 3 include engineering, material excavation and consolidation, construction of the disposal cell, geosynthetic materials, import of clay and barrier layer rock, installation of the cap, re-grading of the Site, installation of the groundwater monitoring wells around the repository, long-term maintenance and inspection of the cap, and long-term groundwater monitoring. Assuming only the cost for 100 years of annual and more robust five year inspections of the disposal cell the cost is estimated to be $660,000. In addition to the above net present value cost, there is a cost associated with the loss in property value because of the remaining contaminants and the land use restrictions ($0.37 million). Groundwater cost are not considered here but will be addressed in a separate RI/FS for OU1. The estimated schedule for Alternative 3 is about seven months.

Alternative 3 - State Acceptance

The School is unlikely to accept an onsite disposal alternative. Problems associated with onsite disposal at the Shattuck Chemical Superfund Site in nearby Denver may reduce CDPHE acceptance. CDPHE has stated in meetings that it will not support an onsite disposal remedy.

Alternative 3 - Community Acceptance

Comments received during the open house conducted by the School in 2010 indicated that local residents preferred the off-site disposal of the material. In addition, considerable time would be needed for public meetings and to subsequently address any and all community concerns.

Alternative 4: Onsite Solidification and Placement into an Above-Grade Repository

The stockpiled soil would be consolidated for this option and disposed of onsite using solidified matrix (soil/concrete/cement kiln dust,/fly ash or other reagent mixture) with an engineered cap constructed over the top. An estimated 1,400 cy of soil would be solidified. Alternative 4 consolidates all soils with radionuclides above DCGLs and metals above proposed residential soil standards.

Alternative 4 would begin with the solidification operation preparation. The required equipment would be mobilized to the Site and required materials would be stockpiled. A properly sized area would be graded to hold the total volume of the consolidated material and reagent mixture. A clay liner base would be installed followed by a geosynthetic liner. The affected soil would then be sorted for use in the process. After the solidification has been completed, the area would be re-graded and a second engineered clay and/or geosynthetic liner will be placed over the cell (encapsulating the material) and a cap will be installed using the material from an offsite location. Fill would need to be placed over the remaining site to bring the area to a useable grade and to control stormwater. A groundwater monitoring network would need to be placed around the solidified matrix.

Institutional controls would include deed restrictions for the Site, requiring radon mitigation for all structures as well as maintenance requirements for the 1 acre of land affected by the solidified matrix. Deed restrictions associated with the solidified matrix would include limiting construction activities and excavation and ensuring the integrity of the cap. Although construction has been allowed for some capped sites, it makes cap maintenance problematic. In accordance with 40 CFR §192.02(a), a long-term maintenance plan would be required to maintain cap integrity along with long-term groundwater monitoring.

Alternative 4 - Protection of Human Health and the Environment

Residual Ra-226 would be a continuing source of radon gas. Institutional controls are needed to ensure that radon abatement systems are a requirement for building construction at the Site. In the absence of institutional controls, RESRAD predicted a dose of 133 mrem/yr to an urban resident due to radon emanation into the house. The urban resident is not assumed to be a user of Site groundwater. Drinking water for the urban resident is supplied from a public water supply. The data set for the RESRAD model was generated from analytical results of samples collected from the soil stockpiles for waste characterization purposes.

Institutional controls for the disposal area would be required to prevent the degradation of the cap or excavation into the solidified structure or disposal cell as well as to ensure radon mitigation techniques are employed for future residential development. Failure to maintain the institutional controls could jeopardize future protection of human health and the environment.

Alternative 4 - Compliance with ARARs

Alternative 4 complies with the ARARs listed on Table 18, with the exception of groundwater requirements and the radon standard. If the institutional controls failed, the expected dose would exceed 100 mrem/yr. Groundwater radionuclide activities and metals concentrations would be expected to decrease with time once the source material is controlled. Short-term restrictions on groundwater use coupled with a limited groundwater-monitoring program would be needed to meet ARARs and provide unrestricted use of areas not affected by the disposal cell. Long-term groundwater monitoring would be required for the disposal area.

Alternative 4 - Long-term Effectiveness and Permanence

If the cap is maintained, the alternative would be effective; however, permanence is more difficult to predict. Using the 1,000-year life recommended by 40 CFR §192.02, it would be difficult to anticipate the permanence of the remedy. The solidified material would be more resistant to damage than the disposal cell, but loss of the cap would be problematic. Although cap designs are advertised as having life spans of this magnitude, there are no existing examples of this type of performance. A number of claims are made about caps providing a radon barrier but this is highly dependent on maintaining moisture content. Semiarid climates make prescribed moisture content difficult to maintain. The long-term integrity of the solidified matrix for Alternative 4 also is uncertain. Recent problems at the Shattuck Site in Denver demonstrate this.

Alternative 4 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 addresses the toxicity (reduces bioavailability) and mobility of the material through treatment (solidification), but the volume actually increases (typically 20 percent or more) due to the addition of reagents. Alternative 4 addresses the mobility and toxicity. There would be no volume reduction.

Alternative 4 – Short-Term Effectiveness

Excavation activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Alternative 4 potentially would generate additional air particulate because of mixing and grinding operations. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. RESRAD-predicted worker doses and risks associated with soil handling activities would essentially be the same as those predicted for alternative 2. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment.

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.

A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and supplies to the Site (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or counties). A small incremental increase in risk is associated with transportation of equipment and supplies through the neighborhood.

Alternative 4 - Implementability

The technical feasibility of material solidification and placement of an engineered cap over the top relies on the use of conventional technology. Necessary equipment and supplies are readily available for implementation of this alternative. This technology has been used successfully on a number of sites but failures have occurred because of improper determination of the necessary mix of soil and concrete. Pilot tests would be necessary to determine the proper mixture, but these tests can be misleading if there is significant soil heterogeneity.

The alternative is administratively feasible, but long-term institutional controls for the disposal area must be considered. Permits may be required for onsite disposal, and these could take considerable time to obtain.

Alternative 4 - Cost

Cost elements associated with Alternative 4 include engineering, bench testing, material excavation and consolidation, geosynthetic materials, imported clay, mobilization and demobilization of the equipment needed to produce the solidified structure, materials, installation of the cap, re-grading of the Site, installation of the groundwater monitoring wells, long-term maintenance and inspection of the cap, and long-term groundwater monitoring. Assuming only the cost for 100 years of annual and more robust five year inspections of the disposal cell the cost is estimated to be $660,000. In addition to the above net present value cost, there is a cost associated with the loss in property value because of the remaining contaminants and the land use restrictions ($0.37 million). Groundwater cost are not considered here but will be addressed in a separate RI/FS for OU1. The estimated schedule for Alternative 4 is about eight months.

Cost breakdown data for each alternative are provided in Tables 15 and 16.

Alternative 4 - State Acceptance

The School is unlikely to accept an onsite disposal alternative. Recent problems associated with onsite disposal with the Shattuck Chemical Superfund Site in nearby Denver and other reasons may reduce CDPHE acceptance. CDPHE has stated in meetings that it will not support an onsite disposal remedy.

Alternative 4 - Community Acceptance

Comments received during the open house conducted in 2010 by the School indicated that local residents preferred offsite removal of the material.

Implementability

Alternative 1, no action/institutional controls, is relatively easy to implement.

Alternatives 2, 3, and 4 are technically feasible. Each alternative involves standard construction and earth-moving techniques. Alternative 4 has the most uncertainty because a reagent/soil mixture would need to be determined. Proper installation of a disposal cell can be problematic (Alternatives 3 and 4). Alternatives 2, 3, and 4 are sensitive to weather conditions especially during the winter months. Inclement weather conditions will reduce the ability to work efficiently. Wet or frozen soils typically require additional handling time depending on the type of equipment used. Compaction operations are especially problematic when soils are wet or frozen. Weather also can affect the placement of material at offsite disposal locations.

Cost

Costs are assessed below and include the following:

- Capital costs, including both direct and indirect costs;
- Annual operation and maintenance costs; and
- Net present value of capital and operation and maintenance costs.

Detailed Cost Estimate

Cost estimates were prepared for each of the remedial alternatives considered for implementation. Detailed cost estimates for each alternative are provided in Appendix F of the 2011 RI/FS. The summarized cost information for each alternative is presented in Table 15. Detailed cost information for the offsite disposal alternatives were provided by the disposal facility. A number of vendors were contacted for actual cost bids for specific tasks such as transportation, surveying, geotechnical testing, liner installation and consumables. Average industry costs were used for solidification equipment, monitoring well installation, and equipment rental.

Table 15
Cost Information for Each Alternative

Cost Breakout	Alternative Cost (in thousands of dollars)			
	1	2	3	4
Mobilization/demob	$0.00	$52	$89	$113
Construction Cost	$0.00	$88	$985	$669
Equipment Cost	$0.00	$34	incl. w/const.	incl. w/const.
Reclamation Cost	$0.00	$15	$47	$50
Disposal Cost	$0.00	$68	$0.00	$0.00
Engineering Cost	$0.00	$0.00	$66	$72
Long Term O & M (Groundwater only, will be addressed in separate RI/FS)	$0.00	$0.00	$660	$660
Closure Report	$0.00	$32	$57	$64
Total	$0.00	$289	$1,926	$1629
Rank	1	2	4	3
Ratio to Least Expensive	na	1	6.6:1	5.6:1

Based on an appraisal performed on behalf of the Colorado School of Mines in December 2003 (Dyco Real Estate, Inc., December 17, 2003) the value of the entire six acre CSMRI Site (without the Parfet/Golden property – Parfet/Golden property consists primarily of the previously described treed portion of the Site) was $2.4 million when considered for its highest and best use (i.e., residential development). Using the Zillow Market Index, residential home prices in Golden, Colorado have increased 3.4% between December 2003 and October 2011. The essentially unchanged median home price between 2003 and 2011 indicates that the property value assigned in 2003 is likely still within the range of error for the property value today. However, this value would be for a site that never had any contamination. A “stigma” factor would need to be applied to the highest and best use value. For purposes of comparison, a 20-percent stigma value was applied to the property. Application of the stigma value would result in an estimated property value of $2.2 million or about $367,000/acre. The appraisal considered the property to be of no marketable value if contamination remained on Site and it were to be utilized solely for recreational use. A new appraisal was not performed because the potential for lost property value is viewed as incidental to the evaluation of the remedial alternatives. This is based on the fact that the Site has been reduced from six acres to its current size of two acres, and it is unlikely that the parcel of land on the flood plain is developable.

A partial property value loss would be applied to Alternatives 3 and 4 for the loss of a percentage of land at the upper terrace area where the waste would have to be placed (disposal area). Table 16 summarizes the effect of including those costs. The addition of the property value does not change the relative ranking of the alternatives: Alternative 2 is still the most cost-effective alternative. A copy of the original Site appraisal document was included in Appendix I of the 2004 RI/FS.

Table 16
Cost Information for Each Alternative including Stigma Value
(in millions of dollars)

Alternative and Description	Cost from Spreadsheet	Property Value Loss	Total Cost
1 - No Action	0	0	0
2 - Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	0.289	0.0	.0.289
3 - Leave Stockpile Material Onsite and design/build a Below-Grade Repository	1.24	.367	1.61
4 - Onsite solidification and Placement into an Above-Grade Repository	.969	.367	1.34

State acceptance
The School and CDPHE prefer the offsite disposal alternative (Alternative 2). Onsite disposal is opposed by CDPHE.

Community acceptance
The local community prefers offsite disposal (Alternative 2). Onsite disposal is not supported. The PRPs who submitted public comments to the 2011 RI/FS and proposed plan support offsite disposal. No person has opposed offsite disposal.

K. Principal Threat Wastes

The principal threat wastes (i.e., the source materials) are radionuclides and metals in the surface and subsurface soils. Only Alternatives 3 and 4 provide for treatment of these wastes through solidification and/or containment in a cell. Given the high cost and technical uncertainties of Alternatives 3 and 4 in comparison to Alternative 2, Alternative 2 is the preferred alternative.

L. Selected Remedy

The preferred alternative presented in the 2011 Revised RI/FS was the offsite disposal of the affected material at a solid waste landfill, with ongoing groundwater monitoring and an environmental covenant for groundwater. The purpose of this document, the ROD, is to notify interested parties of the selected remedy and provide information about the decision process. The selected remedy is offsite disposal at a solid waste landfill.

Summary of Rationale for the Selected Remedy
Alternative 1 is not protective, does not comply with ARARs, and is the least likely to be accepted by CDPHE, the School, and the local community. Alternatives 3 and 4 meet most ARARs and are protective, but have long-term maintenance and monitoring issues, technical uncertainty, and elevated costs. Alternative 2 is the selected option because of the elimination of maintenance and monitoring, elimination of uncertainties, and the lowest cost. Alternative 2 also is the selected alternative of CDPHE, the School, the local community, and the PRPs who commented. Foothills Landfill is the selected facility for final disposition of the stockpiled material because it is less expensive and has less administrative uncertainty than the other landfill options.

The selected alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing and modifying criteria. The selected alternative was selected over the other alternatives because it is expected to achieve substantial and long-term risk reduction for the Site. It also is the least expensive remedy. The alternative also allows residential future use for more of the property than the other alternatives, which is the most protective and preferred type of cleanup, and is a reasonably foreseeable use for the Site. Uranium in the groundwater in the vicinity of the Site is expected to return to acceptable values after the stockpile is disposed of offsite. Eliminating the risk of re-contamination of the groundwater and exposing users of the property is better than leaving contaminated materials on Site with the uncertainty of remedy failure over 1,000 years. Alternative 2 reduces the risk within a reasonable timeframe and at reasonable cost (compared to the other alternatives). Alternative 3 does not comply with ARARs if there were a failure of institutional controls while Alternative 4 does comply with ARARs is there is such failure.

Alternative 2 is protective of human health and the environment, complies with ARARs, is cost effective, and provides a long-term effective and permanent solution.

Description of the Selected Remedy

Alternative 2 involves the transportation and disposal of the stockpile at the local Foothills Landfill.

The Foothills Landfill route from the Site starts from the Site and continues north along Washington Street and then State Route 93 to the landfill. The total distance is about 8 miles. Trucks hauling the material will be loaded on Site and will be screened for radioactivity prior to entry and exit from the Site.

Quarterly groundwater monitoring will be performed for two years (from the time of the RI). Monitoring will include measurement of field parameters (dissolved oxygen, pH, specific conductance, and temperature) and the collection and analysis of groundwater samples for identified contaminants of concern, primarily uranium.

The following eight tasks break down components of the remedy. Table 17 includes estimated costs for each task.

Table 17
Summary of Estimated Remedy Costs

Task	Cost (in dollars)
Complete Update of Administrative Record	$25,000
Prepare Work Plans	$40,000
Load Out Soil	$30,000
Transport Soil to Landfills and Disposal Fees	$120,000
Collect and Analyze Confirmatory Samples	$5,000
Site Stabilization and Demobilization	$8,500
Prepare Final Report	$40,000
Groundwater Monitoring and Analysis	$185,000
Total Estimated Cost	**$453,500**

Task 1 – Update the Administrative Record
Make hard-copy reproductions of all field notes, field drawings, log books, chain of custody documents, sample logs, sample results, transmittal letters, project-related correspondence, subcontractor invoices, and subcontractor daily report forms and turn over this package to the School for inclusion in the Administrative Record.

Task 2 – Work Control Documents
Prepare, submit for review, and finalize the documents necessary to complete the soil disposal. Documents will provide details of the material load-out, transportation, health and safety requirements, CDOT requirements, and final confirmatory sampling. These documents will conform to State requirements as well as applicable federal regulations and will consist of the following.

> **Material Transportation Plan –** This plan will detail the traffic control devices employed to safely transport the material off-site. Also included in this document will be any and all CDOT requirements as well as any requirements of the receiving landfill.
> **Material Disposal Work Plan –** This document will detail the equipment, personnel, procedures, and project controls that will be implemented during the soil disposal. Also detailed will be the collection and analysis of confirmatory samples from beneath the stockpile to verify all contaminated soil was disposed.
> **Health and Safety Plan –** This document will detail the procedures, engineering controls, and personnel monitoring required ensuring the health and safety of all persons involved with this effort.

All final documents will be submitted to the School in both hard copy and PDF formats.

Task 3 – Soil Load-out
Perform load-out of soil and site stabilization work. Soil will be loaded into haul trucks and transported to the Foothills Landfill. Collect and maintain all records, including radiological scans of each truck prior to departure from the site. The number of trucks used each day will be optimized to match the turnaround time so as to eliminate stand-by time. Soil load out will be performed so as to match the hours of operation of the receiving disposal facility.

Besides each truck being radiologically screened prior to each departure from the site, trucks will be scanned for unrestricted release at the end of the project. All earth moving equipment will also be screened for unrestricted release prior to demobilization from the site. This procedure will ensure that no contamination or contaminated soil remains in or on the equipment.

Task 4 – Soil Shipment and Disposal Fees
Transport soil to disposal facility. Departing trucks will be prepared and monitored in a similar manner to those during the bulk soil disposal in 2007.

Per the Allied Waste Foothills Landfill risk assessment, GPS readings of the location of the soil within the landfill will be taken to ensure compliance with the risk document.

Task 5 – Confirmatory Sampling
Design and implement a cost effective sampling program to demonstrate to the CDPHE and all interested parties the complete excavation and transportation of all stockpiled soils from the site.

Task 6 – Site Stabilization and Demobilization
Design and oversee the implementation of a site stabilization program, with direct input from Golden stormwater control personnel that protects the waters of the State from impacts due to stormwater runoff. Remove from site all equipment and support facilities involved with this project.

Task 7 – Final Remedial Implementation Report
Prepare a final report consistent with the NCP that details the remedy implementation and request for license termination. The report will also detail all remaining groundwater monitoring and deed restrictions. All documentation generated during the soil disposal will be included as well as final confirmatory sample results from beneath the soil stockpile. The report will be submitted to the CDPHE for their approval.

Task 8 – Groundwater Monitoring
Conduct regularly scheduled sampling of the groundwater monitor wells and inspection of the storm-water control system.

Expected Outcomes of Selected Remedy
Upon completion of the offsite disposal, the soils and surface of the Site will be available for all uses with the implementation of the environmental covenant placing use restrictions on groundwater and a radon mitigation system for residential structures. The remedy will improve environmental and ecological conditions at the Site: contaminants will be taken away from the Site. It is also desirable for socio-economic and community reasons to have the Site returned to a broader range of beneficial uses. Backfill material is required for storm water control and safety.

The soil DCGLs will be met upon completion of the remedy. RESRAD predicted a dose of 16.1 mrem/yr above background after the stockpile is taken to an offsite facility and DCGLs have been attained for the Site soils. A radon mitigation system will reduce exposure levels below 25 mrem/yr and 15 mrem/yr, which also attains CERCLA's acceptable carcinogenic risk range

The status of the groundwater is uncertain. At this time it may not be used for drinking. Five groundwater wells exceed the 30 ug/L MCL for uranium. The success of excavating and taking the contaminated soil offsite on improving groundwater quality is unknown. It will not be determined until after sufficient monitoring has occurred. Groundwater will be addressed as a separate operable unit in the future after a two-year monitoring period.

M. Statutory Determinations

The purpose of this section is to provide a brief, site-specific description of how the selected remedy satisfies the statutory requirements of CERCLA §121 (as required by NCP §300.430(f)(5)(ii)). The following sections describe how Alternative 2 meets the nine criteria.

The selected remedy requires the off-site disposal of the stockpiled contaminated soil. After remedy implementation an environmental covenant would be put in place requiring radon mitigation systems for future residences, and continued groundwater monitoring for the near future.

Overall protection of human health and the environment
RESRAD predicted a dose of 16.1 mrem/yr above background after the stockpile is taken to an offsite facility and DCGLs have been attained for the Site soils. A radon mitigation system will reduce exposure levels below 25 mrem/yr and 15 mrem/yr, which also attains CERCLA's acceptable carcinogenic risk range.

Groundwater quality at the down gradient Site boundaries, along Clear Creek (which is a drinking water source), exceeds the MCL and groundwater protection standard for uranium. Continued monitoring of the groundwater is necessary to determine the effect that offsite disposal of soils above DCGLs has on improving groundwater quality and returning it to below the MCL. It is anticipated that offsite disposal will eliminate the source material that is causing the exceedance of the MCL and groundwater protection standard. But, that cannot be determined until after additional groundwater monitoring is performed and an opportunity to see the effects over a critical time period.

Alternative 2 is protective of human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
Alternative 2 complies with ARARs identified in the 2011 RI/FS for Site soils. The current groundwater and surface-water monitoring program will continue and is designed to demonstrate the effectiveness of the remedy in attaining the groundwater MCL and groundwater protection standard for dissolved uranium over the long term.

The principal ARARs are presented in Table18.

Table 18
ARARs for Soils, Groundwater, and Surface Water

Media	Site-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered
Soil	10 CFR §20.1402 and 1403, NRC Standards for Protection Against Radiation, Radiological Criteria for Unrestricted and Restricted Use – Requires that exposures to onsite receptors do not result in a dose in excess of 25 mrem/yr plus ALARA, and 100 mrem/yr if institutional controls fail for restricted use cleanups.
	6 CCR 1007-1, §4.61.2 – 4.61.3, Colorado Radiation Control regulations, Radiological Criteria for Unrestricted and Restricted Use - Requires that exposures to onsite receptors do not result in a dose in excess of 25 mrem/yr plus ALARA, and 100 mrem/yr if institutional controls fail for restricted use cleanups.
	EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, August 1997 – Uses a risk-based approach to recommend limiting exposures to less than 15 mrem/yr for NCP compliance.
	EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, July 22, 1996 – Initial discussion that resulted in the recommended 15 mrem/yr dose.

Table 18
ARARs for Soils, Groundwater, and Surface Water

Media	Site-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered
	EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, Directive No. 9200.4-25, February 1998 – Clarification of the use of 40 CFR 192 for the development of radionuclide soil standards.
	40 CFR §192.12, Subpart B; 6 CCR 1007-1, Part 18 Appendix A —Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites, Standards – Limits radium-226 surface activities (up to 15 cm) to 5 pCi/g and subsurface activities (greater than 15 cm) to 15 pCi/g. For occupied or habitable structures it requires that remedial efforts result in an annual radon decay product concentration (including background) of less than 0.2 WL (in any case the concentration should not exceed 0.3 WL). And interior gamma shall not exceed background by more than 20 microroentgens per hour.
	40 CFR §192.02, Subpart A; 6 CCR 1007-1, Part 18 Appendix A —Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites, Standards – Specifies that the control of residual radioactive materials and their listed constituents shall be designed to be effective for up to 1,000 years, and in any case for at least 200 years. Also imposes limits on acceptable radon air concentrations and requires groundwater monitoring when necessary.
	CDPHE, Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011
	EPA Region 9 Memorandum, Memorandum, Region 9 Regional Screening Levels (formerly PRGs), updated as of June 2011– Describes risk-based approach to soil cleanup and provides table of preliminary remediation goals for soils. CDPHE recommends the use of these levels for materials not covered by their proposed soil standards.
Groundwater and Surface Water	40 CFR §192.02 Standards, §192.03 Monitoring, §192.04 Corrective Action, Subpart A—Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites – Details the requirements specific to groundwater.
	40 CFR §192.20 Guidance for implementation, §192.20 Criteria for applying supplemental standards, Subpart C – Implementation – Additional groundwater requirements.
	40 CFR 141.11, National Primary Drinking Water Regulations, Maximum contaminant levels for inorganic chemicals.
	40 CFR 141.15, National Primary Drinking Water Regulations, Maximum contaminant levels for uranium, radium-226, radium-228, and gross alpha particle radioactivity in community water systems.
	40 CFR 141.51, National Primary Drinking Water Regulations, Maximum contaminant level goals for inorganic contaminants.
	40 CFR 141.55, National Primary Drinking Water Regulations, Maximum contaminant level goals for radionuclides.
	5 CCR 1003-1, Colorado Primary Drinking Water Regulations, Maximum contaminant levels for uranium and arsenic, among other substances.
	5 CCR 1002-41, Colorado Department Of Health, Water Quality Control Commission Regulation No. 41, Basic Standards for Ground Water.
	5 CCR 1002-8, §3.1.1, Colorado Department Of Health, Water Quality Control Commission Regulation No. 8, Establishes basic standards, anti-degradation standard, and system for classifying State water.
	5 CCR 1002-38, Colorado Department Of Health, Water Quality Control Commission Regulation No. 38, Classifications And Numeric Standards South Platte River Basin (including Clear Creek as a tributary), Laramie River Basin, Republican River Basin, Smoky Hill River Basin.

Table 18
ARARs for Soils, Groundwater, and Surface Water

Media	Site-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered
	5 CCR 1002-31, Colorado Department Of Public Health And Environment, Water Quality Control Commission, Regulation No. 31, The Basic Standards And Methodologies For Surface Water, Section 31.8 Antidegradation Rule.

Long-Term Effectiveness and Permanence
Disposal at an offsite landfill successfully and permanently mitigates the potential long-term effects associated with the elevated metals and radionuclides on the Site. This alternative provides all uses for the soils at the Site. The permanence and long-term effectiveness with regard to groundwater will be evaluated over time with ongoing monitoring.

Reduction of Toxicity, Mobility, or Volume through Treatment
All of the material is disposed at an offsite landfill where it can be properly managed, and no treatment would be expected. Treatment is not used because it is not as reliable as offsite disposal, it is more expensive, it may lead to more contamination of groundwater, and it may expose individuals onsite given the 1,000 year time horizon.

Short Term Effectiveness
Excavation and transport activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation; however, this will be minimized through the use of dust suppression techniques. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. Assumptions included direct access to the soil when in fact workers will spend most of their time in enclosed excavation equipment.

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.

A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and material (i.e., traffic accidents). Access to State Highway 6 which was used during the implementation of the 2007 remedy would limit the risk to the immediate neighborhood. This option may no longer be available, however, due to the expansion of School athletic facilities and the construction of a new pedestrian/bike path. A somewhat higher risk is associated with transportation of the material through the neighborhood. This risk is regarded as low due to the limited number of truckloads (less than 100) that would be required to transport the material to the landfill.

Based on worker risk assessment evaluations, there is a small incremental short-term risk of potential adverse health consequences during a transportation-related accident. Exposure times would result in a risk significantly lower than the $1x10^{-6}$ threshold (assumes cleanup operations are completed within 24 hours and the only receptors are emergency response personnel). Typically, access to transportation-related spills is not allowed to members of the general public. An accident involving an overturned truckload of affected material would have a small environmental risk if the material were to enter a drainage channel. However, the environmental risk would be limited because of the nature of the material (soil versus liquid) and containment procedures followed by emergency response teams.

Truck traffic on 11thStreetmayresult in public annoyance due to short-term noise and vibration in a residential area. Some operational noise would be expected that could be noticed by nearby residents.

Cost

Cost elements associated with Alternative 2 include loading the stockpiled material into trucks, transportation to the selected landfill, and re-grading and site reclamation. After the offsite disposal is performed, the two years of groundwater monitoring will be continued to confirm the effectiveness of the excavation in the flood plain, which will be assessed during the OU2 groundwater RI/FS at a later date. The total present value of these cost elements is estimated at $0.72 million. Property values are not significantly affected by this alternative because the land will be available for residential and other use with an environmental covenant. The estimated schedule for Alternative 2 is about six weeks from the time the CDPHE approves the selected remedy.

State Acceptance

The School and CDPHE prefer offsite disposal, Alternative 2.

Community Acceptance

Comments received during an open house and a public meeting indicated that local residents preferred Alternative 2 and they supported remedy implementation in December. PRP written comments support Alternative 2.

Five-Year Review Requirements

The environmental covenant, with its annual certification of compliance requirements eliminates the need for a five-year review for soils, which contain Ra-226 above background at levels that do not allow for unrestricted uses. A five-year review may be required for groundwater. It will depend upon the results of the continuing groundwater monitoring program scheduled to run through end 2012.

N. Documentation of Significant Changes from Preferred Alternative of Proposed Plan

There are no significant changes from the preferred alternative identified in the Proposed Plan. The Proposed Plan for the CSMRI Site was released for public comment November 8. 2011. The Proposed Plan identified Alternative 2, offsite disposal at a solid waste landfill, as the Preferred Alternative for soil remediation. The School reviewed all written and oral comments submitted during the public comment period. It was determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

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PART 3: RESPONSIVENESS SUMMARY

A. Stakeholder Issues and Lead Agency Responses

The 2011 RI/FS was published in November 2011. Only some PRPs submitted written substantive comments. A couple of oral comments were made during the public meeting by local residents.

A summary of the comments received and the School's responses to the comments are listed below.

Local Resident Comments
Residents stated during the public meeting that they supported the Proposed Plan and the schedule to dispose of the soil in December.

School Response:
No response is necessary.
PRP Comments
One commentator writing on behalf of some PRPs wrote a letter to say that those PRPs support Alternative 2 and an appropriate environmental covenant.

School Response
No substantive response is necessary.

B. Technical and Legal Issues

These issues were addressed in Part IIIA. No expansion on them is necessary here.

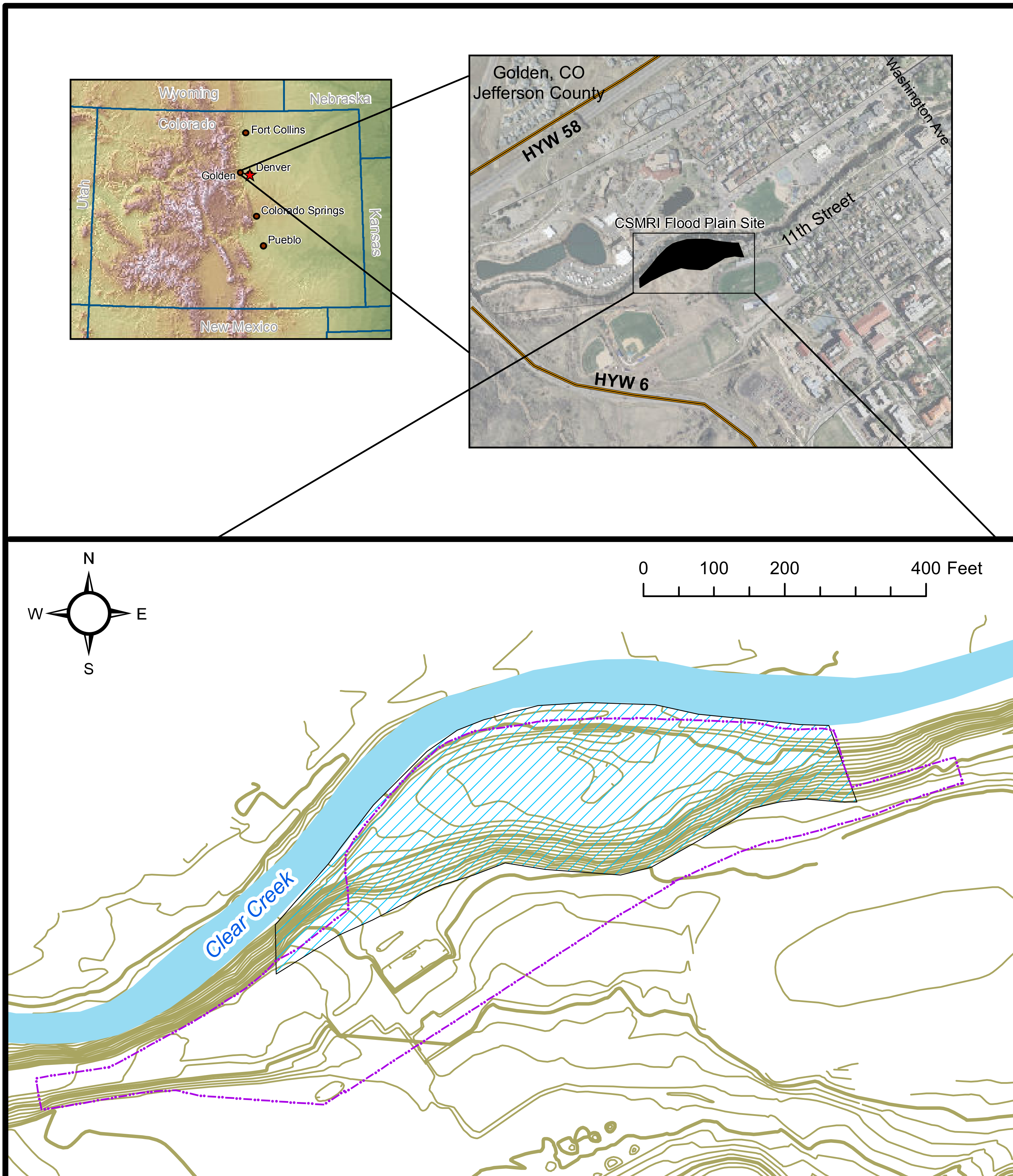

Figure 1-1

CSMRI Site Location Map
Flood Plain Area

Explanation

CSMRI Flood Plain Site

Fences

Topography (2Ft Intervals)

Topography (10Ft Intervals)

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

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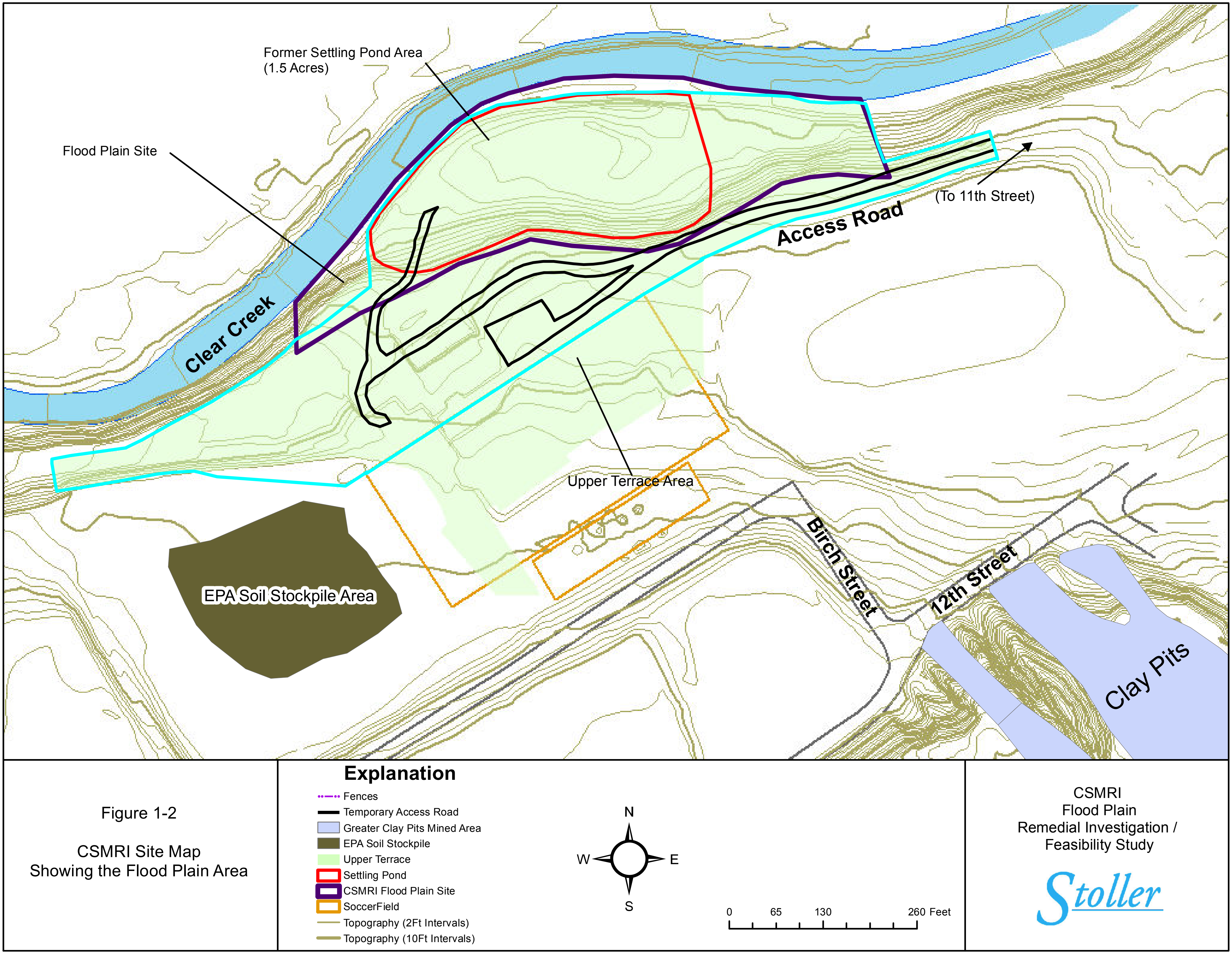

Figure 1-2

CSMRI Site Map
Showing the Flood Plain Area

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

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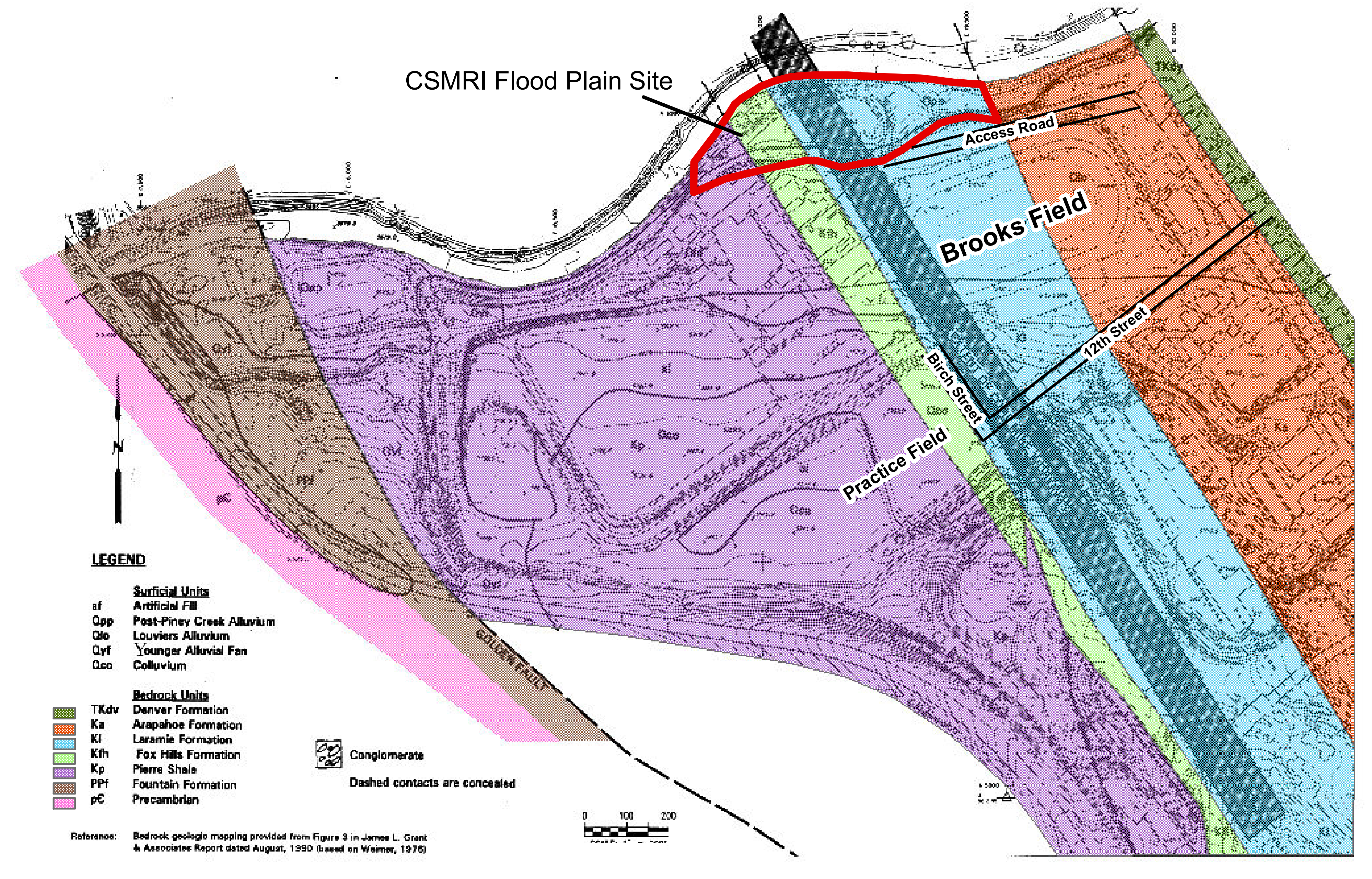

Figure 2-3

Bedrock Geologic Map of Site

CSMRI Flood Plain Remedial Investigation / Feasibility Study

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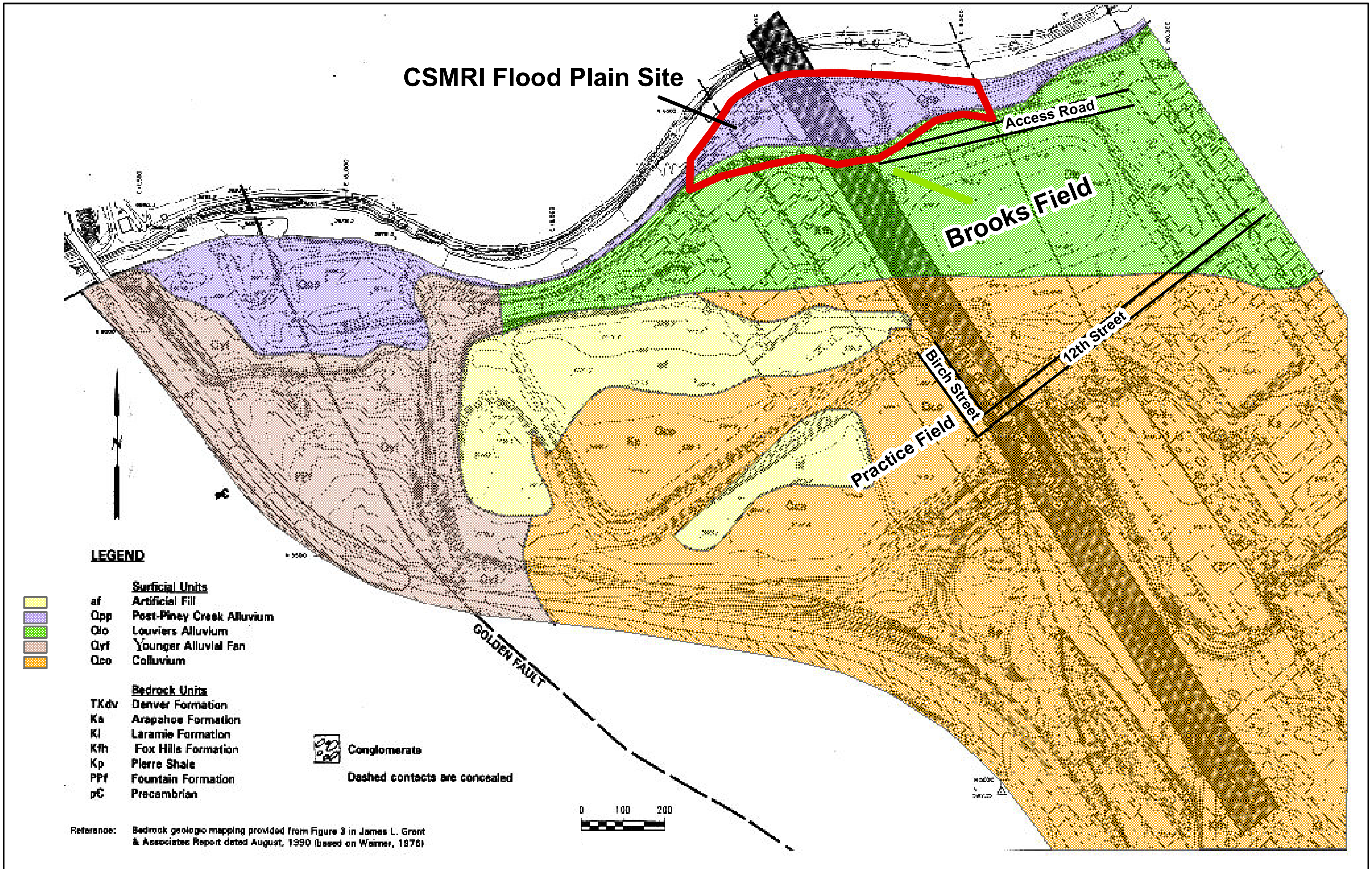

Figure 2-4

Surficial Geologic Map of Site

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

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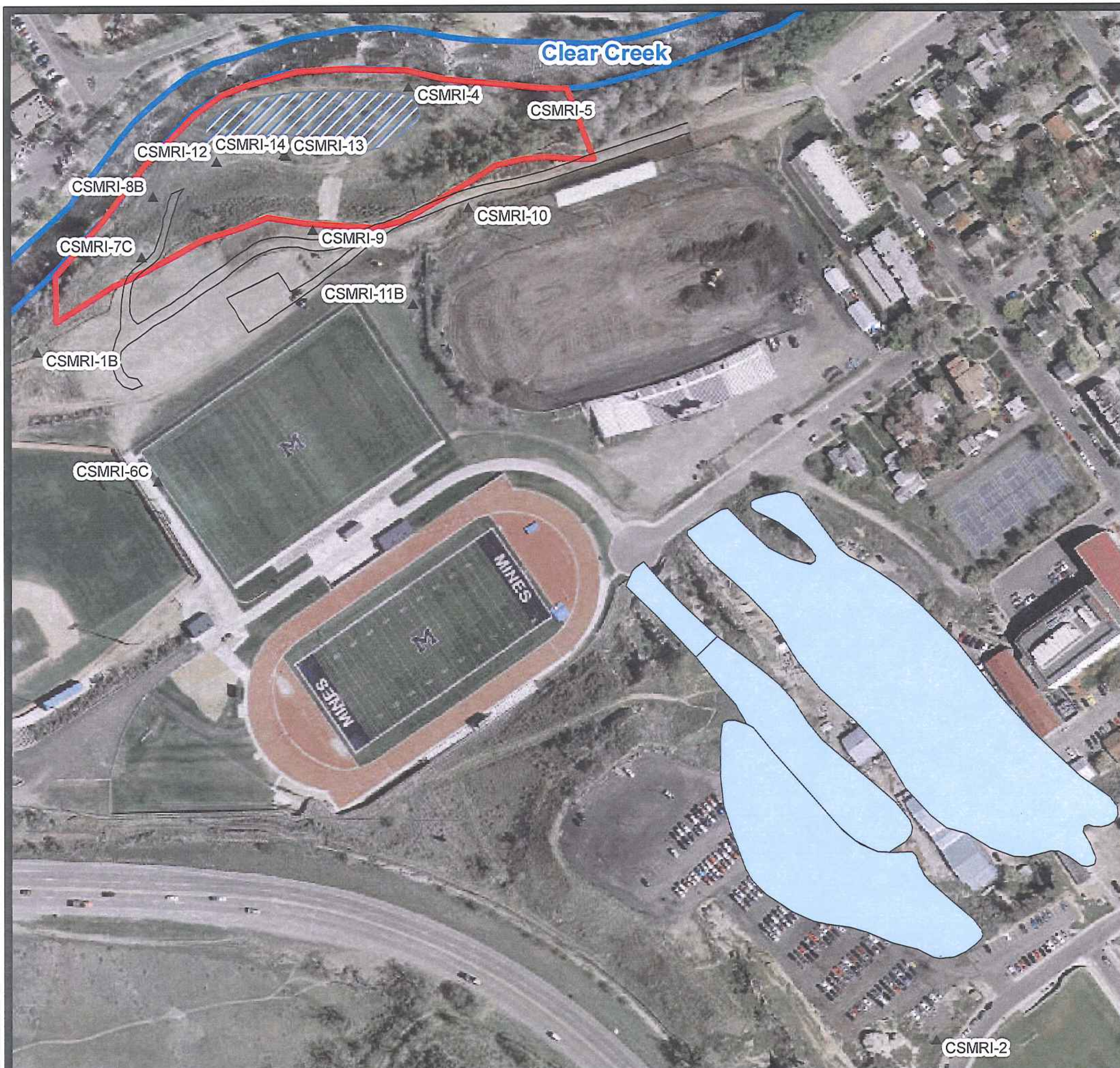

Figure 6

Existing Monitor Wells

CSMRI
Flood Plain
Record of Desicion

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