

Abandoned Mine Waste Repositories:

Site Selection, Design, and Cost

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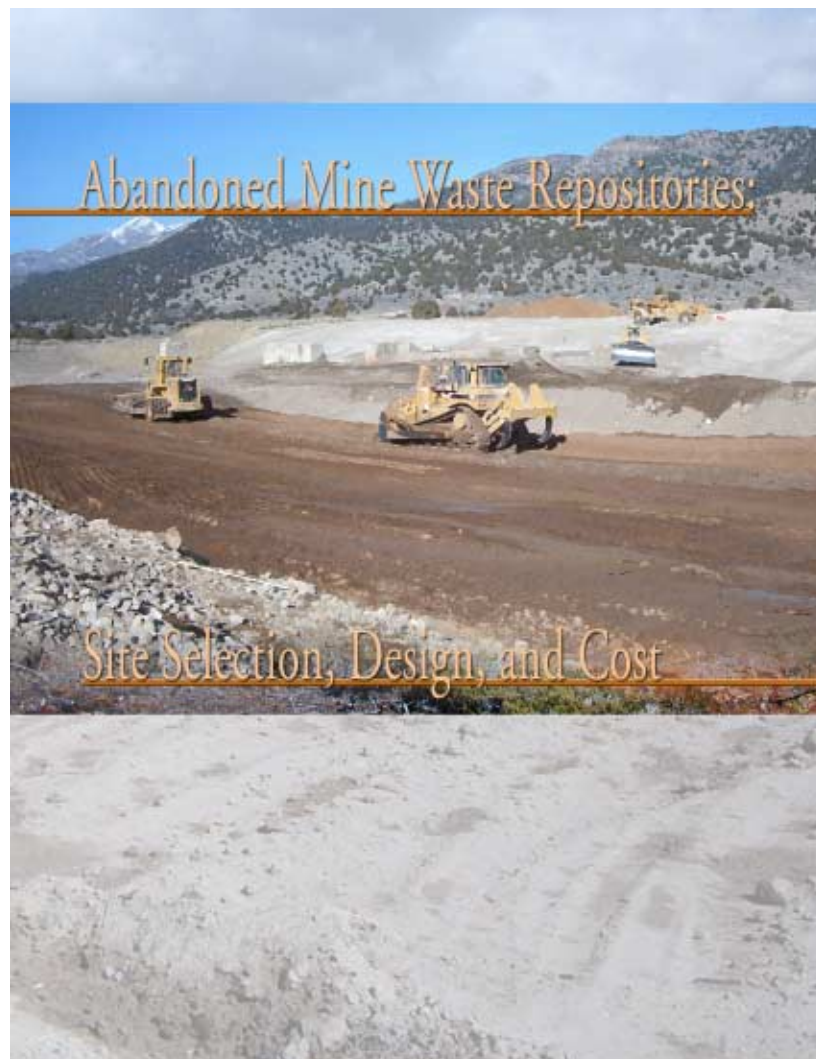
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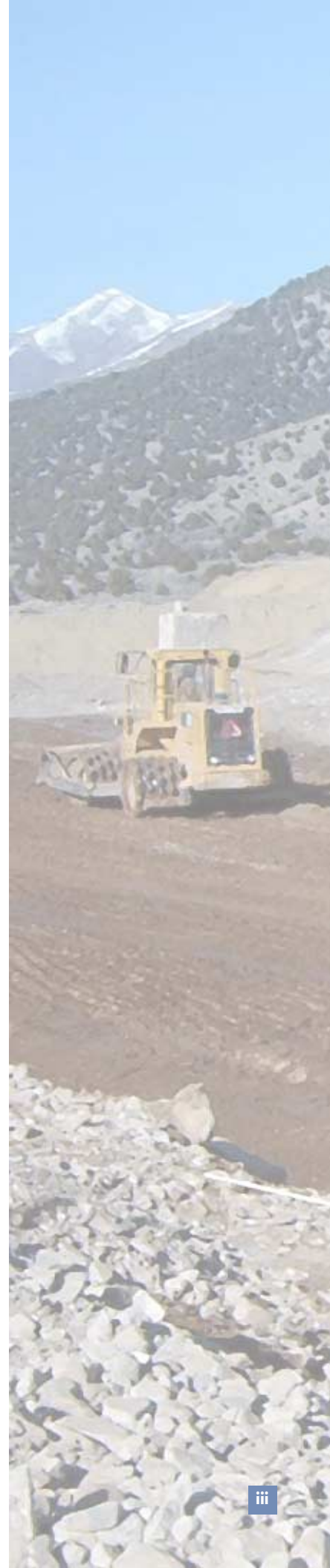


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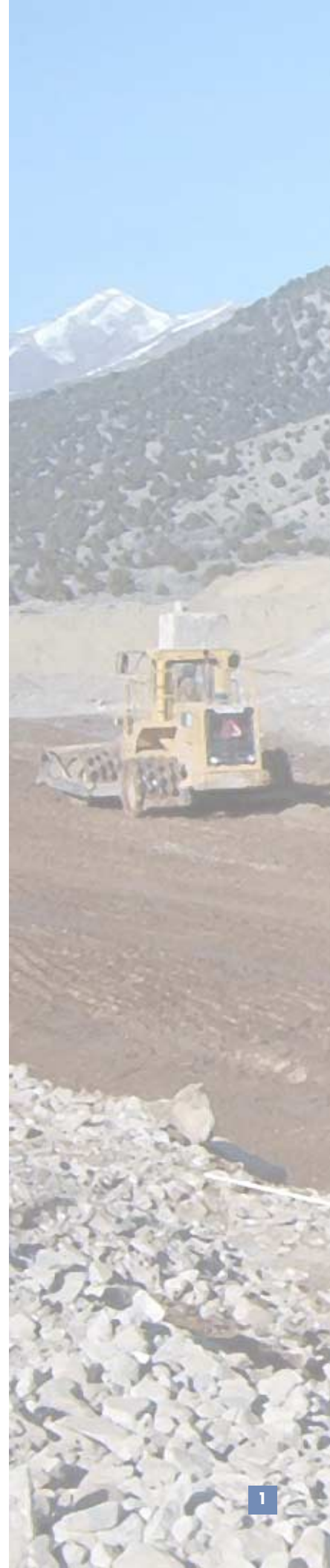


Abstract

THE BUREAU OF LAND MANAGEMENT (BLM) is conducting priority cleanups of abandoned mine sites on public lands. Typically, these sites contain tailings piles, cyanide heaps, and rock dumps that historically were constructed in or near drainages and now are releasing pollutants into watersheds. In compliance with regulations, BLM selects the most environmentally suitable site for removing mining waste and placing it into repositories. Repositories have different design features, and the design selected should be based on site-specific conditions and the results of water balance models. A Geographic Information System (GIS) can be a useful tool for screening and selecting a repository site. Industry sources and construction data from existing repositories can be used to predict construction costs. BLM found that the key factor in predicting cost is the volume of wastes to be placed.

Keywords

Abandoned mines
Hazardous waste
Mine waste
Repository
Surface water contamination
Tailings





Introduction

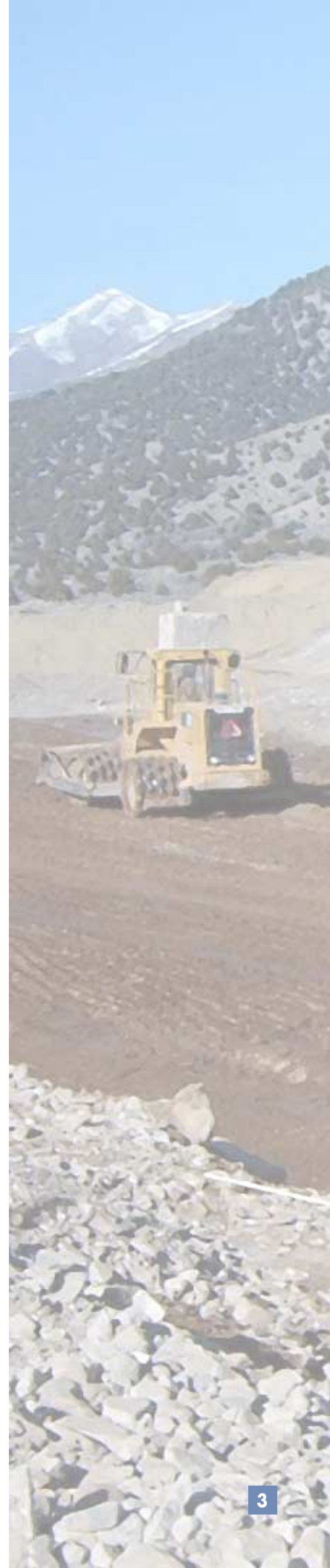
THERE ARE A LARGE NUMBER of abandoned hard rock mining sites on the 261 million acres of public lands administered by the Bureau of Land Management (BLM) in the 12 Western States. While the actual number is not known, there are currently over 9,000 such sites in BLM's inventory. The National Science and Technology Center (NSTC) is BLM's technical support center for investigation and cleanup of abandoned mines and hazardous waste sites. Within the constraints of available funding, NSTC has investigated hundreds of abandoned mine sites and has assisted in the cleanup of 15–20 of the worst sites identified.

Typically, these sites involve old milling operations where ores were crushed and milled using mercury amalgamation, flotation, or cyanide leaching. Thus, there are often tailings or heap material remaining at the site. These wastes, which contain high concentrations of metals, cyanide, and often acidity, were usually placed in drainages with tailing dams. When the dams were no longer maintained, they often breached and became an ongoing source of contamination to surface waters. The mining wastes are typically handled as Superfund wastes under the National Contingency Plan (40 CFR 300.415). One method for handling historic tailings is to use mine waste repositories. This Technical Note provides information on site selection, repository design, and the cost of constructing a repository on BLM public lands.

Site Selection

BLM IS REQUIRED TO LOCATE REPOSITORIES in the most environmentally suitable locations. Several criteria are used to evaluate these locations, including whether they are:

- administered by BLM
- out of the 100-year floodplain and wetlands
- away from shallow ground water
- in an area of generally flat topography
- within a reasonable haul distance
- in an area where soil borrow material is available



- away from cultural features and threatened and endangered species habitat
- away from other geologic hazards

A Geographic Information System (GIS) can be used to evaluate sites against these criteria. The NSTC used ArcView to evaluate potential repository locations at the Ute-Ulay site in the Henson Creek watershed in Colorado. Data on each of the criteria were obtained, weighted as to suitability, and entered into ArcView as separate layers. The composite view is shown in Figure 1. The darkest shading shows the most suitable areas. Though few areas were found to be suitable, the GIS was helpful in identifying potential repository areas in this steep, high-altitude valley.

GIS Analysis Results

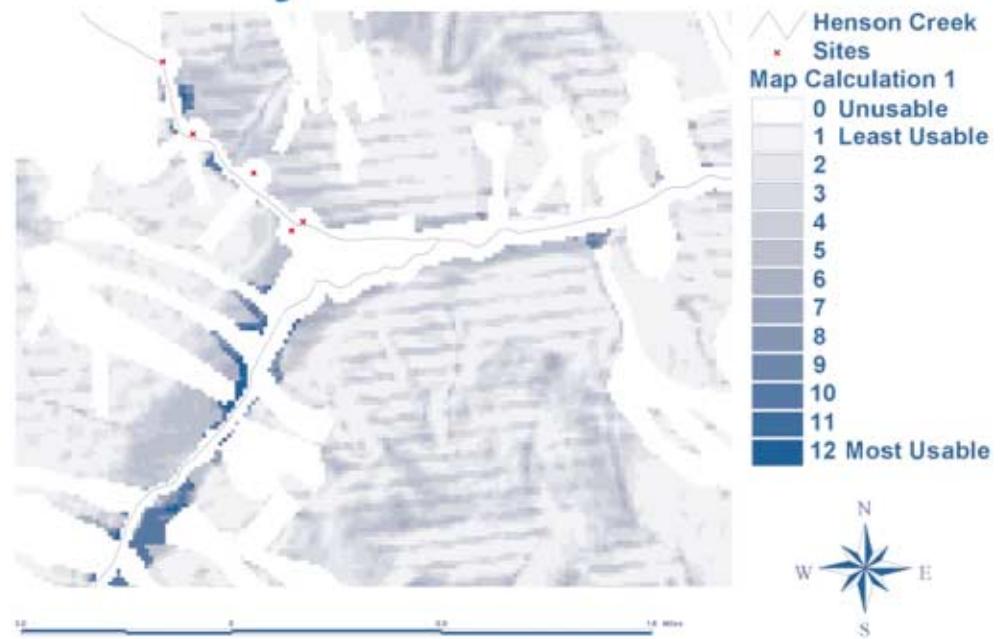


Figure 1. Repository suitability analysis for Henson Creek watershed.

Design

DESIGNS DEPEND ON SITE CONDITIONS, especially the characteristics of the waste and the climate, hydrology, and topography of the site. These factors are evaluated during site characterization. Waste characteristics are investigated through total metal and leachable metal concentrations, acid-base accounting, and permeability. Repository locations are investigated with

drilling or test pits to determine depth to ground water and to collect samples for grain size, Proctor compaction, permeability, and agronomic analyses. Floodplain determinations are made from existing flood insurance maps or watershed modeling.

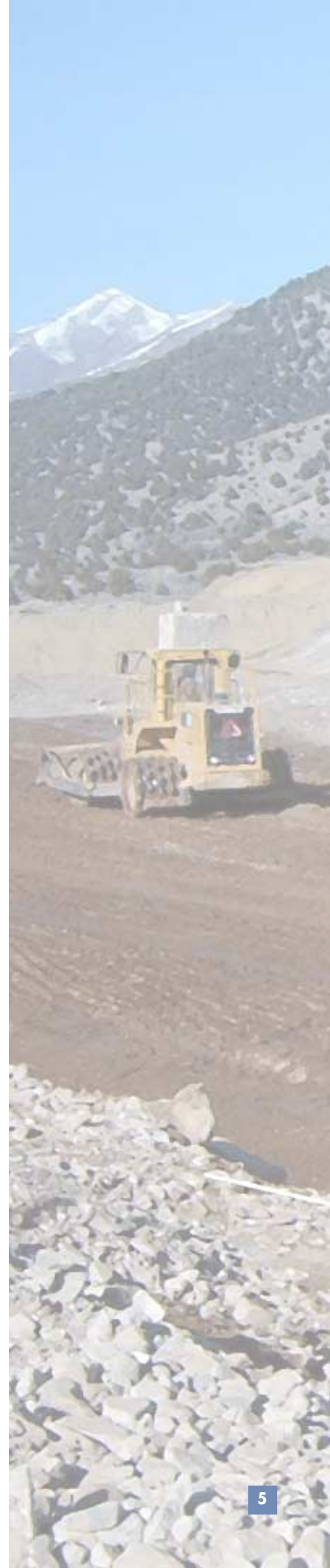
BLM lands are mostly arid, receiving less than 12 inches of precipitation annually, and are subject to long, hot summers with high evapotranspiration rates. Some BLM lands are wetter and more mountainous, with cooler temperatures. For convenience in discussing design, these climatic conditions have been separated into four categories:

1. Less than 12 inches precipitation, no shallow ground water
2. Less than 12 inches precipitation, shallow ground water
3. Greater than 12 inches precipitation, no shallow ground water
4. Greater than 12 inches precipitation, shallow ground water

BLM uses the Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07, or other models, such as SoilCover, to determine infiltration through the cap material and to investigate the utility of different cap configurations. Generally, for category 1 in our arid environments, 24 inches of suitable soil cover with a hydraulic conductivity of 10^{-5} cm/sec or less will show no infiltration through the mine waste. In marginally wet conditions (>12 inches/year), or if the tailings are very acid-generating or leachable, a capillary barrier composed of 6–12 inches of gravel in combination with the soil cover will preclude infiltration. For highly acidic tailings, deep amendment with lime has been used to stabilize the tailings. For wetter areas (categories 3 and 4), an impermeable liner is required to prevent infiltration. When shallow ground water (less than 15 feet below the waste) is encountered, a bottom liner may be required in combination with a top liner.

Cost of Mine Waste Repositories

BLM IS INTERESTED in evaluating the cost of repositories to ensure that government funding is reasonably spent and to help predict costs during the planning stages of cleanup. Although there are costs associated with site



characterization, design, construction oversight, permits, operation, and maintenance, only the direct capital costs of constructing the repository are addressed in this section. Construction costs include mobilization, excavation, hauling and placement of mine waste, cap placement, revegetation on the repository, and run-on controls. Costs for stream restoration or reclamation of cleaned-up areas are not included.

Cost data for BLM repositories are presented in Table 1. Since 1998, BLM has designed or constructed 13 repositories in several States, including South Dakota (Figure 2), Montana, Idaho, Colorado, Utah, Nevada, Arizona, Oregon, and Washington. For each repository, hauling distance, which is an important cost factor, was less than 4 miles round trip.

Table 1. Mean unit costs/cubic yard disposed for different types of repositories.

	Unlined Repositories (n=8)	Lined Repositories (n=5)
Mobilization	\$0.42	\$1.83
Repository preparation	\$0.67	\$3.09
Excavation, hauling, placement, and compaction of mine waste	\$4.10	\$10.69
Soil cap construction	\$1.59	\$6.81
Revegetation	\$0.33	\$1.41
Run-on controls and fencing	\$0.13	\$2.35
Total	\$7.24	\$26.18

The costs shown in Table 1 were estimated using industry sources such as R.S. Means Environmental Cost Data or acquired from bidding and construction cost data. Based on costs, the repositories were subdivided into two categories:

1. repositories with simple soil covers or simple soil covers with capillary barriers
2. lined repositories

For unlined repositories, BLM's experience is that the total volume of wastes to be placed in the repository is the key factor that can predict cost (2001 dollars). Smaller sites require a higher cost per cubic yard disposed than larger sites due to economies of scale. Linear regression was used to investigate the



Figure 2. Belle Eldridge repository, Deadwood, South Dakota.

relationship between volume and cost (Figure 3). Because the relationship is not linear, the natural logarithm (ln) of the volume was regressed with the cost per cubic yard and the following equation was determined:

$$\text{Cost} = -1.98 \times \ln(\text{volume}) + 31(\text{unlined sites})$$

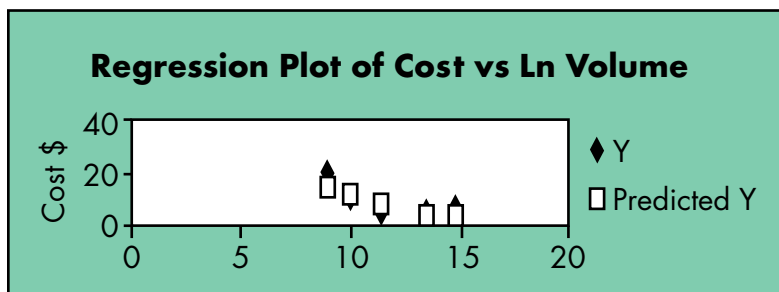
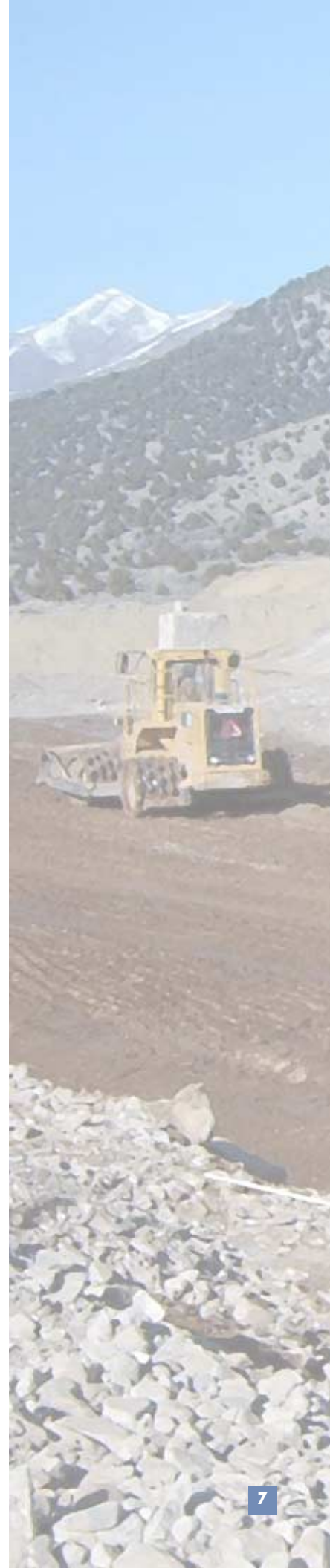


Figure 3. Regression plot for unlined repositories.

The correlation coefficient (R^2) for this relationship is 0.6, indicating that more data points are needed to satisfy normal statistical confidence. However, this information is helpful in preliminary project planning and cost estimating.

The relationship between volume and cost seems to hold for volumes up to approximately 500,000 cubic yards. While additional data are needed to better predict the costs for larger sites, costs are expected to level out around \$5 to \$6 per cubic yard.



To date, too few sites have been completed with liners to estimate the costs using regression. The 2001 mean cost per cubic yard is \$26.18 for lined sites.

Conclusion

ONE OF BLM'S PRIMARY STRATEGIES to help remediate abandoned mine tailings sites in stream channels is to construct mine waste repositories. Repository sites are selected using environmental criteria that consider flooding and ground-water conditions, cultural features, and endangered species habitat, and practical criteria such as hauling distance, availability of soil borrow, and site slope. Various designs are used for repositories, ranging from simple soil covers in arid environments to engineered caps with capillary barriers or geosynthetic liners, depending on precipitation and characteristics of the waste. Repository construction costs appear to be related to the volume of waste to be placed.

The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Federal Government.

