SHATTUCK CHEMICAL SUPERFUND SITE CHALLENGES OF A ¾-Acre MOVABLE CONTAINMENT STRUCTURE AND CHANGING REMEDIAL ACTION OBJECTIVES

J. M. Gabriele
Shaw Environmental, Inc.

J. A. Peterson
US Army Corps of Engineers, HTRW Center of Expertise

ABSTRACT

This case study describes technical and operational challenges encountered and solutions developed during implementation of the "second" remedy at the Shattuck Chemical Superfund Site, in accordance with the Amended Record of Decision. The off-site remedy requires "mining" of cement-stabilized "monolith" material from the previous remedy, and excavation of soil above the Remedial Action Objectives.

The remedy is complicated by significant involvement of stakeholders, including the City of Denver, members of the public, and elected officials, who expressed significant concerns about dust generation. As a direct result, it was determined that the remedy would be conducted under a project structure to contain dust. A "movable" ¾-acre structure was selected in lieu of a 5.5-acre structure. Technical and operational challenges of working with the project structure include: 1) moving a structure across a trapezoidal-shaped property; 2) meeting Uniform Building Code wind and snow loads in a high wind area and the use of ground anchors to tie down the structure; 3) erection of a building on wheels; 4) moving the structure across varying terrain, keeping the structure level as it moves across the remedied areas and controlling the move speed; 5) maintaining indoor air quality; 6) maintaining worker safety; and 7) maintaining public safety.

The remedy is further complicated by changing Remedial Action Objectives. The Amended Record of Decision changed (lowered) the Remedial Action Objectives for two radionuclides of concern. Compliance must be demonstrated in two locations, both of which had been remedied to the previous, less stringent standards: 1) a 20 ft perimeter strip of property surrounding the Site between the monolith and the property line; and 2) up to 8 ft of vadose zone soil below the monolith.

INTRODUCTION

The Shattuck Chemical Site (Site) is Operable Unit 8 of the larger Denver Radium Superfund Sites, consisting of 65 properties abandoned after the City's radium industry collapsed in the 1920's. Radium was extracted from ore mined on the Colorado Plateau, and used for commercial purposes in the early 1900's. Ore facilities were built in the Denver area to provide a domestic source of radium. As land uses changed, the residues were used as fill material or left in place. The S.W. Shattuck Chemical Company processed a variety of materials at the Site

from 1917 to 1984, including ores, radium slimes and uranium. Radionuclides of concern at the Site are Radium-226 (Ra-226), Thorium-230 (Th-230), and natural Uranium (U-nat).
The first Record of Decision, signed in January 1992 [1], required that material be stabilized and solidified on-site. This remedy was completed in September 1998. Soil, crushed debris, cement and flyash were mixed to create a “monolith” that is up to 18 ft thick, covers 5 acres, and extends more than 10 ft above the surrounding streets. A cover system consisting of clay, sand, gravel, and riprap layers was placed over the monolith. The Remedial Action Objectives (RAOs) for this remedy were to stabilize any Site soil containing greater than 0.555 Bq/g (15 picoCuries per gram [pCi/g]) of Ra-226, 1.55 Bq/g (42 pCi/g) of Th-230, and 2.78 Bq/g (75 pCi/g) of U-nat.

The neighborhood is a mix of residential homes, light and medium industrial/commercial properties, and retail properties. The monolith is an eye sore for neighbors. After construction of the monolith, the community mobilized and contacted their elected officials. The City of Denver pushed for the removal of the waste under the premise that the monolith was an un-permitted landfill within the City limits. A U.S. Senator and a U.S. Congresswoman responded and became involved. The U.S. Environmental Protection Agency (USEPA) designated an Ombudsman, conducted a 5-year review of the remedy, and subsequently issued an Amended Record of Decision in June 2000 (Amended ROD) [2]. The Amended ROD changed (lowered) the action levels for two of the three radionuclides of concern to 0.185 Bq/g (5 pCi/g) each of Ra-226 and Th-230, and required removal and off-site disposal of the monolith and any soil above the new action levels.

“Success” at Shattuck hinges on the ability to complete the remedy safely, cost-effectively, and in a compliant manner. Success is also defined by stakeholder perceptions; the project will continue to attract the attention of the community and elected officials until the remedy is complete. USEPA has stated that un-restricted reuse of the property is the objective of the remedy. This case study details some of the challenges and solutions developed at Shattuck in light of the goals of the project.

TECHNICAL, OPERATIONAL, AND SAFETY CHALLENGES OF THE PROJECT CONTAINMENT STRUCTURES

Developing a Concept

The decision was made to perform monolith removal under a containment structure. This was based, in large part, on community concerns that breakup and removal (i.e., mining) of the monolith would release airborne radionuclides. The trapezoidal shape of the Site complicated the selection of any containment structure. A range of options was evaluated, including an air-supported fabric dome structure covering the entire 5.5-acre monolith footprint and a variety of movable/liftable structures covering a portion of the Site. Due to liability issues surrounding a potential catastrophic failure of the fabric dome, the concept of a Site-wide structure became unworkable. A detailed conceptual analysis of the movable/liftable building concept was conducted, integrating monolith mining operations with on-site materials handling and rail transport (selected as the method of transportation of the waste from the Site), and evaluating potential dust control and air management and monitoring methods.

In June 2002, the project team determined that a stationary railcar Loadout Structure, a modular Conveyor Structure, and a movable Mining Structure would be used. The movable Mining Structure is described in detail in the Section below. To convey mined material from the Mining Structure to the stationary Loadout Structure, a catenary conveyor was installed. The conveyor and Conveyor Structure are shortened by 80-feet each time the Mining Structure is relocated, so both are modular designs. At Mining Structure Setup #1 (the initial setup), the conveyor and Conveyor Structure were 700 feet long. At Mining Structure Setup #10 (the final setup), the conveyor and Conveyor Structure are eliminated. To load material into railcars, a 7,200 SF Loadout Structure is designed to accommodate two gondola railcars. The north position is used for lining and loading railcars, and the south position is used to close railcar liners, perform free-release sampling and scanning, and perform final inspections. Figure 1 provides a plan view of the Site, with the three project structures shown.

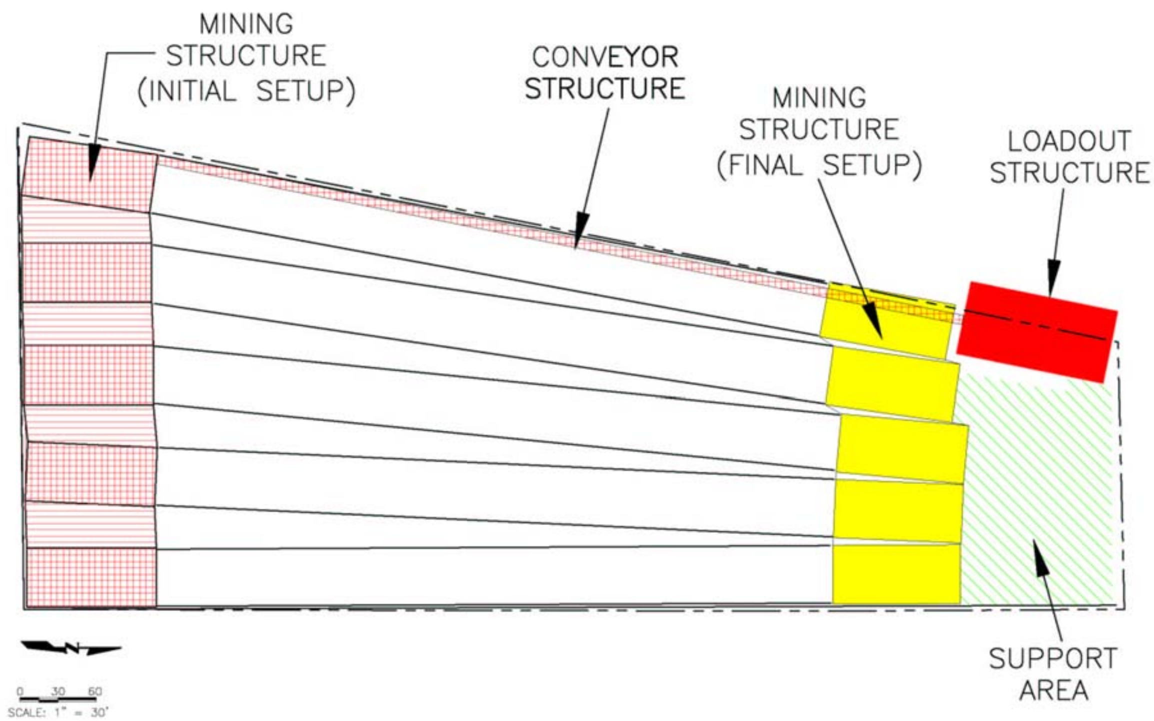


Fig. 1. Plan View of Trapezoidal Site with Project Structures Shown

A design concept and cost estimate were developed as the baseline for a competitively bid, performance-based, design-construct procurement for the three structures. A number of movable and liftable concepts were proposed by the bidders. In August 2002, a subcontractor was selected and the aggressive design-build process was initiated. The structures were erected by late January 2003. As of November 2003, approximately twenty-five percent (25%) of the waste has been mined and transported to off-site disposal, and the movable Mining Structure has been moved twice (presently at Setup #3 out of 10).

Technical and Erection Issues – Movable Mining Structure

Some of the technical and erection issues that were encountered and solved during design-build of the Mining Structure include:

- Accommodating the trapezoidal shape of the Site with a moving building;
- Designing a structure that meets Uniform Building Code (UBC) wind and snow loads;
- Erecting a structure on wheels; and,
- Moving the Mining Structure.

To address moving across a trapezoidal-shaped property, the Mining Structure consists of five (5) steel frame and sheet metal "modules" linked by four (4) tension fabric "links." The Mining Structure is 36,800 SF at Setup #1. The four fabric links are re-tensioned or "pleated" as the building moves north. At Setup #10, the structure will be about 22,500 SF, with the five steel modules nearly touching one another. Figure 1 represents the Mining Structure at the initial and final setups, and shows the converging steel "modules." Figure 2 provides a photograph of the Mining Structure, showing two modules and a tension fabric link.

Fig. 2 Mining Structure Photograph - North Side with Fabric Links (Upper Left), Foundation Anchor Detail (Upper Right), North Side Rail-type Wheel (Lower Left),Inside Structure During a Move (Lower Right)

The structure was designed to meet UBC wind and snow loads, and Denver is a high wind area. Because the dead weight required to anchor the building would not be feasible to construct and relocate, grout-in foundation anchors are used to tie down the structure. Figure 2 provides a photograph of a grouted foundation anchor. Anchors are placed at each column line (4 per module), both at the north and south sides of the structure (a total of 40 locations per Setup). Anchors are rated between 80 kips and 160 kips per column line, depending on the contributory width – for example, the anchors adjacent to fabric links are designed for a significantly higher load for the early setups (when fabric links are extended), and are designed for less load for each subsequent setup moving north (when fabric links are tensioned or "pleated"). As described below, four wheel sets (two on the north side and two on the south side) are used to support each module during the move. However, in order to meet UBC wind and snow loads, all eight column locations (four on the north side and four on the south side) must be anchored. As a result, wind and precipitation conditions are monitored closely during the moves, and anchors and dunnage under columns are removed only for a short time during the actual relocation process. During the Mining Structure Setup #1 in Spring 2003, the Denver metro area received a heavy, wet snowfall event that is reported as a 100-year occurrence storm – nearly 280 structures in Denver collapsed. Structural engineers in Denver estimated that the snowfall event likely exceeded the 25 pounds per square foot design snow load by as much as 20%. The Mining Structure responded well, with the steel trusses and bolted column connections "flexing" to absorb the snow loading and unloading. While two of the fabric links had damage (and one had to be replaced entirely), engineering inspections indicated that the steel modules had very little damage - several areas were re-welded at bolt plate connections. The loading and unloading did cause movement at the wheel sets, bending some jack supports and straining against anchors.

Erection of a building on wheels presented challenges. Since typical building erection begins by connecting structural columns to a fixed foundation, the method of erection had to be worked out in the field. The Mining Structure was initially erected by pre-assembling the columns on the ground, and raising the columns with a crane. Significant temporary cabling and permanent cross-bracing cables between columns was required to support the columns until girts and purlins were installed to connect column to column. Temporary dunnage was initially used to minimize wheel rolling and movement during erection. However, the "flexing" of the columns presented significant erection challenges, even when only adding the weight of the sheet metal "R-panel" siding, roofing, and flashing. Two cranes, temporary cabling and anchoring, and the use of telescoping man-lifts to install purlins, girts, and sheeting were used effectively by the erection contractor to safely erect each module. A benefit of Site configuration is that the south wall of the Mining Structure in Setup #1 was only partially constructed - the south wall was placed on dunnage with no wheel sets. Then, in order to move to Setup #2, where the south wall was located within the completed excavation, the south wheel sets and hydraulic leg extensions were added. During this move, the same level of caution, multiple cranes, temporary cabling and anchoring, and the effective use of man-lifts to install components without climbing on or tying off from the structure were used effectively by the erection contractor. Figure 2 provides photographs of the north rail-type wheels and the south rubber tire sets, and a perspective from inside the Mining Structure.

Each "move" of the Mining Structure is approximately 75-feet to the north. The Mining Structure north-to-south dimension is approximately 100-feet. The 25-feet overlap allows for the physical dimensions of the wheel sets and column lines, the footprint of the conveyor hopper tail section extending into the Mining Structure, and the slope of the "working face" of the monolith. On the south side, the wheel set extends more than 5-feet into the structure. On the north side, the monolith is as thick as 18-feet and is sloped to approximately 1H:2V, resulting in a 9-foot minimum horizontal footprint. In addition, the north wheel sets, dunnage, and columns are set back at least 2-feet from the top of slope, and the columns contribute more than 4-feet of footprint. In total, there is less than 5-feet of contingency in each move, requiring attention to detail during mining and setup for the move.

As described above, the Mining Structure is on wheels. Ten rail lines extend across the top of the monolith cover (constructed without cut into the cover), and the north side of the building has rail wheels. The south side of the building has rubber tires mounted on hydraulic leg extensions.

The Remedial Action Management Plan [3] identifies that while “pre-verification” scans and soil sampling will be conducted prior to moving the Mining Structure, the “Final Status Survey” is conducted outside the Mining Structure after the building has been moved. The purpose of this approach is to continue production (mining and waste shipment) while Final Status Survey work is completed, and to allow Global Positioning Satellite (GPS) units to assist in documenting 100% gamma walkover scans (which the building roof would shield). As such, the Mining Structure must move across the “pre-verified” surface without disturbing the surface before Final Status Survey. The hydraulic cylinders on the south side allow the structure to adjust to varying terrain and keep the building level as the structure moves across the “pre-verified” areas. During each move, described in the next paragraph, operators control two sets of hydraulic legs on each module to keep the modules level as the structure moves.

Moving the Mining Structure requires two sets of winches, one primary set on the north side to pull the building forward and one “brake” winch set on the south side to keep the building from rolling forward too quickly. Dynamometers are used to monitor the load on individual winch cables. A balance is achieved using Site soil, steel traffic plates, and C-channel steel to increase or decrease “rolling resistance” of the building, depending upon the terrain. Figure 2 provides a photograph of the inside of the structure during a move. The building move takes approximately ½-day to actually move the building (at ½-foot per minute winch speed). Preparation for the move and fabric tensioning and tie-down after the move take more than a week. One significant challenge is to manage the “break-away” of the modules from their current position. Because each Mining Structure setup is twelve to fourteen weeks in duration, the south wheels can become “stuck” with soil, mud or water, or wheels can become “locked” from inactivity. The second significant challenge is to continually manage fabric tension between modules. This is related to the “break-away” in that a burst of motion of one module of two feet or less, while another module remains stationary, creates an immediate differential fabric tension and may lead to failure (derailment) of the north side of the structure. In addition, movement of one module faster than another (e.g., one going uphill under tension, one going downhill under restraint from the “brake winch”) can also result in the same situation. Finally, creative winch bridle configuration is required on the outside modules, which are only subject to fabric tension in one direction. The intent is to create a “toe out” force on the outer module, to counteract the fabric tension force on the opposite side of each outer module. After two moves, the structures have been derailed several times - the failure point has consistently been the rail wheel assemblies on the north side. Although stiffening these assemblies was contemplated, it was determined that the rail wheel assembly should be left as the “weak point” in the Mining Structure, to avoid damage to trusses, joints, or other structural components. The rail wheel assemblies can be replaced quickly and re-fabricated cost-effectively. To date, the Mining Structure has performed well, and each move is expected to become more efficient than the last.

Operational and Safety Issues for Working In Three Project Structures

Some of the operational and safety issues that were encountered and solved during design-build of the Mining Structure include design and monitoring:

- Indoor air quality;
- Worker safety; and
- Public safety.

To address indoor air quality, the Mining and Loadout Structures include air handling systems capable of four (4) air exchanges per hour. To address protection of the public, the air handling system has four-stage filtration capable of 99.99% efficiency at 5 microns particle size. The system capacity (four air exchanges, or 140,000 cubic feet per minute (cfm) in Mining, and 14,000 cfm in Loadout), was determined by a Certified Industrial Hygienist, based on noxious fumes from diesel engines inside the structures. In addition, comparison of worker exposure to the Derived Air Concentrations (DACs, per 10 CFR 20, Appendix B, Table 2) for each radionuclide of concern and comparison of fenceline exposures to standards for protection of the community were taken into account when setting up both the air handling system and the worker and Site perimeter monitoring programs.

Once site operations commenced, concerns about indoor air quality and worker safety have been driven by diesel particulates and carbon monoxide (CO) from heavy equipment, silica from the cement and flyash in the monolith, and ammonia gas generated when dust control water is sprayed on the monolith. Specifically, several issues required creative field solutions:

1. Diesel particulates load the four-stage filters quickly and impact operations by requiring frequent filter changes.
2. Diesel fumes and particulate levels require the use of respiratory protection for workers.
3. CO levels in the mining structure, from diesel engines, have resulted in operational shut-downs, as ½ the OSHA PEL is reached.
4. Air sampling and monitoring has shown silica is a significant concern. Not anticipated in planning for the remedy, a layer of raw Portland Cement is encountered between each of the roller-compacted lifts of the monolith, presumably placed to bond the lifts together but apparently not exposed to enough water to hydrate. This layer creates significant dust concerns during mining.
5. Water applied to control dust during the mining operation generates ammonia. Not anticipated in planning for the remedy, it appears that water reacts with process residues/salts. Though not approaching regulatory levels, crews in the Mining Structure use organic vapor cartridges to reduce the odor from ammonia.
6. Airborne radionuclide levels, based on personal pump sampling, has been less than 10% of the DACs for radionuclides of concern. None-the-less, "As Low As Reasonably Achievable" (ALARA) requires engineering controls and best practices be implemented to the extent practical.

To improve air quality and work environment in the structures and to improve cost performance of the project, several steps were taken. In the Loadout Structure, a series of misting nozzles were installed around the conveyor belt discharge. In both Mining and Loadout, Sootfilter™ catalyst/filters were installed on diesel equipment, significantly reducing particulate and CO levels and significantly extending air filter life. The results of the Sootfilter™ were significant enough to allow personal protective equipment (PPE) down-grade (removal of respiratory protection) in the Loadout Structure. The results of the Sootfilter™ in the Mining Structure were also significant, but silica levels continue to drive a requirement for respiratory protection.

In the Mining Structure, a Martin Engineering Fog Cannon™ was purchased to capture fine particulates (cement) which were virtually unaffected by traditional dust control (e.g., fire hose) methods. The Fog Cannon™ is a two stage device, with 26 atomizer nozzles to match water particle size to the cement/dust particle size to maximize agglomeration of the particles, and a second stage blower fan to project the mist up to 150 feet from the unit. Silica and respirable dust samples were collected while using the Fog Cannon™ and compared to dust suppression using a fire hose nozzle. The Site safety staff determined that total respirable dust was reduced by up to 90% , and silica concentrations decreased by up to 77% using the Fog Cannon™. This was confirmed qualitatively by observing air opacity and comparing ventilation system filter usage. In addition, several methods of mining the monolith material were field tested and compared. Using hydraulic hammers to break the material, when compared to ripping and grinding operations, provided the best value when balancing cost (air filter use and production) and safety (air quality and work environment). Use of the Fog Cannon™ has reduced the quantity of water applied for dust control, and may be reducing ammonia generation, though the odor still persists. Although the Mining Structure requires respiratory protection for silica, air quality has improved significantly, contributing to better production, less frequent filter changes, and better crew morale and achieving ALARA for radionuclides.

To improve worker safety in the Loadout Structure, a fall protection system was installed. The system consists of a continuous 120-foot track with trolleys and retractable lanyards to accommodate four workers at one time. The fall protection system takes advantage of the containment structure over the rail loading operation – many remedies that use gondola railcars do not have an overhead structure capable of supporting an OSHA-compliant fall protection system. The fall protection system makes the railcars liner tie-up process much safer for workers, who must walk on the liner over a load of material and tie up to thirty (30) ropes to secure the liner package – footing can be poor with a high risk of slips, trips, and falls.

Safety Monitoring and Sampling

As described above, worker and public safety are built into the remedial action process and the design of the project structures. To confirm regulatory goals are met, the work area and Site perimeter monitoring program includes:

- CO, ammonia, noise, PM-10 dust, and vibration monitoring are conducted in the work area.
- Worker breathing zone (BZ) samples are analyzed for radionuclides, metals, respirable dust, and silica.
- Workers wear thermoluminescent detectors (TLDs) and radon monitors.

- A series of eight (8) high volume perimeter air sampling stations are used to collect samples for radionuclides, metals, and dust at the fence line.
- A series of eight (8) low volume perimeter air sampling stations are used to collect daily samples for radionuclides and scanned in the onsite lab as a trigger to detect a problem prior to weekly sample analysis.
- A series of detectors at the perimeter fence and at the exhaust discharges are used to measure radon.

Fenceline radionuclide, metals, and radon data are graphed and shared bi-monthly with the Community Advisory Group and the public. The data have been received positively.

CHANGING REMEDIAL ACTION OBJECTIVES

Applicable, Relevant, and Appropriate Requirements (ARARs)

In addition to Site operations issues, meeting the RAOs has presented challenges. The amended ROD changed the RAOs based on the ARAR, 40 CFR 192, and implementing guidance (OSWER Directive 9200.4-25). Action levels were lowered for Ra-226 and Th-230 from 0.555 Bq/g (15 pCi/g) and 1.55 Bq/g (42 pCi/g), respectively, to 0.185 Bq/g (5 pCi/g) for each isotope above background. In order to demonstrate that the more stringent RAOs are met, the Site is divided into two distinct parcels labeled "underlying soils" and "perimeter soils". This is necessary because the pattern of contaminant deposition within these two previously remedied areas is distinctly different and for operational conveniences. A separate compliance demonstration is planned for each parcel.

For reference in the following sections, Figure 3 provides a Site plan with areas of concern identified for both the underlying soil and perimeter soil. The underlying soil areas of concern are represented by the topographic surface within the Site boundary, based on information from the historical 1996/97 Closure Survey (CS) surface. The perimeter soil areas of concern are represented by the hatched area around the perimeter of the Site, based on information from the Perimeter Boring Program.

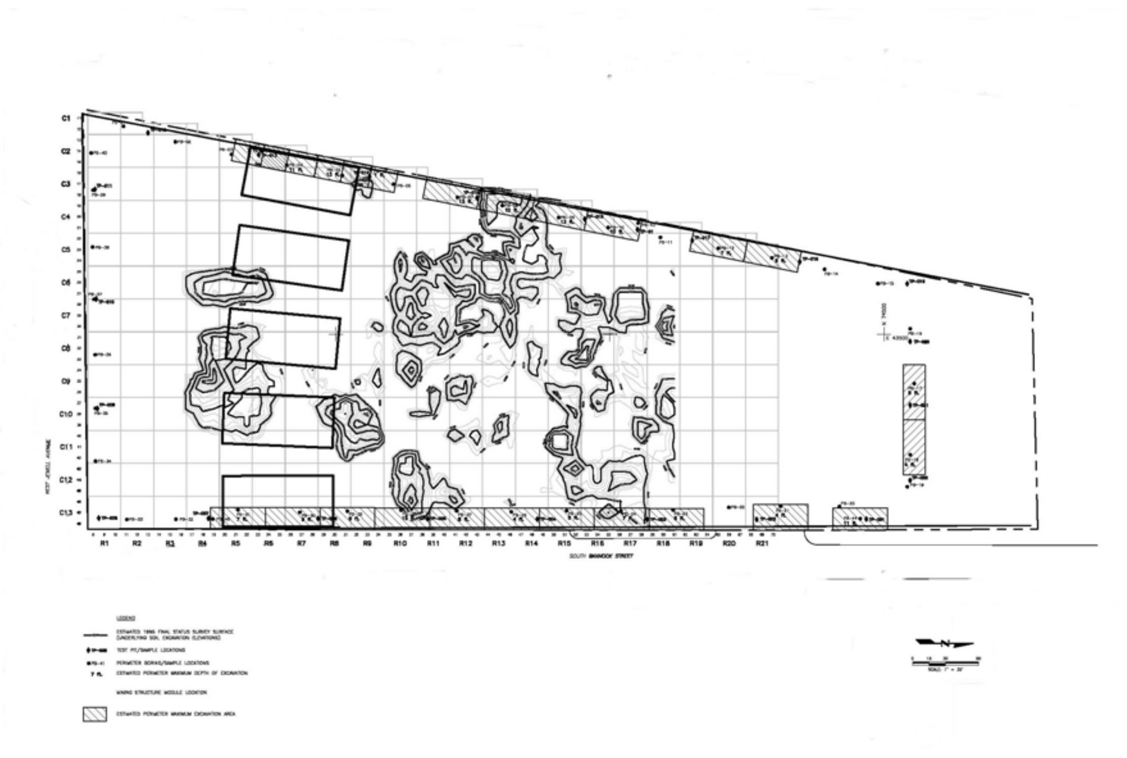
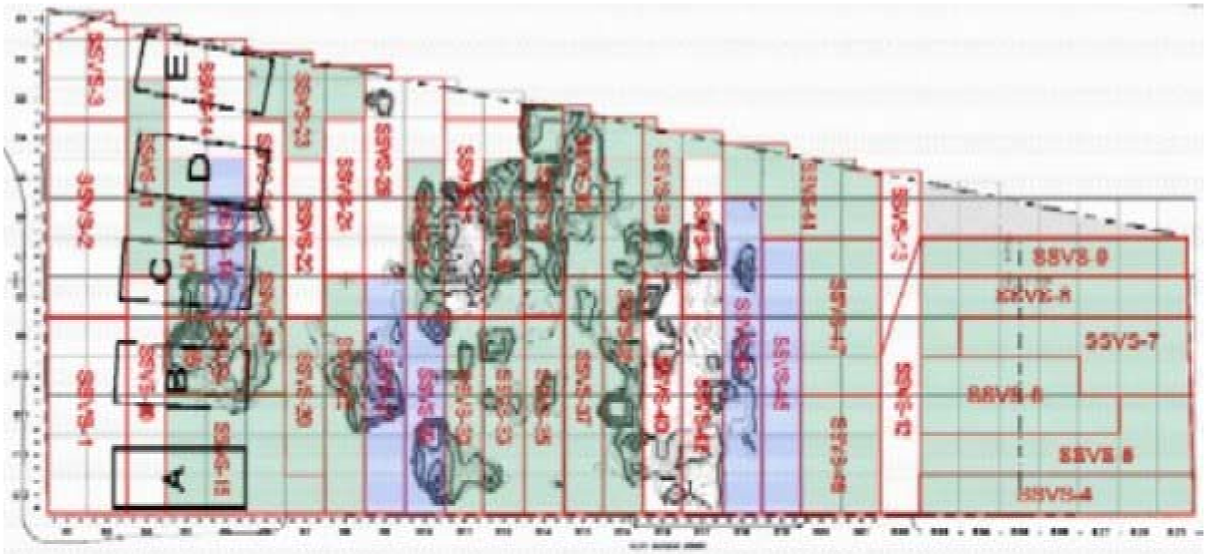


Fig. 3. Underlying and perimeter soil areas to be addressed by the remedy

Underlying Soils

The underlying soils are, as the name implies, those soils directly under the monolith footprint. They consist of up to 8 ft of vadose zone materials. The underlying soils are "layered" as a result of work completed during the previous remedy. Directly beneath the monolith is the first layer of underlying soils. These are the "contact soils" approximately 1 ft thick and assumed to be contaminated. Contact soils are excavated and disposed off-site with the monolith material.

Beneath the contact soils is the 1996/97 CS surface. The 1996/97 CS was utilized during the 1992 ROD compliance demonstration, and was comprised of composite surface soil sampling and direct comparison of analytical values to the RAOs for each radionuclides. The 1996/97 CS surface is the horizontal limit of excavation that was reached during the earlier remedial action. There may be from 0 to 7 ft of backfill material between the contact soils and the 1996/97 CS surface. Backfill material was added to bring the Site to a constant elevation of 5259 ft prior to monolith construction. Because the 1992 ROD RAOs are less stringent, it is necessary to recreate, with elevation measurements, the 1996/97 CS surface to determine if the material between the 1996/97 CS surface and bedrock (or, in some cases, groundwater) meets the ROD amendment RAOs. Project completion records generated during the previous remedy indicate that a significant portion of the material between the 1996/97 CS surface and bedrock/groundwater contains residual radioactivity concentrations between the 5 pCi/g Ra-226 and Th-230 standard and the 15 pCi/g Ra-226 and 42 pCi/g Th-230 standards. As shown visually by Figure 4, as much as ¾ of the 1996/97 CS surface samples were below the original RAOs [1], but now exceed the amended ROD RAOs [2].



Notes: Green Areas indicate Th-230 Exceeding New RAOs [2]
Blue Areas indicate Th-230 and Ra-226 Exceeding New RAOs [2]

Fig. 4. 1996/1997 Closure Survey samples exceeding new remedial action objectives (RAOs)

Once the overlying backfill material is removed and the 1996/97 CS surface is exposed, a gamma walkover survey and systematic sampling can commence. Samples are counted in the on-site laboratory. Elevated areas are identified, excavated, and another sample is collected. If the on-site laboratory results indicate that the residual radioactivity is less than the ROD amendment RAOs, a Final Status Survey (FSS) is conducted in accordance with the Site Final Status Survey Plan [4].

Perimeter Soils

The perimeter soils are the soils within a 20 ft strip of land between the outer monolith edge and the property line. This strip surrounds the monolith on the west, south, and east sides. A larger perimeter area exists at the north side. Radionuclide concentrations in perimeter soils were suspect based on two factors. First, early in 2002, test pit activities were performed in the perimeter soils as part of an investigation for the foundation of the Mining Structure. Test pit sample results revealed subsurface contamination that was unrelated to the 1996/97 CS surface. Second, because the groundwater table has receded, the vadose zone is deeper now than it was during the previous remedial action exposing soils that may not have been addressed during the 1992 ROD remedy.

A soil boring program was implemented in 2003 to expand the test pit data and to generate a complete, ARAR-based assessment of the perimeter soils. Bore hole spacing, 1 every 50 ft, was based on the 40 CFR 142 such that each 100 square meter area was investigated. At every bore hole location, a sample was collected from each 3 ft depth interval (based on the highest field screening measurement) and sent off-site for analysis. The hatched areas around the perimeter on Figure 3 above represent areas of concern identified during this soil boring program.

Bore hole sample results clearly show that residual radioactivity exists in surface and subsurface perimeter soils in concentrations that exceed the amended ROD RAOs. Surface and shallow subsurface contamination will be excavated, disposed off-site, and a FSS (in accordance with the Site Final Status Survey Plan [3]) will commence. Deep subsurface soils (i.e., > 6 ft), however, cannot be excavated using standard techniques. On the west side of the Site is the railroad siding used for transportation of contaminated materials off-site. The south and east perimeters are city streets that support the local businesses. The north boundary is shared with a ready mix plant that uses heavily loaded trucks. Near vertical excavation at any of these boundaries would require substantial shoring. The depth to bedrock is not sufficient to drive standard sheet piling so a specialized form of shoring would be necessary and a substantial cost would be incurred. Meanwhile contamination in the deep subsurface that extends beyond the property line would be left in place and noted for future reference. For these reasons, supplemental standards, as provided for in the ARAR (40 CFR 192) are being considered in those areas.

SUMMARY

Innovative technologies and field applications/solutions described above have resulted in cost-effective and safe remedy at the Site.

Creative approaches to defining ARARs, using available information from the previous remedy, and documenting compliance with RAOs will result in achieving beneficial reuse/ redevelopment of the property.

REFERENCES

1 US Environmental Protection Agency Region VIII, Colorado Department of Health, "Record of Decision, Denver Radium Site Operable Unit #VIII, Denver Colorado," January 28, 1992.

2 US Environmental Protection Agency Region, "Record of Decision Amendment, Denver Radium Site Operable Unit VIII, Denver, Colorado," June 16, 2000.

3 Shaw Environmental and Infrastructure, "Remedial Action Management Plan, Shattuck Chemical Superfund Site, Denver, Colorado," October 2002.

4 Shaw Environmental and Infrastructure, "Final Status Survey Plan, Shattuck Chemical Superfund Site, Denver, Colorado," October 2002.