United States
Environmental Protection
Agency

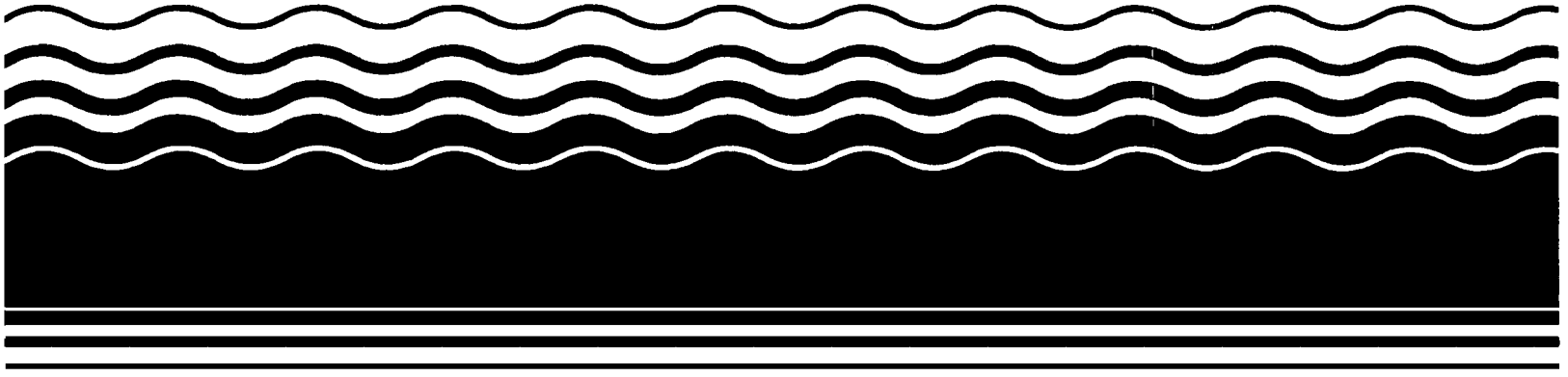
Office of
Emergency and
Remedial Response

EPA/ROD/R08-92/063
January 1992

EPA

Superfund Record of Decision:

Denver Radium (Operable Unit 8), CO



NOTICE

The appendices listed in the index that are not found in this document have been removed at the request of the issuing agency. They contain material which supplement, but adds no further applicable information to the content of the document. All supplemental material is, however, contained in the administrative record for this site.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/ROD/R08-92/063	2.	3. Recipient's Accession No.
4. Title and Subtitle SUPERFUND RECORD OF DECISION Denver Radium (Operable Unit 8), CO Ninth Remedial Action - Final			5. Report Date 01/28/92 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Orgainization Name and Address			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460			13. Type of Report & Period Covered 800/000 14.

15. Supplementary Notes

PB93-964405

16. Abstract (Limit: 200 words)

The 10-acre Denver Radium (Operable Unit 8) site is a former radioactive extraction industry located in Denver, Denver County, Colorado. The site is divided into three areas: the 5.9-acre S.W. Shattuck Chemical Inc. (Shattuck) property; the 4.3-acre railroad right-of-way west of the Shattuck property; and nearby "vicinity" properties. Land use surrounding the site is predominantly industrial, with some residential areas. The site is located within the South Platte River drainage basin. From the 1920's to 1984, the Shattuck property was used to treat and process molybdenum ores, radium slimes, and uranium compounds and ores. The railroad right-of-way has been operational daily since the late 19th century with a spur to the Shattuck property. As a result of extensive mining and processing, radioactive contaminated soil is widely scattered resulting in a variety of radiation levels. A U.S. Bureau of Mines report led EPA to field research 31 radioactive sites in Denver and Denver County. In 1983, EPA conducted remedial investigations, which detected elevated levels of radon gas and gamma radiation. A 1989 emergency removal action at one of the vicinity properties included radon mitigation measures. This ROD addresses a final remedy for radioactive contaminated debris, ground water, and soil, as OU8. Future RODs will address the

(See Attached Page)

17. Document Analysis a. Descriptors

Record of Decision - Denver Radium (Operable Unit 8), CO
Ninth Remedial Action - Final
Contaminated Media: soil, debris, gw
Key Contaminants: inorganics (asbestos), metals (arsenic, lead), radioactive metals

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) None	21. No. of Pages 100
	20. Security Class (This Page) None	22. Price

EPA/ROD/R08-92/063
Denver Radium (Operable Unit 8), CO
Ninth Remedial Action - Final

Abstract (Continued)

remaining contaminated media at 11 OUs not addressed by the previous seven RODs at the Denver Radium sites. The primary contaminants of concern affecting the soil, ground water, and debris are inorganics, including asbestos; metals, including arsenic and lead; and radioactive materials.

The selected remedial action for this site includes demolishing and decontaminating buildings, tanks, and equipment onsite; temporarily storing debris from vicinity properties onsite at the Shattuck area, pending either offsite disposal and/or scrap recycling, or salvaging of debris; disposing of asbestos-containing material from buildings offsite; conducting pilot scale treatability studies during remedial design to optimize stabilization design; excavating and transporting 5,000 cubic yards of radium-contaminated soil from the railroad rights-of-way and 6,000 cubic yards from the vicinity properties; consolidating these with 38,500 cubic yards of soil from the Shattuck property, and treating the soil onsite using cement-based stabilization; placing a cap over the stabilized material, and revegetating the area; filling previously excavated areas with clean fill; testing for, remediating and disposing of any RCRA hazardous waste offsite; allowing the ground water to naturally attenuate; monitoring ground water and air; and implementing institutional controls, including deed, land, and ground water use restrictions. The estimated present worth cost for this remedial action is $26,600,000, which includes an annual O&M cost of $120,000.

PERFORMANCE STANDARDS OR GOALS:

Chemical-specific soil action levels are based on Nuclear Regulatory Commission and Department of Energy standards for Radium-226, exceeding 5 pCi/g above background in the top 15 cm of soil and 15 pCi/g above background in any layer below the top 15 cm; thorium-230, 42 pCi/g; uranium; 75 pCi/g; and risk-based standards for arsenic 160 mg/kg; selenium 490 mg/kg; and lead 540 mg/kg.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

COLORADO DEPARTMENT OF HEALTH

RECORD OF DECISION

DENVER RADIUM SITE
OPERABLE UNIT #VIII
DENVER, COLORADO

JANUARY 28, 1992

DENVER RADIUM SITE
OPERABLE UNIT VIII

DECLARATION FOR THE RECORD OF DECISION

DENVER RADIUM SITE
OPERABLE UNIT VIII

DECLARATION FOR THE RECORD OF DECISION

Site Name and Location

Denver Radium Site Operable Unit VIII

Denver, Colorado

Statement of Basis and Purpose

This decision document presents the selected remedial action for Operable Unit VIII of the Denver Radium Site in Denver, Colorado, chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and, to the extent practicable the National Contingency Plan (NCP), 40 CFR Part 300. This decision document explains the factual and legal basis for selecting the remedy for this site.

The Colorado Department of Health has been the lead agency for the remedial investigation and feasibility study and both concurs with and recommends the selected remedy to the U.S. Environmental Protection Agency (EPA). The information supporting this remedial action decision is contained in the administrative record for this site.

Assessment of the Site

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

Description of the Remedy

The Denver Radium Superfund Site consists of 11 operable units involving a total of more than 40 properties located within the city of Denver which are contaminated by radioactive residues as a result of mineral processing operations.

Operable Unit VIII encompasses the property located at 1805 South Bannock Street, adjacent, and vicinity properties.

The selected remedy for Denver Radium Site Operable Unit VIII is stabilization and disposal of the contaminated soils on-site. The selected remedy addresses the principal threats at the site, which are associated with radium contaminated soils and include radon gas

emissions and direct exposure to gamma radiation. The remedy entails:

* Demolition and off-site disposal of existing facilities on the 1805 South Bannock property.

* Excavation, consolidation, stabilization, and on-site disposal of an estimated 50,000 cubic yards of contaminated soils. Stabilization of the contaminated soils entails mixing the soils with a cement additive resulting in a concrete-like material which physically and chemically stabilizes the contaminated soils. Stabilization will reduce the mobility of contaminants and radon emanation. A cap will be placed over the stabilized materials to protect the materials from erosion and weathering, and to shield gamma radiation.

* Institutional controls, maintenance, and monitoring will be used to supplement the remedy and to assure the protectiveness of the selected remedy is maintained into the future.

Ground water contamination is addressed through source control using stabilization to immobilize contaminants. Attenuation of the contaminated ground water plume will be monitored. The ground water portion of the remedy may be subject to future modification if remedial objectives for ground water are not attained within a reasonable time frame.

Statutory Determinations

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost effective. This remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable. It satisfies the statutory preference for remedies that employ treatment to reduce toxicity, mobility, or volume, as a principal element.

Because this remedy will result in hazardous substances remaining on-site above health based levels, and because the ground water remedy involves source control and attenuation of existing contamination over time, a review will be conducted no less than every five years after commencement of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

Jack W McGraw

Regional Administrator (Region VIII)
U.S. Environmental Protection Agency

1/28/92
Date

Thomas P. Looby

Director, Office of the Environment
Department of Health
State of Colorado

1/27/92
Date

DENVER RADIUM SITE
OPERABLE UNIT VIII

DECISION SUMMARY FOR THE RECORD OF DECISION

DENVER RADIUM SITE OPERABLE UNIT VIII
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DENVER RADIUM SITE
OPERABLE UNIT VIII
DECISION SUMMARY FOR THE RECORD OF DECISION

1.0 SITE NAME, LOCATION AND DESCRIPTION

Denver Radium Site Operable Unit VIII is located in southwest Denver, northeast of the intersection of Evans Avenue and Santa Fe Drive. The site includes the 5.9 acre S.W. Shattuck Chemical Company, Inc. ("Shattuck") property located at 1805 South Bannock Street, the 4.3 acre railroad rights-of-way located to the west of the Shattuck property, and nearby ("vicinity") properties located within the area bounded by South Santa Fe Drive (U.S. Highway 85), South Broadway, Jewell Avenue, and Mexico Avenue (Figure 1-1).

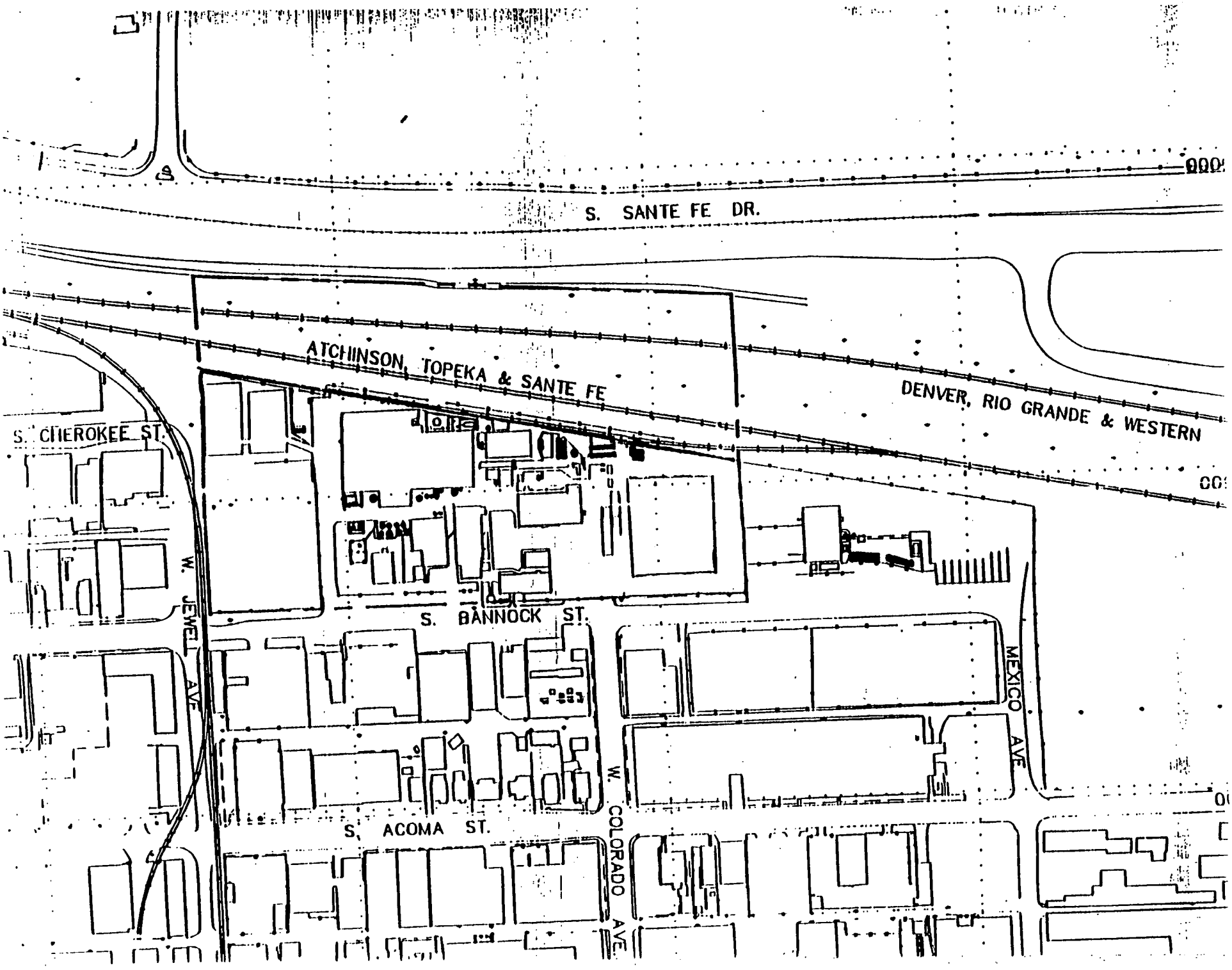
South Santa Fe Drive borders the site west of the railroad rights-of-way. Overland Park Golf Course lies west of South Santa Fe Drive. The South Platte River forms the west boundary of the golf course.

The topography of the area surrounding the site is relatively flat and generally slopes to the north and west toward the South Platte River. Most of the area, with the exception of the Overland Park Golf Course, is typical urban development ranging from industrial to residential.

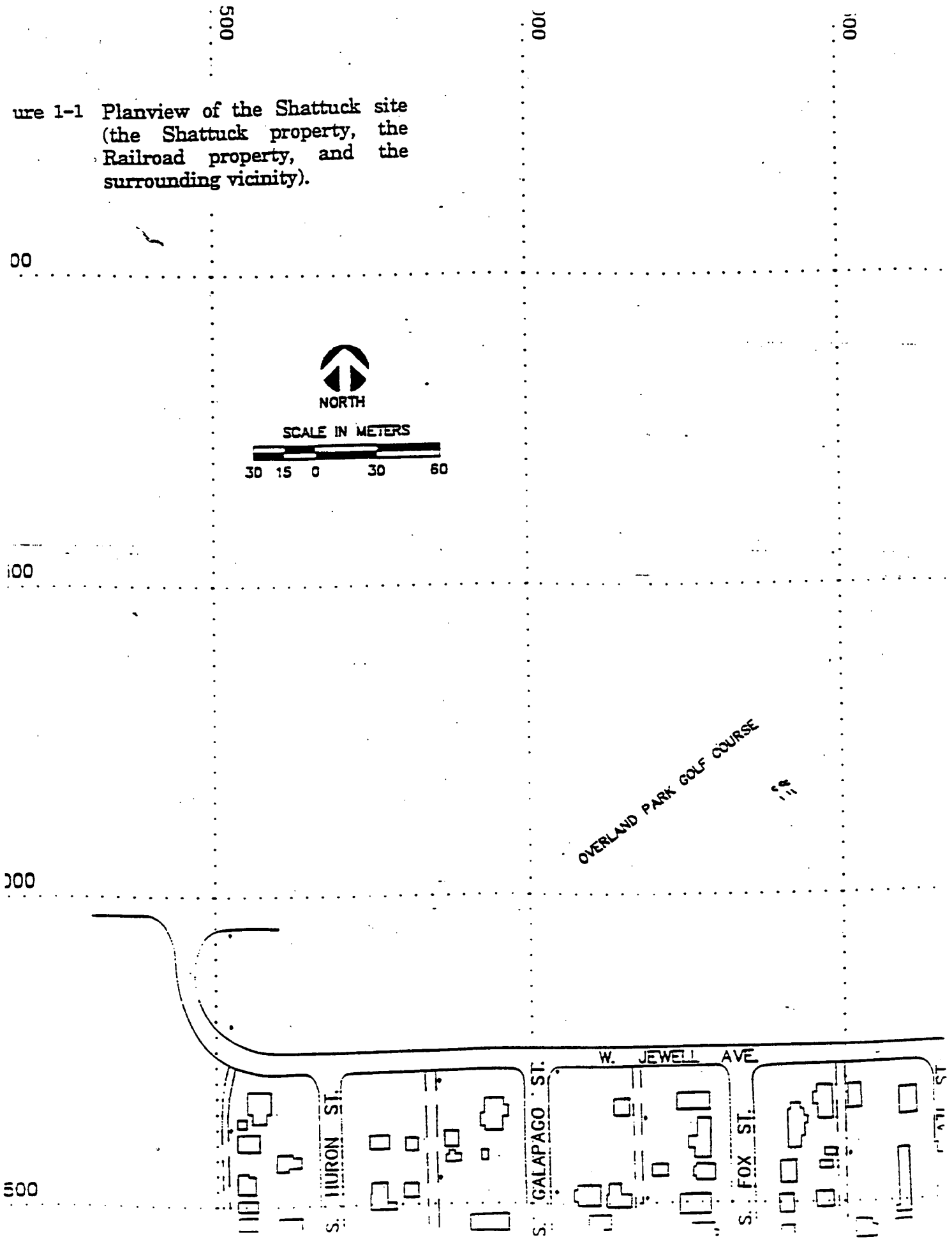
The Shattuck property is located in an area of the city designated as commercial/industrial. Land use within two blocks south and east of the Shattuck property is predominantly industrial, although some residential use exists. The industrial/commercial area extends from the Shattuck property north for several blocks following the railroad lines.

Residential areas are located three blocks east of the Shattuck property (east of South Broadway), and south of the golf course and west of South Santa Fe Drive (approximately 600 feet southwest of the Shattuck property). Water for domestic use is supplied to the area by the Denver Water Department.

The site is located within the drainage basin of the South Platte River, which is located approximately 3000 feet west of the site. A shallow unconfined aquifer exists below the Operable Unit VIII site. The shallow aquifer is perched on bedrock and merges with the alluvial aquifer beneath the floodplain of the South Platte River. The ground water is not used as a drinking water source. Ground water for Operable Unit VIII generally flows west across the site and then northwest toward the South Platte River. Ground water contours within the alluvium indicate that the South Platte River adjacent to the Overland Park Golf Course is a gaining reach that receives discharge from the ground water system.


S. SANTE FE DR.
ATCHINSON, TOPEKA & SANTE FE
DENVER, RIO GRANDE & WESTERN
S. CHEROKEE ST.
W. JEWEL AVE.
S. BANNOCK ST.
MEXICO AVE.
S. ACOMA ST.
W. COLORADO AVE.

ure 1-1 Planview of the Shattuck site (the Shattuck property, the Railroad property, and the surrounding vicinity).



The facilities located on the Shattuck property (figure 1-2) include: six permanent buildings; miscellaneous storage sheds; underground storage facilities; above ground storage tanks; process equipment and piping; and asphalt and concrete paving. Surface water on the site generally follows the topography toward the northwest. A runoff catchment basin, which captures a limited amount of surface runoff, is located on the Shattuck property south of Building 6. The rail lines are elevated above the surrounding grade, impeding the flow of surface runoff, and creating some ponding during rainfall.

2.0 SITE HISTORY AND ENFORCEMENT ACTIVITIES

2.1 INTRODUCTION

The Denver Radium Site had its beginnings with the United States radium, vanadium, and uranium extraction industry of the early 1900s. The United States Bureau of Mines, in cooperation with private industry, established the National Radium Institute (NRI), which successfully developed radium processing in the Denver area.

In 1979, EPA noted a reference to the NRI in a 1916 United States Bureau of Mines Report. Subsequent field research revealed the presence of thirty-one radioactive sites within the City and County of Denver. After identifying these properties, the Radiation Control Division of the Colorado Department of Health (CDH) notified affected property owners of the presence of radiologic contamination. Pursuant to a cooperative agreement with EPA, CDH initiated engineering assessments of the majority of the identified properties. In October 1981, the Denver Radium Site was placed on the Superfund Interim Priorities List. The Site was included on the National Priorities List on September 8, 1983.

In December 1983, EPA began a remedial investigation to determine the nature and extent of the contamination present on those properties which the State did not previously study, as well as several additional properties where contamination was suspected. With the additional properties, the Denver Radium Site totals over forty properties.

Because of the complexity of the Denver Radium Site, response actions were divided into operable units based primarily upon site conditions and location. The Site was grouped into eleven operable units, the property located at 1805 South Bannock Street being Operable Unit VIII. In April 1986, EPA published the Denver Radium Site Remedial Investigation report, which addressed all eleven operable units.

Further information was needed prior to proceeding with the cleanup of Operable Unit VIII. The EPA notified potentially responsible parties of the opportunity to perform a detailed remedial

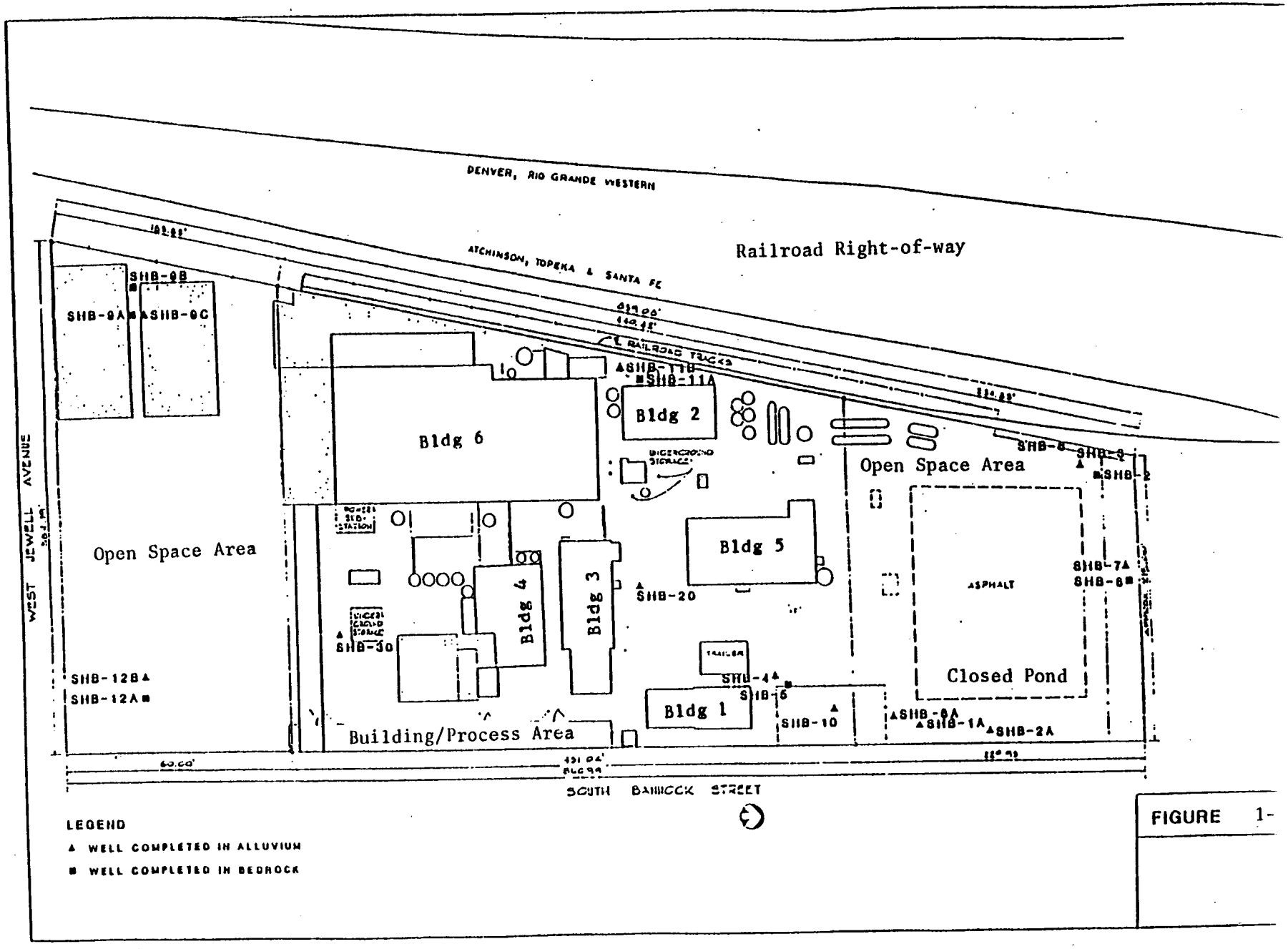

DENVER, RIO GRANDE WESTERN
ATCHINSON, TOPEKA & SANTA FE
Railroad Right-of-way
RAILROAD TRACKS
SHB-9B
SHB-9A
SHB-9C
SHB-11B
SHB-11A
Bldg 6
Bldg 2
UNDERGROUND STORAGE
Open Space Area
SHB-8
SHB-3
SHB-2
Open Space Area
POWER SUB-STATION
Bldg 5
Bldg 4
Bldg 3
SHB-20
ASPHALT
SHB-7A
SHB-6
UNDERGROUND STORAGE
SHB-30
TRAILER
SHB-4
SHB-5
Closed Pond
SHB-12B
SHB-12A
Bldg 1
SHB-10
SHB-8A
SHB-1A
SHB-2A
Building/Process Area
WEST JEWELL AVENUE
SOUTH BANNOCK STREET
LEGEND
WELL COMPLETED IN ALLUVIUM
WELL COMPLETED IN BEDROCK

FIGURE 1-

investigation and feasibility study for Operable Unit VIII. Although negotiations with the S.W. Shattuck Chemical Company, Inc. took place, no potentially responsible parties elected to perform the studies. In conjunction with a grant from the EPA, CDH performed the remedial investigation and feasibility study which support this Record of Decision.

CDH began the remedial investigation in November 1988. Since 1979, CDH, the EPA, and Shattuck have conducted various studies of the site media, which have included a substantial number of soil and ground water samples. The remedial investigation study evaluated the existing data and included collection of additional data to characterize the nature and extent of the contamination.

During the remedial investigation, additional radiological contamination was discovered to the east and north of the 1805 South Bannock property. The extent of this contamination was evaluated by the EPA. These areas are referred to as the "vicinity properties" in this Record of Decision and the supporting documentation. In August 1989, EPA conducted an emergency removal action at one of the vicinity properties, which involved installation of an active radon reduction system in order to reduce excessively high levels of radon present at a commercial property.

A surface impoundment utilized as an evaporation pond when the 1805 South Bannock facility was in operation was excavated and closed in 1987, pursuant to a consent decree between CDH and the S.W. Shattuck Chemical Company, Inc.

2.2 OPERATIONAL HISTORY

The Shattuck property has been the location of several mineral processing operations including the processing of tungsten ores, carnotite ores (for uranium and vanadium), radium slimes, molybdenum ores, and depleted uranium. The contamination of the site is due to the historical use of the site for various mineral processing operations. Approximate time frames for some of the processing activities that have taken place at the site follow:

- 1920s - Treatment of molybdenum ores and extraction of ferric vanadate from vanadium and uranium ores or by-products.
- 1930s - Processing of radium slimes for recovery of radium, as well as production of radium salts, uranium compounds and other rare mineral products from carnotite ores.
- 1940s - Processing of uranium compounds and molybdenum.
- 1950s - Processing of uranium ores.

1960s - Unknown

1970s & 1980s - Processing of uranium compounds, molybdenum and rhenium.

From 1969 to 1984, the operations at the facility consisted primarily of processing molybdenite for the recovery of molybdenum compounds, with recovery of rhenium as a by-product. In addition, a small batch operation for the production of uranium products from depleted uranium existed. Operations at the Shattuck facility ceased in 1984. The Shattuck property is currently fenced, and access is restricted by security provided by Shattuck.

The railroad rights-of-way include two rail lines which have been operating since the late 19th century. In addition, a rail spur onto the Shattuck property was in place by 1915. The two rail lines are utilized as main lines through the Front Range and handle a total of about twenty to thirty general freight and coal trains per day. The east rail line is located on property owned by the Atchison, Topeka & Santa Fe Railway Company, and the western line is owned by the Denver & Rio Grande Western Railroad Company. At present, one line is utilized for northbound traffic and the other is utilized for southbound traffic.

3.0 HIGHLIGHTS OF COMMUNITY PARTICIPATION

The public participation requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), sections 113(k)(2)(B)(i-v) and 117 were met in the remedy selection process.

A mailing list of persons interested in Operable Unit VIII was developed to keep the public informed as to the progress on the Operable Unit VIII remedial investigation/feasibility study. CDH has published fact sheets at project milestones to inform the public of opportunities for input. CDH representatives have also met with a local community group and the local City Council representative to discuss the project.

A draft of the remedial investigation report was made available to the public in December 1990. The comments received on the draft report were considered in revising the document. However, formal response to these comments was not prepared. The formal public comment period for the remedial investigation, baseline risk assessment, feasibility study, and proposed plan began March 29, 1991, and closed May 29, 1991. A public meeting summarizing the remedial investigation/feasibility study and soliciting comments from the public on the proposed plan was held on April 11, 1991. Notice of the public meeting was sent to persons on the mailing

list and was published in the Denver Post and the Rocky Mountain News on April 7, 1991. A transcript of the public meeting is available in the Administrative Record. A summary of significant comments, written or oral, and EPA's and CDH's response is contained in Appendix B of this Record of Decision.

The Decker Branch of the Denver Public Library, located at 1501 South Logan, has been used as a repository in order to make the primary documentation available at a location close to the site. In addition, the administrative record is available at EPA and CDH offices in Denver.

This decision document presents the selected remedial action for the Denver Radium Site, Operable Unit VIII, Denver, Colorado, chosen in accordance with CERCLA, as amended by SARA, and to the extent practicable, the National Contingency Plan (NCP). The decision for the remediation of the site is based on the administrative record.

4.0 SCOPE AND ROLE OF OPERABLE UNIT WITHIN SITE STRATEGY

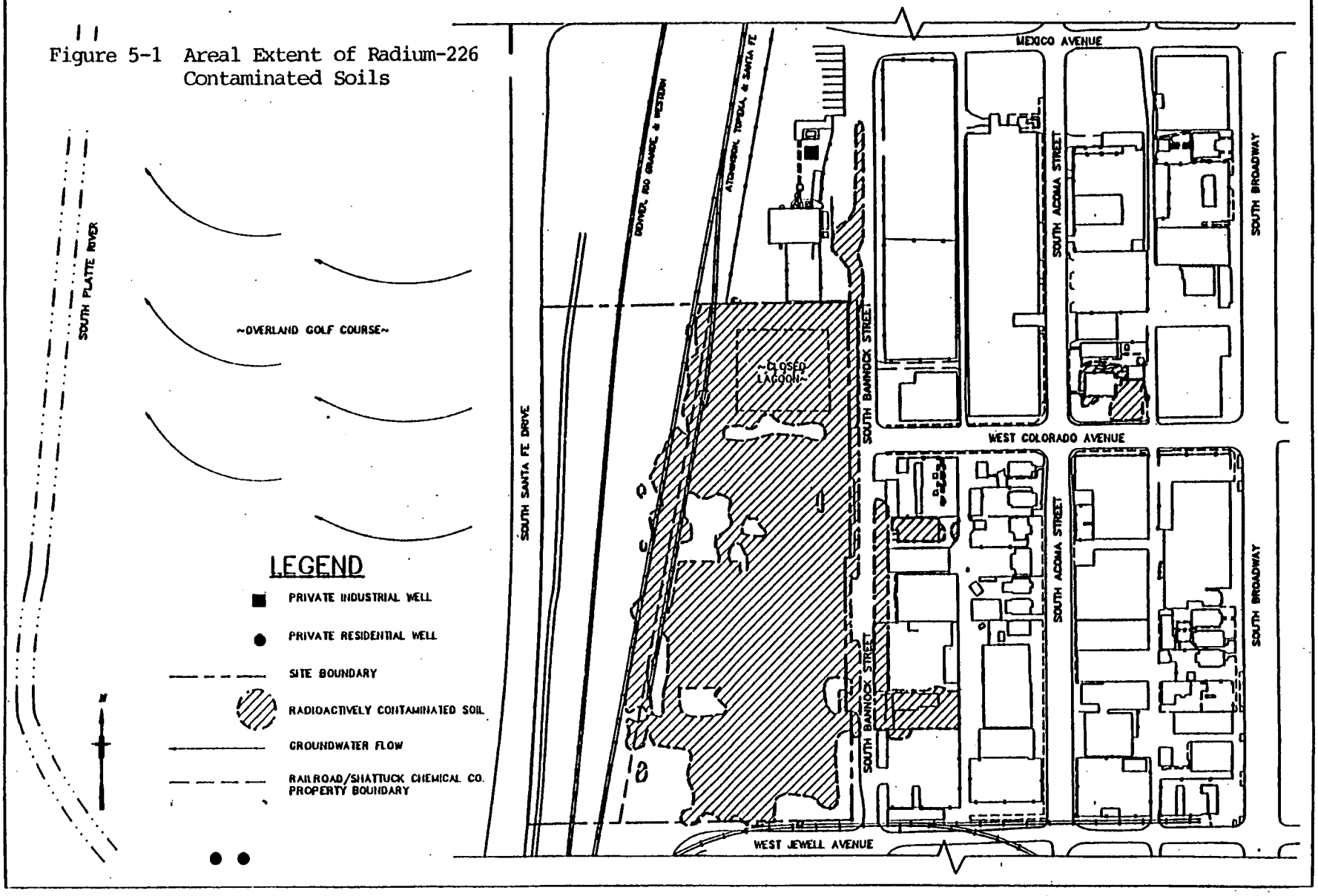
The Denver Radium Site consists of over 40 properties which are grouped into 11 operable units. The Operable Unit VIII Record of Decision is for the last of the operable units addressing radiologic contamination. The Records of Decision for the other operable units addressing radiologic contamination identified excavation and permanent off-site disposal as the ultimate remedy in each case, except Operable Unit VII. (Operable Unit VII includes sections of nine Denver streets where contaminated materials will be left in place based on the limited threat they pose to public health and the environment.) At the time the previous Records of Decision were issued, a permanent disposal site was not available. The Records of Decision incorporated various combinations of consolidation and temporary storage units until a permanent off-site repository would be available. Since that time, an off-site permanent repository has become available in Utah. Remedial action at these operable units is proceeding with a scheduled completion date of September 1992.

5.0 SUMMARY OF SITE CHARACTERISTICS

5.1. SOILS

Radiologically-contaminated soils have been identified on the Shattuck property, the railroad rights-of-way, and the vicinity properties. Figure 5-1 shows the areal extent of radium-226 contaminated soils. Areas are considered contaminated if the radium-226 concentration in soil exceeds 5 pCi/g above background in the top 15 cm of soil or 15 pCi/g above background in any layer below the top 15 cm (40 CFR 192.12).

Figure 5-1 Areal Extent of Radium-226 Contaminated Soils



Radioactive soil contamination on the Shattuck property covers approximately 230,000 square feet. The estimated volume of contaminated soil on this property is 38,500 cubic yards.

Radioactive soil contamination covers approximately 34,000 of the 187,000 square foot railroad rights-of-way. The volume of contaminated materials on the railroad rights-of-way is estimated to be greater than 4,500 cubic yards.

The volume of contaminated soil on the vicinity properties is estimated to total 6,000 cubic yards.

These estimates are based primarily on radium-226 contamination. Additional metals contamination including radioactive lead-210, thorium-230, and uranium, as well as non-radioactive metals such as lead and arsenic have also been identified in site soils. Based on radioactive equilibrium ratios and limited laboratory analysis, it is estimated that 500 cubic yards of the estimated volume on the Shattuck property would require remediation due to thorium-230 and uranium contamination. The majority of the additional contaminants are co-located with the radium-226 contamination and are expected to be addressed by cleanup of the radium-contaminated soils. The shaded areas on figure 5-1 show the location of the contaminated soils. Table 5-1 summarizes gamma radiation measurements and table 5-2 summarizes the sampling data for non-radiologic inorganic constituents.

5.1.1 Shattuck Property

Discussion of the Shattuck property is divided into three areas: (1) the buildings and process area located in the center of the property; (2) the open space areas to the north and south; and, (3) the closed evaporation pond which is located in the north open area of the property (see figure 1-2).

Buildings and process area:

The soils throughout most of the buildings and process area are contaminated. The highest measured one-meter gamma radiation exposure rate in this area was 2800 microroentgens/hour near the southeast corner of Building 6. Subsurface radiation data indicates depths ranging from one to nine feet, with an average depth of about 40 inches and an average equivalent radium-226 concentration of about 90 pCi/g.

Open space areas:

The open areas of the Shattuck property to the north and south of the buildings and process area generally exhibit contamination throughout the area except the southern area near the perimeter of the property, the area near the southwest corner of Building 6, and the areas east and south of the closed evaporation pond. Depth of

Table 5-1

SUMMARY OF RADIOLOGIC DATA

One meter gamma measurements
reported in microroentgen per hour

Outdoor Measurements

Location	low	high	mean	# of measurements
Process/buildings area	20	1460	85	75
Open areas north & south of process /buildings area	15	1300	67	138
Closed lagoon area	16	22	18	9
Railroad right-of-way	14	454	40	147
Overland Park Golf Course (background)			16.1	30

Indoor Measurements

Location	low	high	ave.
Building 1	21	290	41
Building 2	14	20	17
Building 3	20	450	70
Building 4	20	85	49
Building 5	20	50	29
Building 6	15	230	41

Table 5-2

Inorganics Sampled in Soils

Chemical	Average (mg/kg)	Maximum (mg/kg)	Frequency of Detection	Range of Sample Quantitation Limits (mg/kg)	Range of Detected Concentration (mg/kg)	Background Levels (mg/kg)
Aluminum	9121	23,600	10/10		2980 - 23600	12550
Antimony	7	26	7/10	1.6 - 1.9	3.5 - 26	1.7[1]
Arsenic	44	598	63/67	0.45 - 0.5	1.2 - 598	3.5
Barium	786	3340	10/10		22.3 - 3340	221
Beryllium	0.2	0.6	3/10	0.03 - 0.04	0.38 - 0.6	0.9
Cadmium	2.6	10.8	9/21	0.34 - 0.41	0.8 - 10.8	0.6
Calcium	12214	30500	10/10		874 - 30500	4935
Chromium	22	164	19/26	0.95 - 1.05	2.5 - 164	12.4
Cobalt	6	33	5/10	0.45 - 0.55	2 - 33	702
Copper	1220	7730	26/26		44 - 7730	26
Iron	18118	47600	10/10		7890 - 47600	17050

Table 5-2 (Cont.)

Chemical	Average (mg/kg)	Maximum (mg/kg)	Frequency of Detection	Range of Sample Quantitation Limits (mg/kg)	Range of Detected Concentration (mg/kg)	Background Levels (mg/kg)
Lead	297	1260	26/26		7.2 - 1260	54
Magnesium	2086	7440	10/10		793 - 7440	3145
Manganese	245	471	10/10		73 - 471	487
Mercury	2	47	15/26	0.05 - 0.35	0.2 - 47	0.05[1]
Nickel	28	106	10/10		7.6 - 106	10.1
Potassium	2113	9940	10/10		180 - 9940	3410
Selenium	152	7980	56/66	0.18 - 14.25	0.71 - 7980	0.22[1]
Silver	2.6	5.7	17/26	0.75 - 0.90	2.3 - 5.7	0.3[1]
Sodium	1088	5750	10/10		165 - 5750	256
Thallium	2.1	4.7	8/8		0.35 - 4.7	
Vanadium	1159	4190	24/24		14.1 - 4190	31
Zinc	167	432	10/10		35.6 - 432	90
Molybdenum	48800	48800	1/1		48800	

[1] The material was analyzed for but not detected. The associated numerical value is one-half the sample quantitation limit.

contamination for these areas ranges from 0.5 to over 14.5 feet with an average depth of about 39 inches and an average equivalent radium concentration of about 69 pCi/g.

Closed evaporation pond:

Direct gamma radiation measurements on the asphalt surface of the closed pond indicate no surface contamination in this area. Soil immediately beneath the asphalt cover exhibits essentially background concentrations of radioactive contaminants. However, radium-226 contamination exists from about 6 feet to about 7.5 feet below the surface over the western two thirds of the former pond area. Thorium-230 contamination is estimated to exist in this area from a depth of about 5.5 feet to approximately 8.5 feet.

5.1.2 Railroad Rights-of-Way

The 4,500 cubic yard estimate of contaminated soil on the railroad rights-of-way includes nearly the full length of the area between the east rail line and the Shattuck property, as well as some limited areas located to the west of the rail line. The estimated depth of contamination is 0.5 to 2.5 feet along the southern portion and 5 feet for the northern portion.

Although the soil directly beneath the rail line was not sampled, the data for the surrounding area indicate that radium contamination beneath the line is likely. The highest radium equivalent value measured in the railroad rights-of-way was 570 pCi/g.

5.1.3 Vicinity Properties

EPA performed the assessment of the vicinity properties after surface gamma scans indicated the presence of radioactivity on properties in the vicinity of the Shattuck property. The estimated volume of these materials is 6,000 cubic yards. The following is a summary of the primary deposits on the vicinity properties:

- The 1860 South Bannock Street property. Radium-contaminated soils are located beneath the floor slab of a building, the concrete driveway and parking area, and beneath an asphalt covered area extending beyond the property to the north and south. The deposit is approximately 2,700 cubic yards and extends to a depth of over eight feet. In August 1989, an emergency removal action was conducted at this property because of the very high levels of radon gas and decay products measured within the building. The removal action involved radon mitigation measures, including sealing slab joints and installing a vent system. Contaminated source materials were not removed.

o The area adjacent to the west side of South Bannock Street from approximately 1700-1830 South Bannock. The contaminated area consists of uncovered soil, as well as asphalt, concrete, driveways, and parking areas. The deposit includes approximately 1,300 cubic yards of radium-contaminated material ranging to a depth of over three feet.

o The 1822 South Bannock Street property. Radium-contaminated soil exists in the fill material beneath the concrete floor slab of a building and adjacent to the east side of the building. The deposit includes approximately 250 cubic yards of material and extends to a depth of approximately 2.5 feet.

o The 1788 South Acoma Street residential property. Radium-contaminated soil is limited to exterior soils and ranges to about two feet deep, with an estimated volume of 220 cubic yards.

o In addition, 1,100 cubic yards of radium-contaminated soils are estimated to exist beneath South Bannock Street. This estimate is based on adjacent investigations; investigation into the street was not performed because of the presence of numerous utility lines.

The remedial investigation did not attempt to appraise the extent of possible uranium and thorium-230 contamination for the railroad and vicinity properties. Based on the data from the Shattuck property, it is possible that the total amount of radiologically-contaminated soils requiring remediation would be higher than estimated because of radiological constituents other than radium-226 or lead-210. However, such additional materials will not influence the remedy selected in this record of decision.

5.2 FACILITIES

Buildings:

Based on procedures outlined in the Nuclear Regulatory Commission (NRC) Guide 1.86, radioactive contamination was identified in five of the six permanent buildings on the Shattuck property. The volume of the radiologically-contaminated material associated with the buildings is estimated at approximately 2,095 cubic yards. This estimate includes 100 percent of three of the buildings and the floor slabs of two of the buildings. At least one building is contaminated with depleted uranium.

The contamination of the buildings is associated with radioactive constituents which had been processed on the site. Radium-226 and uranium have been identified in building material samples. Based on visual inspection, radiologically-contaminated building materials which are suspected to contain asbestos are relatively abundant in two of the contaminated buildings, with minor amounts in a third building.

Asbestos-containing material which is not radiologically-contaminated was not identified but may exist in the three other buildings. Asbestos-containing building materials require special handling and disposal practices to prevent the inhalation of asbestos particles.

Tanks:

Direct radiation measurements showed elevated levels of total alpha activity for five tanks, indicating these tanks have been contaminated by the processing operations at the site. The averages of the total alpha activity on the five tanks are greater than the NRC Regulatory Guide 1.86 average. However, no maximum measurements exceeded the NRC maximum. The radioactive contamination associated with the tanks is at relatively low levels, and it is expected that the tanks can be adequately decontaminated.

5.3 AIR

Atmospheric contaminants of concern at the site consist primarily of radon, a radioactive gas produced by the decay of radium-226, and airborne thorium-230 particles associated with soil contamination.

Air investigations included indoor and outdoor measurements for radioactive contaminants and organic vapors. Of the six buildings on the Shattuck property, three have exhibited concentrations of radon gas and its decay products in excess of the EPA guideline of 0.02 working levels (WL), a measure associated with radon. Given the gamma radiation levels associated with two additional buildings, it is expected that two more of the six buildings may also periodically exceed the EPA guideline. Table 5-3 is a summary of the indoor air data for the Shattuck property.

Outdoor air monitoring exhibited low atmospheric concentrations of radioactive contaminants. Measurements of alpha activity and thorium-230 concentrations were in the 10^{-14} to 10^{-15} microcuries per milliliter range or lower. Air monitors attached to workers performing the remedial investigation yielded up to 10^{-12} microcuries alpha activity per milliliter for activities disturbing the soils.

The vicinity property upon which an emergency removal was performed to mitigate radon concentrations had very high radon concentrations (up to 4.6 working levels) prior to the removal action. The removal action has reduced radon levels; however, gamma radiation still poses a potential risk. Measurements of radon at other vicinity properties where radium-contaminated soils have been identified were not in excess of the EPA guideline of 0.02 working levels.

Table 5-3

Denver Radium Site Operable Unit VIII

On-site Indoor Air Summary

Building Number	Rn-222 Concentration Range (pCi/l)	Rn-222 Progeny Concentration Range (WL)	HNu (ppm)	Conditions	Data Source
1	13.1 - 27.6	0.048 - 0.092	< 1	Open	Versar, 1989
1	41.8 - 139.3	0.085 - 0.146	N/A	Closed	ARIX, 1982
2	< 0.6 - 1	0.002	< 1	Open	Versar, 1989
3	0.4 - 2.3	0.002	< 1	Open	Versar, 1989
3	4.0 - 14.8	0.012 - 0.038	N/A	Closed	ARIX, 1982
4	1 - 4.1	0.007	< 1	Open	Versar, 1989
4	4.5 - 5.4	0.014 - 0.019	N/A	Closed	ARIX, 1982
5	2 - 3.8	0.010	< 1	Open	Versar, 1989
6	0.5 - 1.4	0.002	< 1	Open	Versar, 1989

Indoor and outdoor measurements of organic vapors were less than the detection limit of approximately one part per million benzene equivalent.

5.4 GROUND WATER

Data from the supplemental monitoring system installed during the remedial investigation was used in conjunction with data from monitoring performed by the Shattuck Chemical Company to characterize ground water flow and quality for the site. Potentiometric surface maps (figure 5-2) prepared during the remedial investigation indicate that contaminated ground water from the site flows in a west to northwest direction from the site and is contained beneath the Overland Park Golf Course. The golf course obtains its water from ponds supplied from the South Platte River. There is no current use of ground water affected by the site. Contaminated ground water from Operable Unit VIII does not flow beneath the residential area located to the south of Overland Park Golf Course. Water for domestic use is supplied to the area by the Denver Water Department.

The flow system immediately below the site flows into a larger flow system associated with the South Platte River. The estimate of the ground water velocity is 0.51 feet/day beneath the site. At this rate, ground water takes an estimated 2.7 years to reach the eastern edge of Overland Park Golf Course. Beneath the golf course the hydraulic gradient increases dramatically as the shallow aquifer beneath the site drops into the valley that was carved by the South Platte River during the Pleistocene era (figure 5-3). The valley is now filled with alluvial sand and gravel. The velocity of the ground water increases through this section, with the total elapsed time for ground water to travel from the site to the South Platte River estimated to be slightly more than three years.

The on-site alluvial ground water is contaminated with gross alpha radioactivity and gross beta radioactivity in excess of Safe Drinking Water Act Maximum Contaminant Levels (MCLs), and uranium in excess of the range of proposed standards. The off-site alluvial aquifer downgradient from the site continues to exhibit significant concentrations which then fall off to background levels as the aquifer is diluted by the system underlying the Platte River. The primary radioactive contaminant in the ground water is uranium.

Volatile organic compounds were detected in concentrations above MCLs in an upgradient well, on-site wells, and downgradient off-site wells. Data from the upgradient well provide strong evidence that significant off-site sources of volatile organic compounds, specifically 1,1,1-trichloroethane, have affected ground water. Soil boring data indicate on-site sources of tetrachloroethene and

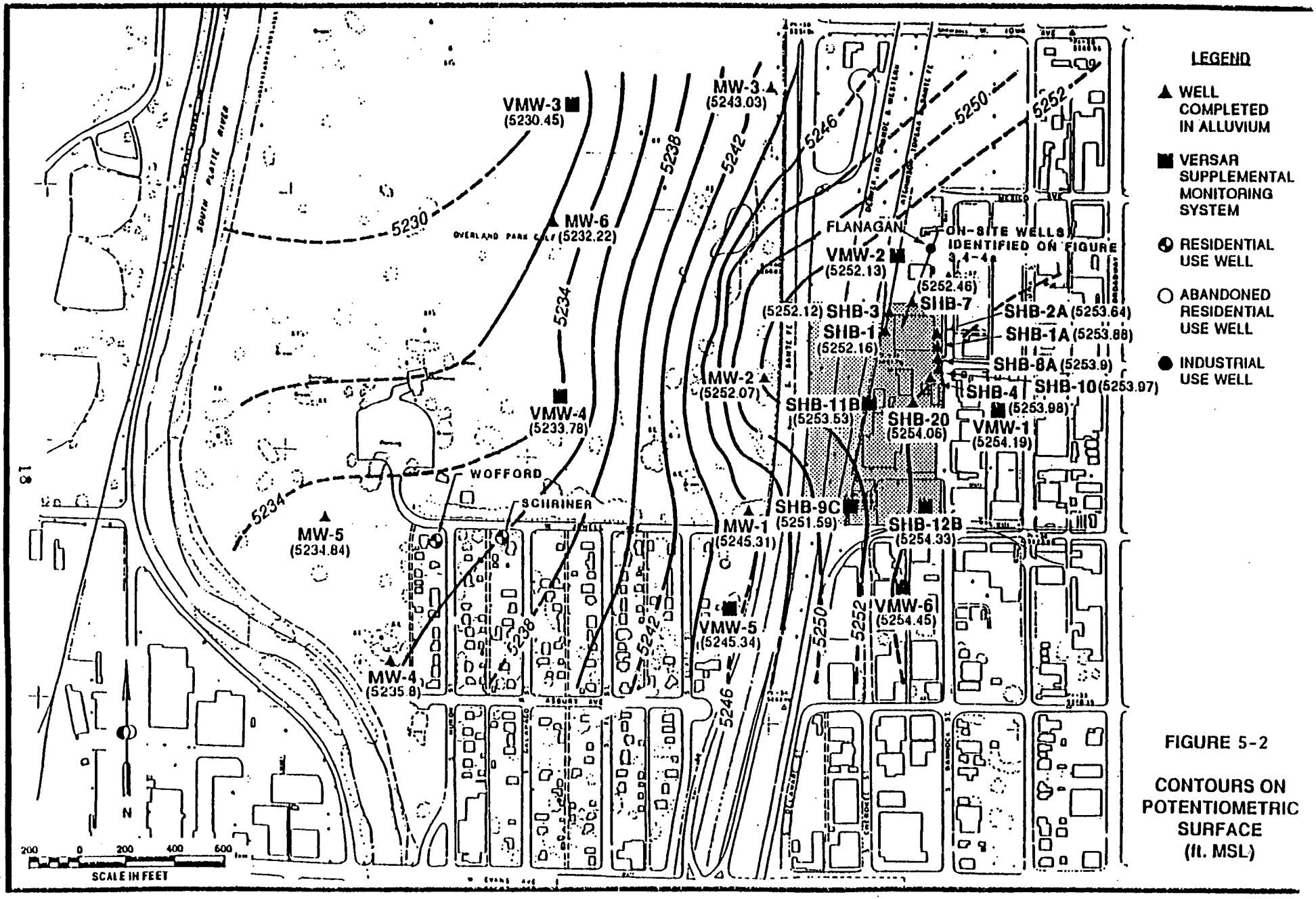


FIGURE 5-2

CONTOURS ON POTENTIOMETRIC SURFACE (ft. MSL)

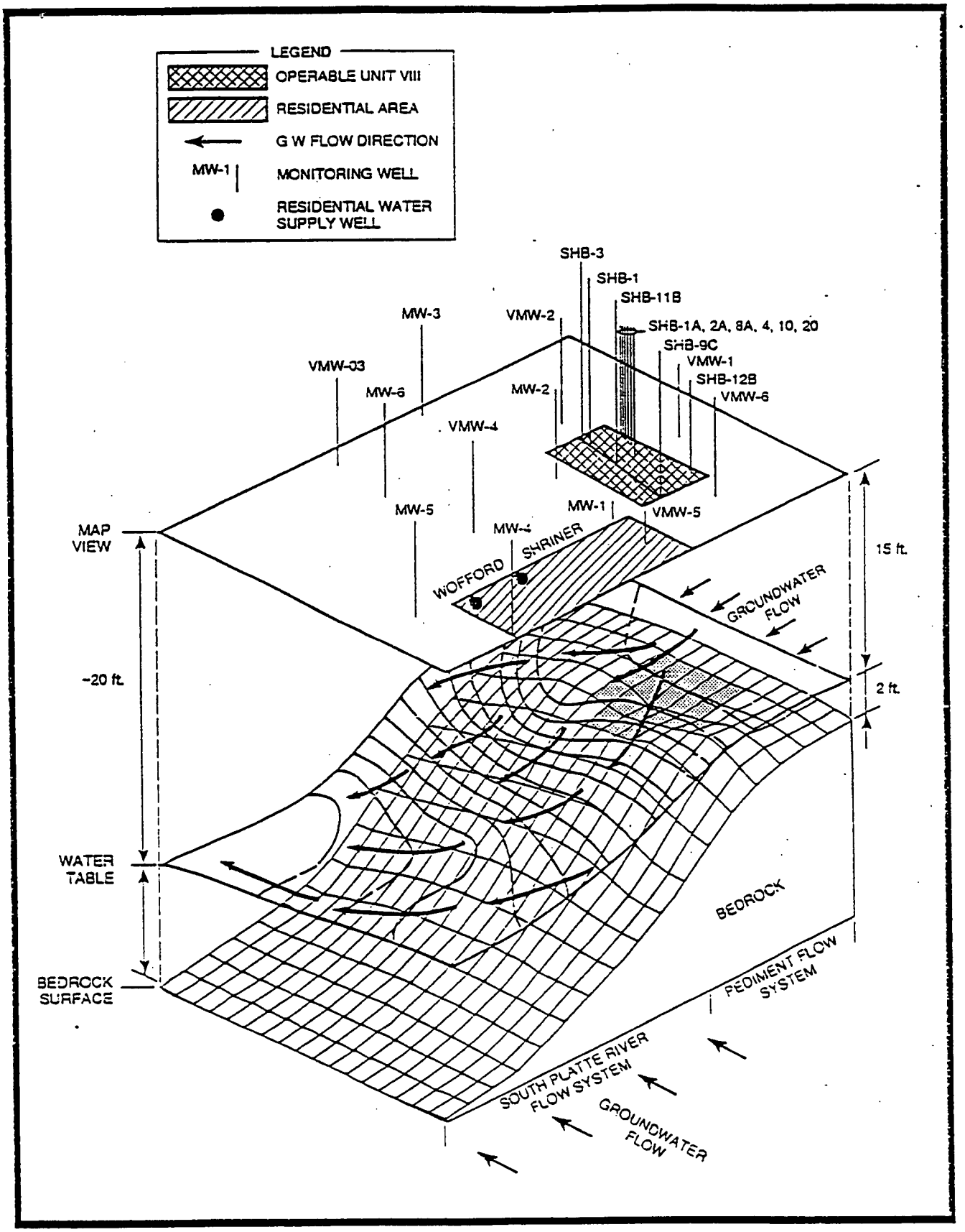


FIGURE 5-3 BLOCK DIAGRAM ILLUSTRATING RELATIONSHIP BETWEEN BEDROCK, SURFACE AND GROUNDWATER FLOW - DENVER RADIUM SITE, OPERABLE UNIT VIII.

associated degradation products may impact ground water quality as well. The semi-volatile compounds phenol, benzoic acid and phthalates were detected in on-site wells.

The metals arsenic, cadmium, and selenium were measured in levels exceeding MCLs, and very high concentrations of molybdenum were observed in on-site and off-site well samples.

Data submitted by the City and County of Denver, and confirmed by CDH, indicate that ground water associated with the site is infiltrating a storm sewer located along South Santa Fe Drive. The storm sewer discharges into the South Platte river just south of Louisiana Avenue (figure 5-4). Data for samples obtained from manhole 23A and the storm sewer outfall show elevated levels of ammonia, molybdenum, copper, and uranium.

At the time CDH sampled, the manhole upgradient (south) of manhole 23A was dry, indicating the water sampled in manhole 23A was infiltrating the storm sewer at a point between the manholes. Contours on the potentiometric surface measured in 1989 (figure 5-2) indicate the portion of the storm sewer into which ground water is infiltrating is located downgradient of the site.

Data for well SHB-3 show elevated levels of ammonia, molybdenum, copper, and uranium. The SHB-3 data is generally higher than the data for the manhole, indicating some dilution occurs between SHB-3 and the storm sewer.

6.0 SUMMARY OF SITE RISKS

A baseline risk assessment was conducted as part of the remedial investigation/feasibility study to characterize the current or potential threat to human health and the environment that may be posed by the contamination on the site.

The principal health threat posed by the site is carcinogenic risk related to radium-226 contaminated soils. Risk estimates were calculated based on the concentration of contamination found on the site. The potential pathways of exposure evaluated in the baseline risk assessment include future residential or occupational use of the site based on the past and present use of the site and surrounding area and the site's location within a large metropolitan area. Exposure durations are evaluated in conjunction with the contamination identified at the site to calculate the baseline risk values. The following potential exposure pathways have been evaluated:

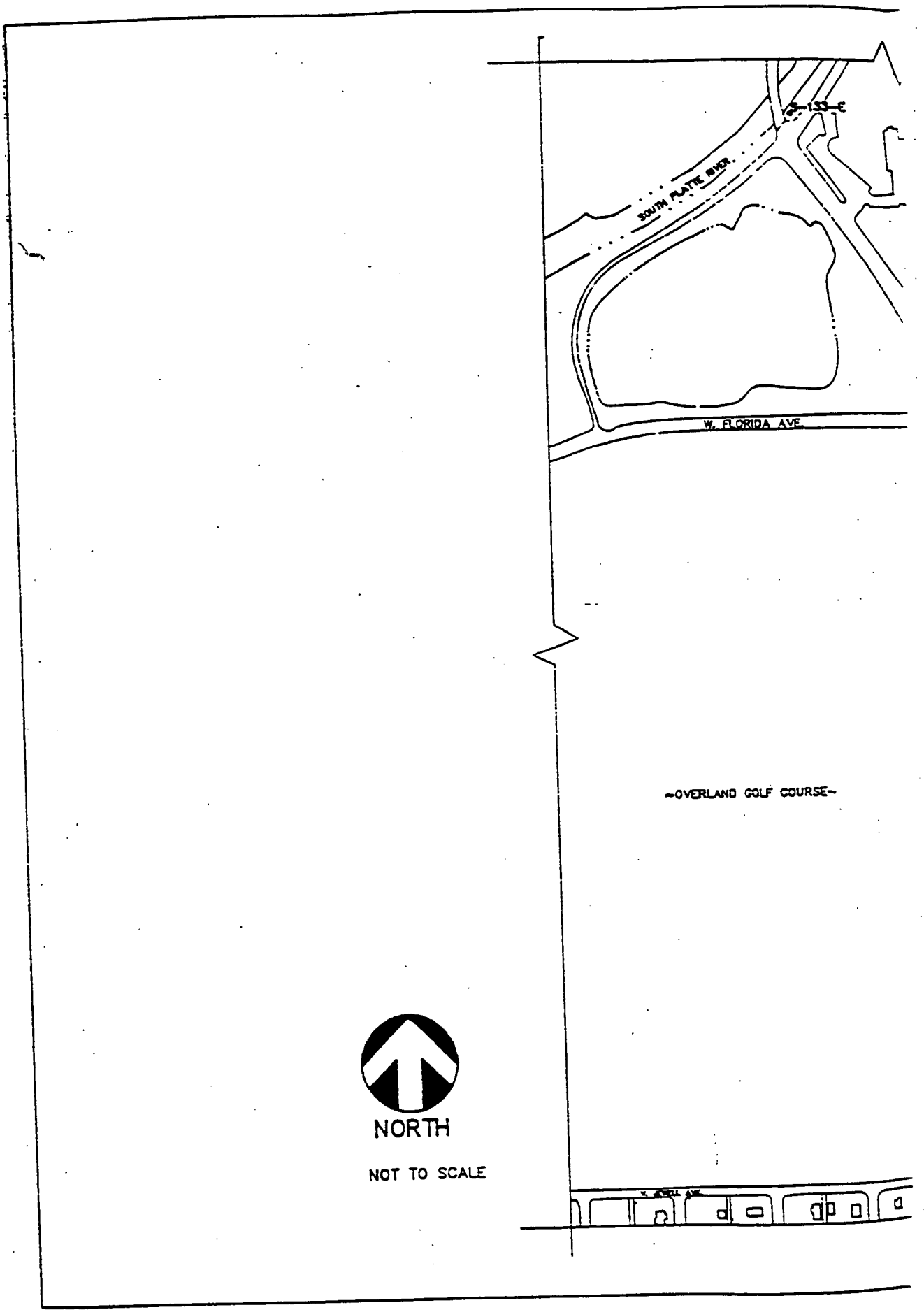
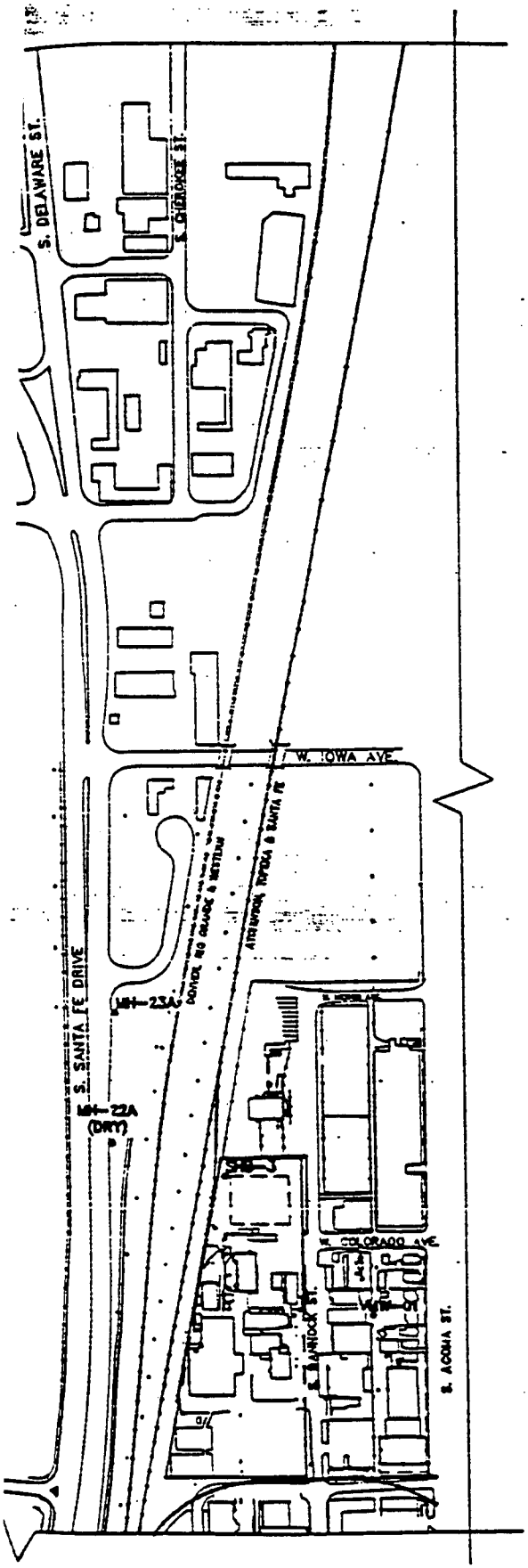

I-25-I-33-E
SOUTH PLATTE RIVER
W. FLORIDA AVE
~OVERLAND GOLF COURSE~
NORTH
NOT TO SCALE

Figure 5-4 Storm Sewer Sampling Locations



- o inhalation of radon, particulate, and organic compounds;
- o direct exposure to gamma radiation;
- o ingestion of contaminated soil;
- o ingestion of ground water; and
- o ingestion of garden produce grown in contaminated soil.

In risk characterization, carcinogenic risk is presented in the form of a probability (i.e. the increased chance of contracting cancer over a lifetime attributable to the site). As required by the NCP, the risk range of one in ten thousand to one in one million (10^{-4} to 10^{-6}) is used as the range to indicate whether or not an unacceptable risk is posed by the site. For non-carcinogenic compounds, hazard quotients are calculated by comparing a reference dose (Rfd), which is a dose for which there is a potential for adverse health effects, to the estimated potential dose for a given pathway of exposure. The hazard quotients for a potential pathway of exposure are summed to obtain a hazard index. A hazard index greater than one poses unacceptable risk.

6.1 HUMAN HEALTH RISKS

6.1.1 Principal threats posed by the site

The two major contaminants of concern for radiological exposure are radon gas and gamma radiation, both of which are attributable to the radium-contaminated soil located on the site. Radon gas is a decay product of radium. Radon gas migrates from contaminated soil into the atmosphere. The risks associated with radon gas arise from inhalation of its short-lived decay products which can expose the internal tissue of the lungs to bursts of energy if they decay within the lungs.

Prolonged inhalation of air with a high concentration of radon decay products has been conclusively shown to increase the risk of contracting lung cancer in uranium miners. When radon gas emanates from radium-contaminated soil, dispersion into the air generally dilutes the radon. In open spaces, such dispersion usually reduces radon concentrations to the extent that outdoor risks of radon exposure are insignificant. However, radon decay products can accumulate to unacceptable concentrations in buildings built over contamination, because structures tend to trap radon gas.

The radioactive decay of radium and its decay products also results in the emission of highly penetrating gamma radiation. Gamma radiation is continuously emitted from radiologically-contaminated soil. Gamma radiation is emitted in all directions from a source, and exposure is dependent on proximity to the source and whether or not physical materials shield the source. Gamma radiation emitted by unshielded radium-containing soil penetrates the soil to give anyone standing over a contaminated area a radiation dose over the

whole body. The greater the duration and intensity of this exposure, the larger the dose, and hence the greater the risk of adverse health effects.

Radon

Seasonally corrected interior radon concentrations of 0.12 working levels were observed on the Shattuck property. These concentrations correspond to a 5 X 10^{-2} lifetime cancer risk to a future resident for a 30-year exposure or a 1 X 10^{-2} lifetime cancer risk to a future worker with a 20-year exposure.

Dispersion modelling was used to estimate the off-site radon concentration attributable to the site. The results indicate that the contribution of the Shattuck property to off-site radon concentrations is negligible, with levels calculated as 0.00023 working levels for the 1800 block of South Acoma modelled as the nearest residential area, and 0.008 working levels immediately north of the Shattuck property, modelled as the nearest off-site worker location.

Gamma Radiation

The projected lifetime cancer risk from gamma radiation to an individual working 75% indoors and 25% outdoors on the Shattuck property for 20 years is 1 X 10^{-3}. The calculated lifetime cancer risk from gamma radiation exposure for the future residential scenario on the Shattuck property is 5.6 X 10^{-3}, based on a 30-year exposure and the average one-meter gamma radiation measurements in the vicinity of the process buildings.

The risks calculated for radon inhalation and gamma radiation are independent of each other. Hence the total risk potentially posed by radium-contaminated soil is the sum of the radon and gamma risks.

The risks represented herein are the calculated risks attributable to the site. For comparison, the background gamma risk, based on gamma measurements taken at the Overland Park Golf Course are 1.2 X 10^{-3} for the future on-site residential scenario and 1.9 X 10^{-4} for the future on-site worker scenario. A background risk for indoor radon was not calculated. Indoor levels for radon can vary widely, depending on natural soils as well as the physical aspects of a building.

6.1.2 Additional Risks

The lifetime risk of cancer based on inhalation of airborne radioactive particulates was calculated as 4.4×10^{-7} for future on-site workers with a 20-year exposure. This risk was calculated using air modelling of potential particulate concentrations based on contaminant concentrations in surface soil. Air dispersion modelling was used to calculate a lifetime cancer risk of 2.9×10^{-8} for off-site residents, with a 30-year exposure based upon contaminant concentrations in surface soils.
Inadvertent ingestion of soil was also evaluated. The sum of the lifetime cancer risks for radium-226, thorium-230, lead-210 and uranium results in a risk of 1.7×10^{-5} for a 30-year on-site residential setting, and 1.7×10^{-5} for a 20-year future on-site worker scenario.

Ground water ingestion was evaluated to estimate risk if ground water from beneath the site were utilized as a drinking water source. For radioactive contaminants, uranium was the most significant contributor, with a calculated lifetime risk of 6.7×10^{-5} based on drinking two liters of water per day for 30 years. Calculations for non-radioactive contaminants indicate that arsenic is the carcinogen of highest concern, with a lifetime risk of 2.7×10^{-4}, while the lifetime risks from other carcinogens are below 1×10^{-6}. The non-carcinogenic contaminants molybdenum and antimony are of concern with hazard indices of 160 and 5 respectively. The ground water is not currently utilized as a drinking water source. Therefore, there is no present exposure occurring via this medium.

Ingestion of garden vegetables grown in contaminated soil was evaluated using soil contaminant concentrations which exist on a residential vicinity property. Utilizing the assumption that 40 percent of an individual's annual vegetable intake is home grown, the increased lifetime risk of contracting cancer due to vegetable consumption was calculated to be 6×10^{-6} for one year of consumption and 1.9×10^{-4} for thirty years of consumption.

Data collected during the remedial investigation indicate a number of volatile organic compounds, including common industrial solvents, have contaminated soils on the site. Evaluation of potential inhalation of organic compounds indicated that this pathway for exposure poses some risk to human health with risk factors calculated at 4×10^{-4} for the future on-site residential scenario and 9.7×10^{-6} for the off-site residential exposure based on a 30-year exposure period.

Tables 6-1, 6-2, and 6-3 summarize the baseline radiologic risk, hazard quotients, and non-radiologic cancer risks.

Table 6-1

Summary of Radiation Risks

Receptor	Scenario	Total Risk	Background	Site Risk
Offsite Residents	Gamma	1.8×10^{-3}		
	Radon	1.1×10^{-2}		-
	Thorium-Dust	2.8×10^{-8}		2.8×10^{-8}
	Lead-Dust	6.5×10^{-10}		6.5×10^{-10}
	Radium-Dust	8.0×10^{-12}		8.0×10^{-12}
	Uranium-Dust	1.8×10^{-10}		1.8×10^{-10}
Onsite Workers				
	Gamma	1.2×10^{-3}	1.9×10^{-4}	1.0×10^{-3}
	Radon	1.0×10^{-2}		-
	Thorium-Dust	4.3×10^{-7}		4.3×10^{-7}
	Lead-Dust	3.6×10^{-9}		3.6×10^{-9}
	Radium-Dust	1.3×10^{-10}		1.3×10^{-10}
	Uranium-Dust	2.8×10^{-9}		2.8×10^{-9}
	Thorium-soil ingestion	4.3×10^{-6}	2.7×10^{-7}	4.0×10^{-6}
	Lead-soil ingestion	8.5×10^{-6}	1.7×10^{-7}	8.3×10^{-6}
	Radium-soil ingestion	2.3×10^{-6}	5×10^{-8}	2.2×10^{-6}
	Uranium-soil ingestion	2.0×10^{-6}	1.3×10^{-8}	2.0×10^{-6}
			TOTAL = 1.0×10^{-3} (except radon)	

Table 6-1 (Cont.)

Receptor	Scenario	Total Risk	Background	Site Risk
Future Residents				
	Gamma	6.8×10^{-3}	1.2×10^{-3}	5.6×10^{-3}
	Radon	5.0×10^{-2}		-
	Radium-Drinking Water	5.23×10^{-7}	5.23×10^{-7}	0
	Thorium-Drinking Water	2.34×10^{-7}	-	2.34×10^{-7}
	Uranium-Drinking Water	8.0×10^{-5}	1.3×10^{-5}	6.7×10^{-5}
	Thorium-Soil	4.3×10^{-6}	2.7×10^{-7}	4.0×10^{-6}
	Lead-Soil	9.0×10^{-6}	1.7×10^{-7}	8.8×10^{-6}
	Radium-Soil	2.4×10^{-6}	5×10^{-8}	2.3×10^{-6}
	Uranium-Soil	2.0×10^{-6}	1.3×10^{-8}	2.0×10^{-6}
			TOTAL = 5.7×10^{-3} (except radon)	
Offsite Workers	Thorium-Dust	2.7×10^{-7}		2.7×10^{-7}
	Lead-Dust	2.2×10^{-9}		2.2×10^{-9}
	Radium-Dust	8.0×10^{-11}		8.0×10^{-11}
	Uranium-Dust	1.8×10^{-9}		1.8×10^{-9}
			TOTAL = 2.7×10^{-7}	
Trespassers	Gamma	2.2×10^{-5}	4×10^{-6}	1.8×10^{-5}
	Thorium-Dust	9.0×10^{-9}		9.0×10^{-9}
	Lead-Dust	7.5×10^{-11}		7.5×10^{-11}
	Radium-Dust	2.8×10^{-12}		2.8×10^{-12}
	Uranium-Dust	6.0×10^{-11}		6.0×10^{-11}
	Thorium-soil ingestion	3.3×10^{-7}	2.1×10^{-8}	3.1×10^{-7}
	Lead-soil ingestion	6.5×10^{-7}	1.3×10^{-8}	6.4×10^{-7}
	Radium-soil ingestion	1.8×10^{-7}	4.0×10^{-9}	1.8×10^{-7}
	Uranium-soil ingestion	2.9×10^{-7}	1.5×10^{-9}	2.9×10^{-7}
			TOTAL = 1.9×10^{-5}	

Table 6-2

Hazard Quotients for Metals, VOC's and Semi-volatile Compounds

Chemical	R,D		Hazard quotient							
	Inhalation	Oral	Worker on the Shattuck property (inhalation)	Resident on the offsite property (inhalation)	Resident on the Shattuck property			Worker on the offsite property (inhalation)	Trespasser on Shattuck property	
					Inhalation	Soil ingestion	Ground water ingestion		Inhalation	Soil ingestion
METALS										
Antimony		4E-04					4.8			
Arsenic		1E-03				8.9E-02	1.6E-1			7.6E-02
Barium	1E-04	7E-02	2.3E-05	4.1E-06	3.2E-05	1.1E-03	1.7E-02	2.8E-06		
Cadmium		5E-04				1.5E-02				1.3E-02
Chromium	7E-03	5E-03	4.0E-09	4.9E-10	5.8E-09	2.2E-04		7.3E-09	2.0E-09	1.8E-04
Mercury	3E-04	3E-04	1.9E-08	3.7E-09	2.7E-08	7.0E-03	1.9E-02	2.6E-09		
Molybdenum		3E-03				17	160			14
Nickel		2E-02				1.4E-03	6.0E-02			
Selenium		3E-03				5.0E-02	1.5E-01			
Zinc		2E-01				9.0E-04				
VOC'S										
Chloroform		1E-02				2.0E-02	8.6E-03			1.6E-03
Methylene chloride	1.05E+01	6E-02	1.9E-03	1.1E-04	5.4E-03	2.8E-03	1.2E-02	3.8E-05	9.3E-04	1.1E-02
Toluene	7E+00	2E-01	4.0E-03	2.6E-04	1.2E-02			9.1E-05	2.0E-03	2.9E-03
Semi-Volatiles										
Bis(2-(ethylhexyl)phthalate		2E-02				1.1E-04				
Phenol		6E-01				3.5E-07	6.2E-04			

Table 6-3

Summary of Aggregate Cancer Risks

Route	Scenario	Cancer risk	Comments
Inhalation	Onsite workers	9.1E-05	VOC's contribute greatest risk
	Future onsite residents	4.0E-04	VOC's contribute greatest risk
	Offsite workers	2.2E-06	VOC's contribute greatest risk
	Offsite residents	9.7E-06	VOC's contribute greatest risk
	Trespassers	2.1E-06	VOC's contribute greatest risk
Groundwater ingestion	Future onsite residents	2.7E-04	Arsenic contributes greatest risk
Soil ingestion	Onsite workers	2.2E-05	Arsenic contributes greatest risk
	Onsite residents	7.2E-05	Arsenic contributes greatest risk
	Trespassers	8.4E-06	Arsenic contributes greatest risk

Conclusion

As noted in the text and the tables, potential cancer risks for several contaminants exceed the acceptable risk range of 10^{-4} to 10^{-6} and non-carcinogenic risks for several contaminants exceed a hazard quotient of one. Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this record of decision, may pose an imminent and substantial endangerment to public health, welfare, or the environment.

6.2 ENVIRONMENTAL RISKS

Risks to the natural environment were initially considered in the remedial investigation. No threatened or endangered species were observed during the remedial investigation field work performed in 1989. The wildlife and fauna observed were typical to the Denver metropolitan area. Ground water modelling indicated that impacts on the South Platte River from the site, while contributing to the contaminant loading of the river system, are so dilute by the time of impact that effect on the river ecosystem is negligible. No further investigation of environmental risk was conducted.

7.0 DESCRIPTION OF ALTERNATIVES

A feasibility study was conducted to evaluate remedial action alternatives for the Denver Radium, Operable Unit VIII, site. The remedial alternatives were evaluated in accordance with CERCLA, as amended by SARA, and to the extent practicable, the NCP. A broad range of response actions and technologies was initially considered and screened based on relative effectiveness, implementability, and cost. The technology screening was used to develop a limited number of alternatives which focus on technologies showing the most promise and covering an appropriate range in methodology. The range of alternatives developed for a detailed analysis and comparison included: on-site control or containment; treatment; off-site disposal; and combinations of technologies. In addition to remedial alternatives, the NCP requires a no action alternative be considered at every site. The no action alternative serves primarily as a point of comparison for the other alternatives.

As described in the feasibility study, remedial action objectives were identified on the basis of the site characterization results. A brief discussion of the primary applicable or relevant and appropriate requirements (ARARs) related to each alternative is included in the description of alternatives contained in Section 7.2.

7.1 SCREENING

During screening, technologies were considered for the media of soils, facilities, and ground water.

- o Soils: Screening identified capping, in-situ treatment, excavation and treatment, disposal off-site, and combinations of these technologies as potentially viable technologies.

- o Facilities: Screening identified shielding, sealants, passive collection, active collection, decontamination, and demolition and disposal as potentially viable technologies.

- o Ground water: Screening identified barriers, source control, and treatment as potentially viable technologies.

Potentially viable technologies and process options were then combined into site-wide alternatives for a more detailed evaluation. Cross media considerations utilized in developing site-wide alternatives resulted in additional narrowing of the technologies for facilities and ground water as detailed below:

Facilities - The technologies considered for remediation of the facilities located on the Shattuck property focused on those which included removal of the facilities because remediation of the soil is easier and more effective with the facilities removed. The technologies consistent with removal of the facilities include demolition and disposal, or reuse. Since some of the facilities are radiologically-contaminated, the ability to decontaminate or clean building materials prior to disposal was evaluated.

Ground water - During the development of alternatives, treatment of ground water was screened out. Alternatives then focused on source control in conjunction with monitoring, with further action in the future, if necessary. This approach was based on the information collected during the remedial investigation which indicated:

- o There are no current uses of ground water impacted by the site.
- o The extent of the contamination is limited, and potential for use is minimal in the short-term.
- o Ground water contamination appears to be decreasing over time.
- o Remedies which remove or immobilize the source are expected to accelerate improvement in ground water quality.

The decision to focus on source control as a remedy for ground water contamination is reasonable for the circumstances of this site. Source control is expected to result in long-term protection and attainment of remedial action objectives.

If monitoring shows that attenuation is not adequately protective of human health and the environment, additional remediation would be initiated at a future date. The remedial action standards for ground water, which will be utilized to assess the effectiveness of attenuation, are the Safe Drinking Water Act MCLs, state ground water standards, and proposed 40 CFR 192 standards (See the chemical-specific state and federal ARARs for ground water, table 3, in appendix A).

As a result of the screening process, seven remedial action alternatives were developed for detailed analysis.

7.2 SUMMARY OF ALTERNATIVES

The alternatives presented in the feasibility study report are summarized below. The alternatives are:

- •Alternative I — No Action
- •Alternative II — Restrict site access, excavate railroad and vicinity properties
- •Alternative III — Cap site with clean soil
- •Alternative IV — In-situ vitrification
- •Alternative V — Excavation, stabilization, on-site disposal
- •Alternative VI — Excavate, remove and replace all contaminated soil
- •Alternative VII — Excavate, physical/chemical treatment of soils

The proposed plan identified Alternative VI, excavate and replace, as the preferred alternative. Alternative V, stabilization, was also identified in the proposed plan and feasibility study as a potentially viable and adequately protective alternative. Based on consideration of public comments, new cost information, and the remedy selection criteria, CDH and EPA have selected Alternative V, stabilization, for cleanup of the Denver Radium Site, Operable Unit VIII. A detailed discussion of the changes from the proposed plan is contained in section 9.3.

7.2.1 Common Elements:

Railroad and vicinity properties:

All alternatives (except no action) include excavation of the contaminated soils on the railroad rights-of-way and the vicinity properties. In Alternative II, the contaminated materials from the railroad property would be placed on the Shattuck property, while the contaminated materials from the vicinity properties would be disposed of at an off-site facility. In Alternatives III through VII, the contaminated materials from the railroad properties and the vicinity properties would be placed on the Shattuck property and managed in the same manner as the materials on the Shattuck property.

EPA and CDH will evaluate the use of supplemental standards beneath the rail lines and South Bannock Street during remedial design. Supplemental standards are a part of the 40 CFR 192 regulations which are ARARs for the site. They allow leaving contamination in place under specified conditions. When evaluating the applicability of supplemental standards, EPA and CDH are required to select remedial actions that come as close to meeting the otherwise applicable standard as is reasonable under the circumstances.

Facilities:

Alternatives III through VII include demolition and disposal of all the buildings, equipment and facilities on the Shattuck property prior to remediation of the soils. This step is considered necessary because of the contamination of the facilities and the need to remove the facilities in order to implement the remedial actions. Treatability studies of facility decontamination were performed to evaluate the ability to physically remove radioactive contamination from building materials. The methods employed included brushing, washing, abrasion, and planing techniques. The materials tested included painted metal, painted wood, concrete, brick and cinderblock. The test results indicated that moderately contaminated facilities could be successfully cleaned while more heavily contaminated surfaces probably could not be adequately decontaminated. It is anticipated that materials associated with buildings 5 and 6 (identified in the FS), as well as contaminated tanks and equipment can be effectively decontaminated. Cost estimates for disposal of the facilities are based on disposal of the radioactive materials associated with the facilities at a low level radioactive waste disposal site in Nevada, and disposal of solid wastes, including asbestos, locally.

On-site alternatives:

With Alternatives I, II, III, IV, or V, radioactive materials would remain on site, and the site would be controlled in the future, thus limiting future land use.

Alternatives involving excavation:

The excavation of contaminated soils would be based on health-based action levels. The action levels are derived from the risk assessment, health-based standards set out in regulations, and other requirements.

The radioactive contamination of the soils is predominantly in the fine particles. Treatability studies of physical separation were conducted to test the technical feasibility of screening the soils to reduce the volume of radioactive soils. The results obtained by both CDH and Shattuck indicate a significant volume reduction may be technically feasible. Screening separates the soils into coarse particles and fine particles. The studies showed that for some of the contaminated soils, wet screening separates the contaminants such that only the fine particles require management as contaminated materials, thereby reducing the volume of contaminated materials. This technology can potentially be utilized with Alternatives V, VI, and VII, each of which involve excavation of contaminated soils. Since the treatability studies were not extensive enough to definitively determine the overall cost, effectiveness, and implementability of screening, the potential volume reduction that screening could account for was not factored into the alternatives.

Storm Sewer:

The ground water which infiltrates the storm sewer located west of the site along south Santa Fe Drive results in a point source discharge into the South Platte River. Corrective action as required to comply with the Clean Water Act and Colorado Water Quality Control regulations (5 CCR 1002-2 3.1, 3.8 & 6.1 et seq.) would be included under Alternatives II through VII. The means of compliance could involve eliminating the infiltration or treating the discharge, and will be determined during remedial design. The costs associated with remedial action for the storm sewer are not included in the alternatives, but would be similar under each alternative.

7.2.2 Description of Alternatives:

Alternative I - No Action

Capital Cost: $0
Operation and Maintenance (O&M) Cost: $323,000/5 years
TOTAL: $323,000
Time to implement: 0

The NCP requires that the "no action" alternative be evaluated at every site to establish a baseline for comparison. Under this alternative, no further action would be taken at the site to prevent exposure to the contamination. No treatment or containment of contaminants is envisioned under this alternative. ARARs relating to the management of radiologically-contaminated soils would not be attained. Ground water conditions would not change except by attenuation. This alternative is not expected to attain ARARs for ground water. Monitoring of fugitive dust emissions, radioactivity, and ground water is included for five years to verify conditions near the site.

Alternative II - Restrict site access; excavate railroad and vicinity properties

Capital Cost: $3,900,000
Annual O&M Costs: $120,000
PAV: $6,300,000 (PAV = Present Annuity Value = amount to fund capital work plus that which must be invested now to have funds available for future costs, such as operation and maintenance. Annual future costs are discounted at 5% for 200 years. The term of 200 years was utilized because of the nature of the materials and is consistent with other situations addressing radioactive materials. This same assumption was used for Alternatives III through V.)
Time to implement: 1 month

Approximately 5,000 cubic yards of contaminated soil would be excavated from the railroad rights-of-way and placed on the Shattuck property. Approximately 6,000 cubic yards of contaminated soil from the vicinity properties would be removed and disposed of at an off-site facility. Institutional controls such as deed restrictions would be permanently utilized along with security fencing and monitoring to limit public exposure to contaminants and monitor site conditions. Although the health risks posed by the railroad and vicinity properties would be addressed, the health risks posed by the Shattuck property would remain essentially unchanged. No treatment or containment of the materials on the Shattuck property would occur. ARARs relating to the management of radiologically-contaminated soils would not be attained. Ground water conditions would not change except by attenuation. This alternative is not expected to attain ARARs for ground water.

Alternative III - Cap site with clean soil

Capital Cost: $12,600,000
Annual O&M Costs: $120,000
PAV: $15,000,000
Time to implement: 9 months

This remedy involves clearing the facilities from the Shattuck property. The estimated 38,500 cubic yards of contaminated soil on the Shattuck property would be left in place. Approximately 11,000 cubic yards of contaminated soils from the railroad and vicinity properties would be placed on the Shattuck property. A clay cap covered by topsoil would be installed over the 5.9 acre Shattuck property.

The cap would be designed and constructed to promote drainage, minimize erosion of the cover, provide long-term minimization of migration of liquids through the underlying contaminated soils, and provide a shield from gamma radiation. Consistent with the requirements of 40 CFR 192 Subpart A, the cap would be required to reduce radon emanation and achieve 1000 year permanence to the extent practicable. The remedy as a whole would be designed to attain a reduction in post-remedial risk consistent with NCP requirements. The performance standards of 6 CCR 1007-1 part 14.19-14.22 would be relevant and appropriate to this alternative. Capping the contaminants on-site would rely heavily on institutional controls to prevent future intrusion into the contaminated soils. This would be necessary to assure long-term effectiveness because the contaminated soils would not be treated.

The ability of this alternative to comply with 6 CCR 1007-1 part 14.19-14.22 requirements of long term isolation is uncertain because of the potential for the contaminants to leach to ground water. The cap would be vegetated or armored with rock to control surface erosion. Since much of the site is currently covered by asphalt, concrete, and structures, the cap might not result in a significant reduction of infiltration, and it is uncertain whether this alternative would lead to improvement in ground water quality. Ground water monitoring consistent with 6 CCR 1007-1 part 14.26.3 and 40 CFR 192 regulations would be required. The health threat posed by the site could potentially be acceptably reduced for soils, but it is doubtful that the remedy would be adequately protective for the ground water pathway.

Alternative IV - In-situ vitrification

Capital Cost: $35,900,000
Annual O&M Costs: $120,000
PAV: $38,300,000
Time to implement: 4 years

This remedy involves clearing the facilities from the Shattuck property. The estimated 11,000 cubic yards of contaminated soils from the railroad rights-of-way and vicinity properties would be placed on the Shattuck property. A total of approximately 50,000 cubic yards of soil would be vitrified. Vitrification involves electrically melting the soil in place, leaving an essentially impermeable, but still radioactive, deposit.

A bench scale test of vitrification was conducted as part of the remedial investigation/feasibility study. The test involved vitrification of an 8" by 8" by 10" sample of contaminated soil. Power was applied to electrodes surrounding the sample. Over a period of about six hours the sample soils melted. After cooling, the mass assumed a glass-like structure which is effective at immobilizing heavy metals and radioactive contaminants. Larger scale pilot testing would be necessary prior to full scale implementation in order to refine design parameters and as additional verification of the implementability of the technology.

A compacted soil cap would be placed over the deposit to provide a shield from gamma radiation. The cap would be designed and constructed to promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the vitrified soil. Consistent with the requirements of 40 CFR 192 Subpart A, vitrification of the contaminated soils would reduce radon emanation to below the disposal standard of 20 $pCi/m^2/s$ and the cap would be designed to achieve 1000 year permanence to the extent practicable. The remedy as a whole would be designed to attain a reduction in post-remedial risk consistent with NCP requirements. The performance standards of 6 CCR 1007-1 part 14.19-14.22 would be relevant and appropriate to in-situ vitrification. The nature of the vitrified mass would discourage intrusion into the treated materials and reduce the potential that the vitrified soil would be inadvertently used as fill material. Institutional controls to prevent future intrusion into the treated soils would be used to supplement the remedy and assure long-term effectiveness. The cap would be vegetated or armored with rock to control surface erosion. Ground water monitoring consistent with 6 CCR 1007-1 part 14.26.3 and 40 CFR 192 regulations would be used to monitor the effectiveness of vitrification in immobilizing the contaminants and providing source control. This alternative would reduce the health threat posed by the site to an acceptable level.

Alternative V - Stabilization

Capital Cost: $24,200,000
Annual O&M Costs: $120,000
PAV: $26,600,000
Time to implement: 15 months

This alternative is the selected alternative. This remedy involves clearing the facilities from the Shattuck property. The contaminated soils from the entire site (estimated at 50,000 cubic yards of soil from the railroad rights-of-way, the vicinity properties, and the Shattuck property) would be excavated, stabilized, placed on the Shattuck property, and capped. Stabilization would be achieved using an on-site batch plant operation to mix the soil with cement or a similar material.

Treatability testing of stabilization was conducted by the Shattuck Chemical Company. The tests consisted of mixing site soils with differing amounts of cement, fly ash, and silica flour. The mixtures consisted of 70 to 80 percent soil and 20 to 30 percent cement and additives. The materials were cast into test cylinders. Stabilization immobilized the contaminants, reduced radon emanation and resulted in a concrete-like stabilized mass. Larger scale pilot testing would be necessary prior to full scale implementation in order to refine design parameters and as additional verification of the implementability of this technology.

Stabilization results in a matrix which is similar to concrete. Treatment reduces the permeability of the contaminated soils, and provides chemical as well as physical protection. The gamma radiation toxicity of the contaminated soils would decrease somewhat with the addition of the cement.

A compacted soil cap would be placed over the stabilized materials to provide a shield from gamma radiation. The cap would be designed and constructed to promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the stabilized soils. Bench scale treatability tests indicate stabilization of the contaminated soils would reduce radon emanation to below the 40 CFR 192 Subpart A disposal standard of 20 $pCi/m^2/s$. Consistent with the requirements of 40 CFR 192 Subpart A, the cap would be designed to achieve 1000 year permanence to the extent practicable. The remedy as a whole would be designed to attain a reduction in post-remedial risk consistent with NCP requirements. The performance standards of 6 CCR 1007-1 part 14.19-14.22 would be relevant and appropriate to on-site stabilization.

The physical nature of the stabilized soils would discourage intrusion into the treated materials and reduce the potential of the contamination being inadvertently used as fill material. Institutional controls to prevent future intrusion into the treated soils would be used to supplement the remedy and assure long-term effectiveness. The cap would be vegetated or armored with rock to control surface erosion. Ground water monitoring consistent with 6 CCR 1007-1 part 14.26.3 and 40 CFR 192 regulations would be required to monitor the effectiveness of stabilization in immobilizing the contaminants and providing source control. This

alternative would reduce the health threat posed by the site to an acceptable level.

Alternative VI - Excavate, remove and replace all contaminated soil

Capital Cost: $36,800,000 - 48,800,000
Annual O&M Costs: 0
PAV: $36,800,000 - $48,800,000
Time to implement: 1 year

This remedy involves clearing the facilities from the Shattuck property. The estimated 50,000 cubic yards of contaminated soil would be excavated and disposed off site at a waste disposal site permitted to accept the wastes and in compliance with EPA's off-site policy (OSWER Directive 9834.11). This remedy would attain the 5 pCi/g and 15 pCi/g surface and subsurface standards of 40 CFR 192 Subpart B by excavating the contaminated materials for off-site disposal. The excavated area would be backfilled with clean soil. It is anticipated that the need for long-term monitoring and maintenance would be eliminated. Ground water monitoring would be required until attainment of ground water ARARs. This alternative would reduce the health threat posed by the site to approximately background level.

Alternative VII - Physical/chemical treatment of soils

Capital Cost: $43,300,000
Annual O&M Costs: $0
PAV: $43,300,000
Time to implement: 18 months

This remedy involves clearing the facilities from the Shattuck property. The estimated 50,000 cubic yards of contaminated soil would be excavated and processed on the Shattuck property in a plant designed to remove contaminants to an acceptable level. The decontaminated soils would be used to backfill the site, and the concentrated contaminants would be hauled to an appropriate waste disposal site. This alternative involves a complex, but tested, chemical processing scheme which has relatively high capital costs.

Treatability studies were performed during the remedial investigation/feasibility study. The studies explored the feasibility of utilizing chemical leaching schemes to remove radioactive contaminants from site soils. Chemical treatment was demonstrated as a means which could remove the contaminants from the soils, enabling the bulk of the contaminated soils to be placed back on the site. The contaminants would be concentrated, resulting in a smaller volume of higher toxicity materials, which would be disposed of off-site.

This remedy would attain the 5 pCi/g and 15 pCi/g surface and subsurface standards of 40 CFR 192 Subpart B by removal of the contaminants from the soils for off-site disposal. It is anticipated that the need for long-term monitoring and maintenance would be eliminated. However, ground water monitoring would be required until attainment of ground water ARARs. This alternative would reduce the health threat posed by the site to approximately background level.

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The following discussion summarizes the evaluation and comparison of alternatives. The alternatives identified in the feasibility study were evaluated utilizing the nine criteria set forth by the NCP. These criteria are:

(1) **Overall protection of human health and environment.**

(2) **Compliance with applicable or relevant and appropriate requirements** (detailed in section 10.0).

(3) **Long-term effectiveness and permanence** in protecting human health and the environment.

(4) **Reduction of toxicity, mobility, or volume of the contaminants through treatment.**

(5) **Short-term effectiveness** in protecting human health and the environment.

(6) **Implementability.**

(7) **Cost.**

(8) **Community acceptance.**

(9) **State acceptance.**

Criteria 1 and 2 are threshold criteria which must be attained by the selected remedial action. Criteria 3, 4, 5, 6, and 7 are balancing criteria. The final two criteria are modifying criteria.

8.1 EVALUATION OF ALTERNATIVES

8.1.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment addresses whether a remedy provides adequate protection and how risks posed through each exposure pathway are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.

Alternatives IV through VII would all achieve adequate overall protection of human health and the environment. It is somewhat less certain whether Alternative III would achieve adequate protectiveness.

Alternative I, no action, would not be adequately protective. Risks from all of the exposure pathways (See section 6.0 of this ROD) would remain at unacceptable levels.

Alternative II, restrict access, would not be adequately protective. Risks at the vicinity properties and the railroad rights-of way would be addressed by removing contaminated soils. Risks based on the contaminated soils at the Shattuck property would not be adequately addressed, because the only measure which would be taken would be restriction of access. No treatment or containment would occur. In addition, contaminants could continue to leach to ground water and health-based ground water ARARs would not be met.

Human Health:

Alternatives IV through VII would address all potential exposure pathways: inhalation of radon, exposure to gamma radiation, inhalation of particulates and organic compounds, ingestion of contaminated soil, ingestion of produce grown in contaminated soil, and ingestion of contaminated ground water. The following is a comparison of how these alternatives would address risks arising from the exposure pathways.

For Alternatives III through VII, the facilities on-site would be demolished, and future construction would be limited for the alternatives where waste is left on-site, thereby precluding the buildup of indoor radon.

Alternative VI, excavate and replace, and Alternative VII, chemical/physical, would be equally protective in addressing the risks from all pathways. These two alternatives would remove the radium-contaminated soils from the site, thus eliminating the source of radon precursors and particulates and organic compounds. Contaminants in the soil that could be ingested or serve as a source of contaminant loading to the ground water would be removed from the site, thus addressing the risks from the ingestion pathways.

Alternative IV, vitrification, and Alternative V, stabilization would effectively reduce exposure to gamma radiation and reduce exposure through the inhalation pathway for radon to acceptable levels in the following ways:

- the contaminated soils would be vitrified or stabilized which would diminish radon emanation from the soils and slightly reduce the emission of gamma radiation;

- following on-site disposal, the treated soils would be capped which would further reduce radon emanation and shield gamma radiation emitted from the soils;

- institutional controls would limit future construction of buildings, land use at the site, and intrusion into the treated soils.

Exposure to particulates and organic compounds through the inhalation pathway would be reduced to acceptable levels for Alternative IV, vitrification, and Alternative V, stabilization, through the treatment processes involved, isolation of the soils beneath a cap, and institutional controls.

For Alternative IV, vitrification, and Alternative V, stabilization, ingestion of contaminated soils would be eliminated through capping and institutional controls. The treated form of the soils would also inhibit ingestion.

Alternative IV, vitrification, and Alternative V, stabilization, would eliminate the pathway of ingestion of garden produce grown in contaminated soil through excavation, treatment, and isolation of the contaminated soils. The solidified form of the soils would discourage inadvertent use of the treated soils and institutional controls would provide additional assurance that the treated soils would not be removed or used.

The contaminated ground water currently does not pose a threat and is diluted prior to reaching the Platte River. However, the ground water contamination could pose a health risk if it were to be used as drinking water in the future. Controlling the source of ground water contamination would reduce and over time eliminate the potential health threat as the ground water contamination attenuates or flushes. Alternative IV, vitrification, and Alternative V, stabilization, would address the pathway of ingestion of contaminated ground water by source control. The contaminated soils at the site would be vitrified or stabilized, immobilizing the contaminants and limiting the loading to the ground water. Coordination with property owners downgradient of the site, including surveys of downgradient ground water use would be pursued, to ensure that ground water is not used for drinking.

Alternative III, cap site, would limit exposure to radon and particulates and organic compounds through the inhalation pathway, would reduce exposure to gamma radiation, and would reduce the potential for ingestion of contaminated soil and produce grown in

contaminated soil, by capping the contaminated soils. The protectiveness of this remedy is less certain than for Alternatives IV through VII because the contaminated soil would be left on-site untreated. There would be a greater reliance on the integrity of the cap and institutional controls.

The ability of ground water contamination to attenuate is uncertain for Alternative III, cap site, because contaminated soils could continue to act as a source of contamination. Capping may reduce the infiltration of water into the contaminated soils, thereby reducing the migration of the contaminants into the ground water. However, since much of the site is currently covered by asphalt, concrete, and structures, the cap may not result in a significant reduction of infiltration, and it is uncertain whether this alternative would lead to a significant improvement in ground water quality over time. If improvement in ground water quality were to occur under this alternative, it would take longer than for Alternatives IV through VII.

Alternative VI, excavate and replace, and Alternative VII, physical/chemical, would provide the most protection of human health by eliminating all of the exposure pathways of concern by removing the contamination. Alternative IV, vitrification, and Alternative V, stabilization, which provide for on-site disposal, would also provide adequate protection of human health by use of treatment, engineered containment, and institutional controls to eliminate and/or control the pathways of concern. The protectiveness of Alternative III is less certain, particularly with regard to its reliance on institutional controls, and the potential ingestion of contaminated ground water.

Environment:

Relative to environmental protection (such as wildlife, fisheries, etc.), no hazards or degradation to the environment have been identified as baseline or remediation risks. The potential impact of the infiltration to the storm sewer and subsequent discharge to the South Platte River will be addressed by treatment or elimination of the infiltration under any of the alternatives.

8.1.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Compliance with applicable or relevant and appropriate requirements (ARARs) addresses whether or not a remedy would meet all federal and state environmental laws and regulations (or provides grounds for invoking a waiver).

Alternatives IV, V, VI, and VII would all attain ARARs.

40 CFR 192 Subpart B is the primary ARAR where soils will be excavated and removed. The primary ARARs for on-site disposal are 40 CFR 192 Subpart A and 6 CCR 1007-1 Part 14.19-14.22. On-site disposal would be designed to attain a 1000-year permanence to the extent practicable, and in any event 200 years, as required by 40 CFR 192 Subpart A. The ARARs and other regulations to be considered (TBCs) for ground water, which will be utilized to assess the effectiveness of attenuation, are the Safe Drinking Water Act MCLs, state ground water standards, and proposed 40 CFR 192 standards. (See the contaminant-specific state and federal ARARs for ground water, table 3, in appendix A).

Alternatives III through VII would attain soil-based ARARs at the railroad rights-of-way and the vicinity properties by excavating soils contaminated at levels in excess of the 40 CFR 192 Subpart B standards. (EPA and CDH will evaluate the use of 40 CFR 192 Subpart C supplemental standards for the rail lines and South Bannock Street. These standards allow leaving contaminated soils in place under specified conditions.) Alternatives IV through VII are expected to attain ground water ARARs, because source materials would be either removed or treated to reduce their mobility limiting the loading of contamination into the ground water.

Alternative VI, excavate and replace, and Alternative VII, physical/ chemical, would meet 40 CFR 192 Subpart B standards by excavating any soils exceeding the standards and disposing them off-site. Disposal of the soils, or treatment residue in the case of Alternative VII, would comply with EPA's off-site policy (OSWER Directive 9834.11). Ground water monitoring for these alternatives could be discontinued after the contaminated ground water attenuates to ARARs.

Alternative IV, vitrification, and Alternative V, stabilization, would attain the standards of 40 CFR 192 Subpart A on the Shattuck property by consolidating, treating, and capping the contaminated soils to immobilize the contaminants and reduce radon emanation. The performance requirements of 6 CCR 1007-1 Part 14.19-14.22 would be relevant and appropriate to on-site disposal. Monitoring, maintenance, and institutional controls would allow the on-site disposal alternatives to meet the substantive requirements of 6 CCR 1007-1 Part 14. Compliance with these requirements would be verified prior to implementation and would have to be demonstrated by the remedial action design. Ground water monitoring near the disposed materials would be continued over the long-term to assure that contaminants remain bound in the treatment matrix.

Alternative III, cap site, would attain the soil-based ARARs on the Shattuck property by consolidating and covering the contaminated soils with a cap designed to meet the performance standards for radon emanation and permanence of 40 CFR 192 Subpart A. However, capping alone would rely heavily on institutional controls. Ground water monitoring near the disposed materials would be continued

over the long-term to evaluate whether capping adequately controls the source materials. Capping the site could lead to some improvement in existing ground water quality, but the improvement is not expected to be as effective as for Alternatives IV through VII because the contaminants would not be immobilized or removed.

Alternative I, no action, and Alternative II, restrict access, would not attain the soil-based ARARs of 40 CFR 192 Subparts A or B. Alternative I, no action, would take no action with regard to contaminated soils. Alternative II, restrict access, would attain 40 CFR 192 Subpart B requirements for the railroad rights-of-way and the vicinity properties. However, it would not meet the requirements of 40 CFR 192 Subparts A or B for the contaminated soil located on the Shattuck property. Alternative I, no action, and Alternative II, restrict access, are not expected to attain ground water ARARs. The source materials would remain in their current state and could continue to impact ground water.

Because Alternative I, no action, and Alternative II, restrict access, would not attain the threshold requirements of overall protection of human health and the environment and compliance with ARARs, they are not discussed in detail with regard to the remaining criteria. Alternative III, cap site, would attain ARARs for soils, but it is uncertain whether it would attain ground water ARARs. Alternatives IV through VII would attain the threshold requirements of overall protection of human health and the environment and compliance with ARARs.

8.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to the magnitude of residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time once cleanup goals have been met.

Alternative VI, excavate and replace, and Alternative VII, physical/chemical, would provide the best long-term effectiveness and permanence for the site, since the contaminants would be removed from the site. Removal of contaminants from the site would reduce risks at the site to approximately background levels. It is expected that ground water monitoring and reviews would be discontinued after ground water ARARs are attained.

Alternative IV, vitrification, and Alternative V, stabilization, would each achieve long-term effectiveness and permanence by immobilizing the soil contaminants, reducing radon emanation, and shielding gamma radiation. The treated waste form and the cap would isolate the radioactive materials and prevent inadvertent intrusion. Monitoring, maintenance, and institutional controls would enhance the long-term effectiveness and permanence of these alternatives by assuring the continued isolation of the treated materials. Where contaminants remain on site, CERCLA requires that

the site be reviewed at least every five years to ensure protection of human health. Therefore, ground water monitoring near the disposal unit and five year reviews would be continued in the future, even after ARARs are attained.

Stabilization would result in a mass which is similar to concrete and would reduce the permeability of and radon emanation from the contaminated soil. Structural concrete encapsulation has been utilized as a component in the management of higher level radioactive wastes, and cement-soil mixtures are commonly used for the stabilization of inorganic materials. Treatability studies performed on soil obtained from the site indicate stabilization can achieve long-term effectiveness and permanence.

Vitrification results in a glass-like matrix which also reduces the permeability of and radon emanation from the contaminated soil. Vitrification is anticipated to be permanent.

Alternative III, cap site, is the least reliable of the alternatives. Failure or breach of the cap is of greater concern for Alternative III, cap site, than for Alternatives IV, vitrification, or V, stabilization, because the underlying wastes would be in an untreated form. In addition, the untreated contaminated soils beneath the cap could continue to leach contaminants into the ground water. The effectiveness of the source control provided by capping alone is uncertain. Ground water contamination could potentially pose a health threat in the future if the untreated contaminated soils continue to act as a source of contamination and the ground water were used as drinking water. Since wastes would remain on-site, CERCLA would require that the site be reviewed at least every five years to ensure protection of human health.

For Alternative III, cap site, Alternative IV, vitrification, and Alternative V, stabilization, evaluation of the monitoring data would determine whether ground water quality was improving adequately or whether active restoration measures would be warranted. Ground water monitoring near the disposal unit and five year reviews would continue in the future even if ARARs were attained.

Alternative VI, excavate and replace, or Alternative VII, physical/chemical would provide the best remedy in terms of long-term effectiveness and permanence since contaminated materials would be disposed off-site. Alternative IV, in-situ vitrification, and Alternative V, stabilization, each would achieve long-term effectiveness and permanence by using treatment technologies in conjunction with capping and institutional controls. Alternative III, cap site, would be the least effective since contaminated soils would be left untreated and the soils could continue to leach contaminants into ground water.

8.1.4 Reduction of Toxicity, Mobility or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment is the anticipated performance of the treatment technologies that may be employed in a remedy. CERCLA contains a statutory preference for on-site remedies which include a treatment component.

Alternative IV, in-situ vitrification, and Alternative V, stabilization, would satisfy the statutory preference since each is an on-site remedy which uses a treatment technology to immobilize the contaminants. The benefit of immobilization is a reduction in the number of pathways by which the radioactive contaminants can pose a health threat. Stabilization and vitrification would reduce the potential for dispersion of contaminants in dust particulates, would reduce the radon threat by limiting radon emissions, would reduce the leachability of contaminants to ground water, and would discourage intrusion into the treated materials. The radioactive nature of the contaminants is not a "treatable" characteristic, and the immobilized materials would continue to require management as radioactive material because they would continue to exhibit gamma radioactivity. While both alternatives would reduce the mobility of the contaminants, in-situ vitrification would also reduce the volume of contaminated soils by approximately 25%, while stabilization, due to the addition of cement to the soil, would increase the volume of the contaminated soils. Since mobility is reduced through stabilization, this increase in volume is not significant from a risk standpoint.

Alternative VII, physical/chemical, utilizes chemical treatment to separate the contaminants from the soil. While this technology would reduce the volume of the contaminated soil, the resultant product would be higher in toxicity and would need to be disposed off-site.

Alternative III, cap site, and Alternative VI, excavate and replace, would not attain the statutory preference to utilize treatment as a central component to reduce the toxicity, mobility or volume of the contaminated soils. In neither case would the chemical and physical characteristics of the soils be changed. Alternative III, cap site, would leave untreated soils on-site. Alternative VI, excavate and replace, would require untreated soil to be transported to an off-site disposal facility.

Alternative IV, in-situ vitrification, and Alternative V, stabilization, both would satisfy the statutory preference for an on-site remedy including a treatment component by immobilizing contaminated soils. In-situ vitrification also would reduce the volume of the contaminated material. Alternative VII, while using a treatment technology, would require off-site disposal of the treated material. Alternative III, cap site, and Alternative VI, excavate and replace, do not use treatment to reduce the toxicity, mobility, or volume of the contaminants.

8.1.5 Short-Term Effectiveness

Short-term effectiveness refers to the speed with which the remedy achieves protection, as well as the remedy's potential to create adverse impacts on human health and the environment during the construction and implementation period.

The following are the approximate implementation times for each alternative, from the shortest to the longest (exclusive of the time for design, vegetation, and monitoring):

Alternative		Implementation Time
III	Cap site	One year
VI	Excavate	One year
V	Stabilization	Fifteen months
VII	Phys./chem.	Eighteen months
IV	Vitrification	Four years

Potential hazards during the remediation can be effectively limited through the use of engineering controls for Alternatives III through VII. All work would be performed using controls designed to reduce radioactive exposure and to reduce dust exposure to below regulatory health and safety standards. Security measures would be used during remediation to protect against trespasser exposure to gamma radiation. The alternatives with the potential to create dust, or alternatives which take a longer time to implement and require the most care to prevent worker exposure during remediation are discussed below. The differences outlined below highlight concerns that would be controlled during remediation.

Alternatives III through VII would each involve excavation of the contaminated soils located on the railroad rights-of-way and the vicinity properties, and thus would require dust control measures. Alternatives V, VI, and VII would also involve excavation of the contaminated soils located on the Shattuck property and thus would require the greatest amount of care to suppress potential dust generation during remediation. Ongoing work at the other Denver Radium Site Operable Units has demonstrated that conventional dust control methods are effective.

The chemical treatment facility needed for Alternative VII, physical/chemical, would involve handling a more concentrated waste than currently exists on the site, and would therefore present potential health and safety concerns for remedial workers. Automation of some of the process facilities could be required in order to reduce worker exposure.

The longer period of time required to implement Alternative IV, vitrification, creates a concern with the potential gamma radiation exposure to workers. This concern is due to the length of exposure and the proximity to the gamma radiation sources. Gamma radiation exposure would be addressed through monitoring the workers and could be limited, if necessary, by rotating workers.

8.1.6 Implementability

Implementability is the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement an alternative.

Alternatives III, V, and VI are considered generally equivalent for implementability. The implementability of alternatives IV and VII is less certain.

Alternatives III through VII all require conventional removal and replacement of the contaminated soils on the railroad rights-of-way and vicinity properties. Alternatives III through VII also include demolition and off-site disposal of facilities located on the Shattuck property. These aspects of the alternatives are technically feasible and utilize readily available equipment and techniques.

Alternatives III, cap site, V, stabilization, and VI, excavate and replace, employ conventional construction techniques. Excavation, capping, and stabilization utilize equipment, materials and design expertise that are currently available.

Alternatives IV, vitrification, V, stabilization, and VII, physical/chemical, all require pilot testing to further refine the design prior to implementation. Although treatability studies of these technologies demonstrated their potential implementability, the treatability studies were all small-scale bench tests.

Alternative V, stabilization, uses a technology and construction techniques that have been implemented on a large scale at other hazardous waste sites to immobilize inorganics in soils.

Alternative IV, vitrification, uses a technology that requires dry soils to implement. A significant concern associated with Alternative IV, vitrification, is the technical feasibility of adequately dewatering the site to facilitate in-situ vitrification. In addition, the implementability of the technology on a large scale is somewhat uncertain since the technology is innovative and experience with large-scale implementation is very limited.

Alternative VII, physical/chemical, involves concentrating the radioactive materials such that handling requirements for the resulting radioactive wastes significantly complicate the implementability of this alternative.

Alternatives V, stabilization, VI, excavate and replace, and VII, physical/chemical, each include excavation of materials prior to final disposal. Excavation permits direct verification that the contaminated materials have been removed. This is an advantage over Alternative IV, vitrification, which treats the soil in-situ. In-situ treatment relies on sampling efforts to identify locations requiring treatment and for verification that contaminated materials have been remediated.

8.1.7 Cost

Cost includes capital and operation and maintenance costs.

Cost ranks as follows from lowest to highest:

	Alternative	Present Annuity Value
III	Cap site	15,000,000
V	Stabilization	26,600,000
IV	Vitrification	38,300,000
VI	Excavate and replace	36,800,000 - 48,800,000
VII	Physical/chemical	43,300,000

These costs are the estimated present values of the alternatives, including annual monitoring and operation and maintenance (for on-site remedies) utilizing a 5% discount rate for 200 years. The term of 200 years was utilized because of the nature of the material and is consistent with other situations addressing radioactive materials. The total present value of the annual costs for monitoring and operation and maintenance for 200 years for Alternatives III through V is $2,400,000. These costs were not included for Alternatives VI and VII because the off-site disposal facility would assume operation and maintenance responsibilities.

Information indicates that the cost for off-site disposal of wastes similar to the contaminated soils at this site has varied significantly and was potentially underestimated in the Feasibility Study. The cost of Alternative VI, excavate and replace, is shown as a range, because the cost of the alternative is highly dependent upon the cost of off-site disposal of the contaminated soils. The cost for off-site disposal could potentially exceed the range used for comparison. Currently there is only one facility available which could accept the wastes.

Capital costs can potentially be reduced for Alternatives V, stabilization, VI, excavate and replace, and VII, physical/chemical, if physical screening proves to be an effective method of reducing the volume of contaminated soil.

8.1.8 Community Acceptance

Most local residents and two community associations exhibited strong support for Alternative VI, excavate and replace, which was presented as the preferred alternative in the proposed plan. Some residents questioned the need for cleanup, while others felt the proposed remediation would not be protective enough. Little comment was received on the range of alternatives except for Alternatives V and VI. Alternative VI, excavate and replace, was favored over Alternative V, stabilization, by some residents because the potential for unrestricted future land use was viewed as a greater asset to the community than a parcel with restrictions resulting from on-site disposal.

Shattuck Chemical Company, the property owner of the processing facility, indicated a strong preference for Alternative V, stabilization.

Responses to the significant comments received are found in the attached responsiveness summary (Appendix B).

8.1.9 State Acceptance

As the lead agency for conducting the remedial investigation and feasibility study, CDH both recommends and agrees with Alternative V, stabilization, as providing the best balance of the nine criteria. Both EPA and CDH have participated in the development of the Record of Decision.

9.0 SELECTED REMEDY

The selected remedy for the Denver Radium Site Operable Unit VIII is Alternative V, stabilization. The selected alternative involves remediation of contaminated materials located on the Shattuck property, the railroad rights-of-way, and the vicinity properties, including the following components: (1) removal and reuse or disposal of the facilities on the Shattuck property; (2) excavation and consolidation of the contaminated soils onto the Shattuck property, stabilization, disposal of the treated soils on-site, and capping; (3) remedial action as required to address the contaminated ground water which infiltrates the storm sewer located west of the site; and (4) implementation of monitoring, institutional controls, and operation and maintenance.

The selected remedy addresses ground water contamination through source control. Additional active measures for ground water restoration are not presently contemplated (except as required to address the contaminated ground water which infiltrates the storm sewer). Ground water monitoring will be used to monitor the disposal unit as well as to track the improvement in ground water quality downgradient of the site. Evaluation of the monitoring

data will determine whether ground water quality is improving adequately or whether active restoration measures are warranted. The scope and extent of the ground water monitoring of the existing contamination may be reduced or discontinued as the downgradient ground water quality attains ARARs, although ground water monitoring of the disposal unit will continue. Where waste is left in place, CERCLA requires that the site be reviewed at least every five years to ensure protection of human health. Therefore, ground water monitoring of the disposal unit and five year reviews would be continued in the future, even after ARARs are attained in the downgradient plume.

Operable Unit VIII will address approximately 50,000 cubic yards of contaminated soil. The cost estimate based on this total volume is detailed in Table 9-1. The total cost of the selected remedy is estimated at $26,600,000. As with the estimates for all alternatives, this cost estimate is preliminary, with an accuracy of minus 30% to plus 50%. The length of time required to implement the selected alternative is approximately fifteen months. This is the estimated time for the construction activities and does not include the time required for remedial design. A more detailed schedule and cost estimate will be developed in conjunction with the remedial design.

Further consideration of whether physical screening of the soils will be implemented for the project will take place during remedial design.

The selection of this remedy is based upon the comparative analysis of alternatives presented in Section 8, and provides the best balance of the nine evaluation criteria.

The following description of the selected remedy includes discussion of the remediation goals, compliance objectives, and methods that would be utilized to achieve these objectives.

9.1 DESCRIPTION OF SELECTED REMEDY

The objective of the remedial action is to eliminate the potential health threat posed by the site, based on contaminants which exceed standards, or which pose unacceptable risks based on the 10^{-4} to 10^{-6} range specified in the NCP. The selected alternative consists of stabilization of contaminated soils in conjunction with capping and institutional controls to reduce the risk posed by the site to acceptable levels. The primary objectives are to reduce the potential for exposure to excess gamma radiation and radon gas which pose the principal threats associated with the site.

Table 9-1

Cost Estimate for Alternative V Stabilization

1.	Remove and replace soil	$ 3,300,000
2.	Railroad remediation	800,000
3.	Site clearance	8,100,000
4.	Process soil - 50,000 cy x $200/cy	10,000,000
5.	Cap site	1,600,000
6.	Add for handling vicinity property materials	400,000
7.	Total capital	$24,200,000
8.	O &M - $120,000/year, or $2,400,000 present worth for 200 years	2,400,000
9.	Total illustrative cost	$26,600,000

Specific objectives include:

- o prevent excess cancer risk due to inhalation of radon and radon decay products;
- o prevent exposure, contact with and/or ingestion and inhalation of soils or dust posing an excess cancer risk due to gamma radiation;
- o prevent ingestion of garden produce grown in contaminated soil;
- o prevent potential exposure to soils having radium-226 concentrations greater than 5 pCi/g above background in the top 15 cm and/or 15 pCi/g above background below 15 cm in depth;
- o prevent potential exposure to non-radioactive contaminants in soils; and
- o prevent ingestion of ground water with contaminants in excess of ARARs or health-based concentrations if no ARARs exist.

Stabilization will reduce radon emanation from the contaminated soils. Facilities on the Shattuck property will be removed, and future construction will be limited, providing additional assurance that radon will not pose a threat. Capping will be used to shield gamma radiation and to prevent contact with the treated soils. Both stabilization and capping will reduce the potential for dust inhalation, ingestion, and direct contact with radiologically and non-radiologically contaminated soils. Excavation and stabilization of the contaminated soils will also reduce potential risks associated with inhalation of organic compounds. Table 9-2 contains the action levels (including health-based action levels for arsenic, selenium, and lead) for determining materials to be excavated from all areas of the site.

Excavating soils above these action levels from the railroad rights-of-way and the vicinity properties will prevent direct contact with, or inhalation or ingestion of soils or contaminants above acceptable standards. Excavation will also prevent the ingestion of garden produce grown in contaminated soils.

The ground water quality will improve after stabilization by attenuation. The mobility of the contaminants will be reduced, thus limiting contaminant loading on the ground water. ARARs and health-based concentrations will be met.

9.1.1 Removal and Reuse or Disposal of Facilities

Disposal methods for the buildings and equipment will depend on the extent of contamination. Non-contaminated materials and contaminated materials which are adequately decontaminated during remediation can be recycled, sold as salvage, or disposed in a sanitary landfill. More heavily contaminated materials which cannot be adequately decontaminated, and radioactive residue from

decontamination, will be disposed off-site as radioactive waste. It is anticipated that the materials associated with Buildings 5 and 6, as well as the contaminated tanks and equipment, can be effectively decontaminated. The safety of the general public will be a primary consideration in the transportation of contaminated materials to a disposal facility.

Demolition of asbestos-containing structures will be performed in accordance with federal, state, and local requirements. Non-radiologic asbestos-containing materials can be disposed of as a solid waste at permitted landfills.

9.1.2 Excavation and Stabilization of Contaminated Soils

The estimated 38,500 cubic yards of contaminated soil on the Shattuck property are roughly 80% of the total for the site. The other 20% of the contaminated soil is located on the railroad rights-of-way and the vicinity properties. The contaminated soils consist predominantly of soils contaminated with radium-226. Other contaminants of concern, including thorium-230, uranium, selenium, and other heavy metals, have been identified in excess of health-based action levels. These contaminants are predominantly co-located with the radium-226 contaminated soils. Excavation of the radium-contaminated soils should result in excavation of these other contaminants where they exist above action levels.

Verification sampling will be used to determine the limits of excavation. Contamination above health-based levels, as defined in Table 9-2, will be excavated and treated.

Excavation of Contaminated Soils from the Railroad Rights-of-Way and the Vicinity Properties

The selected remedy includes excavation and transport to the Shattuck property of approximately 5,000 cubic yards of radium-contaminated soils from the railroad rights-of-way, and 6,000 cubic yards from the vicinity properties. The primary deposits referred to as the vicinity properties are located as discussed in Section 5.1.3. These soils will be stabilized and disposed of on the Shattuck property. The soils removed from the railroad rights-of-way and the vicinity properties will be replaced with clean fill.

The potential health threat posed at the property located at 1860 South Bannock is the most immediate in comparison to the other vicinity properties. Design and implementation of the excavation and removal of the contamination located at this property will be undertaken independent of the rest of the site to insure that it is addressed expeditiously. The materials removed from this property will be temporarily stored on the Shattuck property until remedial design for the entire site is complete.

Table 9-2

Action Levels and basis for determining the materials to be excavated

Contaminant	Action Level	Comments
Radium-226	5 pCi/g above background	Surface soils, 40 CFR 192 Subpart B, averaged over 100 m^2.
	15 pCi/g above background	Subsurface soils, 40 CFR 192 Subpart B, averaged over 100 m^2.
Thorium-230	42 pCi/g	Subsurface soils based on decay to radium-226 in 1000 years to achieve the subsurface standard of 15 pCi/g if the concentration of radium-226 is 0 pCi/g. If the radium-226 concentration is greater than 0 pCi/g the thorium-230 action level will be lower. Generic protocol for excavation of thorium-230, DOE, January 25, 1989.
Uranium - Natural	75 pCi/g	U.S.D.O.E. Order 5480.1
Gamma Radiation	20 micro-Roentgens per hour above background	Based on the gamma radiation standard for inside buildings of 40 CFR 192, Subpart B; relevant to identifying areas of contamination.
ALARA	As Low As Reasonably Achievable	Excavate radioactive materials beyond the requirements of the numeric standards where consistent with remedial objective to maintain release of radioactivity to the general environment as low as is reasonably achievable.
Arsenic Selenium Lead	160 mg/kg 490 mg/kg 540 mg/kg	These action levels are health-based values for a trespasser scenario, and thus are appropriate for surface areas where future use will be restricted.

Evaluation of Supplemental Standards

EPA and CDH will evaluate the use of supplemental standards for contamination located beneath the rail lines and South Bannock Street during remedial design. Supplemental standards are a part of the 40 CFR 192 regulations, Subpart C, which are relevant and appropriate to the remedy. They allow contamination to be left in place under specified conditions. When evaluating the applicability of supplemental standards, EPA and CDH are required to select remedial actions that come as close to meeting the otherwise applicable standard as is reasonable under the circumstances.

If it is determined that supplemental standards are not applicable to the material located beneath the rail line and South Bannock Street, the standards of 40 CFR 192 Subpart B will be met.

Stabilization and On-site Disposal

Implementation of the selected remedy requires the Shattuck property to be permanently dedicated as a disposal site. Stabilization will be achieved by mixing the soil with a cement mixture designed specifically for the site based on treatability studies. The contaminated soil will be excavated, processed by an on-site batch plant, and placed on the Shattuck property.

Bench scale treatability testing of stabilization was conducted by Shattuck. The tests consisted of mixing site soils with differing amounts of cement, fly ash, and silica flour. The studies indicated that stabilization immobilized radioactive contaminants to a leachability factor of greater than 10 based on American Nuclear Society leach tests, indicating that the mobility of the contaminants within the stabilized mass is low. Radon emanation of the treated materials was approximately one half of the 40 CFR 192 standard of 20 $pCi/m^2/s$ and structural stability of the stabilized materials was in excess of 500 psi.

Pilot scale treatability testing will be conducted during remedial design to optimize the stabilization design, and to further demonstrate and verify that the technology will attain performance standards. The additional treatability testing must demonstrate the reduction in mobility achievable by stabilization is adequate to comply with ARARs. Modelling of the potential post-remedial contaminant loading on the ground water, based on the treatability studies and the remedial design, will be used to evaluate and verify that ground water and disposal ARARs will be attained. In addition, the remedial design must demonstrate that the remedy manages the contamination in a manner such that any potential release of radioactivity is at or below levels which are protective of human health and are as low as is reasonably achievable.

The potential advantages and disadvantages associated with utilizing a clay liner beneath the stabilized materials will be considered during remedial design. The post-remedial reduction of risks will be calculated based on the physical parameters developed in the remedial design, and must demonstrate the remedy will achieve the 6 CCR 1007-1 Part 14.19 requirement to protect the general population from release of radioactivity such that the annual equivalent dose levels set forth in the regulation will not be exceeded.

The stabilized materials will be disposed of above the ground water table. An impermeable compacted clay cap and cover will be placed over the stabilized materials. The cap and cover will be designed and constructed in a manner which will provide a shield from gamma radiation, promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the stabilized soils. The cap and cover must be of adequate design to withstand and protect the stabilized material from freeze/thaw conditions. The cover will be vegetated or armored with rock designed to control surface erosion in the event of a probable maximum precipitation (PMP) event. The remedy as a whole will be designed to attain a reduction in post-remedial risk consistent with NCP requirements. See Table 9-3.

9.1.3 Institutional Controls, Maintenance, and Monitoring

Disposal of the stabilized materials on-site will be supplemented by the use of institutional controls, maintenance, and monitoring to ensure the protectiveness of the selected remedy is maintained into the future. A summary of the requirements follows:

Institutional Controls

An institutional controls program will be developed to control access to the stabilized materials. Security measures such as fencing may be considered, but will not be relied on as a means of reducing the risk posed by the site.

Deed restrictions or annotations denoting that the property is dedicated as a waste disposal site, shall include the following restrictions:

- restriction against excavating into the cover and stabilized materials
- restriction to prohibit the construction of enclosed structures on the disposal site
- restriction against using the ground water located beneath the site, and
- restriction to prevent agricultural use of the site.

Table 9-3

Disposal Criteria

Criteria	Standard	Comments
Permanence	1000 years	40 CFR 192 Subpart A, Design for up to 1000 years to the extent reasonably achievable, and, in any case, for at least 200 years. Design for the probable maximum precipitation event.
Radon - Flux	20 $pCi/m^2/s$	40 CFR 192 Subpart A, Average release rate.
- Ambient	0.5 pCi/l	40 CFR 192 Subpart A, Maximum annual average at edge of disposal unit.
Gamma Radiation		Design disposal unit such that the level of gamma radiation present at the surface will not exceed background by more than the level that would be present from 5 pCi/g radium in soil.
ALARA	As Low As Reasonably Achievable	Dispose materials in a manner which will maintain release of radioactivity to the general environment as low as is reasonably achievable.
Radioactive Release	.25/.75/.25 millirem	6 CCR 1007-1 Part 14.19, annual dose based limitation for release of radiation to the public.
Inadvertent Intrusion		6 CCR 1007-1 Part 14.20, design closure to ensure protection against inadvertent intrusion.
Stability		6 CCR 1007-1 Part 14.22, design closure to achieve long term stability and minimize need for active maintenance to surveillance, monitoring and custodial care.

Deed restrictions must be placed on the property by the owner of the disposal facility. The owner of the disposal facility will use reasonable efforts to seek zoning restrictions from the City and County of Denver as further assurance that the institutional requirements associated with the site will not inadvertently be breached in the future.

Financial assurance arrangements will be utilized to assure that adequate funds are available for post remedial monitoring, maintenance, and institutional controls.

Coordination with property owners downgradient of the site, including regularly scheduled surveys of downgradient ground water use will be pursued.

Maintenance

The remedy will be designed to minimize active maintenance requirements. Post-closure maintenance of the impermeable cap and vegetative or rock armor cover will be used to ensure that the integrity and permanence of the cap is maintained. Provisions for surveillance and repair will be established.

Post-remediation care will include a plan for taking corrective measures if monitoring indicates that performance standards may not be met.

Monitoring

The monitoring system for the site will be designed and operated to provide early warning of releases of waste from the disposal site.

Ground water monitoring will be performed with two objectives:

The first objective will be to monitor the effectiveness of stabilization to immobilize the contaminants. The impact on ground water of the disposal unit will be monitored on-site near the downgradient edge of the disposal unit. Ground water monitoring of the disposal unit will be required in perpetuity.

The second objective of ground water monitoring is to monitor the currently existing plume of contamination. Stabilization of the contaminated source material is expected to lead to improvement in ground water quality, with time, as the existing contamination attenuates.

Design of an appropriate network of wells to monitor post-remediation ground water quality will be performed as a part of remedial design. Existing wells will be utilized to the extent possible; however, further definition of the plume of contamination

to the northwest of the site is required. When the existing contaminated plume has attenuated or flushed to the point that ARARs are maintained, monitoring of the plume may be reduced or discontinued. Where waste is left in place, CERCLA requires that the site be reviewed at least every five years to ensure protection of human health. Therefore, ground water near the disposal unit will continue to be monitored as part of the five-year review requirements even after ARARs are attained in the plume. Evaluation of the ground water monitoring data will be used to determine whether ground water quality is improving adequately or whether active restoration measures are warranted.

9.1.4 Storm Sewer Discharge

The ground water which infiltrates into the storm sewer located to the west of the site along south Santa Fe Drive results in a point source discharge into the South Platte River. Corrective action as required to comply with the Clean Water Act and Colorado Water Quality Control regulations will be undertaken as part of the remedial action. The means of compliance could involve eliminating the infiltration or treating the discharge, and will be determined during remedial design. The cost associated with remedial action for the storm sewer is not known and will be further defined during design.

9.2 REMEDIATION REQUIREMENTS AND PERFORMANCE STANDARDS

9.2.1 Facilities

For facilities, the remediation requirement is to remove and re-use or dispose of all facilities on the Shattuck property. Non-contaminated materials and contaminated materials which are adequately decontaminated during remediation may be recycled, sold as salvage, or disposed in a sanitary landfill. Materials which cannot be adequately decontaminated, and radioactive residue from decontamination processes, will be disposed off-site as radioactive waste. Off-site disposal will comply with EPA's off-site policy (OSWER Directive 9834.11). Demolition and disposal of asbestos-containing structures must be performed in accordance with federal, state, and local requirements.

Specific performance standards, used to ensure attainment of the requirements for the facilities, are:

1. Decontamination of facilities must comply with Nuclear Regulatory Commission (NRC) Guide 1.86, as modified by utilization of methodologies in the NRC draft report, "Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Dose". (NUREG/CR-5512)

2. Radioactive waste must be disposed of at a facility permitted to accept such waste.

3. Solid wastes must be disposed at a facility permitted to accept such wastes.

4. 5 CCR 1001-10 Regulation 8 contains specific requirements for asbestos abatement and handling. These regulations shall be met.

5. Asbestos-containing materials must be disposed at a facility permitted to accept such wastes. Radiologically-contaminated asbestos-containing materials will be disposed off-site as a radioactive waste in compliance with EPA's off-site policy.

6. All other ARARs identified in this ROD for decontamination and disposal of the facilities must be met.

9.2.2 Soils

Remediation requirements for soils include excavating all contaminated soils from the vicinity properties and the railroad rights-of-way for treatment and disposal on the Shattuck property. Soils removed from the vicinity properties and rights-of-way will be replaced with clean fill. Contaminated soils from the Shattuck property will also be excavated and all contaminated soils will be stabilized for permanent disposal on the Shattuck property. Finally, the disposal area will be capped.

Specific performance standards, used to ensure attainment of the requirements for the soils, are:

Excavation

1. The surface and subsurface standards for radium-226 in soils as defined in 40 CFR 192 Subpart B shall be used as action levels to determine which soils must be excavated for stabilization. Verification sampling will be used to determine the limits of excavation. Verification of thorium-230 and other contaminants will also be required. The extent of the remediation will be based on monitoring and sampling as the excavation progresses. See Table 9-2 for action levels and basis for determining the materials to be excavated.

2. Design and implementation of the excavation and removal of the contamination at the 1860 South Bannock property will be undertaken independently of the rest of the site to ensure that it is addressed expeditiously. The

materials from this property will be temporarily stored on the Shattuck property until remedial design for the entire site is complete.

3. Toxicity characteristic (TC) testing will be utilized to evaluate whether there are Resource Recovery and Conservation Act (RCRA) characteristic wastes present at the site. To the extent that RCRA characteristic wastes or radiologic mixed wastes are discovered during remedial action, they shall be remediated and disposed in accordance with state and federal requirements.

4. Contaminated soils removed from the vicinity and railroad properties will be replaced with clean fill material.

5. 40 CFR 192 Subpart C identifies the criteria for supplemental standards which will be met if contaminated materials will be left in place under the rail lines or South Bannock Street. These supplemental standards may only be substituted for 40 CFR 192 Subpart B standards if approved during the design phase.

6. All other ARARs identified in this ROD for excavation must be met.

Stabilization and Disposal

7. 40 CFR 192 Subpart A and Colorado Radiation Control Regulations 6 CCR 1007-1 Parts 14.19-14.22 must be met to implement the remedy which requires the Shattuck property to be permanently dedicated as a disposal site. See Table 9-3 for specific disposal criteria.

8. Pilot scale treatability testing will be conducted during remedial design to optimize the stabilization design and to verify that the technology will attain performance requirements for long-term disposal.

   Treatability testing must demonstrate the reduction in mobility to comply with ARARs.

9. The selected remedy will be designed to be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years. (40 CFR 192.02)

10. Institutional controls as described in Section 9.1.3 will be required.

11. Financial assurance arrangements will be utilized to assure that adequate funds are available for post remedial monitoring, maintenance and institutional controls.

12. All other ARARs identified in this ROD for stabilization and disposal must be met.

Capping

13. The cap will be designed to provide a shield from gamma radiation, promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the stabilized soils. Stabilization of the contaminated soils is expected to reduce radon emanation to below the 40 CFR 192 Subpart A standard of 20 pCi/m2/s.

14. Operation and maintenance of the cap will be required to ensure that the performance standards are maintained.

15. The cap will be designed such that the level of gamma radiation present at the surface will not exceed the background level by more than the gamma radiation that would be present from 5 pCi/g of radium in soil.

16. The cover of the cap will be vegetated or armored with rock to control surface erosion.

17. All other ARARs identified in this ROD for capping must be met.

9.2.3 GROUND WATER

For ground water, the remediation requirement is to prevent the ingestion of ground water with contaminants in excess of ARARs, TBCs or health-based concentrations if no ARARs exist. Attenuation will improve the ground water quality after the remedy is complete. Stabilization of the contamination will reduce the mobility of contaminants and reduce the loading on the ground water. Remedial action will be required to address the contaminated ground water which infiltrates the storm sewer located west of the site.

Specific performance standards, used to ensure attainment of the requirements for the ground water, are:

1. Ground water monitoring will be performed to monitor the effectiveness of stabilization such that any ground water loading from the disposal unit will not cause the ground water to exceed ARARs and TBCs. (See Table 3 of Appendix A.)

2. Ground water monitoring will also be performed to monitor the existing plume of contamination. Design of a network of wells to monitor post-remediation ground water quality will be developed during remedial design. When monitoring indicates that ARARs are being maintained for the contaminated plume, the frequency of the plume monitoring may be reduced or discontinued. However, monitoring of ground water near the disposal unit will continue.

3. Further ground water remediation may be required if monitoring shows that attenuation of the contamination will not achieve ARARs.

4. Corrective action as required to comply with the Clean Water Act and Colorado Water Quality Control regulations (5 CCR 1002-2 Sections 3.1, 3.8, and 6.1 et seq.) will be undertaken to address the contaminated ground water which infiltrates the storm sewer west of the site. The means of compliance will be determined during remedial design.

5. 5 CCR 1002-8 section 3.12.0, Classifications and Water Quality Standards for Ground Water, is an applicable requirement for ground water at the site. The regulation sets an interim narrative standard that requires that ground water be maintained at the less restrictive of: (i) existing ambient quality as of October 30, 1991, or (ii) that quality which meets the most stringent criteria set forth in Tables 1 through 4 of "The Basic Standards for Ground Water." The regulation provides that for contaminated ground water, the intent is not to limit remediation. This requirement will be met by controlling the source of contaminants and attenuation of the ground water to the contaminant-specific levels set forth in Table 3 of Appendix A.

6. All other ARARs identified in this ROD for ground water must be met.

9.2.4 Air

Remediation requirements for air will ensure that remedial workers and the local population are not adversely impacted by the remedial action. An air quality monitoring plan will be developed during remedial design.

Specific performance standards, used to ensure attainment of the requirements for air, are:

1. Perimeter monitoring and compliance with Colorado Air Quality Control Regulations (5 CCR 1001-3) for particulate and non-radiologic parameters and monitoring and compliance pursuant to 10 CFR 20 for radiologic constituents will be required. (Appendix B of 10 CFR Part 20 provides limits for airborne concentrations of uranium, thorium-230, and radium-226.)

2. Monitoring of non-radiologic constituents will be conducted for total suspended particulate (TSP), particulate ten microns or less in diameter (PM10), and certain metals selected during remedial design.

3. Remedial design will include development of an air quality monitoring plan. During design, the number and location of air monitoring stations will be determined and the necessity of monitoring for volatile and semi-volatile compounds will be assessed.

4. All other ARARs identified in this ROD for air must be met.

9.3 SIGNIFICANT CHANGES

Change of Preferred Alternative

The selected remedy represents a significant change from the preferred alternative presented in the proposed plan. The proposed plan identified Alternative VI, excavate and replace, as the agencies' preferred alternative. Based on comments and new cost information, CDH and EPA have re-evaluated the remedy selection criteria and determined that Alternative V, stabilization, provides the most appropriate balance of the nine evaluation criteria. Alternative V, stabilization, was presented as an alternative under consideration in the feasibility study and the proposed plan. Of the alternatives considered in the proposed plan, Alternative VI, excavate and replace, and Alternative V, stabilization, were presented as the most effective potential remedies based on the initial evaluation in the proposed plan.

The primary comments which initiated re-evaluation of the comparison of the stabilization alternative to the excavation alternative were the comments on the statutory preference of CERCLA for on-site remedies; and the statutory preference for remedies involving treatment to reduce toxicity, mobility, or volume through treatment. Information indicating the cost for permanent off-site disposal of the contaminated soil may be substantially higher than the original estimate was also factored into the evaluation.

A summary of the comparison of all the alternatives was presented in Section 8. The following discussion highlights the comparison of Alternatives V and VI and the most decisive factors in the selection decision.

Both alternatives would attain the threshold criteria, overall protection of human health and the environment, and compliance with ARARs. Alternative V, stabilization, involves institutional controls as added assurance against inadvertent intrusion into the cap, and dedicates the site as a disposal location. Alternative VI, excavate and replace, involves off-site disposal of the contaminated soils, potentially allowing unrestricted future use of the site; the long-term risk associated with the contaminated soils would be managed at the off-site disposal location. Having met the threshold criteria, either remedy is eligible for selection.

Of the balancing criteria, both alternatives would provide adequate long-term effectiveness and permanence, and short-term effectiveness. In addition, both alternatives are implementable using conventional construction equipment and techniques and have been implemented on a large scale at other hazardous waste sites.

The reduction of toxicity, mobility, or volume through treatment, and the cost balancing criteria were the most decisive factors in selecting Alternative V, stabilization. Stabilization satisfies the statutory preference for treatment, utilizing stabilization to reduce mobility. Stabilization involves mixing the contaminated soils with cement to create a cement-like matrix which will reduce the mobility of the contaminants, reduce the radon emanation of the materials, and discourage inadvertent intrusion into the treated materials. Alternative VI, excavate and replace, would not satisfy the statutory preference for treatment. CERCLA indicates off-site disposal without treatment is to be the least favored alternative, where practicable treatment technologies are available.

Alternative V, stabilization, is estimated to cost $26.6 million. This cost is reasonably firm in that the unit cost of stabilizing the materials is not expected to differ significantly if implemented. Alternative VI, excavate and replace, is estimated to cost $10.2 to $22.2 million more than Alternative V, stabilization. The cost for Alternative VI, excavate and replace, is reflected as a range to indicate the uncertainty associated with the disposal cost at a location which is currently the only commercially available facility. Based on the additional cost, Alternative VI, excavate and replace, may not be cost effective in proportion to its overall effectiveness and it does not appear to be as cost effective as Alternative V, stabilization.

The input from the community acceptance modifying criterion was taken into consideration. Although local citizens and community organizations expressed a strong preference for Alternative VI,

excavate and replace, CDH and EPA are in agreement that Alternative V, stabilization, provides the best overall balance of the nine criteria.

The following discussion further clarifies reasons Alternative V, stabilization, was selected rather than the preferred alternative presented in the proposed plan.

CDH and EPA have concluded that the preferred alternative in the proposed plan offers small incremental benefits regarding the certainty and long-term effectiveness of the remedy. When compared to the benefits and effectiveness of Alternative V, stabilization, the large additional cost associated with Alternative VI, excavate and replace, does not appear to be justified.

Local citizens expressed a preference for a remedy which would allow unrestricted future use of the property. Future land use is not specifically addressed in the criteria; CERCLA requires selection of the most cost effective remedy based on a balancing of the nine criteria. The land owner of the site that would be used for on-site disposal has expressed a desire to manage the property as a disposal site, accepting limited land use. Continued monitoring and institutional controls associated with the selected alternative, stabilization, would assure the site will be controlled.

For newly generated waste, or the consideration of siting locations for a new commercial disposal facility, a preference for disposal outside of a metropolitan area may be desirable and valid. However, when addressing cleanup of existing contaminated areas, CERCLA and the NCP require consideration of on-site alternatives. Where an on-site alternative would be protective, the location of the site in a metropolitan area should not dictate selection of an off-site remedy, especially where CERCLA and the NCP state that an off-site remedy without treatment is the least favored.

The design of the remedy for permanence, the nature of the stabilized materials, monitoring, and restrictions placed on the property would adequately address any potential uncertainty with long-term permanence. These factors would limit the potential for future intrusion and subsequent exposure to the stabilized materials.

A final consideration which factored into the remedy selection is CERCLA's specific encouragement to consider on-site remedies for sites such as Operable Unit VIII, including the use of innovative or alternative methods instead of excavation and off-site disposal, to encourage cost effective remediation. Section 118(m) of CERCLA states:

> It is the sense of the Congress that the President, in selecting response action for facilities included on the National Priorities List published under section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 because of the presence of radon, is not required by statute or regulations to use fully demonstrated methods, particularly those involving the offsite transport and disposition of contaminated material, but may use innovative or alternative methods which protect human health and the environment in a more cost-effective manner.

Considering that both remedies would be protective of human health and the environment, the CERCLA preference for on-site remedies which utilize treatment as a primary component, and costs, CDH and EPA have determined that Alternative V, stabilization, provides the most appropriate balance of the nine evaluation criteria.

Additional Changes

An additional change from the proposed plan which is contained in the Record of Decision is the requirement for remedial action in order to eliminate or treat the discharge of site-related ground water contamination which infiltrates the storm sewer located west of the site. The required action will be included in the remedial design of the selected remedy.

The selected alternative differs from the preferred alternative presented in the proposed plan. While this remedy selection is considered a significant change, a new public comment period is not required because the selection is a logical outgrowth of the feasibility study and the proposed plan. The public's preference for excavation and off-site disposal and objections to on-site stabilization were expressed in the comments on the proposed plan.

10.0 STATUTORY DETERMINATIONS

The selected remedy meets the statutory requirements of Section 121 of CERCLA.

Remedial actions selected at Superfund sites must be protective of human health and the environment. In addition, section 121 of CERCLA establishes several other statutory requirements and

preferences. These specify that when complete, the selected remedial action for this site must comply with applicable or relevant and appropriate environmental standards established under state and federal environmental laws unless a statutory waiver is justified. The selected remedy also must be cost-effective and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Finally, the statute also contains a preference for remedies that include treatment as a principal element. The following sections discuss how the selected remedy meets these requirements.

10.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected remedy for Operable Unit VIII protects human health and the environment through excavation and removal of contaminated soils at the railroad rights-of-way and at the vicinity properties and consolidation and stabilization of these soils and other contaminated soils at the site on the Shattuck property. The treated material will be capped in accordance with the standards specified in 40 CFR 192 and table 9-3, and institutional controls will supplement the remedy.

The selected remedy will reduce site risks to potentially exposed populations by stabilization and capping of the contaminated soils. The site will not pose a health threat to nearby residents and workers after remediation is completed. Off-site risks will be below 10^{-6}. Design of the cap to prevent gamma radiation will be required to limit the on-site maximum potential exposure to an acceptable level. The selected alternative attains the health protection requirements of CERCLA and the NCP.

During remedial design, the applicability of supplemental standards for the materials located beneath the rail lines and South Bannock Street will be considered. Supplemental standards will not be applied if they compromise the protectiveness of the remedy. If supplemental standards are applied, the remedial action will come as close to meeting the otherwise applicable standard as is reasonable under the circumstances. If employed, supplemental standards will be evaluated under five year reviews to assure continued protectiveness of the remedial action.

The selected remedy will immobilize the source of ground water contamination. Restoration of ground water quality is expected to occur through attenuation over time. The potential short-term risk posed by contaminated ground water is acceptable, since the area of contamination is limited, ground water is not used, and contaminant concentrations are expected to decrease after source materials are immobilized by stabilization.

10.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The selected remedy will attain applicable or relevant and appropriate requirements (ARARs) and other standards to be considered (TBCs) which are appropriate to the remedy. The following discussion summarizes the primary ARARs and TBCs for the site. Section 9.2 and Appendix A identify the ARARs and TBCs for the site in detail.

10.2.1 Contaminant-Specific Requirements

Soils:

40 CFR 192 Subpart B is relevant and appropriate for the railroad rights-of-way and the vicinity properties. And, the standards in 40 CFR 192 Subpart B will be used as action levels to determine the extent of excavation on the Shattuck property.

Table 9-2 contains the action levels for materials to excavated.

These requirements will be met by excavation and removal of soils above the standards.

Facilities:

U.S. NRC Regulatory Guide 1.86, as modified by methodologies of NRC draft report "Residual Radioactive Contamination from Decommissioning: Technical basis for Translating Contamination Levels to Annual Dose," (NUREG/CR-5512) is a TBC for decontamination of facilities.

Ground Water:

Safe Drinking Water Act MCLs are relevant and appropriate requirements for ground water.

5 CCR 1002-8 Section 3.11.0, Basic Standards for Ground Water, state-wide standards are applicable requirements for ground water; human health, secondary drinking water, and agricultural standards are relevant and appropriate requirements for ground water.

5 CCR 1002-8 Section 3.12.0, Classifications and Water Quality Standards for Ground Water, is an applicable requirement for ground water.

Proposed ground water protection standards for uranium mill tailings (40 CFR 192), including proposed standards for uranium and molybdenum are TBCs for ground water.

These requirements will be met by controlling the source of the contaminants and attenuation of the ground water.

Standards in 5 CCR 1002-2 3.1, 3.8 & 6.1 et seq. are applicable for the infiltration into the storm sewer.

These standards will be met by eliminating or treating the infiltrating ground water.

10.2.2 Action-Specific requirements

40 CFR 192 subpart A is relevant and appropriate for on-site disposal.

Colorado Radiation Control regulations, 6 CCR 1007-1 part 14.19-14.22, 14.24, and 14.26.3 are relevant and appropriate for on-site disposal.

These requirements will be met by excavating contaminated soils, stabilization, capping, and institutional controls.

10.2.3 Location-Specific Requirements

The State Historic Preservation Office will be notified of the remedial action selected in this Record of Decision and coordination of requirements, if any, to document buildings or other items at the site will be performed during remedial action.

10.3 COST EFFECTIVENESS

The selected remedy is cost-effective in mitigating the principal threat posed by the radiologically-contaminated soils, facilities, and ground water. Cost-effectiveness is determined by evaluating the following three balancing criteria to determine overall effectiveness: long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness. Overall effectiveness is then compared to cost to ensure that the remedy is cost-effective.

The selected remedy provides the best overall effectiveness of all alternatives considered proportional to its cost. The selected remedy will provide long-term effectiveness and permanence by reducing the radon emanation of the contaminated soils, shielding gamma radioactive material to near background levels, and reducing the potential for contaminants to leach to the ground water. The selected remedy utilizes treatment to reduce the mobility of the contaminants. The selected remedy will be effective in the short-term because any short-term risks will be controlled.

Alternatives IV, VI, and VII also would provide high overall effectiveness. However, Alternatives IV and VII are significantly more expensive than the selected remedy as well as having significant uncertainty as to their implementability. Alternative VI is also significantly more expensive, and involves off-site disposal without treatment, which is disfavored by CERCLA when practicable on-site technologies exist. The selected remedy effectively reduces the hazards posed by all of the contaminants at the site at a lower cost than the other alternatives.

10.4 UTILIZATION OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES TO THE MAXIMUM EXTENT PRACTICABLE

The selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a cost effective manner at the site. The selected remedy employs stabilization as a treatment method to immobilize the contaminants. Of those alternatives that are protective of human health and the environment and would comply with ARARs, EPA and CDH have determined that this selected remedy provides the best balance of tradeoffs in terms of long-term effectiveness and permanence, reduction in toxicity, mobility, or volume achieved through treatment, short-term effectiveness, implementability, and cost. The selection of this remedy also considered the statutory preference for treatment as a principal element and State and community acceptance.

Of the alternatives considered, Alternatives IV, V, VI, and VII would provide adequate long-term effectiveness and permanence. Since potential short-term risks could be addressed for all alternatives, the short-term effectiveness criterion was not a decisive factor in the selection decision. Alternatives IV, vitrification, and VII, physical/chemical, are not favored because of uncertainty as to their implementability and since they are more costly than the selected remedy.

Alternative VI, excavate and replace, is an implementable alternative, but is significantly more costly than the selected alternative and does not reduce the toxicity, mobility or volume of the contaminated soils through treatment. Since both the selected alternative, stabilization, and Alternative VI, excavate and replace, offer adequate long-term effectiveness and permanence, have similar short-term effectiveness, and are implementable, the major tradeoffs that provide the basis for this selection decision are the reduction of toxicity, mobility, or volume through treatment, and cost.

10.5 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

Stabilization of the soils results in a concrete-like material which physically and chemically stabilizes the contaminated soil, reducing radon emanation, and reducing the mobility of the contaminants. The selected remedy will effectively address the principal threats posed by the site by reducing radon emanation through treatment, and shielding gamma radiation by capping the treated materials. Therefore, the statutory preference for remedies that employ treatment as a principal element is satisfied.

APPENDIX A

Applicable or Relevant and Appropriate Requirements

(ARARs)

Table 1

Identification of ARARs
Denver Radium Site Operable Unit VIII

Regulation	Citation	Description	Applicable or Relevant & Appropriate or TBC	Comments
Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings	40 CFR Part 192	Standards for control and clean-up of uranium processing sites.	R & A	Regulations are relevant and and appropriate because of site similarities.
Standards for Protection against Radiation/Licensing of Radioactive Materials	10 CFR Parts 20, 30, 40, 70; 6 CCR 1007-1 Parts 1, 2, 4, 10	Standards to limit radiation hazards caused by licensed activities; licensing requirements.	Applicable R & A	Authority is delegated to the State. Applicable to areas of Operable Unit VIII included in Shattuck's license; relevant and appropriate to the rest of the site.
Licensing Requirements for Disposal of Radioactive Waste	10 CFR Part 61 6 CCR 1007-1 Part 14, Subparts .2, .7, .8, .15, .19-.22, .23.1.1, .23.1.5, .23.1.6, .24, .26		Applicable R & A	State regulations apply if radioactive materials are land-disposed at an off-site facility. Substantive portions are relevant and appropriate to on-site disposal.
Basic Standards for Ground Water. Safe Drinking Water Act MCLs.	5 CCR 1002-8 Section 3.11.0 40 CFR 141	Establishes a system for classifying groundwater and adopting water quality standards. MCLs are standards for public drinking water systems.	Applicable R & A	Radioactive and organic standards apply to all State ground waters. Other standards relevant and appropriate to non-classified groundwaters. Safe Drinking Water Act MCLs are the operative ARAR unless state standards are applicable or more stringent.
Basic Standards and Methodologies for Surface Water Classifications and Numeric Standards for the South Platte River Basin/Regulations for the State Discharge Permit System	5 CCR 1002-8 Sections 3.1.0, 3.8.0 and 5 CCR 1002-2 Section 6.1.0	Establishes system for classifying surface waters and assigns numerical and narrative standards according to use. Point source discharge permitting system requirements.	Applicable	Applicable to sewer discharge and would apply to other discharges to surface water associated with the remedial action.

Table 1 (continued)

Identification of ARARs
Denver Radium Site Operable Unit VIII

Regulation	Citation	Description	Applicable or Relevant & Appropriate or TBC	Comments
Colorado Hazardous Waste Regulations	6 CCR 1007-3	Sets forth regulations applicable to generators and transporters of hazardous waste and for treatment, storage, and disposal facilities.	Potentially Applicable or R & A	Would apply to management of characteristic or listed hazardous wastes if encountered. Portions of regulations are relevant and appropriate to radioactive or solid wastes.
Land Disposal Restrictions	40 CFR 268		Potentially Applicable or R & A	Potentially applicable or R & A to on-site placement if restricted RCRA wastes are encountered.
Regulations Pertaining to Solid Waste Disposal Sites and Facilities	6 CCR 1007-2	Establishes regulations for disposal of solid (non-hazardous) wastes.	Applicable	Applies to off-site disposal of solid waste (not hazardous or radioactive).
Colorado Air Quality Control Act Regulations	5 CCR 1001-2 to 1001-14	Regulations for the control of air emissions.	Applicable R & A	Dust control, odor requirements and asbestos requirements applicable. Other portions of regulations are potentially applicable or relevant and appropriate if an air emissions source is a component of the remedy.
Occupational Safety and Health Act	29 USC 651-678 29 CFR 1910.96 29 CFR 1926.58	Regulates worker health and safety.	Applicable	Independently applicable. Requirements of this act apply to all response activities under the NCP.

Table 2

Chemical-Specific State and Federal ARARs
Denver Radium Site Operable Unit VIII

Contaminant	Standard	Citation	Applicable or Relevant & Appropriate or TBC	Comments
Pertaining to Radioactive Contamination of Soils and Buildings				
Radium-226	Less than or equal to 5 pCi/g above background within 15 cm of the surface. Less than or equal to 15 pCi/g above background within subsequent 15 cm layers of soil averaged over 100 m^2	40 CFR 192.12(a)	R & A	Standard for clean-up of land at inactive uranium processing sites. Relevant and appropriate to the railroad and vicinity properties.
Thorium-230	Clean-up level calculated using initial Ra-226 concentration and assuming period for Th-230 ingrowth; depth of backfill may be considered.	Generic protocol for excavation of thorium-230, DOE, January 25, 1989.	TBC	Protocol for excavation of Th-230 for UMTRA projects. To achieve 15 pCi/g Ra-226 after 1000 years, Th-230 clean-up level is 42 pCi/g if initial Ra-226 concentration is zero.
Radon Decay Products	Objective of remedial action to achieve an annual average not to exceed 0.02 WL. In any case, not to exceed 0.03 WL.**	40 CFR 192.12(b)(1)	R & A	Standard for clean-up of inactive uranium processing sites. For occupied or habitable buildings.
Radon-222, Radon-220	Average release rate from uranium or thorium by-product materials not to exceed 20 picoCuries per square meter per second (pCi/m^2-s), or increase the annual average concentration by more than 0.5 pCi/l outside the disposal site.	40 CFR 192.01 (b)(1)(2) 40 CFR 192.32 (b)(1)(ii)	R & A	Standard for post-closure management of uranium or thorium by-product material. R & A to on-site disposal.
Radiation	Gamma radiation shall not exceed background levels by more than 20 microRoentgens per hour.	40 CFR 192.12(b)(2)	R & A	Standard for clean-up of inactive uranium processing sites. For occupied or habitable buildings.
Radiation	Standards for protection against radiation.	6 CCR 1007-1 Part 4	Applicable	Applicable to all State licensees and registrants of radioactive materials. Substantive portions are relevant and appropriate to non-licensed materials.

** WL (Working Level) = Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130 billion electron volts.

Table 2(continued)

Chemical-Specific State and Federal ARARs
Denver Radium Site Operable Unit VIII

Contaminant	Standard	Citation	Applicable or Relevant & Appropriate or TBC	Comments
Radiation	Standards for protection against radiation.	10 CFR 20 (as revised 5/21/91 FR 23360ff)	R & A	Applicable to NRC-licensed activities. Otherwise relevant and appropriate. Refer to regulations for specific requirements.
Radiation	Annual dose equivalent shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as a result of release of radioactive materials to the general public.	40 CFR 192.32(a) 40 CFR 192.41(d) 6 CCR 1007-1-14.19	R & A	Standard for management of uranium and thorium by-product materials. Relevant and appropriate to on-site disposal.
Radiation Dose	Federal Radiation Protection Guidance (25 FR 4402, May 13, 1960) as implemented by the Federal Radiation Council (FRC) recommends limiting doses to members of the general public to less than 0.5 rem/year.	FRC 1960	TBC	To the extent that members of the general public receive doses from site wastes, this Federal guidance is to be considered.
Radiation Dose	ICRP Publication 26 recommends a whole-body dose equivalent limit of 0.5 rem/year as applied to critical groups of the public. In any cases where the doses were actually found to be received at high rates over prolonged periods, ICRP recommends restriction of the lifetime dose to the individual member of the public to a value that corresponds to 0.1 rem/year.	ICRP 26	TBC	To the extent that members of the public receive doses from site wastes, this international guidance is to be considered.
Radiation Dose	ICRP Publication 30 provides recommended Annual Limits on Intake and Derived Air Concentrations designed to limit the intake of radioactive materials by workers.	ICRP 30	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this international guidance is to be considered.

Table 2(continued)

Chemical-Specific State and Federal ARARs
Denver Radium Site Operable Unit VIII

Contaminant	Standard	Citation	Applicable or Relevant & Appropriate or TBC	Comments
Radiation Dose	Federal Guidance Report No. 11 provides Annual Limits on Intake and Derived Air Concentrations to be implemented by Federal agencies to limit the intake of radioactive materials by workers.	Federal Guidance Report No. 11	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this Federal guidance is to be considered.
Alpha and Beta-Gamma Emitters	Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Radioactive Material.	U.S. NRC Regulatory Guide 1.86. NRC draft report - Residual radioactive contamination from decommissioning: technical basis for translating contamination levels to annual dose - methodologies. NUREG/CR-5512.	TBC	These guides will be followed for decontamination and disposal of radiologically contaminated facilities.
Air Pollutants	National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61	R & A	To the extent the remedial action involves the emission of regulated constituents, the regulations may be relevant and appropriate.

Table 3

Chemical-Specific State and Federal ARARs for Ground Water

Contaminant	Standard	ARAR	Comments
Ra-226 and Ra-228	5 pCi/l	Applicable	Statewide standard[1] (also MCL)
Th-230 and Th-232	60 pCi/l	Applicable	Statewide standard[1] (also MCL)
Gross alpha	15 pCi/l	R & A	MCL
Beta & photon emitters	4 mrem/yr	R & A	MCL
Uranium	30 pCi/l	TBC	Proposed 40 CFR 192 standard
1,1-dichloroethene	7 ug/l	Applicable	Statewide standard[1] (also MCL)
1,1,1-trichloroethane	200 ug/l	Applicable	Statewide standard[1] (also MCL)
Trichloroethene	5 ug/l	Applicable	Statewide standard[1] (also MCL)
Tetrachloroethene	5 ug/l	Applicable	Statewide standard[1] (also MCL)
Arsenic	0.05 mg/l	R & A	MCL
Barium	1.0 mg/l	R & A	MCL
Cadmium	0.010 mg/l	R & A	MCL
Chromium	0.05 mg/l	R & A	MCL
Fluoride	2.0 mg/l	R & A	Agricultural standard[1]
Lead	0.05 mg/l	R & A	MCL
Mercury	0.002 mg/l	R & A	MCL
Nitrate	10.0 mg/l	R & A	MCL
Nitrite	1.0 mg/l	R & A	Human Health standard[1]
Selenium	0.01 mg/l	R & A	MCL
Silver	0.05 mg/l	R & A	MCL
Chloride	250 mg/l	R & A	Secondary Drinking Water[1]
Copper	0.2 mg/l	R & A	Agricultural standard[1]
Iron	0.3 mg/l	R & A	Secondary Drinking Water[1]
Manganese	0.05 mg/l	R & A	Secondary Drinking Water[1]

Table 3(continued)

Chemical-Specific State and Federal ARARs for Ground Water

Contaminant	Standard	ARAR	Comments
pH	6.5 - 8.5	R & A	Secondary Drinking Water[1]
Sulfate	250 mg/l	R & A	Secondary Drinking Water[1]
Zinc	2.0 mg/l	R & A	Agricultural standard[1]
Aluminum	5.0 mg/l	R & A	Agricultural standard[1]
Beryllium	0.1 mg/l	R & A	Agricultural standard[1]
Cobalt	0.05 mg/l	R & A	Agricultural standard[1]
Molybdenum	0.10 mg/l	TBC	Proposed 40 CFR 192 standard
Nickel	0.20 mg/l	R & A	Agricultural standard[1]
Vanadium	0.1 mg/l	R & A	Agricultural standard[1]

1 5 CCR 1002-8 3.11.0

Denver Radium Site
Operable Unit VIII
Action Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
Clean Air Act	40 CFR 50 to 69			
New Source Performance Requirements	40 CFR 60	Establishes emission standards for new air emissions	Potentially R & A	If temporary air pollution sources are constructed in conjuction with treatment process for soils the regulations may be relevant and appropriate.
Colorado Air Quality Control Act	CRS 25-7-101 to 512			
Common Provision Regulations	5 CCR 1001-2, Sec. II	Conduct performance tests, emissions monitoring, and recordkeeping	Applicable	Substantive requirements are applicable to air emission component of the remedy.
Regulation No. 1	5 CCR 1001-3, Reg 1	Establishes emission control regulations for particulates, smokes, carbon monoxide, sulfur oxides, and fugitive particulate emissions	Portions are Applicable	See below for description of specific provisions.
Regulation 1, Stationary Emissions Source	5 CCR 1001-3, Reg 1, Sec. II.A.1	Comply with opacity limitations	Applicable	Less than 20 % opacity emitted, specific sources may have other limitations.
	5 CCR 1001-3, Reg 1, Sec. III.D	Minimize fugitive particulate emissions	Applicable	Applicable to construction activities, storage and handling operations, haul roads and haul trucks. R & A to non-specific sources.
	5 CCR 1001-3 Reg 1, Sec. III.D	Submit fugitive particulate emission control plan	Applicable	Substanative requirements applicable.

Denver Radium Site
Operable Unit VIII
Action Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
Regulation No. 2	5 CCR 1001-4	Establishes odor emission regulations	Applicable	
Regulation 3	5 CCR 1001-5, Reg 3, Sec. II	File APEN including estimation of emissions rates	Applicable	Substantive portions are applicable to all sources including earthwork and existing sources unless specifically exempt.
	5 CCR 1001-5, Reg 3, Sec. IV.D.	No source or activity should cause exceedence of NAAQS or State Standard in an attainment area	Applicable	Denver is nonattainment, however particulate less than ten microns (PM10) does not have nonattainment areas, therefore applicable to PM10.
	5 CCR 1001-5, Reg 3, Sec. IV.D.3	Undergo review procedure which estimates public health impacts from toxic pollutants	Applicable	Substantive requirements are applicable.
Regulation No. 7	5 CCR 1001-9, Reg 7	Establishes regulations to control emissions of VOC's (new and existing sources)	Applicable	Apply Reasonably Available Control Technology (RACT). Section V requirements regarding evaporation as the method of disposal are applicable.
Regulation 8	5 CCR 1001-10, Reg 8	Comply with hazardous air pollutants limitations	Applicable	Contains specific requirements for asbestos handling and abatement.
Ambient Air Quality Standards	5 CCR 1001-14	Sets ambient standards for total suspended particulates, sulfur dioxide, oxidant, CO, nitrogen dioxide	Applicable	Would be applicable if remedial action would cause emission of regulated constituents.
Hazardous Materials Transportation Act	49 USC 1801 to 1813			

Denver Radium Site
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Action Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
Transportation Regulations	49 CFR parts 107, 171 to 177	Regulates transportation of hazardous materials. Part 173 is specific to radioactive materials.	Applicable	Applicable to transportation of radioactive wastes from buildings and facilities to off-site disposal facility.
Colorado Hazardous Waste Regulations, Waste characteration	6 CCR 1007-3. parts 260, 261, 262.11	Defines hazardous wastes, requires waste characterization.	Applicable	TC testing will be performed during excavation to evaluate whether hazardous wastes are present.
	6 CCR 1007-3, Part 264	Standards for owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	Portions potentially applicable or R & A	Requirements for management of hazardous wastes based uopn the mode of management, i.e. container storage, waste piles, impoundments, etc. Potentially applicable or relevant and appropriate if characteristic or listed RCRA wastes are encountered during remediation.
Radiation Control Act	CRS 25-11-101 tO 25-11-305			
	6 CCR 1007-1. Part 1	General provisions (including definitions) for 6 CCR 1007-1	Applicable	
	6 CCR 1007-1 Part 3	Regulations concerning licensing of radioactive materials	Portions Applicable, Portions R & A	Substantive portions are applicable or R & A, for remedies which dispose of radioactive materials on-site substantive requirements are applicable.

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Action Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
	6 CCR 1007-1, Part 4	Establishes standards for protection against radiation hazards	Applicable or R & A	This part applies to all licenses and registrants. Substantive portions are relevant and appropriate to non-licensed areas.
	6 CCR 1007-1, Part 10	Notes, instructions, and reports to workers	Applicable or R & A	Substantive portions are applicable to licnsed areas, R & A to nonlicensed areas.
	6 CCR 1007-1, Part 14	Establishes procedures, criteria, and terms and conditions upon which the Department issues licenses for land disposal of low-level radioactive wastes	Portions R & A	Portions of substantive requirements including the performance requirements are relevant and appropriate to on-site disposal.
	6 CCR 1007-1, Part 17	Transportation of radioactive materials	Applicable or R & A	Substantive portions are applicable or relevant and appropriate.
	6 CCR 1007-1, Part 18	Licensing requirements for milling facilities and for the disposition of products of milling operations for uranium, thorium and related materials	Portions R & A	Portions of substantive requirements are relevant and appropriate.
Solid Wastes Disposal Sites and Facilities Act	CRS 30-20-101 to 118			
Solid Wastes Disposal Sites and Facilities Regulations	6 CCR 1007-2	Establishes minimum standards, closure requirements, site standards, and engineering design standards for solid waste disposal facilities.	Potentially Applicable or R & A	The substantive requirements would apply to on-site disposal of solid waste.

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Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
Prohibition on burial of sludge	6 CCR 1007-2, 2.2.11, 2.2.12	Prohibits both onsite and offsite burial of liquid waste	Potentially Applicable	
Solid Waste Regulations, Asbestos Disposal	6 CCR 1007-2 Sec. 8	Requirements for the disposal of asbestos containing materials	Applicable	Applicable to non-radioactive asbestos materials, radioactive asbestos materials require disposal at a facility permitted to accept such wastes.
Clean Water Act	33 USC 1251 to 1376			
Storm water discharge regulations	40 CFR 122, 123, 124	Regulates discharges of storm water and run off water	Applicable	Utilize Best Available Technology (BAT) and Best Conventional Pollutant Control Technology
Colorado Water Quality Control Act	CRS 25-8-101 to 703			
Basic Standards and Methodologies for surface water	5 CCR 1002-8, Section 3.1.0	Establishes basic standards, anti-degradation standard, system for classifying state waters	Applicable	Applicable to component of remedy impacting surface water.
Classifications and Numeric Standards, S. Platte R. Basin, et al.	5 CCR 1002-8, Section 3.8.0	Used in conjunction with Basic Standards and Methodologies (Sec. 3.1.0)	Applicable	For any surface water discharge identified, compliance is required for segment #14 of S. Platte River.
State Discharge Permit Regulations	5 CCR 1002-2 Sec. 6.1.0	Requires a permit for the discharge of pollutants from any point source into waters of the State.	Potentially Applicable	Must comply with substanative requirements. Applicable to storm sewer discharge unless infiltration is eliminated.

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Action Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
	5 CCR 1002-2 Sec. 6.9.7	Perform acute and chronic biomonitoring tests before discharge is permitted	Potentially Applicable	Discretionary requirement under the CDPS program, these monitoring requirements may be required for point source surface water discharge.
Basic Standards for Ground Water	5 CCR 1002-8, Section 3.11.0	Establishes a system for classifying ground water and adopting water quality standards to protect existing and potential beneficial uses	Portions Applicable, Portions R & A	Establishes framework, site-specific classifications and standards. Statewide standards are applicable. Standards based on classification are R & A.
Storm Water Discharge Regulations	5 CCR 1002-7	Establishes requirements relating to run-off waters and discharge into storm sewers.	Applicable	Colorado and federal storm water regulations are applicable to run-off from the site.
Water Well and pump Installation Contractors Regulations	2 CCR 402-2	License requirements for well construction and pump installation contractors and minimum standards for well construction and abandonment	Applicable	Establishes regulations for construction and abandonment of wells.

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Location Specific ARARs

Standard, Requirement, criteria, or limitation	CITATION	DESCRIPTION OR REQUIREMENTS	Status	COMMENTS
Colorado Hazardous Waste Act	CRS 25-15-101 to 313	Establishes broad siting criteria and site evaluation procedures for individual storage or disposal units (i.e., impoundments, landfills).	Potentially Applicable or R & A	Relevant and appropriate if waste characterization is hazardous.
Radiation Control Regulation, Siting requirements	6 CCR 1007-1, Part 14	Siting and design criteria for land disposal of low level radioactive waste. Design of repository required to meet performance standards of 14.19-22.	Portions R & A	Substantive portions are relevant and appropriate to on-site disposal of radioactive soil.
	6 CCR 1007-1 Part 18	Siting and design criteria for uranium and thorium milling facilities.	R & A	Substantive portions are relevant and appropriate to on-site disposal of radioactive soils.
Solid Waste Regulations, Siting requirements	6 CCR 1007-2, secs. 1.1, 1.2, 1.3.2, 2.1.1,	Siting requirements for solid waste disposal sites.	Potentially Applicable	Would be applicable if solid waste is disposed on-site.
National Historic Preservation Act	16 USC 470, 40 CFR 6.301(b), 36 CFR 800	Requires federal agencies to take into account the effect of federal projects on sites included in or eligible for the National Register	Potentially Applicable	If site is determined to have national historic significance, requirements may be applicable.
Archaeological and Historic Preservation Act	16 USC 470, 40 CFR 6301(c)	Procedures to provide for preservation of historical and archeological data that might be destroyed during a federal project	Potentially Applicable	see above
Colorado State Historical Requirements	CRS 25-80-201 to 211	Regulates historical, prehistorical and archeological resources.	Potentially Applicable	State historic preservation office will be notified of selected alternative during remdial design to coordinate historical requirements, if any.