



SUPERFUND FINAL CLOSE OUT REPORT

**Denver Radium Superfund Site
Denver, Denver County, Colorado**

September 25, 2006

I. Introduction & Background

This Final Close Out Report (FCOR) documents that the U.S. Environmental Protection Agency (EPA) completed all response actions for the Denver Radium Site in accordance with *Close Out Procedures for National Priorities List Site* (OSWER Directive 9320.2-09A-P). The Denver Radium Superfund Site consisted of over 65 properties separated into eleven Operable Units (OUs) located throughout Denver, Colorado. These properties were contaminated by radioactive residues derived from the processing of radium ore in the early 1900's. In 1979, EPA noted a reference to the National Radium Institute (NRI) in a 1916 U.S. Bureau of Mines report. This reference revealed the presence of 31 radioactive sites in the Denver Metropolitan area. In 1913, the NRI was established in Denver as a domestic source of radium, which was in high demand in cancer therapy and research. Subsequently, the Denver radium, vanadium and uranium industry thrived until the early 1920s, when rich ore deposits were discovered in Africa. The Site was added to the Superfund National Priorities List (NPL) in September 1983. The 65 properties were divided into eleven OUs, based on their location, in order to simplify the remedial process.

Nine Records of Decision (RODs) were written to document the remedial actions at the eleven Operable Units.

ROD Name:	Date of Signature:
Denver Radium OU1	September 1987
Denver Radium OU2	September 1987
Denver Radium OU3	September 1987
Denver Radium OU4/OU5	September 1986
Denver Radium OU6, 9, & 11	September 1987
Denver Radium OU 7	March 1986
Denver Radium OU8	January 1992
Denver Radium OU10	June 1987

This report documents the actions taken by the EPA at each individual operable unit as described above and is organized according to a modified version of the Final Close Out Report Summary outline provided in the guidance listed above. In order to prevent duplication of information, the sections on ROD Findings and Design Criteria have been combined. The total site cost for all of Denver Radium's operable units from October 1, 1980 through August 11, 2006 has been calculated at \$327,606,323. Total costs per OU

are difficult to track because costs were not tracked by individual OU until after 1996. Most remedial work performed at the Denver Radium OUs precedes this date. A summary of the best available information has been included in the OU report.

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Unit 1

II. Summary of Site Conditions/OU1

A. Background

Denver Radium Operable Unit 1 (OU1), also known as the 12th and Quivas Properties, is an 8-acre block bounded by Quivas Street to the east, Shoshone Street to the west, and West 12th Avenue to the north. Denver Radium OU1 included the following properties in Denver, Colorado:

Operable Unit	Property Name at time of ROD	Address
OU1	B & C Metals <i>(now Martin Shea Millworks)</i>	1623 – 1625 West 12 th Ave.
OU1	Erickson Monuments	1241 – 1245 Quivas St.
OU1	Materials Handling, Inc.	1740 West 13 th Ave.
OU1	Rudd	1223 – 1229 Quivas St.
OU1	City/County of Denver Alley/ Driveway	East of B & C Metals, between 12 th Ave. and Erickson Monuments

For almost 100 years, this unit has been represented by several addresses and has been used by numerous businesses that engaged in a wide variety of activities. Radiological contamination at OU1 resulted from radium, vanadium, and uranium processing facility located at 1201 Quivas Street that was owned by the Pittsburgh Radium Company, a division of the National Vanadium Products Company, (PRC) from 1925 to 1926. The Radium Ores Company, which was associated with PRC, operated the facility until approximately 1927. Approximately 120 tons of carnotite and 500 tons of vanadium are believed to have been processed monthly at the facility. Products produced included medicinal materials, luminous materials, and alloy for tools and automobile manufacturing.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, two of which comprise the OU1 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative

agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983.

C. RI/FS

A Remedial Investigation (RI) of OU1 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The draft Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in July 1987. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest is radium-226 (Ra-226), its associated radioactivity (gamma radiation and radon-decay products) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,
- 15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.

The background level used for the Denver Radium Site is 2.0 pCi/g.

Approximately 10,700 cubic yards of contaminated soil with depths to 90 inches were identified on the OU1 properties. The contamination involved both exterior and interior areas; the interior areas were in the Materials Handling building, the B&C Metals building, and the included Rudd Investments building. As part of the EPA study of OU1, a vented plenum wall was installed in the B&C Metals building to determine whether immediate mitigation measures were required to protect the health of workers. The system significantly reduced the radon levels and the remedial action on the building proceeded under the same schedule as the other buildings in the unit.

A groundwater monitoring well was installed on the northern portion of OU1 between the Materials Handling and Rudd Investments buildings. The well was installed to investigate a possible plume in the groundwater that may have been contaminated with organic chemicals and was believed to have been associated with an adjacent property. Results of the data showed the plume did not extend into OU1.

The FS addressed the following Remedial Action Alternatives:

- No Action;
- Defer removal until availability of Off-Site Permanent Disposal facility;
- On-Site Reprocessing/Permanent Disposal;
- In-situ Vitrification;
- On-Site Permanent Disposal;
- Off-Site Permanent Disposal;
- On-Site Temporary Land Storage/Off-Site Permanent Disposal;
- On-Site Temporary Storage Building/Off-Site Permanent;
- On-Site Temporary Containment (capping); and,
- Temporary Storage Building at Unit X/Off-Site Permanent Disposal.

D. ROD Findings & Design Criteria

The ROD documented the remedial action alternative preferred by the EPA for OU1 was Off-Site Permanent Disposal. However, because a permanent disposal facility was not available at the time of the ROD was issued in September 1987, EPA selected the On-Site Temporary Containment (capping) with the Off-Site Permanent Disposal alternative. The scope of the ROD's proposed remedial action entailed the following:

- Placing a cap over the identified open areas of soil contamination;
- Excavating the contaminated soil lying under several structures on the property and placing this material into a temporary storage facility on site;
- Maintaining the cap and temporary storage facility until a facility suitable for the permanent disposal becomes available; and,
- Final removal of the contaminated material to the permanent disposal facility.

The plan for On-Site Temporary Containment was abandoned when a permanent disposal facility operated by Envirocare in Toole County, UT, became available.

E. Cleanup Activities performed

Remediation activities were conducted in three phases (A, B, and C) to facilitate construction and to accommodate the various on-going business activities within the unit. Phase A remediation activities involved the areas to the south and west of the Materials Handling building. Phase B remediation activities involved the Materials Handling building in the northwest portion of OU1. Phase C remediation occurred east of the Materials Handling building in the center portion of the unit. Construction at OU1 began on October 2, 1989, and concluded on July 18, 1991. The total quantity of material removed during remediation was 32,665 tons (approximately 27,220 cubic yards). The exterior (open land) standard was used to verify that all material removed was in compliance with regulations and requirements.

Excavation of contaminated material was performed using front-end loaders directed by field personnel measuring radiation levels in the excavations with hand-held detectors. Excavation was also guided by soil sample analysis. After the removal of material was completed based on the readings of the field instruments, verification sampling and analysis was performed.

Contaminated materials were transported by rail in covered gondola cars to the permanent off-site disposal-storage area. Material was loaded directly onto the cars at the site by the Geotech subcontractor. Each gondola car was filled with material and the inspected to ensure the no spillage of waste material occurred. The cars were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulations did not require labeling of material of low level radioactive concentrations, the waste were labeled Denver Radium Superfund Waste as an extra measure of protectiveness. Composite samples were taken from each rail car during loadout and were analyzed to ensure that the material was acceptable under the requirements of the disposal facility. Approximately 99 tons of material exempt under the Bevill Exclusion Amendment of RCRA was also removed from the site. This material was also transported to Envirocare.

During remediation activities of Phase B and C, several areas on the unit required additional assessment or the use of area averaging calculations because of considerations that prevented cost-effective and safe removal of contaminated material. These areas area as follows:

Materials Left in Place as Averaged Areas – OU1¹
Phase B

AREA	Size	Description	Area Avg. (pCi/g)
Area A	60 sq/ft.	Materials Handling bldg., beneath south foundation	6.8 pCi/g Ra-226 (Conforms to EPA subsurface std.)
Area B	27 sq/ft	Materials Handling bldg., south foundation	5.6 pCi/g Ra-226 (Conforms to EPA subsurface std.)
Area C	360 sq/ft	Materials Handling bldg., northern portion	No contamination found – excluded from remedial action
Area D	800 sq/ft	Materials Handling bldg., eastern wall	No contamination found – excluded from remedial action
Area E	105 sq/ft	Materials Handling bldg. under the west side of showroom	7.7 pCi/g Ra-226 (Conforms to EPA subsurface std.)

¹ Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above

background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

Materials Left in Place as Averaged Areas - OU1¹
Phase C

AREA	Size	Description	Area Avg. (pCi/g)
Area A	193.5 sq/ft	Beneath the restrooms and front office of the Erickson Monuments bldg.	12.0 pCi/g Ra-226 (below EPA subsurface stnd.)
Area B	430.5 sq/ft	Under shed north of Rudd Inv. Bldg.	12.0 pCi/g Ra-226 (below EPA subsurface stnd.)
Area C	2,400 sq/ft	Inside B&C bldg	No contamination found – excluded from remedial action
Area D1 Area D2	305 sq/ft 307 sq/ft	Two deposits in B&C bldg	Area D1 9.3 pCi/g Ra-226 (below EPA subsurface stnd.) Area D2 8.0 pCi/g Ra-226 (below EPA subsurface stnd.)
Area E	18 sq/ft	Beneath footer in B&C Metals	10.0 pCi/g Ra-226 (below EPA subsurface stnd.)
Area F	119 sq/ft	Beneath the hallway at north end, B&C Metals bldg.	8.8 pCi/g Ra-226 (below EPA subsurface stnd.)
Area G	462 sq/ft	East side, Materials Handling warehouse	16.4 pCi/g Ra-226 (below EPA subsurface stnd.)

¹ Area averaging calculates the exposure risk of several readings from 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

F. Community Involvement activities performed

EPA's Community Relations Plan for OU1 involved the community in the decision-making process relating to the remedy to be implemented at Operable Unit 1, and promoted communications among interested parties throughout the course of the project. General community concerns of the project. General community concerns were the impacts of cleanup and storage on property values, the need for temporary storage of wastes, the health risks from the cleanup, the transportation risks, and the possibility of the temporary storage facility becoming permanent.

Community relations activities OU1 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meetings to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;
- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizens groups, State and local governments, EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Informing communities along the transportation route (through meetings and mailings) of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU1 was already developed and utilized for commercial and light industrial uses at the time of the remedial action. In a site visit performed in August 2003, all properties at OU1 were being used for the same purposes.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech Quality Assurance Manual, which was developed in response to the DOE Field Office, ID, Order 5700.6. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA

Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU1* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental air monitoring was required to adequately define the possible health effects of the remedial activities undertaken at OU1 on off-site air quality. Off-site air quality monitoring data were collected during a baseline period, during the construction period, and after the remedial action was completed. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter were placed at each measurement location. There was no significant difference between the data set for the baseline period, the construction period, and the post-remedial action period.

V. Summary of Operation and Maintenance

OU1 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD and in accordance with CERCLA, 42 U.S.C. Section 9601, et.seq., as amended by SARA and the NCP, 40 CFR Part 300. No operation and maintenance is required for the remedy undertaken at OU1.

VI. Summary of Remediation Costs

The Remedial Action Completion report for OU1 lists the cost for remediation as \$9,561,306. This figure may not be an accurate accounting for the total cost associated with OU1, as cost were not tracked by operable unit for Denver Radium until after 1996.

VII. Protectiveness

Health hazards associated with the radium waste present at OU1 prior to the remedial action were the result of direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU1 have been excavated in accordance with the Federal and State standards cited in the documents for addressing the remedial action at OU1. Excavated wastes were disposed of at a permanent off-site disposal site. All work was done in accordance with the ROD and applicable EPA directives. The remedial action at OU1 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU1.

- Though the waste material found at OU1 did not meet the U.S. Department of Transportation (DOT)'s definition of radioactive material, it was transported as if it were a low-specified activity (LSA), naturally occurring radioactive material. In addition, substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and particle emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU1 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of releases during the transportation of wastes, fires, and adverse weather conditions.

VIII. Five-Year Review

The levels of waste material remaining at the OU1 where area averaging was used allow for unrestricted use and unrestricted exposure. OU1 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that all ROD requirements had been met through the remedial action, all contamination had been removed from OU1, and the remedy is protective of human health and the environment. While a Five-Year Review is not required at OU1, the locations where waste was left in place should be tracked with the established GIS database for proper disposal during potential future development. The conditions of the individual properties that comprise OU1, and the requirements of future five year reviews are as follows:

Status of OU1 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
B & C Metals (now Martin Shea Millworks)	1623 – 1625 West 12 th Ave.	Yes	Yes	No
Erickson Monuments	1241 – 1245 Quivas St.	Yes	Yes	No

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
Materials Handling, Inc.	1740 West 13 th Ave.	Yes	Yes	No
Rudd	1223 – 1229 Quivas St.	Yes	Yes	No

IX. Bibliography

- Superfund Record of Decision: Denver Radium/12th & Quivas, CO – EPA/ROD/R08-87/013 - Region 8
- Denver Radium Site/Operable Unit 1 Closeout Report for the U.S. Environmental Protection Agency – August 1992 – Chem-Nuclear Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

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Denver Radium Operable Unit 2

II. Summary of Site Conditions/OU2

A. Background

Denver Radium Operable Unit 2 (OU2), also known as the 11th and Umatilla Properties, is an 24-acre area bounded on the east by the Burlington Northern Railroad, on the north by West 11th Street, on the west by Yuma Street, and on the south by West 10th Avenue. I-25 is located approximately 75 feet west of the western portion of the property. Denver Radium OU2 included the following properties in Denver, Colorado:

Operable Unit	Property Name at time of ROD	Address
OU2	DuWald Steel <i>(now Atlas Metals & Iron)</i>	1100 Umatilla Street
OU2	Rocky Mountain Research Corporation <i>(now AI Transmission and Nationwide Courier)</i>	1020 – 1030 Yuma Street
OU2	G&K Services	999 Vallejo Street
OU2	Jenkins Property	2191 West 10 th Street
OU2	Staab Property	2121 West 10 th Street
OU2	Air Conditioning, Inc.	1001 South Tejon Street
OU2	Colorado DOT – Jerome Maintenance Yard	2300 West 11 th Avenue
OU2	Burlington Northern Railroad	Between 10 th & 11 th Avenues
OU2	Flame Spray, Inc.	1900 West 12 th Avenue
OU2	Alpha Omega Electronics	1010 Yuma Street
OU2	Capital Management Realty <i>(now Royal Textile)</i>	1050 Yuma Street
OU2	Denver Water Board	1600 West 12 th Avenue

The contamination of OU2 is believed to be the result of activities of the Schlesinger Radium Company, which commenced operations in 1914, where DuWald Steel Corporation is currently located. In 1917, Schlesinger Radium Company became the Denver Radium Company of Colorado (RCC), which reportedly processed between 1,000 and 1,200 tons of radium ore per year. RCC ceased operations at the site in 1924. The site was occupied until 1928 by the Complex Ores Recovery Company, which was

financially involved with RCC, and it is not known if that company also processed radium ore.

Rocky Mountain Research Corporation received a license from the U.S. Atomic Energy Commission in 1955 to possess uranium ore. Residual radioactive contamination on the Rocky Mountain Research Corporation property may be associated with operations related to that license. The DuWald Steel Corporation and the Rocky Mountain Research Corporation properties constituted OU2 as originally defined. The remaining properties associated with OU2 are contiguous with the two original OU2 properties and were included as subsequent investigations revealed the presence of additional contamination. Remediation activities at the Denver Water Board Headquarters were not included in the original Record of Decision (ROD). Historically, two ditches crossed OU2 in the late 1800s. These were later abandoned and gradually filled with rubble and, presumably, radium mill tailings. Approximately 65 percent of the OU2 land area lies within a designated 100-year flood plain.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, two of which comprise the OU2 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU2.

C. RI/FS

A Remedial Investigation (RI) of OU2 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The draft Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in September 1987. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest was radium-226 (Ra-226), its associated radioactivity (gamma radiation and radon-decay products) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters

(1,076 square feet) shall not exceed the background level by more than:

- 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,
- 15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.

The background level used for the Denver Radium Site is 2.0 pCi/g.

The RI for OU2 identified approximately 15,400 cubic yards of contaminated soil at depths ranging from 6-inches to 144-inches below ground surface, with Ra-226 concentrations as high as 931 pCi/g. The interior areas of contamination were in the DuWald Steel Corporation scale house, which includes the corporation's business offices. High radon decay product concentration (RDC) values were found in the basement of the Capital Management Realty building. Radiological contamination was identified on the roof of the Rocky Mountain Research Corporation building. A groundwater monitoring well was installed on the northern portion of OU2 between the Materials Handling and Rudd Investments buildings. The well was installed to investigate a possible plume in the groundwater that may have been contaminated with organic chemicals and was believed to have been associated with an adjacent property. Results of the data showed the plume did not extend into OU2.

The FS addressed the following Remedial Action Alternatives, which were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Defer removal until an Off-Site Permanent Disposal facility became available;
- On-Site Reprocessing/Off-Site Permanent Disposal;
- On-Site Permanent Disposal;
- Off-Site Permanent Disposal;
- On-Site Temporary Land Storage/Off-Site Permanent Disposal;
- On-Site Temporary Storage Building/Off-Site Permanent;
- On-Site Temporary Containment (capping), Off-Site Permanent Disposal; and,
- Temporary Storage Building at Operable Unit 10/Off-Site Permanent Disposal.

D. ROD Findings & Design Criteria

The remedial action alternative preferred by EPA for OU2 was Off-Site Permanent Disposal. Because a permanent disposal facility was not available when the ROD was issued in September 1987, the remedy selected by EPA was a combination of On-Site Temporary Land Storage and On-Site Temporary Containment with subsequent Off-Site Permanent Disposal.

The scope of the ROD's proposed remedial action entailed the following:

- Decontaminating the roof of the Rocky Mountain Research Corporation building and excavating the majority of the approximately 15,400 cubic yards of contaminated material located under buildings and in open areas on the properties, and placing the material in a temporary on-site land storage facility;
- Maintaining the 6-inch thick concrete pad covering contaminated soil on the northeast part of the DuWald Steel Corporation property; and,
- Removing the contaminated material from the temporary storage and containment locations to the permanent disposal facility when such a facility became available.

The plan for On-Site Temporary Land Storage and On-Site Temporary Containment at OU2 was abandoned when a permanent disposal facility operated by Envirocare in Toole County, UT, became available.

The actual remediation conducted at OU2 differed from the remedial action selection and scope of the cleanup described in the ROD because of the on-site conditions that became apparent after the ROD was signed. EPA issued an Explanation of Significant Differences (ESD) in September 1993 to address the following changes:

- The area of contamination and associated volume of contaminated soils was greater than anticipated;
- Contamination was left in place beneath or in a one-to-one slope adjacent to the scale, scale house, and attached warehouse, southeast warehouse, east storage building, and shredder structure, on the Burlington Northern Railroad right-of-way, around major utility lines that cross the property, and below groundwater.
- Temporary storage of contamination was not required because all contaminated materials were disposed of in a permanent disposal facility; and,
- Radiologic contamination mixed with lead was identified on the property, treated, and disposed.

Also, EPA prepared a memorandum to the file that modifies the ROD to include the alley property east of Yuma Street in OU2 and to include the alley in the Institutional Controls Plan.

E. Cleanup Activities performed

Radiological Contamination

Remedial actions at OU2 were conducted from August 1990 through August 1993. This remedial action resulted in the excavation and off-site disposal of 92,798 tons of radium contaminated soil. The on-site businesses were able to maintain operations throughout the excavation and shipment contaminated soils. This required four phases of the excavation and reconstruction activities to permit continued access to the site for ongoing business operations. The four phases were as follows:

- Phase A – Conducted August 1990 through October 1990*
Properties:
Flame Spray, Inc.
Alpha Omega Electronics
Capital Management
Colorado Department of Transportation-Jerome Park Maintenance Shop
- Phase B - Conducted January 1990 through September 1990*
Properties:
Staab Building
Jenkins Building
- Phase C - Conducted September 1991 through December 1991*
Properties:
DuWald Steel
- Phase D - Conducted January 1992 through November 1992*
Properties:
DuWald Steel
Burlington Northern Rail Road Right-of-way

A total of 1,359 tons of radiologically contaminated soil were excavated and disposed of offsite during Phase A. In Phase B, a total of 3,622 tons of contamination was removed. For Phase C, both radiological and heavy metal (lead) contamination were found on the 1100 Umatilla Street property. A total of 14,211 tons of radiological and commingled material was excavated and shipped offsite. The commingled material was stabilized by solidification prior to offsite disposal. During Phase D, a total of 73,606 tons of radiologically contaminated soil were disposed offsite. In a separate removal action conducted in 1993, a total of 933 tons of lead-contaminated soils from the 1100 Umatilla Street property were treated and shipped to Weld County (Subtitle D) Landfill in Erie, CO.

The ESD issued for OU2 in September 1993 presents the changes that were made to the remedy selected for OU2; briefly, the differences were:

- A greater volume of radium-contaminated soil was excavated and removed;
- Relatively small amounts of radium contamination were left on the 1100 Umatilla Street property;
- There was no temporary onsite storage of waste material; and,
- Soils containing commingled radium and lead were solidified in a cement matrix prior to shipment to a permanent, offsite disposal facility.

A Supplemental Standards Report was prepared in May 1994 to document that 11,060 cubic yards of radiological contaminated soil were left in place on the Burlington Northern Railroad property and the 1100 Umatilla Street property at OU2.

Seven additional deposits of contamination at OU2 were left in place because levels of contamination met the standards when averaged over a 100 square meter area. There areas are as follows:

Materials Left in Place as Averaged Areas – OU2¹

AREA	Size	Description	Area Avg. (pCi/g)
Area AA	120 sq/ft.	Contaminated soil beneath the floor slab of north shop building at CO DOT- Jerome Park	9.6 pCi/g Ra-226 (conforms to EPA stnd.)
Area AB	70 sq/ft	Telephone line inside the east property boundary of CO DOT-Jerome Park	8.9 pCi/g Ra-226 (conforms to EPA stnd.)
Area AD	75 sq/ft	Telephone line inside the east property boundary of CO DOT-Jerome Park	16.3 pCi/g Ra-226 (conforms to EPA stnd.)
Area DT	210 sq/ft	Northeast corner of the Jenkins Building foundation – greater than 10 feet deep	14.2 pCi/g Ra-226 (conforms to EPA stnd.)
Area ED	470 sq/ft	East side of Staab Building – greater than 8 feet deep	13.5 pCi/g Ra-226 (conforms to EPA stnd.)
Area EE	187 sq/ft	North side of Air Conditioning, Inc.	8.8 pCi/g Ra-226 (conforms to EPA stnd.)
Area EF	408 sq/ft	North side of G&K Services property – greater than 8 feet deep	12.5 pCi/g Ra-226 (conforms to EPA stnd.)

¹ Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

Non-Radiological Contamination

Regulated wastes were identified in three instances in OU2. Soil contaminated with lead at concentrations regulated by the Resource Conservation and Recovery Act (RCRA) was

identified around the east storage building and near the southwest corner of the DuWald Steel Corporation property where broken battery casings were discovered. Based on analytical results, the soil was determined to be a RCRA-toxicity-characteristic waste as defined in 40 CFR 261 Subpart C.

During remediation of the lead-contaminated area, radium-contaminated soil was segregated from non-radium contaminated soils. The non-radium contaminated soil and broken battery casings were isolated and stabilized by solidification. The radium and lead contaminated soil and broken battery casings (approximately 4,774 tons) also were stabilized on site by solidification. In both instances the treated soil was sampled and analyzed in accordance with the Toxicity Characteristic Leaching Procedure and determined to be non-hazardous because it no longer exhibited the RCRA toxicity characteristic for lead.

Radium contaminated soil located near the center of DuWald Steel Corporation property was found to contain lead at concentrations above the corresponding RCRA-toxicity characteristic regulatory limit. The results of analysis for other metals and contaminants in this area were negative. Because the lead in the mill tailings was the result of radium ore processing operations, the soil was exempt from RCRA regulation in accordance with 40 CFR 261.4(b)(7).

Also, vinyl asbestos tile (VAT) was found adhering to concrete rubble unearthed south of the Staab building.

Disposal Operations

Contaminated materials were transported by rail in covered gondola cars to the permanent off-site disposal facility. The disposal contractor loaded material directly onto the cars at the site.

Each gondola car was sealed, surveyed, and decontaminated, as necessary. The cars were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness.

A composite sample was collected from each railcar during loading and analyzed to ensure that the material conformed to the acceptance requirements of the disposal facility. Both the treated (solidified) nonhazardous radium/lead contaminated soil and the lead contaminated mill tailings (a RCRA-exempt waste) were shipped to the Envirocare of Utah, Inc., facility for disposal.

The treated lead contaminated soil that was not also contaminated with radium was disposed of in a municipal landfill.

The VAT removed from the Staab building (approximately 165 pounds or 10 cubic feet) was disposed of at an approved disposal facility. The soil removed from the Denver Water Board property satisfied the EPA-approved criteria for off-site backfill material and was used as subsurface fill at OU2.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU2 and promoted communications among interested parties throughout the duration of the project. General community concerns were the impacts of cleanup and storage on property values, the health risks associated with the cleanup, the transportation risks, the need for temporary storage of wastes, and the possibility of the temporary storage facility becoming permanent.

Community relations activities OU2 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meetings to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;
- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizens groups, State and local governments, EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Informing communities along the transportation route (through meetings and mailings) of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU2 was already developed and utilized for commercial and light industrial uses at the time of the remedial action. In a site visit performed in August 2003, all properties at OU2 were being used for the same purposes.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech *Quality Assurance Manual* (Manual 101), which was developed in response to the DOE Field Office, ID, Order

5700.6. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU2* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental monitoring was required to determine whether the remedial action adversely affected off-site air quality at OU2. Off-site air quality monitoring data were collected before, during, and after the remedial action. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter were placed at each of five measurement locations. There were no significant difference between the data set for the baseline period, the construction period, and the post-remedial action period.

Air Particulate Measurement

Air particulate samples were collected with Model LV1 low-volume air particulate samplers manufactured by F&J Specialty Products, Inc. Each sampler was contained in its own environmentally protected shelter and connected to a dedicated electrical power outlet. The samplers were operated continuously for 7 days at a nominal rate of 5 liters per minute. The filters were analyzed by Geotech analytical laboratory for natural uranium, Th-230, Ra-226, and polonium-210 (Po-210).

EPA designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for airborne radionuclides. These standards are expressed as concentrations above background as follows:

Natural Uranium	-	5.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Th - 230	-	8.0×10^{-14} microcuries per milliliter ($\mu\text{Ci/mL}$)
Ra - 226	-	3.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Po - 210	-	2.0×10^{-11} microcuries per milliliter ($\mu\text{Ci/mL}$)

All airborne radionuclide concentrations measured during the reporting period were below the applicable regulatory standard.

Atmospheric Radon Measurements

Terradex outdoor Type F Track Etch ® radon detectors were used to determine atmospheric radon concentrations. Two detectors were exposed in an environmentally

protected enclosure approximately 1 meter above ground level. Each detector consisted of an alpha-sensitive film protected by a membrane analyzed by Terradex Corporation for the density of the alpha tracks produced by radon decay, which is proportional to the radon concentration in the atmosphere sampled.

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for atmospheric radon concentration. The regulatory standard is 3.0 picocuries per liter above background. All atmospheric radon concentrations measured during the reporting period were below this standard.

Direct External Gamma Exposure Measurement

TMA/Eberline thermoanalytical environmental dosimeters were used to measure the external gamma radiation at each sample location. A dosimeter was exposed approximately 1 meter above ground level at each sample location and was submitted to TMA/Eberline Thermo Analytical, Inc., for analysis.

The background gamma exposure rates for the Denver area range from 130 to 175 mrem/yr (CH2M Hill, 1986). All gamma exposures measured during the reporting period were below this limit.

V. Summary of Operation and Maintenance

OU2 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD, as modified by an ESD and a memorandum to the file, and in accordance with CERCLA, 42 U.S.C. Section 9601, et seq., as amended by SARA and the NCP, 40 CFR Part 300. Supplemental standards have been applied in some instances; therefore, land use restrictions will apply, and EPA conducted a 5-year review of the remedial action in September 2003. In June 2006, an Environmental Covenant was put into place for relevant portions of OU2. This covenant provides an enforceable Institutional Control (IC) for OU2 properties.

Operation and Maintenance (O&M) at OU2 is, by statute, the responsibility of the State of Colorado and is required at the following properties:

- 1100 Umatilla Street; and,
- Along the Burlington Northern Railroad right-of-way immediately east of 1100 Umatilla Street.

The alley between Yuma Street and Umatilla Street in OU2 was remediated in 2005 as part of Operations and Maintenance under the Denver Radium Streets Program.

It is the property owners' responsibility to ensure that the radon vent system installed in the former DuWald Steel Corporation office/scale house is functioning properly and in good repair. CDPHE conducted a Risk Assessment evaluation at the Atlas Metals (formerly known as DuWald Steel). This review concluded that with the existing

Institutional Controls at the property with the existing use, the remedy remains protective of human health and the environment.

VI. Summary of Remediation Costs

The Remedial Action Completion report for OU2 lists the cost for remediation as \$22,536,367. This figure may not be an accurate accounting for the total cost associated with OU2, as cost were not tracked by operable unit for Denver Radium until after 1996.

VII. Protectiveness

Health hazards associated with the radium waste present at OU2 prior to the remedial action were the result of direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU2 have been excavated in accordance with the Federal and State standards cited in the documents for addressing the remedial action at OU2. Excavated wastes were disposed of at a permanent off-site disposal site. All work was done in accordance with the ROD and applicable EPA directives. The remedial action at OU2 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU2.

- Though the waste material found at OU2 did not meet the U.S. Department of Transportation (DOT)'s definition of radioactive material, it was transported as if it were a low-specified activity (LSA), naturally occurring radioactive material. In addition, substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and particle emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU2 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of releases during the transportation of wastes, fires, and adverse weather conditions.
- For waste remaining at OU2, ICs are in place that are sufficient to protect human health and the environment.

CDPHE conducted a Risk Assessment evaluation at the Atlas Metals (formerly known as DuWald Steel) during the 2003 Five-Year review. This review concluded

that with the existing Institutional Controls at the property where consistent with the existing use and the remedy remains protective of human health and the environment.

VIII. Five-Year Review

The levels of waste material remaining at OU2 where area averaging was used allow for unrestricted use and unrestricted exposure. OU2 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that although all ROD requirements had been met through the remedial action, the risk assessment did not meet the current ARAR of CRR 1007 4.61.3.2 – 4.61.3.3 and the ICs had yet to be put in place. After the 5-year was concluded, the ICs have been put in place as Environmental Covenants and the strict use of these institutional controls should sufficiently protect human health and the environment from the remaining contamination at OU2. Areas where waste material was left in place with Supplemental Standards in accordance with 40 CFR Part 192, Subpart C, require the maintenance of Institutional Controls (ICs) and do not allow for unrestricted use and unrestricted exposure. These areas will require inclusion in future Denver Radium 5-year reviews. The conditions of the individual properties that comprise OU2, and the requirements of future five year reviews are as follows:

Status of OU2 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
DuWald Steel <i>(now Atlas Metals & Iron)</i>	1100 Umatilla Street	Supplemental Standards ²	Yes	Yes
Rocky Mountain Research Corporation <i>(now AI Transmission and Nationwide Courier)</i>	1020 – 1030 Yuma Street	No	Yes	No
G&K Services	999 Vallejo Street	Yes	Yes	No
Jenkins Property	2191 West 10 th Street	Yes	Yes	No
Staab Property	2121 West 10 th Street	Yes	Yes	No
Air Conditioning, Inc.	1001 South Tejon Street	Yes	Yes	No
Colorado DOT – Jerome	2300 West 11 th Avenue	Yes	Yes	No

Maintenance Yard				
Burlington Northern Railroad	Between 10 th & 11 th Avenues	Supplemental Standards ²	No	Yes
Flame Spray, Inc.	1900 West 12 th Avenue	No	Yes	No
Alpha Omega Electronics	1010 Yuma Street	No	Yes	No
Capital Management Realty <i>(now Royal Textile)</i>	1050 Yuma Street	No	Yes	No
Denver Water Board	1600 West 12 th Avenue	No	Yes	No

2 Supplemental standards were applied to deposits of Ra-226 contaminated soil in accordance with 40 CFR 192.21(c). Supplemental standards were used when removal was cost-prohibitive or infeasible. The average Ra-226 concentration of these areas exceeds EPA standards. The contamination does not present a significant health risk to the public.

IX. Bibliography

- Superfund Record of Decision: Denver Radium/11th & Umatilla, CO – EPA/ROD/R08-87/015 - Region 8 – September 29, 1987
- Denver Radium Site Operable Unit II Remedial Action Completion Report – June 7, 1993
- Superfund Explanation of Significant Difference for the Record of Decision: Denver Radium Superfund Site (OU2), CO – September 17, 1993
- Denver Radium Site/Operable Unit II Interim Closeout Report for the U.S. Environmental Protection Agency – July 1994 – RUST Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Unit 3

II. Summary of Site Conditions/OU3

A. Background

Denver Radium Operable Unit 3 (OU3), also known as the 1000 West Louisiana Properties, is a 15-acre area and encompasses several properties in the area of West Louisiana Avenue, South Jason Street, and South Platte Drive. Denver Radium OU3 included the following properties in Denver, Colorado:

Operable Unit	Property Name at time of ROD	Address
OU3	Creative Illumination, Inc.	1298 South Kalamath Street
OU3	Packaging Corporation of America (PCA) <i>(now Caranstar Custom Packaging)</i>	1377 South Jason Street
OU3	Central and Sierra Railroad right-of-way	Between West Louisiana and West Florida Streets
OU3	GT Car Shop/Aspen Design and Manufacturing	1235 South Jason Street
OU3	Kwan Sang Noodle Company, formerly Titan Labels	1140 West Louisiana
OU3	Various tenets	1300 South Jason Street

The OU3 properties were added to the NPL as part of the Denver Radium Site in September 1983. It is believed that the vacant lot, located at 1000 South Louisiana and owned by Packaging Corporation of America, may have been the site of a smelter that operated in the late 19th century. This smelter may have been turned into a radium-processing facility in the early 20th century. The Chemical Products Company, which occupied portions of OU3 between 1919 and 1921, separated radium and vanadium from uranium ores for the National Radium Institute. Most of the buildings associated with radium processing were demolished prior to 1970. The exception was a brick building located at 1298 South Kalamath Street, which was purchased by Creative Illumination, Inc., and used for light-fixture fabrication. The Creative Illumination, Inc., building was demolished during remediation activities. Other businesses that operated at the OU3 area are summarized in Appendix A of the Operable Unit III Interim Closeout Report, April 1994, drafted by RUST Geotech, Inc.

Depth to bedrock (the Denver Formation) is approximately 16 feet. OU3 is not within the South Platte River 100-year flood plain.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, two of which comprise the OU3 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU3.

C. RI/FS

A Remedial Investigation (RI) of OU3 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The draft Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in September 1987. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest was radium-226 (Ra-226) because of its associated radioactivity (gamma radiation and radon-decay products) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- *5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,*
- *15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.*

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) *The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and*
- (2) *The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour ($\mu\text{R/h}$).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm²); and,
- Removable alpha particle activity of 20 dpm/100 cm².

EPA Region 8 proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

The RI for OU3 identified approximately 15,738 cubic yards of contaminated soil at depths to 96 inches on the property. The contamination involved both interior and exterior areas; the interior areas of contamination were in the Creative Illumination building.

The FS addressed the following Remedial Action Alternatives, which were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Defer removal until an Off-Site Permanent Disposal facility became available;
- On-Site Reprocessing/Off-Site Permanent Disposal;
- In situ vitrification (converting soil to a glass-like matrix);
- On-Site Permanent Disposal;
- Off-Site Permanent Disposal;
- On-Site Temporary Land Storage/Off-Site Permanent Disposal;
- On-Site Temporary Storage Building/Off-Site Permanent;
- On-Site Temporary Containment (capping), Off-Site Permanent Disposal; and,
- Temporary Storage Building at Operable Unit 10/Off-Site Permanent Disposal.
-

D. ROD Findings & Design Criteria

The remedial action alternative preferred by EPA for OU3 was Off-Site Permanent Disposal. Because a permanent disposal facility was not available when the ROD was issued in September 1987, EPA selected the on-site temporary containment (capping) with the off-site permanent disposal alternative.

The scope of the ROD's proposed remedial action entailed the following:

- Cleaning up the Creative Illumination property and storing the approximately 200 cubic yards of contaminated material in a temporary storage facility at OU 10;
- Excavating contaminated soil on the 1000 West Louisiana Avenue properties and consolidating and capping the material on the vacant lot at 1000 West Louisiana Ave.;
- Maintaining the cap at 1000 West Louisiana Ave. and the temporary storage facility at OU 10 until a facility suitable for the permanent disposal of Denver Radium Site wastes became available; and,
- Removing the contaminated material from both locations to the permanent disposal facility.

The plan for On-Site Temporary Containment and Temporary Storage at OU 10 for OU3 was abandoned when a permanent disposal facility operated by Envirocare in Toole County, UT, became available.

The actual remediation conducted at OU3 differed from the remedial action selection and scope of the cleanup described in the ROD because of the on-site conditions that became apparent after the ROD was signed. EPA issued an Explanation of Significant Differences (ESD) in September 1993 to address the following changes:

- Temporary storage of the contaminated material was not required;
- The area of contamination and associated volume of contaminated soils increased;
- The contaminated portion of the Creative Illumination building was demolished, rather than decontaminated and restored; and,
- Relatively small volumes of Ra-226 contamination were left in place.

Also, the ESD recommended that the Management Plan developed by the city and county of Denver for OU 7 streets be amended to include the affected portions of South Jason Street and South Platte River Drive.

E. Cleanup Activities performed

Radiological Contamination

Remediation activities were conducted in four phases to facilitate construction and to accommodate the various business activities at OU3. Construction began in August 1989

and concluded in 1991. The quantity of material removed was 63,403 tons (approximately 53,000 cubic yards). The four phases were as follows:

Phase A – Conducted August 1989 through January 1990

Properties:
Creative Illumination property

Phase B - Conducted June 1990 through January 1991

Properties:
PCA, southern portion of Property

South Platte River Drive – Areas adjacent to street which had elevated radium at the surface.

Phase C - Conducted February 1991 through September 1991

Properties:
Harbert Castings property
Courtesy Electric property
Schonewill properties
Titan Labels property

Phase D - Conducted July 1991 through September 1991

Properties:
Aspen Design Manufacturing property

The remedial action design called for removal of the brick portion of the Creative Illumination, Inc., building. The Colorado State Historic Preservation Office concluded that this building was eligible for inclusion in the National Register of Historic Places. Prior to demolition, documentation was prepared in accordance with guidelines of the National Park Service Historic American Engineering Record. The documentation was furnished to the National Park Service and the State of Colorado.

All Geotech data for OU3 was acquired according to DOE-approved procedures. Interior standards were applied to the Packaging Corporation of America building. All other areas were verified according to exterior (open land) standards.

Contaminated material was excavated with front-end loaders while field personnel monitored the excavated area for remaining contamination with hand-held radiation detectors. Soil samples were collected and analyzed to verify that excavation activities achieved conformance with the applicable standards.

During Phase A, the Creative Illumination building was demolished and 3,657 tons of radium-contaminated materials were excavated and removed from this location. A total of 32,389 tons of radium-contaminated soils were excavated and removed from the PCA property and a vacant lot owned by PCA located at 1000 West Louisiana during Phase B. Phase C activities included the excavation and offsite disposal of 27,626 tons of

radiologically contaminated soil. Remediation of OU3 was completed during Phase D when 50 tons of radiologically contaminated soils were excavated from the GT Car Shop and Aspen Design and Manufacturing properties for offsite disposal.

A Supplemental Standards Report was prepared in June 1995 to document the 5,868 cubic yards of radiological contaminated soil that remain onsite under South Jason Street, around the PCA building, and along South Platte River Drive at OU3

During the summer of 1999, Metro Wastewater rehabilitated a sewer line under West Louisiana Street. This sewer line was completed under a CDPHE and City and County of Denver approved Soils Management Plan. The sewer was installed by digging two holes on opposite sides of the presumed contamination. A tunnel-boring device was then used to bore underneath the location of the presumed contamination, pulling the new sewer line as it progressed underneath West Louisiana Street. All soils were segregated, containerized, characterized, and managed under the Soils Management Plan.

Previous sampling conducted in 2001 in the area of OU3 identified a monitoring well at Hospital Shared Services (HSS) with elevated levels of gross alpha and gross beta. This sparked concern as to the source of this contamination. Theories exist that this contamination may originate from OU3, OU8, or a potential new source of contamination. In July 2003, SM Stoller, under contract from the EPA and CDPHE, installed and developed five new ground water monitoring wells surrounding the OU3 site. These wells, along with the one existing well, are located at the Hospital Shared Services site. Analytical results revealed significantly lower concentrations of contaminants in original HSS well as compared to the December 2001 results. Preliminary review of the samples collected in July 2003 indicated that while MCL's for gross alpha and gross beta are exceeded in well OU3-GW5 (located within supplemental standards waste left in place) and the well immediately downgradient of that location (OU3-GW4), this contamination just exceeds drinking water MCL's.

Five additional deposits of contamination at OU3 were left in place because levels of contamination met the standards when averaged over a 100 square meter area. There areas are as follows:

Materials Left in Place as Averaged Areas – OU3¹

AREA	Size	Description	Area Avg. (pCi/g)
Area A	25 sq/ft.	East of South Jason – At base of mature trees – Denver right-of-way	5.0 pCi/g Ra-226 (conforms to EPA stnd.)
Area B	25 sq/ft	East of South Jason – At base of mature trees – Denver right-of-way	5.0 pCi/g Ra-226 (conforms to EPA stnd.)
Area C	105 sq/ft	Kwan Sang property	10.9 pCi/g Ra-226.

		– along underground utility lines at West Louisiana Ave.	(conforms to EPA std.)
Area D	506 sq/ft	North of Harbert Castings building – along foundation	13.8 pCi/g Ra-226 (conforms to EPA std.)
Area E	509 sq/ft	Alley east of Creative Illumination, Inc.	10.3 pCi/g Ra-226 (conforms to EPA std.)

1 Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

Supplemental standards were applied to areas of Ra-226 contaminated soil in accordance with 40 CFR 192.21(c) where removal as either cost-prohibitive or infeasible. The average Ra-226 concentration of these areas exceeds EPA standards. The contamination does not present a significant health risk to the public. The deposits are as follows:

- Deposits of Ra-226 contaminated soil left in place alongside of and beneath South Jason Street and South Platte River Drive and contamination associated with a water line beside South Platte River Drive;
- Deposits of Ra-226 contaminated soil left in place below groundwater south and northwest of the Packaging Corporation of America building; and,
- Deposits of Ra-226 contaminated soil in the 1:1 slope around the foundation of the Packaging Corporation of America building left in place to avoid causing structural damage to the building.
- Th-230 was identified in a verification area, V-122, in concentrations that exceeded the proposed cleanup criteria for that radionuclide (EPA 1992). As a result of analysis of similar occurrences using the RAETRAN computer code, EPA determined that this occurrence did not present a risk to human health and the environment.

Interior Verification

The Packaging Corporation of America building was verified to conform to EPA standards for occupied or habitable buildings. Two areas of residual radioactive material were identified under the floor of the building. These areas were not remediated because gamma scan of the building ranged from 16 to 22 μ R/h, which conforms to the EPA standard.

Following exterior remediation activities, an Eberline WLM-1(A) working level monitor was installed for 100 hours in the Packaging Corporation of America building to measure

to RDC. The average of the RDC results was 0.0067 WL, which conforms to EPA standards for occupied or habitable buildings.

Investigations before remediation activities indicated an elevated RDC in the Fellowship of Christian Firefighters building that was attributed to residual radioactive material outside the building. An Eberline WLM-1(A) working level monitor was installed for 100 hours following remediation activities. The RDC result was 0.0238 WL, which conforms to EPA standards for occupied or habitable buildings.

Disposal Operations

Contaminated materials were transported by rail in covered gondola cars to the permanent off-site disposal facility. The disposal contractor loaded material directly onto the cars at the site.

Each gondola car was sealed, surveyed, and decontaminated, as necessary. The cars were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness.

A composite sample was collected from each railcar as it was loaded and analyzed to ensure that the material conformed to the acceptance requirements of the disposal facility.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU3 and promoted communications among interested parties throughout the duration of the project. General community concerns were the impacts of cleanup and storage on property values, the health risks associated with the cleanup, the transportation risks, the need for temporary storage of wastes, and the possibility of the temporary storage facility becoming permanent.

Community relations activities OU3 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meetings to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
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- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;

- Organizing a committee of representatives from citizens groups, State and local governments, EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Informing communities along the transportation route (through meetings and mailings) of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU3 was already developed and utilized for commercial and light industrial uses at the time of the remedial action. In a site visit performed in August 2003, all properties at OU3 were being used for the same purposes.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech *Quality Assurance Manual* (Manual 101), which was developed in response to the DOE Field Office, ID, Order 5700.6C. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU3* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental monitoring was required to determine whether the remedial action adversely affected off-site air quality at OU3. Off-site air quality monitoring data were collected before, during, and after the remedial action. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter were placed at each of five measurement locations. There were no significant difference between the data set for the baseline period, the construction period, and the post-remedial action period.

Air Particulate Measurement

Air particulate samples were collected with Model LV1 low-volume air particulate samplers manufactured by F&J Specialty Products, Inc. Each sampler was contained in its own environmentally protected shelter and connected to a dedicated electrical power outlet. The samplers were operated continuously for 7 days at a nominal rate of 5 liters

per minute. The filters were analyzed by Geotech analytical laboratory for natural uranium, Th-230, Ra-226, and polonium-210 (Po-210).

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for airborne radionuclides. These standards are expressed as concentrations above background as follows:

Natural Uranium	-	5.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Th - 230	-	8.0×10^{-14} microcuries per milliliter ($\mu\text{Ci/mL}$)
Ra - 226	-	3.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Po - 210	-	2.0×10^{-11} microcuries per milliliter ($\mu\text{Ci/mL}$)

All airborne radionuclide concentrations measured during the reporting period were below the applicable regulatory standard.

Atmospheric Radon Measurements

Terradex outdoor Type F Track Etch ® radon detectors were used to determine atmospheric radon concentrations. Two detectors were exposed in an environmentally protected enclosure approximately 1 meter above ground level. Each detector consisted of an alpha-sensitive film protected by a membrane analyzed by Terradex Corporation for the density of the alpha tracks produced by radon decay, which is proportional to the radon concentration in the atmosphere sampled.

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for atmospheric radon concentration. The regulatory standard is 3.0 picocuries per liter above background. All atmospheric radon concentrations measured during the reporting period were below this standard.

Direct External Gamma Exposure Measurement

TMA/Eberline thermoanalytical environmental dosimeters were used to measure the external gamma radiation at each sample location. A dosimeter was exposed approximately 1 meter above ground level at each sample location and was submitted to TMA/Eberline Thermo Analytical, Inc., for analysis.

EPA has designated DOE Order 5480.1B as the relevant and appropriate standard regulating direct gamma exposure. The limit, 100 millirems per year (mrem/yr) above background, is referred to in recommendations of the National Council on Radiation Protection and Measurements (1977). The background gamma exposure rates for the Denver area range from 130 to 175 mrem/yr (CH2M Hill, 1986). If an average value of 150 mrem/yr is used the site-specific limit is 250 mrem/yr. All gamma exposures measured during the reporting period were below this limit

V. Summary of Operation and Maintenance

OU3 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD, as modified by an ESD, in accordance with CERCLA, 42 U.S.C. Section 9601, et.seq., as amended by SARA of 1986, and the NCP, 40 CFR Part 300. Supplemental standards have been applied in some instances; therefore, land usage restrictions will apply. CDPHE conducted a Risk Assessment evaluation at OU3 during its 2003 5-year review of the remedial action. This review concluded that with the existing Institutional Controls at the property, the remedy remains protective of human health and the environment.

Locations where contamination was removed are released for unrestricted use and have no requirement of Operation and Maintenance. At these locations, the remedy is protective of human health and the environment. This includes the following properties:

- 1298 South Kalamath Street – Creative Illumination, Inc.;
- 1235 South Jason Street – GT Car Shop and Aspen Design and Manufacturing;
- 1140 West Louisiana Street – Kwan Sang Noodle Company; and,
- 1300 South Jason Street – Various Offices.

Operation and Maintenance (O&M) at OU3 is, by statute, the responsibility of the State of Colorado and is required at the following properties:

- South Jason Street – around Packaging Corporation of America building; and,
- Along South Platte River Drive.

The City and County of Denver has enacted sufficient ordinances to provide Institutional Controls over the areas where radiation remains that OU3. Ground water Institutional Controls have also been established for OU3. The City and County of Denver has agreed to implement management plans for radium contaminated soils in Denver's right-of-way and to continue to enforce Denver's zoning ordinance. Its radium fee ordinance is a institutional controls at private properties where radium contaminated soils remain in place and where Supplemental Standards were applied. These ordinances provide adequate Institutional Controls of OU3.

VI. Summary of Remediation Costs

The Remedial Action Completion report for OU3 lists the cost for remediation as \$13,591, 560. This figure may not be an accurate accounting for the total cost associated with OU3, as cost were not tracked by operable unit for Denver Radium until after 1996.

VII. Protectiveness

Health hazards associated with the radium waste present at OU3 prior to the remedial action were the result of direct contact with the wastes, long-term exposure to gamma

radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU3 have been excavated in accordance with the Federal and State standards cited in the documents for addressing the remedial action at OU3. Excavated wastes were disposed of at a permanent off-site disposal site. Supplemental Standards and Institutional Controls have been put into place where radioactively contaminated materials were left in place. All work was done in accordance with the ROD and applicable EPA directives. The remedial action at OU3 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU3.

- Though the waste material found at OU3 did not meet the U.S. Department of Transportation (DOT)'s definition of radioactive material, it was transported as if it were a low-specified activity (LSA), naturally occurring radioactive material. In addition, substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and particle emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU3 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of releases during the transportation of wastes, fires, and adverse weather conditions.
- For waste remaining at OU3, ICs are in place that are sufficient to protect human health and the environment.

VIII. Five-Year Review

The levels of waste material remaining at OU3 where area averaging was used allow for unrestricted use and unrestricted exposure. OU3 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that although all ROD requirements had been met through the remedial action, the risk assessment did not meet the current ARAR of CRR 1007 4.61.3.2 – 4.61.3.3 and the ICs had yet to be put in place. After the 5-year was concluded, the ICs were put in place and the strict use of these institutional controls should sufficiently protect human health and the environment from the remaining contamination at OU3. Areas where waste material was left in place with Supplemental Standards in accordance with 40 CFR Part 192, Subpart C, require the maintenance of ICs and do not allow for unrestricted use and unrestricted exposure. These areas will require inclusion in future Denver Radium 5-year reviews.

The conditions of the individual properties that comprise OU3, and the requirements of future five year reviews are as follows:

Status of OU3 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
Creative Illumination, Inc.	1298 South Kalamath Street	No	Yes	No
Packaging Corporation of America (PCA) (now Caraustar Custom Packaging)	1377 South Jason Street	Supplemental Standards ²	Yes	Yes
Central and Sierra Railroad right-of-way	Between West Louisiana and West Florida Streets	Supplemental Standards ²	No	Yes
GT Car Shop/Aspen Design and Manufacturing	1235 South Jason Street	No	Yes	No
Kwan Sang Noodle Company, formerly Titan Labels	1140 West Louisiana	Yes	Yes	Yes
Various tenets	1300 South Jason Street	No	Yes	No

² Supplemental standards were applied to deposits of Ra-226 contaminated soil in accordance with 40 CFR 192.21(c). Supplemental standards were used when removal was cost-prohibitive or infeasible. The average Ra-226 concentration of these areas exceeds EPA standards. The contamination does not present a significant health risk to the public.

IX. Bibliography

- Superfund Record of Decision: Denver Radium/1000 West Louisiana Properties, CO – EPA/ROD/R08-87/017 - Region 8 – September 29, 1987
- Denver Radium Site Operable Unit III Remedial Action Completion Report – September 30, 1991

- Superfund Explanation of Significant Difference for the Record of Decision: Denver Radium Superfund Site (OU3), CO – December 14, 1993
- Denver Radium Site/Operable Unit III Interim Closeout Report for the U.S. Environmental Protection Agency – April 1994 – RUST Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Units 4/5 & OU 9B (Metals)

II. Summary of Site Conditions/OU4/5

A. Background

Denver Radium Operable Unit 4 (OU4) and Operable Unit 5 (OU5) is comprised of the Robinson Brick and Tile Company (ROBCO) property and an adjacent property owned by the Denver and Rio Grande Western Railroad (D&RGWRR). OU4, the ROBCO property, is a 17.3 acre parcel near the South Platte River in Denver. The property is bounded by South Santa Fe Drive on the west and the D&RGWRR right-of-way on the east. The property to the north is occupied by a Regional Transportation District bus maintenance facility. The site consisted of a brick manufacturing plant, and associated equipment, and various other buildings. OU5 consists of a 1.6 acre portion of the D&RGWRR right-of-way in Denver's main rail corridor.

Operable Unit	Property Name at time of ROD	Address
OU4	Robinson Brick and Tile Company (ROBCO) <i>(now Home Depot)</i>	500 South Santa Fe Drive
OU5	Denver and Rio Grande Western Railroad right-of-way (D&RGWRR)	Immediately east of OU4

The OU4/OU5 properties were added to the NPL as part of the Denver Radium Site in September 1983. In the late 1800s, a succession of ore refining and smelting facilities operated at this site under various names. The Merchant's Mill Ditch was in use in the area until 1910, after which it was abandoned and used as a dump by various operations. The South Platte River crossed the property until 1908, when it was diverted to the west.

OU4- ROBCO was the site of a radium processing facility established by the National Radium Institute (NRI) in 1914, a portion of which was located over the course of the Merchant's Mill Ditch. The NRI facility was created for the purpose of developing and demonstrating the commercial feasibility of radium extraction techniques. The primary operation carried out by NRI was to extract and purify radium from carnotite ore using a nitric acid process. This facility operated on the site for approximately four years and then closed after producing 7.5 grams of radium and successfully demonstrating commercially feasible extraction processes. Various businesses occupied this property during the 1930s and 1940s. ROBCO acquired the property in 1940 and commenced operations at 500 South Santa Fe Drive, eventually building a brick plant, a grinding mill,

conveyor belt systems, and storage/transportation facilities. The company used the manufacturing site until the 1980s.

OU5- D&RGWRR covers 1.6 acres. D&RGWRR has several rail lines and spurs on the property. Some areas of OU5 show evidence of use as landfills by various companies that operated on the site. Uranium ore and refuse from processing facilities and laboratories were found at depths to 20 feet. The man-made fill is underlain by alluvial deposits of sand, gravel, clay, and shale. Depth to bedrock (Denver Formation) is approximately 25 feet.

OU 9B (Metals) – Approximately 16,500 cubic yards of soil containing elevated levels of arsenic, cadmium, chromium, copper, lead, selenium, and zinc. This contamination was the result of ore processing operations and was found to be exempt from RCRA regulation in accordance with 40 CFR 261.4(b) (7). Radiological contamination was not associated with this material. The contamination was identified east and west of the pit and in four small discrete outlying deposits. EPA addressed these areas as a separate operable unit (OU 9B – Metals, see EPA 1991), and the selected remedy for OU9 included backfilling the pit created during remedial action activities at OU4/OU5, capping the contaminated areas, maintaining the cap and monitoring the groundwater at the site, imposing institutional controls, and conducting 5-year reviews of the remedy.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, one of these being ROBCO properties that comprise OU4 properties. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU4.

C. RI/FS

A Remedial Investigation (RI) of OU4/OU5 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in September 1986. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest was radium-226 (Ra-226) because of its associated radioactivity (alpha, beta, and gamma radiation emissions of Ra-226 and its daughter isotopes) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,
- 15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) *The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and*
- (2) *The level of gamma radiation shall not exceed the background level by more than 20 microrentgens per hour (μ R/h).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm²); and,
- Removable alpha particle activity of 20 dpm/100 cm².

EPA Region 8 proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

The RI for OU4/OU5 identified approximately 7,200 cubic yards of contaminated soil at depths to 44 inches on the property. Concentrations of Ra-226 as high as 5,093 pCi/g were detected in soils. Alpha and Ra-226 contamination was identified in the grinding

plant and the abandoned NRI office and laboratory buildings. Gamma exposure rates greater than 1,000 $\mu\text{R/h}$ were measured.

The RI also reported detectable amounts of organic contaminants, mostly polynuclear aromatic hydrocarbons, in the area of the sump, the grinding plant, the ROBCO office, and the scales. Analysis of the soil samples by the Extraction Procedure (EP) toxicity method indicated that inorganic contaminant levels were below RCRA regulatory limits.

The FS addressed the following Remedial Action Alternatives, which included the demolition of the three affected buildings and were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Complete removal, Off-Site Permanent Disposal;
- Partial removal (no removal of contamination on railroad property), Off-Site Permanent Disposal;
- On-Site Temporary Consolidation and Capping, Off-Site Permanent Disposal;
- On-Site Temporary Storage/Off-Site Permanent Disposal;
- Off-Site Temporary Storage/Off-Site Permanent Disposal; and,
- On-Site Temporary Consolidation in the Grinding Plant, Off-Site Permanent Disposal.

D. ROD Findings & Design Criteria

The remedial action alternative preferred by EPA for OU4/OU5 was Complete Removal and Off-Site Permanent Disposal. Because a permanent disposal facility was not available when the ROD was issued in September 1986, EPA selected the remedy that included temporary off-site storage of the waste with subsequent off-site permanent disposal.

The scope of the ROD's proposed remedial action entailed the following:

- Removing the approximately 7,000 cubic yards of contaminated soil and 200 cubic yards of building debris from the property and storing it in a temporary off-site storage facility;
- Maintaining the temporary storage facility until a facility suitable for the permanent disposal of Denver Radium Site wastes became available; and,
- Transporting the contaminated material from the off-site temporary storage facility to the off-site permanent disposal facility.

The plan for Off-Site Temporary Storage for OU 4/OU5 was abandoned when a permanent disposal facility operated by Envirocare in Toole County, UT, became available.

The remedial action deviated from the remedial action selected and scope of cleanup defined in the ROD because of on-site conditions that became apparent after the ROD was signed. EPA issued an Explanation of Significant Differences (ESD) in December 1993 to address the following changes:

- The area of contamination and associated volume was greater than estimated in the ROD;
- Relatively small volumes of Ra-226 and Th-230 contamination were left in place; and,
- Soil contaminated with Th-230 was removed from the site and shipped to the permanent disposal facility.

Also, the ESD recommended that the Management Plan developed by the city and county of Denver for OU 7 streets be amended to include the affected portions of South Jason Street and South Platte River Drive.

E. Cleanup Activities performed

Radiological Contamination

Remediation activities were conducted in three phases. Contaminated material from Phase A was temporarily stockpiled on the eastern portion of the property, which was remediated during Phase B. The remainder of the property was remediated during Phase C. Construction began in August 1988 and concluded in March 1991. A total of 57,586 tons of radiologically contaminated material was excavated during Phase A. This material was stockpiled onsite temporarily until it could be transported to the off-site disposal facility. Approximately 1,290 tons of soil contaminated with elevated levels of Th-230 were removed during a later phase of the project. The stockpiled material, as well as an additional 9,677 tons of contaminated material situated immediately below the stockpile, were shipped during Phase B of the cleanup. In Phase C, 29,271 tons of radiologically contaminated soils were excavated and transported by rail in covered gondola cars to a permanent off-site disposal facility operated by Envirocare of Utah, Inc., in Toole County, Utah. 2,100 tons of material disposed were contaminated with metals as well as radioactive material. The three phases were as follows:

Phase A – Conducted April 25, 1988 through November 8, 1989

Phase B - Conducted October 23, 1989 through March 7, 1990

Phase C - Conducted November 1, 1990 through March 7, 1991

Contaminated material was excavated with front-end loaders while field personnel monitored the excavated area for remaining contamination with hand-held radiation detectors. Soil samples were collected and analyzed to verify that excavation activities achieved conformance with the applicable standards.

The remedy, as implemented, differed in two respects from the remedy chosen in the 1986 ROD. Those differences were:

- The volume of contaminated soils increased; and,
- Relatively small volumes of contaminated soil were left in place.

EPA issued a second ESD for OU4/OU5 in December 1994. The ESD describes in more detail the changes that were made to the remedy selected for OU4/OU5.

Four deposits of contamination at OU4/OU5 were left in place because levels of contamination met the standards when averaged over a 100 square meter area. There areas are as follows:

Materials Left in Place as Averaged Areas – OU4/OU5¹

AREA	Size	Description	Area Avg. (pCi/g)
Area E	20 sq/ft.	Adjacent to and beneath the railroad tracks.	7.2 pCi/g Ra-226 (conforms to EPA stdn.)
Area F	225 sq/ft	Adjacent to and beneath the railroad tracks	11.8 pCi/g Ra-226 (conforms to EPA stdn.)
Area F1	9 sq/ft	Adjacent to and beneath the railroad tracks	11.8 pCi/g Ra-226 (conforms to EPA stdn.)
Area G	90 sq/ft	Adjacent to and beneath the railroad tracks	11.0 pCi/g Ra-226 (conforms to EPA stdn.)

¹ Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

Supplemental standards were applied to areas of Ra-226 contaminated soil in accordance with 40 CFR 192.21(c). The average Ra-226 concentration of these areas exceeds EPA standards; however, the contamination does not present a significant health risk to the public. The deposits are as follows:

- Area A: A 91-sq/ft area of Ra-226 contamination situated below groundwater north of excavation pit. Material left in place upon consideration of the safety hazards involved with its excavation, the cost associated with that remediation, and the low hazard posed by the contamination;
- Area B: A 3,637-sq/ft area of Ra-226 and Th-230 contamination situated below groundwater beneath the floor of the excavation pit. Material left in place upon consideration of the safety hazards involved with its excavation, the cost associated with that remediation, and the low hazard posed by the contamination;

- Area D: An area of Th-230 contamination above the north end of the excavation pit. The average Th-230 concentration of 44.4 pCi/g exceeds the proposed Th-230 limits. No remediation was conducted in this area. Material was left in place upon consideration of the cost of remediating the area and the low hazard posed by the contamination; and,
- V-80: Th-230 concentration in area was found to be 41.9 pCi/g, which exceeded the proposed Th-230 limits. Results not available until after area was backfilled.

Non-Radiological Contamination

Analyses of discolored soils exposed in the pit walls revealed elevated concentrations of cadmium, lead, and zinc. As requested by EPA, Geotech conducted an investigation to develop a hydrological model for the site and to assess the non-radiological contamination (UNC Geotech, Inc., 1990). The results of this investigation indicated that concentrations of metals in the soil (arsenic, cadmium, copper, lead, and zinc) exceeded typical urban background levels over much of the site. Local cells of low-pH groundwater were associated with elevated levels of cadmium, uranium, zinc, and gross alpha contamination. This investigation identified Ra-226 and Th-230 contaminated soil beneath the floor of the pit and south of the pit at depths of 11 to 15 feet. As requested by EPA, the pit was not backfilled completely.

Regulated waste (other than residual radioactive material) was identified in three instances:

1. Some of the Ra-226 contaminated soil located in the pit was found to contain lead and cadmium at concentrations above the corresponding RCRA toxicity-characteristic regulatory limits according to results of the EP toxicity method. Because the presence of lead and cadmium in the mill tailings was the result of ore processing operations, the soil was exempt from RCRA regulation in accordance with 40 CFR 261.4(b)(7).
2. Asbestos was found mixed with Ra-226 contaminated soils near the north boundary of the property.
3. Soil containing elevated levels of arsenic, cadmium, chromium, copper, lead, selenium, and zinc was identified east and west of the pit and in four small discrete outlying deposits. Concentrations of some of the contaminants exceeded the corresponding RCRA toxicity-characteristic regulatory limits. This contamination was the result of ore processing operations and was found to be exempt from RCRA regulation in accordance with 40 CFR 261.4(b) (7). Radiological contamination was not associated with this material. This contamination was addressed by the EPA as a separate operable unit (OU 9 – Metals, see EPA 1991). According to the ROD for OU 9 – Metals, issued in December 1991, the selected remedy for this OU included backfilling the pit created during remedial action activities at OU4/OU5, capping the contaminated areas,

maintaining the cap and monitoring the groundwater at the site, imposing institutional controls, and conducting 5-year reviews of the remedy.

Disposal Operations

Contaminated materials were transported by rail in covered gondola cars to the permanent off-site disposal facility operated by Envirocare of Utah, Inc., in Tooele County, Utah. Material was loaded directly onto the cars at the site by the Geotech transportation subcontractor. Each gondola car was filled with material and then sealed, surveyed, and decontaminated, as necessary. The cars were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness.

A composite sample was collected from each railcar and analyzed for Ra-226 and by the EP toxicity method for arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Every tenth sample was analyzed in the laboratory for Ra-226, Th-232, and K-40. Selected samples were analyzed for Th-230.

Approximately 8,750 tons of metals-contaminated radiological mill tailings (a RCRA-exempt waste) was shipped to the Envirocare of Utah, Inc., facility for disposal, where it was placed in a segregated cell that conformed to RCRA disposal-facility standards. Radiological contaminated material containing asbestos was shipped in barrels to the Envirocare facility.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU4/OU5 and promoted communications among interested parties throughout the duration of the project. General community concerns were the impacts of cleanup and storage on property values, the health risks associated with the cleanup, the transportation risks, the need for temporary storage of wastes, and the possibility of the temporary storage facility becoming permanent.

Community relations activities OU4/OU5 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meetings to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;

- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizens groups, State and local governments, EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Informing communities along the transportation route (through meetings and mailings) of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

A site visit was performed in August 2003 during the Five-Year Review process carried out by the State of Colorado. In addition to the construction of the Home Depot and parking lot, two commercial buildings were built to the north of Home Depot. An automotive repair facility (Star Tech Mercedes) and an unoccupied building share a sewer line that was placed through the northern end of the contingency zone for ROBCO Metals wastes. The sewer line was installed properly under the Home Depot O&M Plan. The two buildings are built slab-on-grade, are not located over any materials where supplemental standards were applied, and did not impact any of the remedial action conducted at OU4/OU5.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech *Quality Assurance Manual* (Manual 101), which was developed in response to the DOE Field Office, ID, Order 5700.6C. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU4* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental monitoring was required to determine whether the remedial action adversely affected off-site air quality at OU4/OU5. Off-site air quality monitoring data were collected before, during, and after the remedial action. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter were placed at each of four measurement locations. There were no significant

difference between the data set for the baseline period, the construction period, and the post-remedial action period.

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Air particulate samples were collected with Model LV1 low-volume air particulate samplers manufactured by F&J Specialty Products, Inc. Each sampler was contained in its own environmentally protected shelter and connected to a dedicated electrical power outlet. The samplers were operated continuously for 7 days at a nominal rate of 5 liters per minute. The filters were analyzed by Geotech analytical laboratory for natural uranium, Th-230, Ra-226, and polonium-210 (Po-210).

EPA designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for airborne radionuclides. These standards are expressed as concentrations above background as follows:

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Ra - 226	-	3.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Po - 210	-	2.0×10^{-11} microcuries per milliliter ($\mu\text{Ci/mL}$)

All airborne radionuclide concentrations measured during the reporting period were below the applicable regulatory standard.

Atmospheric Radon Measurements

Terradex outdoor Type F Track Etch ® radon detectors were used to determine atmospheric radon concentrations. Two detectors were exposed in an environmentally protected enclosure approximately 1 meter above ground level. Each detector consisted of an alpha-sensitive film protected by a membrane analyzed by Terradex Corporation for the density of the alpha tracks produced by radon decay, which is proportional to the radon concentration in the atmosphere sampled.

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for atmospheric radon concentration. The regulatory standard is 3.0 picocuries per liter above background. All atmospheric radon concentrations measured during the reporting period were below this standard.

Direct External Gamma Exposure Measurement

TMA/Eberline thermoanalytical environmental dosimeters were used to measure the external gamma radiation at each sample location. A dosimeter was exposed approximately 1 meter above ground level at each sample location and was submitted to TMA/Eberline Thermo Analytical, Inc., for analysis.

EPA has designated DOE Order 5480.1B as the relevant and appropriate standard regulating direct gamma exposure. The limit, 100 millirems per year (mrem/yr) above background, is referred to in recommendations of the National Council on Radiation Protection and Measurements (1977). The background gamma exposure rates for the Denver area range from 130 to 175 mrem/yr (CH2M Hill, 1986). If an average value of 150 mrem/yr is used the site-specific limit is 250 mrem/yr. All gamma exposures measured during the reporting period were below this limit

V. Summary of Operation and Maintenance

OU4/OU5 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD, as modified by an ESD, in accordance with CERCLA, 42 U.S.C. Section 9601, et.seq., as amended by SARA of 1986, and the NCP, 40 CFR Part 300. Supplemental standards have been applied in some instances; therefore, land usage restrictions will apply, and EPA conducted a 5-year review of the remedial action in September 2003.

The remaining radiologically contaminated material at OU4 is addressed under Supplemental Standards and is discussed in the Management Plan for OU9B – ROBCO Metals. The remedy continues to be protective of human health and the environment. Groundwater sampling is performed annually at this site in response to the ROD for OU 9B-ROBCO Metals. Trends in groundwater data show decreasing levels of contamination at individual locations over time as well as concentrations decreasing with distance, thus indicating attenuation is occurring. Ground Water Institutional Controls have been established for OU4/5/9B. There have been no detrimental contaminant concentrations detected in the South Platte River to date.

Operation and Maintenance (O&M) at OU4 is, by statute, the responsibility of the State of Colorado and is required at the following properties:

- 500 South Santa Fe Drive (ROBCO); and,
- Burlington Northern Railroad right-of-way, immediately east of ROBCO (OU4).

OU4 currently has an enforceable IC in place under Home Depot. Home Depot has an amended O&M Plan as of August 18, 2003.

All ROD requirements were met and all contamination was removed from OU5 and the remedy is protective of human health and the environment. The property at OU5 is available for unlimited use and unrestricted access. This property was recommended for deletion from the Denver Radium Site and the NPL. The locations where materials were left in place and area averaging was applied have been released for unrestricted use.

The City and County of Denver has enacted sufficient ordinances to provide Institutional Controls over the areas where radiation remains that OU4/OU5. The City and County of Denver has agreed to implement management plans for radium contaminated soils in Denver's right-of-way and to continue to enforce Denver's zoning ordinance. Its radium

fee ordinance is a institutional controls at private properties where radium contaminated soils remain in place and where Supplemental Standards were applied. These ordinances provide adequate Institutional Controls of OU4/OU5.

VI. Summary of Remediation Costs

The Remedial Action Completion report for OU4/OU5 does not contain information on the cost of the remedial activities undertaken. The ROD for OU4/OU5 estimates the cost of full removal with permanent offsite disposal as \$1,417,700, which may not reflect the actual cost of the remedial action undertaken at OU4/OU5 as costs were not tracked by operable unit for Denver Radium until after 1996.

VII. Protectiveness

Health hazards associated with the radium waste present at OU4/OU5 prior to the remedial action were the result of direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU4/OU5 have been excavated in accordance with the Federal and State standards cited in the documents for addressing the remedial action at OU4. Excavated wastes were disposed of at a permanent off-site disposal site. Supplemental Standards and Institutional Controls have been put into place where radioactively contaminated materials were left in place. All work was done in accordance with the ROD and applicable EPA directives. The remedial action at OU4/OU5 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU4.

- Though the waste material found at OU4/OU5 did not meet the U.S. Department of Transportation (DOT)'s definition of radioactive material, it was transported as if it were a low-specified activity (LSA), naturally occurring radioactive material. In addition, substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and particle emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU4 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,

- An emergency response plan was developed that specified actions to be taken in the event of releases during the transportation of wastes, fires, and adverse weather conditions.
- For waste remaining at OU4/OU5, ICs are in place that are sufficient to protect human health and the environment.

VIII. Five-Year Review

The levels of waste material remaining at OU4/OU5 & OU9B where area averaging was used allow for unrestricted use and unrestricted exposure. OU4/OU5 & OU9B was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that although all ROD requirements had been met through the remedial action, the risk assessment did not meet the current ARAR of CRR 1007 4.61.3.2 – 4.61.3.3 and the ICs had yet to be put in place. After the 5-year was concluded, the ICs were put in place and the strict use of these institutional controls should sufficiently protect human health and the environment from the remaining contamination at OU4/OU5 & OU9B. Areas where waste material was left in place with Supplemental Standards in accordance with 40 CFR Part 192, Subpart C, require the maintenance of ICs and do not allow for unrestricted use and unrestricted exposure. These areas will require inclusion in future Denver Radium 5-year reviews. The conditions of the individual properties that comprise OU4/OU5 & OU9B, and the requirements of future five year reviews are as follows:

Status of OU4/OU5 & OU9B Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
Robinson Brick and Tile Company (ROBCO) (now Home Depot) – OU4	500 South Santa Fe Drive	Supplemental Standards ²	Yes	Yes
Denver and Rio Grande Western Railroad right-of-way (D&RGWRR) – OU5	Immediately east of OU4	Supplemental Standards ²	No	Yes

Robinson Brick and Tile Company (ROBCO) Metals (now Home Depot) – OU9B	500 South Santa Fe Drive	Supplemental Standards ²	Yes	Yes
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2 Supplemental standards were applied to deposits of Ra-226 contaminated soil in accordance with 40 CFR 192.21(c). Supplemental standards were used when removal was cost-prohibitive or infeasible. The average Ra-226 concentration of these areas exceeds EPA standards. The contamination does not present a significant health risk to the public.

IX. Bibliography

- Superfund Record of Decision: Denver Radium/ROBCO Properties, CO – EPA/ROD/R08-86/009 - Region 8 – September 30, 1986
- Denver Radium Site Operable Unit IV & V (ROBCO) Remedial Action Completion Report – June 18, 1991
- Superfund Explanation of Significant Difference for the Record of Decision: Denver Radium Superfund Site (OU4 & 5), CO – December 7, 1994
- Denver Radium Site/Operable Unit IV/V Interim Closeout Report for the U.S. Environmental Protection Agency – July 1994 – RUST Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Units 6, 9A, & 11

II. Summary of Site Conditions

A. Background

Denver Radium Operable Unit 6 (OU6), Operable Unit 9A (OU9A), Operable Unit 11 (OU11) are comprised of numerous contaminated properties known as the "Open Space" properties, located throughout the Denver Metropolitan area. Much of the radiological contamination present on the Open Space properties is believed to be either the direct result of radium and uranium processing on the property or the result of deposition of residual wastes from processing sites. The locations of the Open Space properties are as follows:

Operable Unit	Property Name at time of ROD	Address
OU6	Alley in City and County of Denver right-of-way	Between Mariposa and Lipan Streets and between 5 th and 6 th Avenues.
OU6	Allied (General Chemical)	1271 West Bayaud Avenue
OU6	Brannan Sand and Gravel	61 st Ave. and Clear Creek
OU6	Central and Sierra Railroad right-of-way/Centennial Tire	2301 15 th Street
OU6	Denver Water Department	1190 Yuma Street
OU6	Public Service Company	South Pecos Street and West Arizona Ave.
OU6	Ruby Hill Park	Jewell Street and South Platte River Drive
OU6	Environmental Metals Inc. (building has been razed)	1155 West 5 th Avenue
OU9A	International House of Pancakes and Larry's Trading Post <i>(now Mama's Café, Herbs and Art, and Purple Haze)</i>	2001, 2015, and 2017 East Colfax Avenue
OU11	Commercial Investors Realty (formerly owned by Thomas Real Estate Corp.) <i>(now Murphy Beds and a Starbucks)</i>	1285 – 1295 South Santa Fe Drive

The OU6, OU9A, OU11 properties were added to the NPL as part of the Denver Radium Site in September 1983. A description of activities for the Open Space properties is as follows:

OU6

Alley in City and County of Denver right-of-way: A one-lane paved road owned by the City and County of Denver located between Lipan and Mariposa Streets and extends between 5th and 6th Avenues. The source of the radiological contamination is unknown. This alley initially was described as a part of OU7. The alley is underlain by approximately 30 feet of alluvium, below which is the Denver Formation. The alley is not within the South Platte River 100-year floodplain.

Allied Chemical and Dye Corporation: Occupies approximately 21.5 acres at 1271 West Bayaud Ave. The property included 10 permanent building, 2 ponds, and 4 railroad sidings. The property has been used for chemical manufacturing since the late 1800's. The contamination on this property apparently was the result of approximately 2 feet of fill carried onto the property from construction sites in downtown Denver in the early 1960s. Under the fill is approximately 30 feet of alluvium, below which is bedrock (Denver Formation). The property is with the South Platte River 100-year flood plain.

Brannan Sand and Gravel: Occupies 47.5 acres between 61st Ave. and Clear Creek. The mined-out gravel pit had been used as a municipal landfill between 1960 and 1982. Depth to bedrock is uncertain; the property is within the Clear Creek 100-year flood plain.

Colorado and Southern Railroad (CSRR)/Centennial State Tire and Retread Company (Centennial Tire): Lies adjacent to the South Platte River between 15th and 16th Streets. The property includes a section of Confluence Park, owned by the City and County of Denver. The Farmers and Gardeners Ditch flows parallel to the railroad tracks in a concrete box culvert. The property included a building at 2301 15th Street, occupied by the National Radium Corporation in 1926 and 1927, that was demolished during remedial action activities. The property is underlain by approximately 25 feet of fill and alluvium, below which is the Denver Formation. The Confluence Park portion of the property is within the South Platte River 100-year flood plain.

Denver Water Department: Occupies a 0.1 acre paved lot at 1190 Yuma Street. Contamination on this property may have been related to operations of the Schlesinger Radium Company and the Radium Company of Colorado. These companies processed radium-bearing ore on the nearby DuWald Steel Corporation property, which was remediated as a part of OU2. The property is underlain by 30 feet of alluvium, below which is the Denver Formation, and is not within the South Platte River 100-year flood plain.

Public Service Company of Colorado: Occupies a vacant lot adjacent to an electrical substation at South Pecos Street and West Arizona Avenue. The property slopes from the

north and south ends toward a gully that runs east-west across the center of the property. Radiological contamination from an unknown source was detected in fill materials deposited prior to 1979 on the south end of the property. The property is underlain by approximately 8 feet of fill and soil, below which is the Denver Formation. The property is not within the South Platte River 100-year flood plain.

Ruby Hill Park: Occupies approximately 90 acres of open grass-covered land owned by the City and County of Denver. A maintenance building is located on the property. Portions of this property were used as a landfill. The source of the radiological contamination is unknown. The depth to bedrock is uncertain. The property does not lie within the South Platte River 100-year flood plain.

Environmental Metals Incorporated: Located at 1155 West 5th Avenue, was added to OU6 when contamination was detected on the property during remediation of the alley nearby. The property consists of a 2.4-acre lot, approximately, with a 19,000 sq/foot masonry building with office and shop space, a railroad siding, and two outbuildings. The property is underlain by about 30 feet of alluvium, below which is the Denver Formation. It does not lie within the South Platte River 100-year flood plain.

OU9A

International House of Pancakes (IHOP)/Larry's East Side Amusement Center and Trading Post:

The two businesses were located at 2001 East Colfax Avenue. Schlesinger Radium Company, which operated a radium reduction plant at OU2 in 1915, also operated a laboratory at the East Colfax location. Research, higher fractionation, and radium measurements were conducted at the laboratory. The building that housed the laboratory was demolished prior to 1950. Another part of the unit was occupied by an apartment complex from 1924 to 1939 and a car sales lot from 1939 to 1962. The IHOP restaurant was built in 1965. The other building on this unit houses Larry's East Side Amusement Center and Trading Post. This building existed at the time that Schlesinger operated its laboratory but apparently was not used for radium processing as no contamination was found inside the building. Depth to bedrock (Denver Formation) is approximately 16 feet.

OU11

Commercial Investors Realty (formerly owned by Thomas Real Estate Corp.): Comprises the property located at 1295 South Santa Fe Drive and the Colorado Department of Transportation. The unit is a sloping parcel of approximately 1.25 acres, rising 6 to 8 feet from southwest to northeast. The contamination at OU11 apparently is related to the processing or handling of radium ore by the Rocky Mountain Radium Products plant, which was located on or near the site. OU11 does not lie within a designated 100-year flood plain. The property is underlain by approximately 18 feet of alluvium, below which is bedrock (Denver Formation).

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, one of these being the "Open Space" properties that comprise OU6, OU9A, and OU11 properties. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU6, OU9A, or OU11.

C. RI/FS

A Remedial Investigation (RI) of OU6, OU9A, & OU11 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in September 1986. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest is radium-226 (Ra-226) because of its associated radioactivity (alpha, beta, and gamma radiation emissions of Ra-226 and its daughter isotopes) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- *5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,*
- *15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.*

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon*

decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and

- (2) *The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour ($\mu\text{R/h}$).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm^2); and,
- Removable alpha particle activity of 20 dpm/100 cm^2 .

EPA Region 8 proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

For OU6, the RI identified approximately 848 cubic yards of radiologically contaminated soil at depths ranging from less than 6 inches to 36 inches, with Ra-226 concentrations as high as 2,775 pCi/g. The contamination identified at the initial OU6 properties involved only exterior areas. The contamination on the Environmental Materials property, which was discovered after the RI/FS was issued, involved both interior and exterior areas. Elevated gamma radiation levels were detected at the Brannan, Ruby Hill Park, and alley properties; no samples were collected for analysis for Ra-226 concentrations at these three properties.

For OU9A, the RI identified approximately 96 cubic yards of radiologically contaminated soil with depths to 50 inches identified on the property. The contamination involved only exterior areas.

For OU11, the RI identified approximately 332 cubic yards of contaminated soil at depths ranging from 6 to 30 inches. Concentrations of Ra-226 as high as 690 pCi/g were identified. The contamination involved only exterior areas.

The FS addressed the following Remedial Action Alternatives, which included the demolition of the three affected buildings and were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action (All properties at OU6, OU9A, & OU11);
- Defer removal until an off-site permanent disposal facility became available (All properties at OU6, OU9A, & OU11);

- Off-Site Permanent Disposal (All properties at OU6, OU9A, & OU11);
- On-site temporary land storage, off-site permanent disposal (Allied, Public Service, and Brannan properties - OU6, OU9A, & OU11);
- On-Site temporary storage building, off-site permanent disposal (Allied, Public Service, and Brannan properties - OU6, OU9A, & OU11);
- On-Site Temporary Consolidation and Capping, Off-Site Permanent Disposal (All properties at OU6, OU9A, & OU11); and,
- Temporary storage building at OU10, off-site permanent disposal (All properties at OU6, OU9A, & OU11)

D. ROD Findings & Design Criteria

OU6

The remedial action alternative preferred by EPA for OU6 was off-site permanent disposal for the Allied, CSRR/Centennial Tire, Denver Water Department, and Public Service properties and No Action for the Brannan, Ruby Hill Park, and alley properties. Because a permanent disposal facility was not available when the ROD was issued in September 1987, the remedy selected by the EPA was temporary building storage at OU10 with subsequent off-site permanent disposal for CSRR/Centennial Tire, Denver Water Department, and Public Service properties and on-site temporary containment for the Allied property. The scope of the remedial action detailed in the ROD included the following:

- Determining whether contaminant levels at Brannan, Ruby Hill Park, and alley properties were within the limits specified in 40 CFR 192 to verify that the No Action alternative was appropriate;
- Placing a cap over the contaminated material at the Allied properties and, if necessary, the Brannan and alley properties;
- Removing the contaminated material from the CSRR/Centennial Tire, Denver Water Department, Public Service, and, if necessary, the Ruby Hill Park properties, placing the material in containers, and storing it in a temporary storage facility located at the Card Corporation property (OU10);
- Maintaining the temporary storage facility at OU10 and the containment caps at the Allied and, possibly, Brannan and alley properties until a facility suitable for the permanent disposal of Denver Radium wastes became available;
- Establishing institutional controls for maintenance, repair, and construction activities on the alley properties; and,
- Transporting the contaminated material from Allied, OU10, and, possibly, the Brannan and alley properties to the off-site permanent disposal facility.

The plans for implementing the selected alternatives were abandoned when a permanent disposal facility operated by Envirocare of Utah, Inc., in Tooele County, Utah, became operational.

OU9A

The remedial action preferred by EPA for OU9A was off-site permanent disposal. Because a permanent disposal facility was not available at the time the ROD was issued in September 1987, EPA selected the temporary storage building at OU10 and off-site permanent disposal alternative. The scope of the ROD remedial action entailed the following:

- Cleanup and storage of the contaminated material in the temporary storage facility at OU10;
- Maintenance of the temporary storage facility at OU10 until a facility became available for the permanent disposal of Denver Radium Site wastes; and,
- Final removal of the contaminated material from OU10 and transported to the off-site permanent disposal facility.

The plans for implementing the selected alternatives were abandoned when a permanent disposal facility operated by Envirocare of Utah, Inc., in Tooele County, Utah, became operational.

OU11

The remedial action alternative preferred by EPA for OU11 was off-site permanent disposal. Because a permanent disposal facility was not available when the ORD was issued in September 1987, the remedy selected by EPA was temporary building storage at OU10 and subsequent off-site permanent disposal. The scope of remedial action detailed in the ROD included the following:

- Removing the contaminated material from the property, placing it in containers, and storing it in a temporary storage facility located at OU10;
- Maintaining the temporary storage facility at OU10 until a facility suitable for the permanent disposal of Denver Radium Site wastes became available; and,
- Transporting the contaminated material from OU10 to the off-site permanent disposal facility.

The plans for implementing the selected alternatives were abandoned when a permanent disposal facility operated by Envirocare of Utah, Inc., in Tooele County, Utah, became operational.

E. Cleanup Activities performed

OU6

Radiological Contamination

Remediation activities were conducted in four phases to facilitate construction. Construction began in May 1991 and concluded in January 1994. During Phase A, 118

tons of contaminated soil was excavated from a property at South Pecos Street and West Arizona Avenue and disposed off-site. The excavated area was backfilled with clean soil and re-vegetated. Various properties within OU6, OU9A, and OU11 were remediated during Phase B and a total of 5,365 tons of material were excavated for off-site disposal. A total of 2,403 tons of contaminated soil were excavated from the Environmental Materials, Inc. (EMI) and Regional Transportation District properties. These soils were transported by rail to the permanent disposal facility in Utah during Phase C. In 1993, during the final phase, 450 tons of contaminated soil were excavated from the EMI property and transported by rail to the permanent disposal facility in Utah.

Following the excavation of contaminated materials, soil samples representative of the 6-inch thick (15-cm) soil layer at the bottom of each verification area (V-area) were collected and blended to form a composite sample for that V-area. All composite samples were analyzed for Ra-226. At least 10 percent of these samples were analyzed also for Th-230, thorium-232 (Th-232), and potassium-40. Additional samples were analyzed for Th-230.

Several deposits of contamination at OU6 required area-averaging because conditions that precluded safe or cost-effective removal of contaminated material. The following ten areas within OU6 were area-averaged:

Materials Left in Place as Averaged Areas – OU6¹

AREA	Size	Description	Area Avg. (pCi/g)
Area A	170 sq/ft.	Beneath 15 th Street near CSRR tracks	9.5 pCi/g Ra-226 (conforms to EPA stnd.)
Area B	360 sq/ft	Beneath Confluence Park jogging trail near CSRR tracks	14.4 pCi/g Ra-226 (conforms to EPA stnd.)
Area D	595 sq/ft	North side of Environmental Materials building	14.1 pCi/g Ra-226 (conforms to EPA stnd.)
Area E	192 sq/ft	North side of Environmental Materials building	10.3 pCi/g Ra-226 (conforms to EPA stnd.)
Area F	369 sq/ft	West side of storage yard at Environmental Materials building	10.8 pCi/g Ra-226 (conforms to EPA stnd.)
Area G	10 sq/ft	West side of storage yard at Environmental Materials building	7.3 pCi/g Ra-226 (conforms to EPA stnd.)
Area H	5 sq/ft	West side of Environmental	8.5 pCi/g Ra-226 (conforms to EPA

		Materials building	std.)
Area I	346 sq/ft	Beneath railroad tracks, west of Environmental Materials building	12.4 pCi/g Ra-226 (conforms to EPA std.)
Area J	17 sq/ft	West side of Environmental Materials building	6.8 pCi/g Ra-226 (conforms to EPA std.)
Area K	10 sq/ft	South side of Environmental Materials building	7.8 pCi/g Ra-226 (conforms to EPA std.)

- 1 Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

Non-Radiological Contamination

Lead in concentrations exceeding RCRA toxicity-characteristic regulatory levels was detected in 10 composite samples collected at the Environmental Materials property. The composite samples were collected from containers of radiological waste material prepared for transportation. At the request of EPA, Geotech collected four additional samples from areas of radiological contamination on the Environmental Materials property for toxicity-characteristic metals analysis (minus mercury) using the Toxicity Characteristic Leaching Procedure. Two of the samples exceeded the RCRA toxicity-characteristic regulatory limit for lead. A third sample exceeded the RCRA toxicity-characteristic regulatory limit for cadmium.

The presence of lead and cadmium in the mill tailings on the Environmental Materials property was the result of radium ore processing operations; therefore, the soil on this property was exempt from RCRA regulation in accordance with 40 CFR 261.4(b)(7).

Two transportation samples collected at the Allied property exceeded the RCRA toxicity-characteristic regulatory level for lead. EPA determined that the RCRA exemption, 40 CFR 261.4(b) (7), could not be applied to this property.

Interior Verification

Ra-226 contaminated soil was excavated from three locations beneath the interior floor slab of the Environmental Materials building to bring the building into conformance with EPA standards. Post-construction RDC measurements averaged 0.018 WL. Gamma scans of the interior indicated gamma exposure rates ranging from 14 to 28µR/h.

Disposal Operations

Contaminated materials were transported in either covered gondola cars or bimodal containers. The contractor loaded material directly into the cars or containers at the site, which were then sealed, surveyed, and decontaminated, as necessary, prior to leaving the site. The bimodal containers were transported by truck to a rail facility and loaded onto flatcars for conveyance to the permanent off-site disposal facility operated by Envirocare of Utah, Inc., in Tooele County, Utah. The gondola cars and bimodal containers were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness.

A composite transportation sample was collected from each railcar or container as they were loaded in accordance with EPA directives for each property. The samples were analyzed to ensure that the waste material conformed to the acceptance requirements of the disposal facility.

The metals-contaminated radiological waste that was removed from the Environmental Materials and Allied properties was shipped to the Envirocare of Utah, Inc., facility and disposed of in a segregated mixed-waste cell.

OU9A

Remedial activities at OU9A began in March 1990 and concluded in March 1991. The International House of Pancakes (IHOP) restaurant located on the property was closed for a period of six weeks to allow for cleanup activities. Approximately 89 tons of contamination was removed from the interior of the IHOP and 670 tons of contamination was removed from the parking lot located directly east of the IHOP. Excavation of contaminated material was performed by hand and conveyor belt in interior areas and back-hoe and front-end loader in exterior areas. Removal was directed by field personnel who measured radiation in the excavated areas with hand-held detectors. Excavations were also guided by soil sample analyses. After the removal of the material was completed based on the readings of the field instruments, verification was performed by collecting and analyzing soil samples.

Radiological Contamination

Following excavation of contaminated materials, soil samples representative of the 6-inch-thick (15-cm) soil layer at the bottom of each verification area were collected and blended to form a composite sample for that verification area. All composite samples were analyzed for Ra-226, Th-232, Th-230, and K-40.

During remediation activities at OU9A, three areas (Areas A, B, and C) on the unit required the use of area-averaging calculations because of considerations that precluded

cost-effective and safe removal of all contaminated material. These areas are deposits located beneath the foundation footers of the IHOP building. This material was averaged to avoid safety hazards and the expense associated with remediation beneath the foundation of the building. Area A was a 78-sq/ft deposit, Area B was a 4-sq/ft deposit, and Area C was a 19-sq/ft deposit. Calculations show the Ra-226 concentrations in all three areas average to 5.7 pCi/g, which meets the EPA subsurface standard.

Disposal Operations

Contaminated materials were sealed in containers and delivered by truck to railroad loading areas; the containers were then transported by rail to the permanent off-site disposal/storage area. Material was loaded directly into the containers at the site by the Geotech subcontractor. Each container was filled with contaminated material and then inspected to ensure that no spillage of waste material occurred. The containers were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness. Composite samples were taken from selected containers and were analyzed to ensure that the material was acceptable under the requirements of the disposal facility.

OU11

Construction at OU11 began in June 1991 and concluded in August 1991. The quantity of material removed during remediation was 786 tons (approximately 655 cubic yards). All areas of contamination were verified by field personnel to be in conformance to exterior (open land) standards. Contaminated material was excavated with front-end loaders while field personnel monitored the excavated areas for remaining contamination with hand-held radiation detectors. Soil samples were collected and analyzed to verify that excavation activities achieved conformance with the applicable standards.

Radiological Contamination

Following excavation of contaminated materials, soil samples representative of the 6-inch-thick (15-cm) soil layer at the bottom of each verification area were collected and blended to form a composite sample for that verification area. All composite samples were analyzed for Ra-226, Th-232, Th-230, and K-40.

Th-230 was detected in elevated concentrations in verification areas V-6, V-7, V-8, and V-10. The results of analyses for Th-230 were not available until after the excavation at OU11 was backfilled. Further Th-230 characterization, conducted in November 1991, indicated only one occurrence of Th-230, in area V-9, exceeded the proposed limit and confirmed that Ra-226 concentrations in all locations were in conformance with EPA standards. EPA assessed the health risks associated with the Th-230 contamination left in place at OU11. This assessment included an evaluation of the modeling results of similar

Th-230 occurrences using the RAETRAN computer code. This modeling program predicts the radon flux in a residential structure that might be built over a Th-230 deposit. The RAETRAN results indicated that radon levels in the structure would not exceed current EPA guidelines. EPA determined that Ra-226 concentrations at OU12 would remain below 15 pCi/g for at least 200 years. EPA concluded that the Th-230 contamination does not present a risk to public health or the environment; therefore, further remediation of the property was unnecessary.

Disposal Operations

Contaminated materials were transported in bimodal containers. The contractor loaded material directly into the containers at the site. Each bimodal container was sealed, surveyed, and decontaminated, as necessary, prior to leaving the site. The containers were transported by truck to a rail facility and loaded onto flatcars for conveyance to the permanent off-site disposal facility. A total of 46 bimodal containers were loaded and shipped between June and July 1991. The containers were used only for the transportation of wastes from the Denver Radium Site. Although Federal regulation did not require labeling for material of such low level radioactive concentrations, the loaded cars were labeled "Denver Radium Superfund Waste" as an added measure of protectiveness. A composite sample was collected from every tenth container, or, at a minimum, from one container per day as the containers were loaded. The samples were analyzed to ensure that the material conformed to the acceptance requirements of the disposal facility.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU6, OU9A, and OU11 and promoted communications among interested parties throughout the duration of the project. General community concerns were the impacts of cleanup and storage on property values, the health risks associated with the cleanup, the transportation risks, the need for temporary storage of wastes, and the possibility of the temporary storage facility becoming permanent.

Community relations activities OU6, OU9A, and OU11 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meetings to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;

- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizens groups, State and local governments, EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Informing communities along the transportation route (through meetings and mailings) of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

A site visit was performed in August 2003 during the Five-Year Review process carried out by the State of Colorado. At OU6, demolition of the Centennial Tire building (2301 15th Street) has occurred and the construction of luxury apartments has been completed. Communication with the City and County of Denver indicates that the builder of the apartments at 2301 15th Street was in communication with the City and County of Denver and had taken precautions during excavation to identify potential areas of contamination. Also at OU6, Brannan Sand and Gravel remains a sand and gravel operation. The Denver Water Department building was remediated by Denver Water by a separate contractor aside from any EPA remedial action. The site currently has a slab-on-grade commercial building and is operating as a commercial wholesaler for wine. The Public Service property remains under the same land use category now owned and operated by Excel Energy. Ruby Hill Park remains as public open space owned by the City and County of Denver. The Allied Chemical building (1271 West Bayaud) was converted to General Chemical and currently is vacant. 1155 West 5th Avenue (formerly Environmental Metals Incorporated) was remediated and redeveloped as part of a commercial redevelopment project. Removal occurred on September 16, 2006.

At OU9A, the IHOP and Larry's Trading Post is now occupied by Mama's Café and three retail stores, respectively.

At OU11, a Starbuck Express coffee drive-thru stand has been constructed on the northern portion of the property and what appears to be a vacant office building occupied the southern portion of the property.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech *Quality Assurance Manual* (Manual 101), which was developed in response to the DOE Field Office, ID, Order 5700.6C. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A

listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU4* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental monitoring was required to determine whether the remedial action adversely affected off-site air quality at OU6, OU9A, and OU11. Off-site air quality monitoring data were collected before, during, and after the remedial action. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter were placed at each of four measurement locations. There were no significant difference between the data set for the baseline period, the construction period, and the post-remedial action period.

Air Particulate Measurement

Air particulate samples were collected with Model LV1 low-volume air particulate samplers manufactured by F&J Specialty Products, Inc. Each sampler was contained in its own environmentally protected shelter and connected to a dedicated electrical power outlet. The samplers were operated continuously for 7 days at a nominal rate of 5 liters per minute. The filters were analyzed by Geotech analytical laboratory for natural uranium, Th-230, Ra-226, and polonium-210 (Po-210).

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for airborne radionuclides. These standards are expressed as concentrations above background as follows:

Natural Uranium	-	5.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Th - 230	-	8.0×10^{-14} microcuries per milliliter ($\mu\text{Ci/mL}$)
Ra - 226	-	3.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Po - 210	-	2.0×10^{-11} microcuries per milliliter ($\mu\text{Ci/mL}$)

All airborne radionuclide concentrations measured during the reporting period were below the applicable regulatory standard.

Atmospheric Radon Measurements

Terradex outdoor Type F Track Etch ® radon detectors were used to determine atmospheric radon concentrations. Two detectors were exposed in an environmentally protected enclosure approximately 1 meter above ground level. Each detector consisted of an alpha-sensitive film protected by a membrane analyzed by Terradex Corporation for the density of the alpha tracks produced by radon decay, which is proportional to the radon concentration in the atmosphere sampled.

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for atmospheric radon concentration. The regulatory standard is 3.0 picocuries per liter above background. All atmospheric radon concentrations measured during the reporting period were below this standard.

Direct External Gamma Exposure Measurement

TMA/Eberline thermoanalytical environmental dosimeters were used to measure the external gamma radiation at each sample location. A dosimeter was exposed approximately 1 meter above ground level at each sample location and was submitted to TMA/Eberline Thermo Analytical, Inc., for analysis.

The background gamma exposure rates for the Denver area range from 130 to 175 mrem/yr (CH2M Hill, 1986). All gamma exposures measured during the reporting period were below this limit

V. Summary of Operation and Maintenance

OU6, OU9A, OU11 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD, as modified by an ESD, in accordance with CERCLA, 42 U.S.C. Section 9601, et.seq., as amended by SARA of 1986, and the NCP, 40 CFR Part 300. At OU6, supplemental standards have been applied in some areas; therefore, land usage restrictions will apply, and EPA conducted a 5-year review of the remedial action at OU6. The City and County of Denver Alley right-of-way within OU6 was remediated in 2005 as part of the Operation and Maintenance under the Denver Radium Streets Program and no longer requires restrictions.

VI. Summary of Remediation Costs

The Remedial Action Completion report for does not contain information on the cost of the remedial activities undertaken. The ROD for does not contain an estimate of the cost of full removal with permanent offsite disposal. It is difficult to determine the costs associated with the remedial action for OU6, OU9A, and OU11 as costs were not tracked by operable unit for Denver Radium until after 1996.

VII. Protectiveness

Health hazards associated with the radium waste present at OU6, OU9A, and OU11 prior to the remedial action were the result of direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU6, OU9A, and OU5 have been excavated in accordance with the Federal and State standards cited in the documents for addressing the remedial action at OU4. Excavated wastes were disposed of at a permanent off-site disposal site. Supplemental Standards and Institutional Controls have been put into place where radioloactively contaminated materials were left in place. All work was done in accordance with the ROD and applicable EPA directives. The remedial action at

OU6, OU9A, and OU11 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU4.

- Though the waste material found at OU6, OU9A, and OU11 did not meet the U.S. Department of Transportation (DOT)'s definition of radioactive material, it was transported as if it were a low-specified activity (LSA), naturally occurring radioactive material. In addition, substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and particle emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU4 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of releases during the transportation of wastes, fires, and adverse weather conditions.
- For waste remaining at OU6/OU9A, & OU11, ICs are in place that are sufficient to protect human health and the environment.

VIII. Five-Year Review

The levels of waste material remaining at the OU6, OU9A, and OU11 where area averaging was used allow for unrestricted use and unrestricted exposure. OU6, OU9A, and OU11 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that although all ROD requirements had been met through the remedial action, the risk assessment did not meet the current ARAR of CRR 1007 4.61.3.2 – 4.61.3.3. Although future Five-Year Reviews are not required at OU6, OU9A, and OU11, the locations where waste was left in place should be tracked with the established GIS database for proper disposal during future development. The conditions of the individual properties that comprise OU6, OU9A, and OU11, and the requirements of future five year reviews are as follows:

Status of OU6, OU9A, & OU11 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
Alley in City and County of Denver right-of-way	Between Mariposa and Lipan Streets and between 5 th and 6 th Avenues.	No	Yes	No
Allied (General Chemical)	1271 West Bayaud Avenue	No	Yes	No
Brannan Sand and Gravel	61 st Ave. and Clear Creek	No	Yes	No
Central and Sierra Railroad right-of-way/Centennial Tire	2301 15 th Street	No	Yes	No
Denver Water Department	1190 Yuma Street	No	Yes	No
Public Service Company	South Pecos Street and West Arizona Ave.	No	Yes	No
Ruby Hill Park	Jewell Street and South Platte River Drive	No	Yes	No
Environmental Metals Inc.	1155 West 5 th Avenue (building has been razed)	No	Yes	No
International House of Pancakes and Larry's Trading Post	2001, 2015, and 2017 East Colfax Avenue (<i>now Mama's Café, Herbs and Art, and Purple Haze</i>)	No	Yes	No
Commercial Investors Realty <i>Beds and a Starbucks</i>	1285 – 1295 South Santa Fe Drive (formerly owned by Thomas Real Estate Corp.) (<i>now Murphy</i>)	No	Yes	No

IX. Bibliography

- Superfund Record of Decision: Denver Radium/Open Space Properties, OUVI, OUIX(A), and OUXI, CO – Region 8 – September 29, 1987
- Denver Radium Site Operable Unit VI, Phase D, Remedial Action Completion Report – March 30, 1994
- Denver Radium Site Operable Unit IX Remedial Action Completion Report – September 30, 1991
- Denver Radium Site Operable Unit XI Remedial Action Completion Report – September 30, 1991
- Denver Radium Site/Operable Unit VI Interim Closeout Report for the U.S. Environmental Protection Agency – June 1994 – RUST Geotech, Inc.
- Denver Radium Site/Operable Unit IX Closeout Report for the U.S. Environmental Protection Agency – November 1993 – RUST Geotech, Inc.
- Denver Radium Site/Operable Unit XI Closeout Report for the U.S. Environmental Protection Agency – April 1994 – RUST Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Unit 7

II. Summary of Site Conditions/OU7

A. Background

Denver Radium Operable Unit 7(OU7), also known as the Denver Radium Site Streets, is comprised of the following street segments under which radium-226 (Ra-226) contaminated asphaltic concrete pavement was identified:

Operable Unit	Property Description at time of ROD	Date removed as part of Denver Radium Streets Program
OU7	9 th Avenue from Ogden Street to Cheeseman Park	Estimated for 2007
OU7	11 th Avenue from Josephine Street to Cheesman Park	2003
OU7	23 rd Street from California Street to Lawrence Street	Estimated for 2007
OU7	Corona from 7 th Avenue to 10 th Avenue	Estimated for 2007
OU7	Downing Street from 7 th Avenue to 10 th Avenue	2005
OU7	Humbolt Street from 7 th Avenue to 9 th Avenue	2004
OU7	Lafayette Street from 1 st Avenue to 10 th Avenue	2004
OU7	Marion Street from 6 th Avenue to 10 th Avenue	2003
OU7	York Street from 6 th Avenue to 13 th Avenue	Estimated for 2007

The contamination at the initial OU7 locations was apparently the result of paving operations during the 1920's in which Ra-226 contaminated aggregates were incorporated into asphaltic concrete pavement. The source of the contaminated aggregates is unknown. The impacted areas of OU7 generally contain a 4-to-6-inch layer of radium-contaminated asphalt underlain by compacted gravel road base. Usually, the street segments are overlain by 4-to-12 inches of uncontaminated asphalt pavement. There is an estimated 38,700 cubic yards of radium-contaminated material within OU7. The street segments are owned by the City and County of Denver and extend largely through residential areas. Radioactive contamination does not extend laterally beyond

the paved portion of the streets. The RI identified Ra-226 concentrations as high as 79 pCi/g within OU7. Surface gamma exposure rates as high as 57 μ R/h were identified; however, the gamma values generally were less than 20 μ R/h above background. The contaminated sections of public streets identified during remedial action activities involve Ra-226 contamination in the underlying soils.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, which included the OU7 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU7.

C. RI/FS

A Remedial Investigation (RI) of OU7 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The draft Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in September 1987. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest is radium-226 (Ra-226) because of its associated radioactivity (gamma radiation and radon-decay products) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- *5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,*
- *15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.*

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and*
- (2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour (μ R/h).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm²); and,
- Removable alpha particle activity of 20 dpm/100 cm².

EPA Region 8 has proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

The FS addressed the following Remedial Action Alternatives, which were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Modified no action;
- Limited excavation and disposal;
- Asphalt shielding; and,
- Limited asphalt shielding.

D. ROD Findings & Design Criteria

The remedial action alternative preferred by EPA for OU7 was Modified No Action. The remedy entailed the following:

- Leaving the contaminated material in place;
- Improving institutional controls to ensure monitoring of all maintenance, repair, and construction activities in the affected streets; and,

- Removing contaminated material excavated during routine maintenance, repair, or construction activities in the affected streets to an approved storage or disposal facility.

The ROD was modified by an ESD in September 1992. The ESD allows for reburial and retention of contaminated materials excavated during routine or emergency repairs, maintenance, or construction activities, provided the excavated area does not exceed 20 percent of the total roadway area of one city block. Contaminated materials will be reburied at the depth from which they were removed and covered by at least 6-inches of hard-surface material. When materials cannot be reburied or when more than 20 percent of the roadway area of a city block is excavated, the contaminated materials will either be stored temporarily off-site at an approved licensed facility or transported to and disposed of at a licensed off-site disposal facility. A variance to the 20 percent guideline may be granted by the Colorado Department of Public Health and Environment (CDPHE). The ESD also recommends the inclusion of portions of OU3 into the institutional controls plan for OU7.

E. Cleanup Activities performed

Remediation activities were not conducted at OU7.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU7 and promoted communications among interested parties throughout the duration of the project. EPA solicited feedback from the public and any interested parties prior to issuing the ROD. Comments received from residents and property owners indicated a preference for complete removal and proper disposal of the contaminated material in the streets. Several government agencies responded, expressing concerns about the need to control exposure of the public and workers to the contaminated materials and about the need to dispose of any excavated material properly.

Community relations activities OU7 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;
- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU7 was already developed for residential uses at the time of the remedial action. In a site visit performed in August 2003, all properties at OU7 were being used for the same purposes.

III. Demonstration of Cleanup Activity QA/QC

No cleanup activity was conducted for OU7.

IV. Monitoring Results

No monitoring activities were conducted for OU7.

V. Summary of Operation and Maintenance

In accordance with CERCLA Section 104(c) (3), the State of Colorado is responsible for ensuring the payment of all cost of any operation and maintenance activities required by the ROD for OU7. These activities include the imposition and administration of institutional controls for the Ra-226 contaminated streets and the control of and disposal of contaminated materials. The State has delegated the administration of the institutional controls to the City and County of Denver's Department of Public Work (Public Works) with oversight by CDPHE. The controls are specified in the *Management Plan, Denver Radium Site, Operable Unit 7, Denver Streets* (the Management Plan) (GEI Consultants, Inc., 1993). This plan has been approved by the EPA and CDPHE and conforms to the applicable regulations of those agencies. It establishes procedures and controls for the protection of workers, the public, and the environment; the monitoring of any operation involving radium contaminated materials; and the control, interim storage, and eventual permanent disposal of excavated contaminated material.

Denver's Radium Streets Program is a response to EPA's designation of these streets as part of the Superfund Site. Denver Radium Streets, which EPA calls "Operable Unit 7", is comprised of nine street segments. The City has been managing the radium-contaminated material for about 9 years, including annual training for utility workers and oversight of contractors working in the designated streets. As funding allows, and as a need to reconstruct streets arises, the City will reconstruct the street and remove contaminated materials. This reconstruction process provides a long-term solution to the City's ongoing management of the radium-contaminated material.

The Management Plan contains Special Conditions Procedures to be followed by any private-sector contractor, utility company, or Public Works representative who will disturb the surface of a Ra-226 contaminated street. Procedures are established for three types of activities: 1) pavement repair, replacement, and modification; 2) trenching and utility cuts; and, 3) pavement profiling (rotomilling). The Management Plan also provides for the automatic inclusion into the Plan of any nearby contaminated streets identified subsequent to its adoption.

Each operating division within Denver's Public Works will appoint a Divisional Designated Person to oversee the implementation of the Management Plan as it applies to work activities within that division. The Divisional Designated Person reports to the Public Works Coordinator.

The Public Works Coordinator ensures that all activities of Public Works comply with the provisions of the Management Plan. This individual is appointed by and reports to the Manager of Public Works. The Manager of Public Works is responsible to the Program Administrator for verifying that all Public Works activities comply with the provisions of the Management Plan.

The Program Administrator is responsible for the overall implementation of the Management Plan. This individual ensures that all Public Works, private-sector contractors, and utility company activities conform to the requirements of the Management Plan. This person manages the activities of the Safety Representative and serves as the point of contact for concerns relating to worker safety.

The Safety Representative acts as an independent monitor of all operations within the affected areas. This individual or firm ensures that the safety provisions of the Management Plan and specific Site Health and Safety Plan are followed and has the authority to suspend, postpone, or modify any work activity that might endanger the health and safety of the workers or the public. The Safety Representative reports directly to the Program Administrator.

The Safety Representative coordinates the activities of one or more Assistant Safety Representatives. These individuals oversee operations at the work site, conduct personnel and environmental monitoring, direct the handling and disposition of waste materials, ensure that the provisions of the Management Plan are followed, and observe and document all activities.

A Program Monitor appointed by the City and County of Denver monitors the overall implementation of the Management Plan, acts as liaison between the involved agencies, and responds to inquiries about health concerns relating to the affected streets.

All contractors working within OU7 must obtain a written permit through Denver's Public Works before any work in the affected streets may begin. The permitting process includes determining whether the work location falls within the Special Conditions Area for radium-contaminated streets. If the work location falls within the Special Conditions Area, the applicant will be required also to obtain the approval of the Divisional Designated Person within the appropriate operating division of Public Works. That person will ascertain that the applicant understands and will follow the Special Conditions Procedures outlined in the Management Plan. Personnel in all work activities also must follow all pertinent CDPHE and Occupational Safety and Health Administration (OSHA) regulations.

Before the Public Works division can commence work within a Special Conditions Area, the Safety Representative will prepare a Site Health and Safety Plan. Work supervisors will communicate the contents of this plan to the members of their work crews, after which the members will sign an affidavit signifying their understanding of the Special Conditions Procedures and the Site Health and Safety Plan. Work Supervisors may not deviate from the procedures without the written authorization of the Divisional Designated Person. Private contractors and utility operators also must submit and obtain approval of a Site Health and Safety Plan prior to initiating work activities and must adhere to the provisions of the Management Plan that pertain to informing workers of the hazards associated with the contamination and ensuring their safety.

Public Works supervisors, utility company supervisors, and private contractors must contact the Program Administrator and the Assistant Safety Representative at least 48 hours prior to initiating work. The Program Administrator will approve Site Health and Safety Plans and Work Plans during this time.

Public Works will establish emergency work crews. These crews will be familiar with the provisions of the Management Plan and will have completed all mandatory training. Private utilities and contractors also may establish emergency work crews, the members of which must have documentation verifying for compliance with the provisions of the Management Plan. The Program Administrator and the Assistant Safety Representative must be notified immediately upon the dispatching of any emergency crew.

All individuals who work within the controlled area at job sites within the Special Conditions Area or will come in contact with contaminated material are subject to the training and medical monitoring requirements set forth in 29 CFR 1921.120 (e) and (f) and the Management Plan. Workers and others present at the work sites will be monitored for exposure to gamma radiation and radioactive air particulates. Measures to control exposure of workers to airborne radiological contaminants may include the use of water mist to suppress dust, the use of appropriate personal protective equipment, and the cessation of work when conditions warrant. During rotomilling operations, large-volume air samples will be collected to determine the effectiveness of dust control measures. The Assistant Safety Representative will conduct all monitoring at the site. The monitoring will include gamma surveys to determine the need for personal protective equipment and to determine whether excavated materials are contaminated and will require special handling.

The Management Plan specifies controls that must be followed to prevent the spread of contamination during operations within OU7. Excavated materials will be placed back in the excavation at their original depth unless the area of the excavation exceeds 20 percent of the roadway area of one city block or conditions preclude reburial of the contaminated material. In these instances the contaminated material must be removed and properly stored and disposed. Any contaminated materials that are not reburied will be packaged and transported to an approved temporary storage site or a permanent disposal facility in accordance with the applicable provisions of 49 CFR and any other applicable regulations.

Roadway areas that are to be rotomilled will first be investigated by borings and other methods to determine precisely the location and extent of radiological contamination. Rotomilling operations will be designed to minimize the involvement of contaminated materials.

The Management Plan can be revised by the Program Administrator with the concurrence of CDPHE, EPA, and the City Safety Representative. The ESD for OU3 recommends that the Management Plan be revised to include the affected portions of the South Jason Street and South Platte River Drive and to define the inclusion boundaries for those streets as extending to the edge of the legal right-of-way. The Management Plan is available for public review at CDPHE, EPA, and Public Works.

The remedy selected for OU7; as described in the ROD and amended by an ESD, is in conformance with the standards set forth in CERCLA of 1980, as amended by SARA of 1986, and the National Contingency Plan, 40 CFR 300. EPA conducted a 5-year review of the Denver Radium Operable Units in September 2003, including OU7, which will be apart of subsequent 5-year reviews.

VI. Summary of Remediation Costs

No remediation activity was conducted for OU7 and there is not a clear record of other cost associated with this operable unit.

VII. Protectiveness

Health hazards associated with the radium waste present at OU7 result from direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU7 street sites is largely immobilized within asphaltic concrete and does not present a hazard to public health or the environment when institutional controls are in effect.

An endangerment assessment was conducted as a part of the Feasibility Study to determine the exposure of the public and workers to the detrimental effects of the contamination in the streets. EPA concluded the following:

- Gamma exposure to individuals spending 2 hours-a-day/5 days-a-week at an average gamma exposure rate for the streets of 40 μ R/h above background was considered not to pose a health risk;
- Exposure to radon is not a problem out-of-doors because radon gas disperses readily in air and is diluted to minimal concentrations. The potential for radon buildup in structures adjacent to the affected streets is unlikely because of the low-levels of radium contamination in the streets and because any utility trenches, backfilled with porous materials through which radon might diffuse, are below and isolated from the contamination. Because of its short half-life, radon will not diffuse through the 20 to 30

- feet of compacted soils separating the contaminated areas and the structures before decaying into solid, relatively immobile daughter products; and,
- Ingestion or inhalation of contaminated material is unlikely because the material is contained in or below a layer of asphaltic concrete from which it would have to be deliberately removed. Safeguards will be emplaced to control the excavation and disposal of contaminated materials.

The Ra-226 contamination underlying South Jason Street and South Platte River Drive do not pose a risk to the public while the contamination remains in place. RDC measurements collected in buildings adjacent to South Jason Street and South Platte River Drive at OU3 are within limits specified in 40 CFR 192.12(b).

The Ra-226 contaminated materials will be removed and disposed of as the affected streets and utilities require complete reconstruction; therefore, the application of supplemental standards to the affected streets at OU7 is not required. Upon complete reconstruction of the affected areas, the entire operable unit will be in conformance with the standards in decision documents.

- Geotech conducted an assessment of the health risks associated with the contamination underlying South Jason Street (Chem-Nuclear Geotech, Inc., 1991). The results of this study indicate that the Ra-226 contamination left in place did not pose a significant health risk to the public. Specifically, a full-time employee of a neighboring business and a construction worker would not receive annual effective dose rates above health risks as a result of exposure to the contamination remaining beneath the street. These results were based on worst-case exposure scenarios. The contamination left in place beneath South Platte River Drive is of lower concentration and smaller volume and poses a lesser health risk than the contamination beneath South Jason Street.

VIII. Five-Year Review

OU7 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which concluded that the remedy was protective as long as the ICs were in place. After the 5-year was concluded, the ICs have been put in place and the strict use of these institutional controls should sufficiently protect human health and the environment from the remaining contamination at OU7. As the City and County of Denver conducts removals of the OU7 areas as part of the Management Plan, these areas will be removed from the Five-Year review schedule. The conditions of the individual properties that comprise OU7, and the requirements of future five year reviews are as follows:

Status of OU7 Properties Post-Construction

Property Name	Eligible for Deletion?	Included in Future Five Year Reviews
9 th Avenue from Ogden Street to Cheesman Park	Yes	Yes
11 th Avenue from Josephine Street to Cheesman Park	Yes	No
23 rd Street from California Street to Lawrence Street	Yes	Yes
Corona from 7 th Avenue to 10 th Avenue	Yes	Yes
Downing Street from 7 th Avenue to 10 th Avenue	Yes	Yes
Humbolt Street from 7 th Avenue to 9 th Avenue	Yes	No
Lafayette Street from 1 st Avenue to 10 th Avenue	Yes	No
Marion Street from 6 th Avenue to 10 th Avenue	Yes	No
York Street from 6 th Avenue to 13 th Avenue	Yes	Yes

IX. Bibliography

- Superfund Record of Decision: Denver Radium/1000 West Louisiana Properties, CO – EPA/ROD/R08-87/017 - Region 8 – September 29, 1987
- Denver Radium Site Operable Unit III Remedial Action Completion Report – September 30, 1991
- Superfund Explanation of Significant Difference for the Record of Decision: Denver Radium Superfund Site (OU7), CO – December 14, 1993
- Denver Radium Site/Operable Unit III Interim Closeout Report for the U.S. Environmental Protection Agency – April 1994 – RUST Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Unit 8

II. Summary of Site Conditions/OU8

A. Background

Denver Radium Operable Unit 8 (OU8), also known as the Shattuck property, was the location of the S.W. Shattuck Chemical Company, which processed a variety of radioactive materials from 1917 to 1984. OU8 is located approximately 6 miles southwest of downtown Denver on a 5.9 acre property located at 1805 South Bannock Street. OU8 also includes the adjacent railroad right-of-way property, a portion of South Bannock Street, and a few properties known as vicinity properties east of the Shattuck property where radium contaminated soils were found.

Operable Unit	Property Description at time of ROD
OU8	S.W. Shattuck Chemical Company – 1805 South Bannock Street

Contamination at OU8 is due to historical use of the property for various mineral processing operations. Mineral ores processed included tungsten and caronite ores, radium slimes, molybdenum ores, and depleted uranium. A summary of the processing history is as follows:

- 1920's – Molybdenum ore processing;
- 1930's – Radium slime processing;
- 1940's – Uranium and molybdenum processing;
- 1950's – Uranium processing;
- 1960's – Molybdenum processing; and,
- 1970's & 1980's – Uranium, molybdenum, and rhenium processing.

Many of the processed ore residues remained on the site and became intermixed with site soils. Additionally, a detention pond to hold molybdenum slime wastes was located at the northern end of the property. These activities resulted in contamination of the site with radioactive elements, including Ra-226, Th-230, various Uranium isotopes, and non-radioactive metals such as lead, arsenic, and selenium. Shattuck's operations ceased in 1984.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one

radioactive sites in the Denver metropolitan area, which included the OU8 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. In 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.

C. RI/FS

A Remedial Investigation (RI) was conducted for OU8 by the EPA in 1988. Further study of the site was completed in 1991. Those studies found that radiological contamination was present in site soils over an area of approximately 230,000 sq/ft. The contamination was found to extend from the ground surface to depths ranging to over 14.5 feet below the ground surface. The estimated volume of contaminated soil at the site was 38,500 cubic yards.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,
- 15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and

- (2) *The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour ($\mu R/h$).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm²); and,
- Removable alpha particle activity of 20 dpm/100 cm².

EPA Region 8 has proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

The FS addressed the following Remedial Action Alternatives, which were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Restrict site access, excavate railroad and vicinity properties;
- Cap Site with clean soil;
- In-Situ Vitrification;
- Excavation, stabilization, on-site disposal;
- Excavate, remove and replace all contaminated soil; and,
- Excavate and physical/chemical treatment of soils.

D. ROD Findings & Design Criteria

The original ROD was signed in January 1992 and selected on-site stabilization and solidification as the remedy for soils and natural attenuation with monitoring for groundwater. Also, all buildings and facilities on the property were to be demolished and disposed of off-site. Institutional controls, maintenance, and monitoring were also used to supplement the remedy. The original ROD was largely completed in September 1998 with the creation of an approximately 5-acre cement/soil monolith on the site. In November 1999, EPA completed a 5-year review of the remedy outlined in the original ROD that identified concerns related to the long-term effectiveness of the monolith and the reliability of the IC's imposed in the original ROD. Additionally, the State, City and County of Denver, stakeholders, and the local community requested other alternatives to the on-site containment remedy. The combination of technical concerns, requests to reconsider the original remedy, and the State's withdrawal of support resulted in the EPA amending the original ROD. An Amended ROD was signed on June 16, 2000 and EPA selected off-site removal to best meet Superfund's nine evaluation criteria. The amended ROD stipulated that the monolith at OU8 be removed from the site along with any

additional identified contaminants in excess of cleanup levels specified in the Amended ROD.

E. Cleanup Activities performed

Original ROD

The original ROD called for the on-site stabilization and containment. The initial remedial action at OU8 was conducted in two phases, beginning in September 1992, and was subsequently complete in September 1998. During Phase I, approximately 67,345 tons of radiologically contaminated building debris was disposed at an off-site permanent disposal facility. Demolition was performed using cutting torches, cranes, rams, front-end loaders, dump trucks, air and hydraulic hammers, demolition and paving saws, and miscellaneous powered and hand tools. Approximately 200 cubic yards of asbestos containing material (ACM) was found in several of the on-site structures and was disposed in accordance with all Federal and State regulations. Approximately 400 cubic yards of radiologically contaminated material were excavated from beneath Bannock Street. Rubble resulting from demolition activities of some buildings and the building slabs was retained on-site and crushed for subsequent treatment with the contaminated on-site soils. All performance standards established in the original ROD were met.

Remediation of the vicinity properties resulted in 8,700 cubic yards of contaminated soil being excavated and stockpiled on the Shattuck property for later treatment. The soils were typically excavated with a back-hoe or track-hoe and were transported to the Shattuck site with a front-end loader or dump truck. Clean fill was imported to backfill all excavations and was compacted to the original grade.

The original ROD identified site soils as the principal-threat waste because these materials were considered to be mobile source materials that were generally not contained in a reliable manner. These principal-threat wastes received treatment by the solidification and stabilization process implemented under the first remedial action. The original remedy imposed a minimum 300-year effectiveness criterion, in effect making OU8 a perpetual waste management facility. Consequently, no future land use was anticipated for the site other than as a permanent repository for stabilized waste materials.

Execution of the initial ROD resulted in the actual excavation of 43,214 cubic yards of contaminated on-site soils. These excavated soils were mixed with cement and fly-ash and consolidated into a solidified cement/soil monolith with an approximate volume of 83,610 cubic yards. Stabilization/solidification of the radiologically contaminated material began in July 1996 and was completed in November 1997. Capping of the stabilized material was completed in June 1998.

During the excavation of radiologically contaminated soils, oil-impacted soils were also found on-site. The materials were below the action levels established in the original ROD. Approximately, 2,000 cubic yards of oil-impacted soil were excavated from the Shattuck Site during Phase 2 and was transported by truck to Conservation Services, Inc.,

in Thornton, CO. Bioremediation was used for the oil-impacted soils that extended beneath the completed portion of the monolith. A bio-system was approved by the EPA to treat the remaining oil-impacted soils and installed in September 1998. A Management Plan for OU8 Bannock Street site was developed and adopted in March 1999 by the City and County of Denver to govern all maintenance, repair, or other construction activities at OU8 Bannock Street.

Institutional controls stipulated in the original ROD included site fencing, restrictions against excavating into the cover and stabilized materials, restrictions prohibiting the construction of enclosed structures on the site, restrictions against using groundwater beneath the site, and restrictions to prevent agricultural use of the site.

Groundwater contamination present beneath the site was to be remediated by natural attenuation, or, by removal of the onsite source. Groundwater monitoring was also specified as the means by which the effectiveness of stabilization was in immobilizing the contaminants. The original ROD remedy was designed to minimize active maintenance requirements. Post-closure care was limited to maintenance of the impermeable cap. Provisions for surveillance and repair were established.

Amended ROD

As a result of the statutory 5-year review conducted in 1999 concerns were raised as to the long-term effectiveness of the monolith and the reliability of the IC's. The combination of technical concerns, requests to reconsider the remedy, and the State's withdrawal of support resulted in the USEPA amending the original ROD and the *Record of Decision Amendment, Denver Radium Site, Operable Unit VIII, Denver, Colorado (USEPA, 2000a)* was issued on June 16, 2000. The Amended ROD stipulated that the monolith be removed from the site along with any additionally identified contaminants in excess of cleanup levels specified in the Amended ROD.

Implementation of the remedy stipulated in the Amended ROD began in September 2002 and was completed in September 2006. Remedial operation and the sequence of actions taken during routine demolition and removal of materials at the site include the following:

1. Structure Erection,
2. Cover Material Removal,
3. Monolith Demolition and Removal,
4. Underlying Soil Excavation, including
 - Investigation, and
 - Targeted removal,
5. Pre-Verification Walkover Survey,
6. Pre-Verification Sampling and Analysis,
7. Mining Structure Relocation,
8. Final Status Survey,
9. Independent Verification,
10. Topographic Survey,
11. Bannock Street Remediation,

12. Perimeter Soil Excavation
13. Molybdenum Pond Soils Remediation,
14. Backfill Operations,
15. Site Restoration, and;
16. Operation and Maintenance.

For a detailed description of the activities for each of the operational elements undertaken in Amended ROD remedial action see *Shaw Environmental - Construction Completion Report – Shattuck Chemical Superfund Site – Denver, Colorado, September 2006*. Upon completion of the remedial action for the Amended ROD, approximately 243,872 tons of contaminated materials were excavated and disposed as part of the combined work at both Shattuck and Bannock Street. Radiologically contaminated material was sent to the US Ecology Idaho, Inc., facility near Grand View, Idaho. Molybdenum containing soils were sent to the CBI, Inc., RCRA Subtitle D landfill in Adams County, Colorado.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU8 and promoted communications among interested parties throughout the duration of the project. EPA solicited feedback from the public and any interested parties prior to issuing the ROD.

For the Amended ROD, local residents and property owners indicated a preference for complete removal and proper disposal of the contaminated material present in the on-site containment cell. Several government agencies responded, agreeing with the concerns of the residents and expressing their preference for removal of the treated waste. The remedy selected in the Amended ROD addressed these concerns.

Community relations activities OU8 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meeting to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;
- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizen's groups, state and local governments, the EPA, DOE, USACE, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;

- Information communities along the transportation route, through 46 quarterly meetings and mailings, of health and safety issues associated with waste transportation;
- Technical Assistance Grant (TAG) for neighborhood association to have a technical advisor; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU8 is now cleared of the monolith material and has been hydro-seeded. The property is being marketed for redevelopment according to the current zoning requirements by the property's trustees.

III. Demonstration of Cleanup Activity QA/QC

Work performed at OU8 complied with the requirements of the project plans identified in Section 3.1 of the *Shaw Environmental - Construction Completion Report – Shattuck Chemical Superfund Site – Denver, Colorado, September 2006*, which was developed in response to the DOE Field Office, ID, Order 5700.6C. This program provides a structured approach for the application of quality assurance (QA) principals. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable EPA QA Program requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities conducted at OU8. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Work completed under the Amended ROD consisted of excavation, transportation, and offsite disposal at an approved facility of site materials, including soil and soil-like materials (i.e. monolith). As such, all site materials exhibiting radiological characteristics in excess of the Amended ROD criteria (detailed in Section 2.2 of this report) have been removed from the Shattuck site. Monitoring for compliance with these criteria covered the following:

- *Material Quantities* - Monthly quantity data reports were generated to track material generated during the remediation.
- *Sample Collection and Analysis* – Extensive sampling and analysis was maintained during the remediation of OU8, including clean cover material, transportation and disposal, borrow source, stockpile, and surface wipe sampling.
- *Material Sampling* – All material excavated as part of the remediation work at OU8 were sampled to determine the level of contamination prior to excavation and disposal.

- **Health and Safety** – Sampling and Analysis programs were implemented to ensure site worker safety and community protection during remediation at OU8. These programs are as follows:
 1. An As-Low-As-Reasonably-Achievable (ALARA) Program was implemented as part of the safety plans to reduce the radiation exposures personnel may receive.
 2. Employee exposure to airborne radioactivity and other airborne hazards was monitored by a program of personal and work area air sampling and analysis.
 3. Community/Environmental Health and Safety Monitoring was accomplished by conducting perimeter air monitoring at eight perimeter air sampling stations and a at a single background air quality sampling point.
 4. A vibration monitoring program was implemented at the site to measure vibrations associated with on-site activities.

For greater detail on the monitoring programs conducted during the Amended ROD's remedial action, refer to *Shaw Environmental - Construction Completion Report – Shattuck Chemical Superfund Site – Denver, Colorado, September 2006*.

V. Summary of Operation and Maintenance

OU8 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the Amended ROD, and in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, 42 U.S.C. Section 9601, et. seq., as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Contingency Plan, 40 CFR Part 300. The Amended ROD called for complete removal of treated and untreated contaminated soils present at OU8. Remedial actions performed at OU8 were successful in removing all contaminated materials from the site. As a result, no operation and maintenance activities are necessary to monitor the effectiveness of the remedy. CDPHE will be conducting monitoring of the groundwater associated with OU8. Ground water Institutional Controls have been established for OU8. Care of the property, including watering and mowing the grass, trash pickup, etc., are the responsibility of the trustee until such time as the property is sold to a private entity.

VI. Summary of Remediation Costs

The original ROD remedial activities were estimated to cost \$9.3 million dollars. The approximate actual cost was \$26.6 million. The exact costs of the remedial activities are unknown because the remedy for the original ROD was performed by the PRP. EPA's oversight costs for the original remedy were approximately \$200,000.

The estimated cost provided in the Amended ROD for completing monolith removal at the site was \$20.0 million. The actual cost increased compared to the estimated cost because of two principle factors. First, it was initially estimated that 165,000 tons of

monolith and underlying and perimeter soils would be generated for offsite disposal by remedial actions at the site. At project completion, 243,872 tons of radiologically contaminated materials were delivered from the Shattuck to the U.S. Ecology disposal facility. The final tonnage actually excavated includes additional materials from Bannock Street and the molybdenum pond area at the north end of the Shattuck site. The quantities of material from Bannock Street and molybdenum pond excavations were not included in the original quantity estimates for the project. Second, the average density of the monolith material was estimated to be approximately 2,600 to 3,000 pounds per cubic yard. The actual density of the material ranged from 3,400 to 3,800 pounds per cubic yard. Consequently, less volume of material could be loaded into each railcar thus increasing the number of railcars needed to transport the material resulting in increased transportation cost.

A revised estimate to complete the Amended ROD work was provided to the USEPA and USACE by Shaw in 2003. A cost of \$54,000,000 was proposed in that revised estimate to complete the work was proposed. That estimate is within approximately 10 percent of the final awarded amounts.

In addition to the 243,872 of radiologically contaminated material shipped from the site approximately 31,515 tons of molybdenum containing soil was excavated from beneath the area of the former molybdenum ponds at the north end of the Shattuck site. These materials were analyzed and found to be free of radiological contamination and were shipped to Conservation Service, Inc. a local approved landfill. Therefore, a total of approximately 275,387 tons of material was excavated and disposed at approved offsite facilities. Based on the total tonnage excavated and the total paid out by USACE the unit cost for completing work at Shattuck was \$202.24/ton including remedial action, transportation, and disposal. The estimated final cost for contracts for the Amended ROD remediation is \$57,126,558.06.

VII. Protectiveness

Health hazards associated with the radium waste present at OU8 result from direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU8 have been excavated in accordance with the Federal and State standards and were disposed of in a permanent off-site disposal site. All work was done in accordance with the ROD and EPA directives. The remedial action at OU8 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU8:

- Even though the waste from OU8 did not meet the U.S. Department of Transportation (DOT) definition of radioactive material, it was transported in accordance with all DOT regulations. Waste containers were tightly

sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;

- Air samplers were installed on-site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU8 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of spills during the transportation of the wastes, fires, adverse weather conditions, or leaking containers.

VIII. Five-Year Review

OU8 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which documented that the Amended ROD remedy was being undertaken. Following the completion of the Amended ROD remedy, all contamination has been removed from OU8 and it is not required to be inspected in any future 5-year reviews. Ground water monitoring for natural attenuation will continue and will be considered in future Five-Year reviews. The conditions of the individual properties that comprise OU8, and the requirements of future five year reviews are as follows:

Status of OU8 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five-Year Reviews
S.W. Shattuck Chemical Company	1805 South Bannock Street	No	Yes	Yes – Groundwater monitoring

IX. Bibliography

- Superfund Record of Decision: Denver Radium/Operable Unit 8, CO – EPA/ROD/R08-92/063 - Region 8 – January 28, 1992
- Superfund Record of Decision Amendment - Denver Radium/Operable Unit 8, Denver, CO – June 16, 2000
- Denver Radium Superfund Site/Remedial Action Completion Report/Operable Unit VIII - Shattuck – June 29, 1994
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

- **Shaw Environmental – Construction Completion Report – Shattuck Chemical Superfund Site – Denver, Colorado, September 2006**

**Final Close Out Report (FCOR)
Denver Radium Superfund Site
Denver, Denver County, Colorado**

Denver Radium Operable Unit 10

II. Summary of Site Conditions/OU10

A. Background

Denver Radium Operable Unit 10 (OU10), also known as the Card Corporation property, is owned by Mentor Corporation and Consolidated Freightways. The brick building on this property was built by the Overland Cotton Mill in 1890, at what is now 1314 West Evans Avenue.

Operable Unit	Property Description at time of ROD
OU10	Card Corporation – 1314 West Evans Avenue

A coal strike in 1903 resulted in the closure of the cotton mill. The Pittsburgh Radium Company (PRC), planning to process 120 tons of carnoite ore monthly, purchased the property in 1920 and obtained radium processing equipment from the National Radium Institute. Most radium production in the United States ceased in 1923 due to a reduced demand for the material, but PRC continued in business for 1 more year by converting the facility to a vanadium-producing mill. During 1924, the PRC may have processed as much as 10 tons of vanadium daily from roscoelite.

The PRC property was purchased by the Colorado Builders Supply Company in 1939. During World War II, the brick building was converted to a projectile and munitions manufacturing facility known as the Mariposa Works. The building was gutted by fire in the early 1940s, but was renovated. Projectile manufacturing continued until the mid-1950s.

A variety of industrial operations took place in the following years, including hardware manufacturing, mining equipment manufacturing and repair, and steel truss manufacturing. The following businesses currently occupy the OU10 property:

- Norsaire – A commercial air conditioning manufacturer;
- Mentor Corporation – A real estate firm;
- KAI Enterprises – A woodworking business;
- Henton Steel – A steel supply company;
- Hercules – A sheet metal and duct work manufacturer; and,
- Consolidated Freightways – A trucking terminal.

Structures located on the property include a brick commercial building (originally constructed as a cotton mill), an office building, the U.P.L. building, the True Truss buildings, and a Consolidated Freightways building. The Colorado Historical Society has

placed the brick building originally used as a cotton mill on the National Register of Historic Places.

OU10 is underlain by a sequence of fill, alluvial sand and gravel, and the Denver Formation (siltstone, claystone, or fine-grained sandstone). Depth to groundwater is approximately 20 feet; depth to bedrock is approximately 10 feet (Dames & Moore, 1983). The site does not lie within the 100-year floodplain.

B. Removal Action Performed

In 1979, EPA noted a reference to the National Radium Institute in a 1916 United States Bureau of Mines report. Subsequent field research revealed the presence of thirty-one radioactive sites in the Denver metropolitan area, which included the OU10 properties, including the original location of the mill operated by the Radium Company of Colorado. In August 1981, the Colorado Department of Health, under a cooperative agreement with EPA, assumed lead activities and initiated engineering assessments of the majority of the original 31 properties. In October 1981, the Denver Radium Site was placed on the Interim Priorities List. The Site was included on the Final National Priorities List promulgated on September 8, 1983. Also in June, 1983, the EPA assumed Fund-lead activities because the Colorado State Legislature failed to appropriate the State cost share for remedial planning, as required by the EPA at the time. No removal action was undertaken at OU10.

C. RI/FS

A Remedial Investigation (RI) and Feasibility Study (FS) report for OU10 was prepared by Jacobs Engineering Group and CH2M Hill on behalf of EPA in April of 1986. The draft Feasibility Study (FS), also prepared by Jacobs Engineering Group and CH2M Hill, was issued in June 1987. The RI focused on radium and uranium processing residues discarded in the early 1900s. These residues contained uranium, radium, and thorium. Of prime interest is radium-226 (Ra-226) because of its associated radioactivity (gamma radiation and radon-decay products) and its tendency to decay to radon gas, which constitutes the primary health risk associated with residues from processing facilities. The exposure pathways of concern are direct contact, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The radiological standard applying to open land as set forth by 40 CFR Part 192 Section 192.12(a) is:

The concentration of Ra-226 in land averaged over any area of 100 square meters (1,076 square feet) shall not exceed the background level by more than:

- *5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) – approximately 6 inches – of soil below the surface; and,*
- *15 pCi/g, averaged over 15-cm thick layers of soil more than 15 cm below surface.*

The background level used for the Denver Radium Site is 2.0 pCi/g.

The radiological standard applying to occupied or habitable buildings, as specified in 40 CFR 192.12(b) is:

(b) In any habitable building –

- (1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration of (RDC – including background) not to exceed 0.02 working level (WL). In any case, the RDC shall not exceed 0.03 WL, and*
- (2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour ($\mu\text{R/h}$).*

The appropriate guidance for equipment and surface decontamination established by DOE Order 5480.11 sets the following limits:

- Attached alpha particle activity of 300 disintegrations per minute per 100 square centimeters (dpm/100 cm²); and,
- Removable alpha particle activity of 20 dpm/100 cm².

EPA Region 8 proposed the following limits for thorium-230 (Th-230):

- 14 pCi/g in the 0 – 6-inch (0 – 15-cm) soil layer; and,
- 40 pCi/g in any 6-inch thick layer between 6-inches deep and the maximum probable depth of a foundation, increasing exponentially to 500 pCi/g at a depth of 15 feet below the foundation, provided uncontaminated material overlies any contamination.

The FS addressed the following Remedial Action Alternatives, which were evaluated for effectiveness, ease of implementation on the basis of acceptable engineering practices, and cost:

- No Action;
- Deferred Removal with Off-Site Permanent Disposal;
- On-Site Reprocessing with Permanent Disposal;
- In-Situ Vitrification;
- On-Site Permanent Disposal;
- Off-Site Permanent Disposal;
- On-Site Temporary Land Storage with Off-Site Permanent Disposal;
- On-Site Temporary Building Storage with Off-Site Permanent Disposal; and,
- On-Site Temporary Containment (capping) with Off-Site Permanent Disposal.

D. ROD Findings & Design Criteria

The remedial action alternative preferred by EPA for OU10 was Off-Site Permanent Disposal. Because a permanent disposal facility was not available at the time of the ROD, dated June 1987, the EPA selected the On-Site Temporary Building Storage with Off-Site Permanent Disposal alternative. This alternative entailed the following:

- Excavating contaminated soil;
- Decontaminating structures;
- Draining the waste pond, if necessary, to remove liquids and contaminated sediments; and,
- Consolidating contaminated materials on site for later disposal in a permanent off-site facility.

Originally, the plan was to use the True Truss building for the storage of the contaminated materials in synthetic bags. However, the plan for on-site temporary building storage was abandoned when a permanent disposal facility operated by Envirocare of Utah, in Tooele County, Utah, became available.

E. Cleanup Activities performed

The remedial action plan for OU10 called for two phases of remedial action. Phase I Remedial Action involved the decontamination and reconstruction of the site and temporary on-site stockpiling of contaminated materials. Phase II Remedial Action involved the loading, transportation, and final disposal of contaminated material in the permanent off-site repository.

Cleanup activities at OU10 began in September 1988 and ended September 22, 1989. The Geotech radiological assessment identified 10,694 tons of radioactive material, at depths ranging from 0 – 81 inches. The actual quantity of material removed during the remedial action was 15,021 tons from depths ranging from 0 – 80 inches. The material from OU10 was stockpiled in the southwest corner of the property in a designated load-out area. Following removal of the stockpiled waste material, samples were taken to ensure all contaminated material was removed. These verification areas were designated as V-147 through V-152.

No extensive changes were made to the existing on-site structures, although several small structures were removed and not replaced at the request of the owner. Some unassessed contamination required removal, but the volumes were not large.

Asbestos was known to be present on this site and more was found than was anticipated. Removal of asbestos was limited to what was necessary to conduct remediation activities. The material was removed in accordance with Chapter 4-9 of the Revised Municipal Code of the City and County of Denver.

The extent of radiological contamination associated with three underground storage tanks was deeper than anticipated, and these tanks were removed. Abandoned utilities such as wire and pipes were removed throughout the property.

Excavation of contaminated material was performed using front-end loaders directed by field personnel who measured radiation in the excavations with hand-held detectors. After the removal of material was completed based on the readings of the field instruments, verification was performed by collecting samples based on the readings of the field instruments.

Radiological Contamination

After removal of contaminated materials and prior to backfilling of the excavations, soil samples representative of the 6-inch thick soil layer at the bottom of the excavation were collected. The samples were blended to form composite sample representing an area of approximately 100 m².

All samples used for excavation control and verification purposes were analyzed by the Opposed Crystal System (OCS) to evaluate radium concentrations in the field for excavation-control decisions. Some soil samples, including those analyzed by the OCS, were sent to the Geotech Analytical Laboratory for high-resolution gamma spectrometer confirmatory analysis.

Results of the analyses of the samples obtained from a drilling program were used to verify that thorium-230 (Th-230), which had been found at Denver Radium OU4/OU5, did not exist beneath remediated areas in concentrations exceeding the criteria proposed by EPA's Region 8 Office.

Exterior standards were applied to all indoor excavations due to the large open air spaces in many of the buildings on the property. Neither sub-floor ventilation systems nor radon decay-product concentration measurement were required. Area V-13 was a wood floor that was removed and replaced; therefore, no soil sample was taken.

During remediation activities, two areas on the unit in the Norsair Building required additional investigations and the usage of area-averaging calculations because of considerations that included cost-effective and safe removal of contaminated material. These areas are as follows:

Materials Left in Place as Averaged Areas – OU10¹

AREA	Size	Description	Area Avg. (pCi/g)
Area A	50 sq/ft.	Beneath large air compressor	6.7 pCi/g Ra-226 (conforms to EPA std.)
Area B	445 sq/ft	Beneath a punch press on the Card property	13.6 pCi/g Ra-226 (conforms to EPA std.)

¹ Area averaging calculates the exposure risk of several readings from a 10 meter by 10 meter (100 sq/m) area. These calculations are considered below the EPA surface standard if they are less than 5 pCi/g above background and below the subsurface standard if they are less than 15 pCi/g above

background. Background for the Denver Radium Site is 2 pCi/g. If calculations are below these standards, then the area is considered safe for unrestricted use and unrestricted access.

F. Community Involvement activities performed

EPA's Community Relations Plan involved the community in the decision-making process for selecting the remedy for OU10 and promoted communications among interested parties throughout the duration of the project. EPA solicited feedback from the public and any interested parties prior to issuing the ROD. Comments received from residents and property owners indicated a preference for complete removal and proper disposal of the contaminated material in the streets. Several government agencies responded, expressing concerns about the need to control exposure of the public and workers to the contaminated materials and about the need to dispose of any excavated material properly.

Community relations activities OU10 included the follow:

- Briefing State and local officials, public interest groups, neighborhood associations, interested citizens, and media representatives on the status of the various phases of the project;
- Conducting public meeting to keep citizens informed about the progress of the Denver Radium Site Program and to solicit comments;
- Establishing information centers at the Denver Public Library and at the EPA Region 8 Library in Denver to make the study reports, site air monitoring data, supplemental assessments, and other Denver Radium Site information available to the public for review;
- Maintaining a mailing list of interested parties and distributing information updates to these parties during the course of the remedial action;
- Organizing a committee of representatives from citizen's groups, state and local governments, the EPA, DOE, USBR, and the transportation contractor to provide input to the transportation and disposal activities associated with the Denver Radium Site;
- Information communities along the transportation route, through meetings and mailings, of health and safety issues associated with waste transportation; and,
- Distributing news releases to the major news media outlet in the area.

G. Redevelopment

The area that encompassed Denver Radium OU10 was already developed for commercial and industrial uses at the time of the remedial action. In a site visit performed in August 2003, revealed all properties at OU10 being used for the same purposes.

III. Demonstration of Cleanup Activity QA/QC

Work performed by and for Geotech, Inc., at OU10 complied with the requirements of the Geotech Quality Assurance Program, described in the Geotech *Quality Assurance Manual* (Manual 101), which was developed in response to the DOE Field Office, ID, Order 5700.6C. This program provides a structured approach for the application of quality assurance (QA) principals and is implemented through the Geotech *Quality Assurance Manual*. A Quality Assurance Program Plan (QAPP) was developed to identify the applicable Geotech QA Program and EPA requirements for remedial design, remedial action, sampling, monitoring, program management, and associated support activities. A listing of applicable QA requirements and implementing procedures is presented in *Remedial Action Statement of Work for OU10* and other documents. QA requirements were imposed on subcontractors through appropriate procurement documents. Compliance with these requirements was verified through management and document reviews and by internal audits and observations.

IV. Monitoring Results

Environmental monitoring was required to determine whether the remedial action adversely affected off-site air quality at OU10. Off-site air quality monitoring data were collected during the baseline period (March 1988 to September 1989), during the construction period (September 1988 to June 1989), and after the remedial action. One low-volume air particulate sampler, two atmospheric radon detectors, and one gamma thermoluminescent dosimeter (TLD) were placed at each of four measurement locations. There were no significant difference between the data set for the baseline period, the construction period, and the post-remedial action period.

Air Particulate Measurement

Air particulate samples were collected with Model LV1 low-volume air particulate samplers manufactured by F&J Specialty Products, Inc. A sample was collected on an open-faced, 47-millimeter glass-fiber filter. Each sampler was contained in its own environmentally protected shelter and connected to a dedicated electrical power outlet. The samplers were operated continuously for 7 days at a nominal rate of 5 liters per minute. The filters were analyzed by Geotech analytical laboratory for natural uranium, Th-230, Ra-226, and polonium-210 (Po-210).

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for airborne radionuclides. These standards are expressed as concentrations above background as follows:

Natural Uranium	-	5.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Th - 230	-	8.0×10^{-14} microcuries per milliliter ($\mu\text{Ci/mL}$)
Ra - 226	-	3.0×10^{-12} microcuries per milliliter ($\mu\text{Ci/mL}$)
Po - 210	-	2.0×10^{-11} microcuries per milliliter ($\mu\text{Ci/mL}$)

All airborne radionuclide concentrations measured during the reporting period were below the applicable regulatory standard.

Atmospheric Radon Measurements

Terradex outdoor Type F Track Etch ® radon detectors were used to determine atmospheric radon concentrations. Two detectors were exposed in an environmentally protected enclosure approximately 1 meter above ground level. Each detector consisted of an alpha-sensitive film protected by a membrane filter permeable only by radon. The film was analyzed by Terradex Corporation for the density of the alpha tracks produced by radon decay. The density of the tracks is related to the radon concentration in the atmosphere sampled. Detectors were analyzed by Terradex at the greatest level of sensitivity (0.2 picocuries-month per liter [pCi-m/L]).

EPA has designated 10 CFR 20, Table II, Column I, as the relevant and appropriate standard for atmospheric radon concentration. The regulatory standard is 3.0 pCi/L above background. All atmospheric radon concentrations measured during the reporting period were below this standard.

Direct External Gamma Exposure Measurement

Harshaw TLD dosimeters were used to measure the external gamma radiation at each sample location. The dosimeter was essentially a thin plastic card, approximately 6 cm x 12cm x 0.1 cm, that encapsulates five thermoluminescent elements. One card was mounted approximately 1 meter above ground level at each sample location. The cards were submitted to the DOE-Idaho Falls Dosimetry Laboratory for analysis.

The background gamma exposure rates for the Denver area range from 130 to 175 mrem/yr (CH2M Hill, 1986. All gamma exposures measured during the reporting period were below this limit

V. Summary of Operation and Maintenance

OU10 of the Denver Radium Site has been remediated to meet the cleanup standards specified in the ROD, and in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, 42 U.S.C. Section 9601, et. seq., as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Contingency Plan, 40 CFR Part 300. No operation and maintenance is required for this remedy. Furthermore, the current condition of the site allows for unrestricted use and unrestricted exposure, and thus EPA is not required to conduct a 5-year review of the remedial action. In 2003, OU10 was included in the 5-year review conducted by the State of Colorado, which determined that all ROD requirements had been met and all contamination was removed from OU10. The report further stated that the remedy at OU10 was protective of human health and the environment, that the properties of OU10 were available for unlimited use and unrestricted access, that the properties of OU10 were recommended for deletion from the Denver Radium Site and the NPL, and that locations where materials were left in place where area-averaging was applied are released for unrestricted use.

VI. Summary of Remediation Costs

The ROD for OU10 lists the cost for selected remedy as \$1,148,000. A Remedial Action Completion report could not be located for OU10.

VII. Protectiveness

Health hazards associated with the radium waste present at OU10 result from direct contact with the wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations. Radioactively contaminated materials at OU10 have been excavated in accordance with the Federal and State standards and were disposed of in a permanent off-site disposal site. All work was done in accordance with the ROD and EPA directives. The remedial action at OU10 protects human health and the environment by precluding direct contact with radium wastes, long-term exposure to gamma radiation, and long-term exposure to elevated radon concentrations.

The following activities were undertaken to protect the workers and public during the cleanup, transportation, and disposal of the hazardous waste material from OU10:

- Even though the waste from OU10 did not meet the U.S. Department of Transportation (DOT) definition of radioactive material, it was transported as if it was low-specified activity (LSA), naturally occurring radioactive material as an extra measure of protectiveness. In addition, the substantive provisions of the DOT regulations for LSA wastes were applied to the packaging and transporting activities. Waste containers were tightly sealed, clearly labeled, and accounted for from loadout to arrival at the disposal facility;
- Air samplers were installed on-site and at several nearby locations to monitor the effectiveness of the measures taken to control dust and emissions from the property;
- Security and air monitoring were provided on a 24-hour-a-day basis;
- Individuals, equipment, and vehicles leaving the controlled areas of OU10 were monitored for possible contamination. When necessary, individuals, equipment, and vehicles were decontaminated prior to leaving the property; and,
- An emergency response plan was developed that specified actions to be taken in the event of spills during the transportation of the wastes, fires, adverse weather conditions, or leaking containers.

VIII. Five-Year Review

The levels of waste material remaining at the OU10 where area averaging was used allow for unrestricted use and unrestricted exposure. OU10 was included in a Five-Year Review conducted by the State of Colorado in September 2003, which determined that the remedy was protective. OU10 is not required to be inspected in any future 5-year reviews. Locations where waste was left in place should be tracked with the established GIS database for proper disposal during any potential future development. The conditions of the individual properties that comprise OU10, and the requirements of future five year reviews are as follows:

Status of OU10 Properties Post-Construction

Property Name	Address	Use of Area Averaging	Eligible for Deletion?	Included in Future Five Year Reviews
Card Corporation – 1314 West Evans Avenue	OU10	Yes	Yes	No

IX. Bibliography

- Superfund Record of Decision: Denver Radium/Card Property, CO – EPA/ROD/R08-87/012 - Region 8 – June 30, 1987
- Denver Radium Site/Operable Unit X Interim Closeout Report for the U.S. Environmental Protection Agency – March 1992 – Geotech, Inc.
- Denver Radium Site – Five-Year Review, September 2003 – State of Colorado

Approved by

Date



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