MOON CREEK RECLAMATION PROJECT
CREATIVE SOLUTIONS FOR AN HISTORIC MINE SITE

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ABSTRACT

The Moon Creek Reclamation Project provides a case study in the
development of creative cleanup solutions for an abandoned lead and zinc mine and mill site located in northern Idaho. Innovative design features include construction of a 88,000 cubic yard combined waste containment facility on soft in-situ tailings, water-balance cap, limestone gravel drains, a geocell mattress for stability, and a below-grade scour protection berm. The stream, including a wetlands buffer, will be relocated within an existing road alignment and rehabilitated to provide trout habitat. These elements allow for the integration of reclamation and stabilization measures into an effective site design.

INTRODUCTION

The Moon Creek site is located on the East Fork of Moon Creek within in the Idaho Panhandle National Forest in Northern Idaho. The site is about five miles northeast of Kellogg, Shoshone County, Idaho. This reclamation project encompasses approximately 20 acres and a 3,300-foot reach of the Moon Creek, a third-order perennial stream. The site is approximately one mile upstream of the confluence with the West Fork of Moon Creek. Moon Creek flows into the South Fork of the Coeur d’Alene River. Figure 1 is a map showing the general location of the site.

The site is an abandoned mine and mill complex which includes the Charles Dickens Mine and the Silver Crescent Mine and Mill. The Charles Dickens Mine operated from 1902 until 1930, and the Silver Crescent Mine and Mill operated from 1911 to 1954. These mines, which are part of the Coeur d’Alene Mining District, produced 4,604 tons of ore.

Metals production from the mines is summarized as follows:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>16,022 oz.</td>
</tr>
<tr>
<td>Lead</td>
<td>734,921 lb.</td>
</tr>
<tr>
<td>Zinc</td>
<td>78,971 lb.</td>
</tr>
<tr>
<td>Copper</td>
<td>31,239 lb.</td>
</tr>
<tr>
<td>Gold</td>
<td>31 oz.</td>
</tr>
</tbody>
</table>

(Mitchell & Bennet, 1983)

The Silver Crescent Mill was a custom mill which processed ore from several off-site mines in the Coeur d’Alene Mining District. Therefore, the volume of tailings on the site is proportionally greater than would be expected given the production from the mines on site.

PROJECT OBJECTIVES

The decision to reclaim the Moon Creek site was driven by the potential exposure to elevated metals concentrations which are unsafe to human health and detrimental to the environment. The overall objective of this response action is to reduce the release and threat of release of hazardous substances from the site, thereby reducing risks to human health and the environment. The U.S. Department of Agriculture, Forest Service (USFS) is the lead federal agency addressing sites with uncontrolled hazardous substances located on National Forest lands.

The objectives of the reclamation plan are to (1) achieve a CERCLA non-time critical removal action, (2) develop an area which is safe for human health, (3) rehabilitate the stream and riparian environment to support Westslope cutthroat trout.

The Moon Creek site includes approximately 18 acres which are impacted by mining and milling waste. The mine workings include four adits, two shafts, and abandoned mine and mill structures. Figure 2 is a site plan showing the location of the mine and mill structures, waste piles, and tailings piles.

The volumes of tailings and mine waste material remaining on site are summarized below:

<table>
<thead>
<tr>
<th></th>
<th>Cubic Yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flotation Tailings</td>
<td>42,000</td>
</tr>
<tr>
<td>Waste Dumps</td>
<td></td>
</tr>
<tr>
<td>Main Dump</td>
<td>20,300</td>
</tr>
<tr>
<td>North Dump</td>
<td>4,400</td>
</tr>
<tr>
<td>South Dump</td>
<td>3,900</td>
</tr>
<tr>
<td>Soils and Tailings</td>
<td>17,400</td>
</tr>
<tr>
<td>TOTAL VOLUME</td>
<td>88,000</td>
</tr>
</tbody>
</table>

(Ridolfi Engineers, 1996)

Lead and zinc are the primary contaminants of concern for reclamation planning. The removal and containment of these contaminants and stabilization of the stream and riparian areas are key components of the Moon Creek CERCLA non-time critical removal action.
SITE CHARACTERIZATION

Before developing the reclamation plan for Moon Creek, a thorough investigation and characterization of the site was conducted. This extensive study involved a collaboration of engineers, scientists, and forest managers which was implemented at the earliest stages of the project. This multi-agency team carried out concurrent environmental sampling of the site, developed options and initial concepts, and produced an integrated reclamation design. In this way the environmental conditions at the site, multifaceted options for removing and isolating the sources of contamination, and various ways to stabilize and rehabilitate the site were evaluated considering all aspects and goals of mine reclamation.

Sampling and monitoring at the site were conducted by the USFS, U.S. Bureau of Mines (USBM), and Ridolfi Engineers. Surface water data collected at a monitoring station downstream of the site showed that at low flow conditions, mean concentrations of cadmium, copper, lead, and zinc exceed background concentrations, Federal Water Quality Criteria, or safe drinking water maximum contaminant levels. Ground water data collected from monitoring wells down gradient of the site showed cadmium, copper, and lead concentrations in excess of federal drinking water standards. Extensive soil sampling was conducted throughout the site including waste dumps, upper mine area, lower mill area, and flotation tailings piles.

Soil samples collected from the mine waste dump areas indicated that arsenic, copper, lead, zinc, and mercury exceed background and ecological effects levels by several orders of magnitude. Soil samples from the upper mine area and the lower mill area show contaminant concentrations that exceed background and ecological effects levels. Samples taken in the flotation tailings areas showed mean concentrations of antimony, arsenic, copper, lead, zinc, and mercury that are greater than both background and ecological effects levels.

MINE RECLAMATION PLAN

After site investigation and characterization, topographic surveying, and mapping of the mine and mill structures and waste piles; the technical approach and conceptual plan were developed. From sampling data and field mapping, depths of removal for contaminated soils and the volume needed for the combined waste containment facility were determined. Key objectives of the reclamation plan were to (1) use existing site features to the greatest extent possible, (2) develop an innovative and effective waste containment design, (3) rehabilitate the stream to provide fish habitat, and (4) use bio-engineering for site stabilization.

Existing features which could be used in reclamation included the narrow valley geometry, forested hillsides, boulders, the existing road through the site, and on-site vegetation. The new stream alignment was based on maintaining part of the existing riparian area and providing cover for the stream. The narrow valley and heavily forested side slopes contributed to this goal. Trees and boulders within the area to be disturbed and outside the contaminated areas were identified for salvaging and use in stream habitat measures. The road embankment through the site contains a significant quantity of clean rock and soil which will be used for fill in constructing the reclamation structures. In the upstream reach, the stream will be moved to the road location. This will allow better sequencing during reclamation. Removing the road will also eliminate an existing source of sediment to the stream. On-site vegetation will be used as source of seed and cuttings for native planting. Vegetation from clearing and grubbing is to be composted on site and used for soil amendment.

Consolidating and isolating the mining and milling waste posed the greatest challenge in the planning process. The solution to this problem depended on an innovative waste containment design. Based on synthetic leach testing of the on-site materials, modeling of the cover elements, and review of the metals data from the stream within the middle reach through the tailings; it was determined that the on-site wastes were compatible, and the potential impacts from leachate containing elevated metals concentrations were limited. Therefore, the waste rock, jig and flotation tailings, and soils containing elevated metals concentrations will be consolidated into an unlined combined waste facility. The dimensions of the facility are approximately 800 feet long by 150 feet wide by 30 feet high. Figure 3 is a drawing showing the design of the containment facility in a sectional view.

Design considerations and components of the combined waste containment include physical location, a compacted gravel drain system, geocell mattress, subgrade scour protection berm, and water balance cap to prevent surface water percolation through the waste material within the containment. As shown in Figures 2 and 3, the containment is located within the middle flotation tailings area with one edge benched into the valley wall and a portion of the containment base located on top of the tailings. This limits material excavation costs; however, it presents several design challenges related to a soft foundation conditions. Typically, the geotechnical solutions for soft foundations include reduction of pore pressure, lateral stability measures, and placement of a surcharge prior to loading (Koerner, 1986).

The design for the combined waste containment base incorporates features that perform all three functions. A compacted gravel drain system is provided along the periphery of the containment with lateral headers on 80-foot spacing. This drain provides a preferential drainage path for in-situ ground water. Limestone gravel has been placed in the lower portion of this drain system to attenuate any metals present in the pore water drainage. The initial layer in the containment is comprised of a geocell mattress. This is an eight-inch thick, three-dimensional perforated polyethylene web (Geoweb™) system that is carefully backfilled with waste rock. A geocell mattress has been shown to provide lateral stability, and a surcharge prior to load placement for similar soft foundation conditions (Koerner, et al, 1986).

A five-foot deep impervious scour protection berm provides lateral stability during construction and support for the compacted gravel drain and in-situ tailings within the containment base. The external face of this berm is armored with riprap to provide protection from future stream erosion, should the stream meander toward the containment. This berm also limits ground water intrusion into the containment.

Within the containment, the waste will be placed in alternating layers and mixed for homogeneity. A mid-height gravel drain is included to help dewater the in-situ waste within the upper lifts of the containment.
The Hydraulic Evaluation of Landfill Performance (HELP) computer model developed by the U.S. Environmental Protection Agency (USEPA, 1994) was used to optimize the water balance cap design for the containment. This cap features two feet of growth media underlain by a gravel drainage layer. A combination of evapo-transpiration from the vegetation and a capillary break between the soils and the underlying gravel will act as the primary means of preventing surface water percolation. A geosynthetic clay liner with underlying cushion material has been included to further reduce infiltration.

Stream rehabilitation planning was based on providing suitable habitat to support Westslope cutthroat trout which are native to Moon Creek. The considerations and components of stream rehabilitation include location of the stream, substrate material placed in the stream bed, microhabitat, and a constructed wetlands buffer.

The new stream channel has been designed to accommodate bank-full flow which is approximately a 1.5-year storm event frequency. The channel was designed with input from USFS biologists and Idaho Fish and Game habitat curves. Because the valley slope of three to five percent is greater than the slopes presented in these curves, microhabitat in the form of in-stream spawning substrate material, large woody debris, and boulder pools were included to enhance trout habitat. Because of extensive removal in the existing valley, clean fill will be imported to reconstruct a floodplain outside of the main channel. Meanders following existing patterns on site and based on reference areas immediately upstream of the site were used for the new stream layout.

As shown in Figure 2, the channel has been relocated into the existing road area in the upper segment and into the area at the base of the hillside in the lower segment. The middle segment passes through the existing mill area. Excavation of soils in this area will be done to form a wetlands buffer area adjacent to the stream. This wetlands was established to allow surface water to flow through during spring snow melt and other high-water periods. It is approximately five feet below normal ground water elevation to allow ground water flow into the wetlands. The wetlands is segmented into three areas, each with a separate primary function. The portion adjacent to the stream contains gravel substrate material with a tree revetment to provide off-channel habitat for fish. The middle portion provides sediment storage capacity to help prevent downstream sediment impacts during the initial site stabilization period. The other bank of the sediment pool features grasses, rushes, sedges, and cattails to trap surface sediment and stabilize remaining metals through the phyto-remedial properties of these plants.

Bio-engineering measures were included in the design to provide a natural self-sustaining means to stabilize the site. These measures include cutstakes with coir fabric for streambanks, willow wattles for flood erosion control, block planting, and bio-filters for erosion and sedimentation control.

The stream was designed as a “deformable boundary channel” to allow natural geomorphic processes to perform the majority of the channel shaping. Bank protection using coir fabric and cutstakes will be used in three critical portions of the stream: near the transition with an adjacent wetlands buffer and in the two junctions with the existing stream section. Meandered willow wattling on 50-foot spacing will be installed on the overbanks to trap surface sediment, direct flows back to the channel, and provide upland niches for wildlife.

Vegetation between the willow wattles will be established using staggered block plantings. This involves placing several containerized plants within a 15 by 25-foot area. Block plantings allow shade between the plants, and colonization of other areas by wind, water, and animal vectors. Native plant species selected for these block plantings include shrubs and mid-story trees that are appropriate for the elevation and climate found at this site. Hardiness (western red cedar), litter production (cottonwood, aspen), nitrogen fixation (alders), and wildlife preferences (mountain ash, elderberry, snowberry) were additional considerations and selections for plants.

The slopes remaining after the waste rock is removed will be stabilized using bio-filter bags. These are a recycled plastic mesh tubes each about five feet in length filled with wood chips. These bags are installed like willow wattlings and are staked into the slope on 20-foot spacing. In addition to providing sediment trapping, the wood chips form a weak ion exchange that may attenuate metals remaining in the surface sediment.

SITE RECLAMATION

The USFS solicited bids for the Moon Creek Reclamation Project on July 31, 1998. Environmental Reclamation, Inc. of Smelterville, Idaho was selected to do the reclamation work, and a contract valued at approximately $1.7 million was executed. This contract amount compares to the USFS estimate of approximately $1.8 million.

Notice to proceed was given on October 2, 1998. The contractor mobilized and began clearing for initial construction the week of October 5, 1998. Construction of the waste containment base began the week of October 19, 1998. The first phase of construction and reclamation is scheduled to run through the fall of 1998 until weather prevents continuing operations. Work is scheduled to resume in the spring of 1999 and reach substantial completion in the fall of 1999.

Post-reclamation monitoring will include surface and ground water sampling. For the most part, this will be a continuation of the monitoring that has been done before and during reclamation. At least one ground water monitoring well will be removed and replaced near the center of the reclaimed site. New and transplanted plants will be monitored to determine the success of revegetation.

CONCLUSIONS AND RECOMMENDATIONS

The experience of developing objectives, characterizing the site, planning the reclamation, designing the reclaimed site, and selecting the contractor to perform the reclamation work provided valuable insights that can be used on other projects of this type. The following conclusions and recommendations are offered with this in mind:

- Encourage early collaboration of engineers and scientists.
- Use existing site features to the greatest extent possible.
- Think “outside the box” to develop innovative ways to isolate waste.
Incorporate fish habitat opportunities and constraints in the design.
Use bio-engineering for site stabilization to enhance natural recovery.

REFERENCES


Figure 2. Moon Creek Reclamation Project Site Plan
Figure 3. Section Through Combined Waste Containment