

# LAND APPLICATION OF ADIT WATER ON HISTORIC MINE TAILINGS AT STILLWATER MINE

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## ABSTRACT

Land application disposal (LAD) systems have been used throughout the U.S. for several decades, but land application of wastewater in Montana has little documentation. More importantly is the lack of literature on the **performance** of LAD systems. As companies and municipalities, both public and private, plan for future expansion, wastewater treatment and disposal issues are of significant concern. The State of Montana's "non-degradation" rule places strictly regulated limitations on the discharge of wastewater into Montana's public waters. These regulations have many entities seeking new technological methods and economical solutions for wastewater treatment and disposal that meet current standards. Stillwater Mining Company (SMC) has upgraded LAD systems and developed a water quality monitoring plan to stabilize and reclaim approximately 42 acres (17 hectares) of partially reclaimed chromium tailings. Forage on the LAD area supports resident mule deer and serves as winter range for bighorn sheep. In 1993, SMC commissioned MSE-HKM, Inc. (formerly HKM Associates) to design a new LAD system and monitoring program for the partially reclaimed tailings site. After two years of operation and monitoring, results show high levels of nitrogen utilization and significant forage improvement on the LAD site. The design considerations, operation, monitoring, and results of two years of land application at SMC are presented. Wildlife ecosystem and habitat enhancements have been achieved by increasing natural food sources and cover. Results show that land application disposal systems can be utilized to improve reclamation efforts and can economically provide treatment and disposal solutions to improve water quality.

## INTRODUCTION

Stillwater Mining Company (SMC) is a platinum and palladium mine near Nye, Montana. The only mine of its type outside the former USSR and South Africa, SMC provides precious metals required in the production of items used daily by most Americans, such as catalytic converters and computer chips. Located along a blue ribbon trout stream, the Stillwater River, and at the foot of the Beartooth

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Mountain Range, much of SMC's property supports resident mule deer and wintering bighorn sheep. SMC is continually improving methods of operation to protect and enhance the surrounding ecosystem and environment.

SMC uses nitrogen-based blasting agents to break ore in mine workings on the east and west sides of the Stillwater River. Natural groundwater inside the mine mixes with the nitrogen residues remaining after blasting and flows out of the mine. Most of the mine production water, referred to hereafter as adit water, has historically been diverted to percolation ponds, with a small portion applied to land by big gun sprinklers. Current SMC water and nitrogen disposal methods are well within the existing discharge limits of the permit issued by the State of Montana. However, in an effort to improve "disposal" methods, SMC has installed two state-of-the-art land application systems to spray irrigate a variety of grasses growing on partially reclaimed chromium tailings.

In 1993 SMC commissioned MSE-HKM, Inc. (formerly HKM Associates), a consulting engineering firm in Billings, Montana, to design the LAD system and to prepare a water quality monitoring program that would quantitatively document the nitrogen utilization of the LAD system. The design team used innovative, site-specific design concepts to help develop two center pivot sprinkler systems for the LAD site. The new center pivots are unique in that the spray irrigation system design maximizes the water and nitrogen utilization. To minimize costs of the LAD system, an existing pumping plant and pipeline were utilized to deliver adit water from a storage pond to the two LAD systems. This paper discusses the engineering considerations and design parameters used to develop the LAD system layout.

MSE-HKM developed a water quality monitoring plan to measure the performance of the LAD system. SMC has collected data for two years, 1994 and 1995. An overview of the water quality monitoring plan, including data collection and analyses, is presented. A summary of the LAD performance for 1994 and 1995 is also included.

### BACKGROUND INFORMATION

Mine operations produce year-round adit water flows ranging from approximately 500 to 1,000 gallons per minute (32 to 63 liters/second). About 60% of this flow originates from the east side of the Stillwater River and 40% is produced from the west side. Typical nitrate plus nitrite (referred to herein as nitrogen) concentrations range from approximately 2 to 6 milligrams per liter (mg/l) on the east side to 15 to 20 mg/l on the west side.

Existing soils in the LAD area vary widely depending on location. The soil profile in the southern portion of the LAD area consists of varying depths of chromium

tailings, usually 5 to 10 feet (1.5 to 3.0 m), overlain by varying depths of gravelly loam topsoil, typically 2 to 12 inches (51 to 305 mm). Soils in the northern portion of the LAD area are generally deep gravelly loams overlain by 0 to 6 inches (0 to 152 mm) of chromium tailings. The small depth of chromium tailings over native soil in the northern portion of the LAD area is a result of wind erosion and deposition from the tailings to the south. The native soils and the chromium tailings have high permeabilities, ranging from 2 to 6 inches per hour (51 to 152 mm/hr). Baseline soil samples collected in 1993 and 1994 show very low nitrogen levels.

Site vegetation prior to LAD system operation varied in type and population depending upon topsoil quantities and past irrigation patterns. Vegetation under the portion of the site which had historically been irrigated with big gun sprinklers consisted primarily of alfalfa. The site also had scattered areas of bluegrass, fescue, and assorted wheatgrasses. Sparse vegetation existed over tailings with shallow topsoil. Some areas of exposed chromium sand tailings had no established vegetation. The surrounding areas are a mix of native grasses, brush, aspen, and conifers. Site vegetation is used as a year-round food source for a variety of wildlife.

## ENGINEERING DESIGN CONSIDERATIONS

### LAD System Design

The design of an optimum land application disposal system requires a variety of professional expertise. The design team, consisting of agricultural and civil engineers, environmental specialists, and a soil scientist evaluated water quality, soils, vegetation, climate and topography to design the LAD system. MSE-HKM worked closely with SMC personnel to identify the project objectives and to develop the details of the LAD system and monitoring plan. The LAD system plan and site enhancements were reviewed by a multi-disciplinary team from SMC, MSE-HKM, the Natural Resources Conservation Service (formerly SCS), and the State Department of Environmental Quality.

The shallow topsoil over chromium sands results in an effective root zone depth of approximately 1 foot (305 mm). The water holding capacity in the root zone of the existing vegetation is low, estimated at 0.5 to 1.5 inches (13 to 38mm). Soil fertility tests show little or no residual nutrients, particularly nitrogen, in the soil profile. Topographic characteristics on the site vary from relatively flat areas to steeper slopes (15 to 20 percent) along the base of the mountain. Based on the soils and topography, the use of a mobile, automated sprinkler system that would apply frequent, light applications of irrigation to the site with a high level of control was recommended. A high level of water management is necessary to

maximize crop water and nitrogen use which will result in vigorous plant growth. The goal is to develop the soil profile by increasing the organic matter in the root zone.

Vegetative conditions on the site varied from areas of thick grasses, where historic irrigation had occurred, to areas with limited foliage. Analysis of mine water quality (nitrogen concentration), climate, soils and vegetation indicated that inter-seeding a meadow grass with a high water and nitrogen uptake potential was most suitable for the LAD site. Garrison Creeping Foxtail (*Alopecurus arundinaceus*) was selected to inter-seed with the existing grasses for a variety of reasons: high water use potential, high nitrogen uptake potential, good sod building characteristics, lush growth in a wet environment, excellent forage qualities, and adaptability to a variety of soils. Garrison Creeping Foxtail is a hearty variety that will thrive with the existing species under irrigation. If irrigation ceases, the existing species more adapted to semi-arid conditions will dominate the site. Vegetation establishment in the chromium tailings has proven difficult in the past. Therefore, inter-seeding was completed by drill seeding with a no-till drill to insure minimum disturbance of the tailings.

Climatic conditions during the growing season, typically April through October, were evaluated. The majority of growing season precipitation occurs in April, May and June. Mid-summer and early-fall months (July, August, September, and October) are typically warm, dry and breezy with little rainfall. Climatic conditions of the site indicated that the crop water demand would be highest in the summer and fall, and lower in the spring.

A two-phase conceptual design layout for SMC's land application disposal system was prepared in 1993. The Phase I layout was designed to be a pilot study and included one center pivot sprinkler system that was installed in 1993. Successful results of the pilot study prompted the implementation of the Phase II design layout, which included a second center pivot sprinkler system that was installed in 1994. Center pivot sprinkler systems were selected over other potential methods of land application for several reasons:

- Center pivot irrigation systems provide uniform application distribution which maximizes the consumptive use of the crop and optimizes nitrogen uptake.
- Nozzles can be designed and located to maximize water and nitrogen utilization.
- Operation and management of a center pivot system can be modified throughout the growing season to match the climatic and vegetative demands of the crop.
- Design objectives could be achieved matching the existing pumps at SMC which operate at approximately 80 psi (552 kPa).

- Center pivots are easily automated with computer control panels and thus operate with a high level of management with minimal labor.
- Automated operation of this type of irrigation system provides a higher level of quality control than conventional stationary irrigation systems.
- Computer controls automate the water accounting of system operations.

#### Water Quality Monitoring Plan

An investigation was made of the data required to analyze the system's performance. Field data necessary to analyze the LAD system included: water delivered to the LAD system, rainfall, application depth, and deep percolation. From the field data, calculations of crop uptake and evaporation were made. The water quality monitoring plan to measure the water and nitrogen utilization performance of the LAD system was implemented in two phases. A pilot monitoring program under Pivot #1 began in 1994 and was expanded as Phase II in 1995 to include Pivot #2.

Bucket lysimeters and rain gages were installed to quantify water application, rainfall, deep percolation, and crop uptake. Samples from the lysimeters and rain gages allow quantification of water quantity and quality for both the water applied and the water deep percolated. SMC's monitoring data was summarized by MSE-HKM and presented in two reports (HKM Associates, 1994 and MSE-HKM, Inc., 1995).

Additional water quality monitoring components in place at Stillwater Mine include monitor wells, located down gradient of the LAD area. The monitoring plan also includes periodic soil sampling to assess the long-term effects of applying nitrogen to the soil.

### **LAND APPLICATION DISPOSAL (LAD) SYSTEM**

#### LAD System Layout and Operation

SMC installed two center pivots, Pivot #1 and Pivot #2, in the fall of 1993 and the spring of 1994, respectively. Pivot #1 and Pivot #2 cover 19.5 and 22.0 acres (7.9 and 8.9 hectares), respectively. Pivot #1 operated on a limited basis in the fall of 1993, with full operation and monitoring beginning in 1994. Pivot #2 had limited operation in 1994, with full operation and monitoring beginning in 1995. Twelve lysimeters and rain gages, including three baseline units outside the irrigated area, were installed. Figure 1 shows the layout of the center pivots and monitoring components.



Seasonal operation of the center pivots generally begins in May and ends in late October. During warm, dry autumn seasons, the pivots may operate well into November. Typically, the systems are operated 10 to 12 hours per day, Monday through Friday. During light rain showers, the systems generally continue operation. However, during regional storm fronts producing heavier rainfall, the LAD systems are usually shut off.

#### Water Quality Monitoring Plan

Adit water flows from clarifiers on the east and west sides are measured and sampled continuously, producing a daily composite sample from each side. Flows through the center pivots are measured by flow meters at each pivot's computerized control panel. Water delivered to the LAD system is sampled daily, and composited weekly. Precipitation and irrigation under the LAD system and in the baseline lysimeters are measured daily. Daily samples are combined into a weekly composite for each sampling site. Deep percolation samples are collected weekly from each lysimeter using a suction pump. Soil samples are collected twice per year, before and after the LAD season. Monitor wells are sampled quarterly by SMC personnel. All water quality monitoring samples are analyzed by a certified independent laboratory.

### RESULTS

The overall performance of the LAD system can be defined by the amount of nitrogen deep percolating from the LAD area versus the amount of total nitrogen delivered to the system. In 1994 and 1995, the nitrogen utilization efficiencies of the LAD system were 98% and 83%, respectively. The LAD system performance was lower in 1995 than in 1994 due, in part, to a very wet spring season in 1995. The water utilization efficiencies in 1994 and 1995 were 62% and 43%, respectively. The performance of SMC's LAD system for 1994 and 1995 is summarized in Table 1. Figures 2-7 show graphical representations of the results for 1994 and 1995. Detailed results of this study are presented in two annual LAD performance reports (HKM Associates, 1994 and MSE-HKM, Inc., 1995).

The total annual water delivered to the LAD area exceeded the crop water use potential of the forage, resulting in deep percolation. However, annual nitrogen loads delivered to the LAD area were less than the nitrogen uptake potential of the crop. Therefore, nitrogen utilization efficiencies are significantly higher than the water utilization efficiencies. Total annual nitrogen loads delivered to the pivots averaged 122 lbs/ac (137 kg/ha) and 79 lbs/ac (89 kg/ha) in 1994 and 1995, respectively. An SCS trial at the Bridger, MT plant materials center found that Garrison Creeping Foxtail has increasing yields with nitrogen application up to 240 lbs/ac/yr (270 kg/ha/yr) (SCS, 1979).

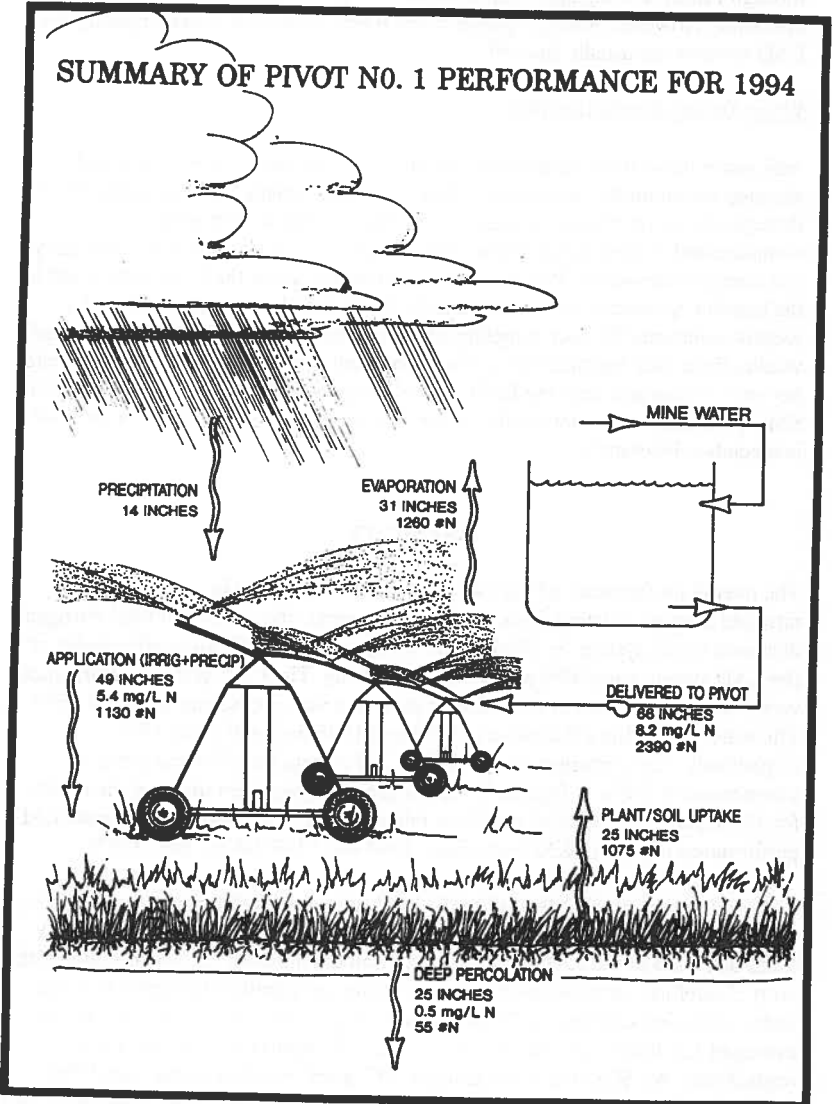


Fig. 2. 1994 LAD Performance

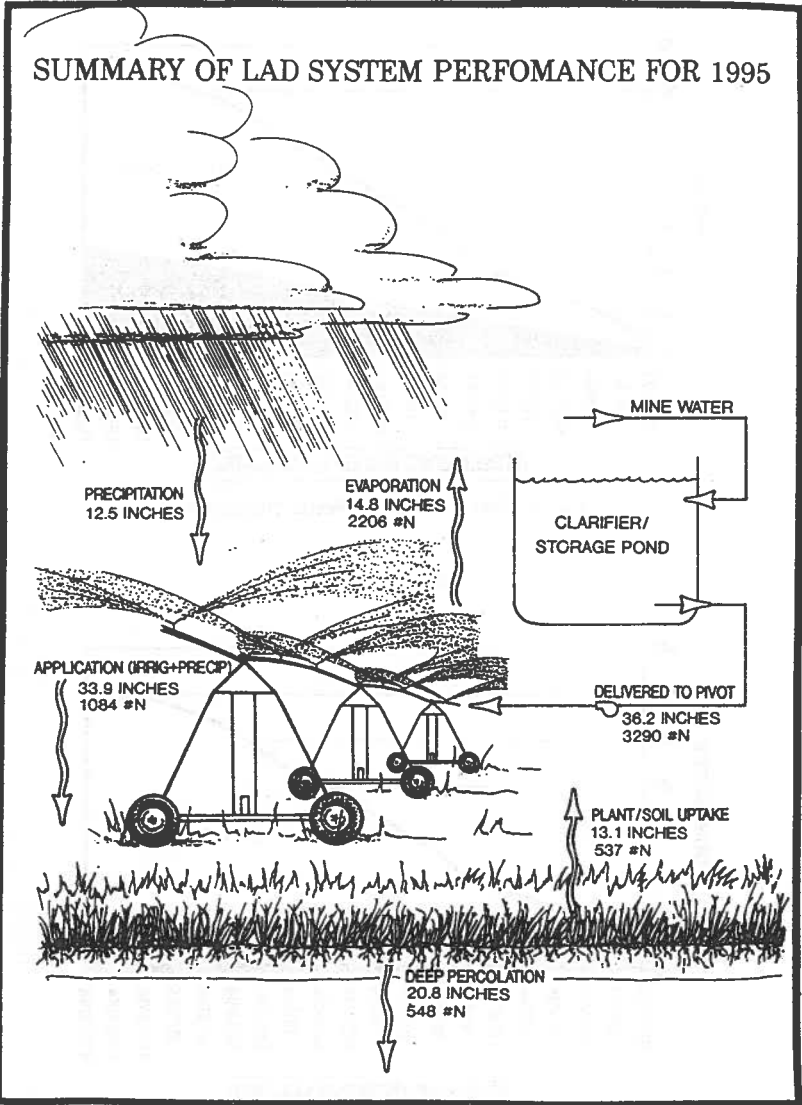


Fig. 3. 1995 LAD Performance

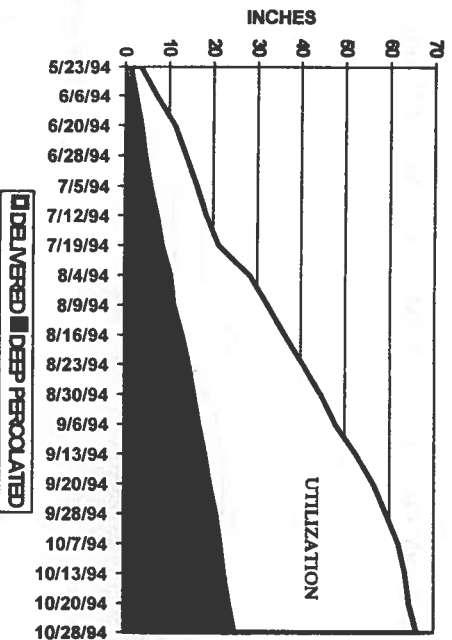


Fig. 4. 1994 Cumulative Water Utilization

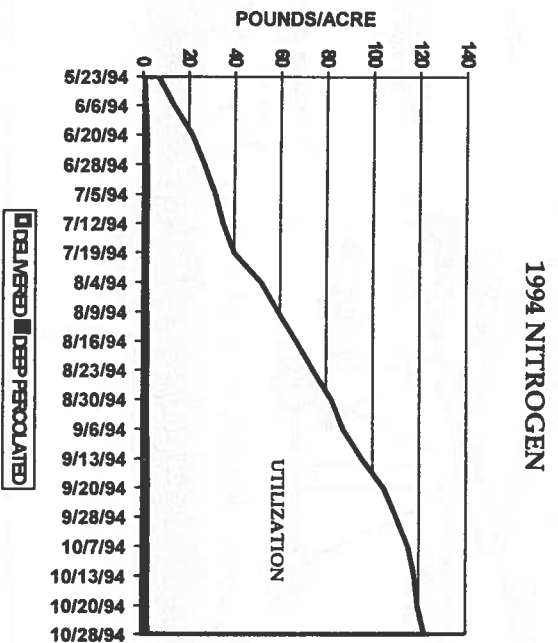


Fig. 5. 1994 Cumulative Nitrogen Utilization

1995 WATER

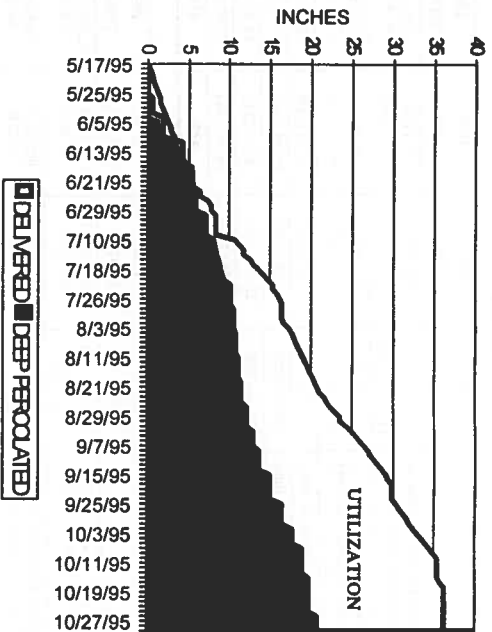


Fig. 6. 1995 Cumulative Water Utilization

1995 NITROGEN

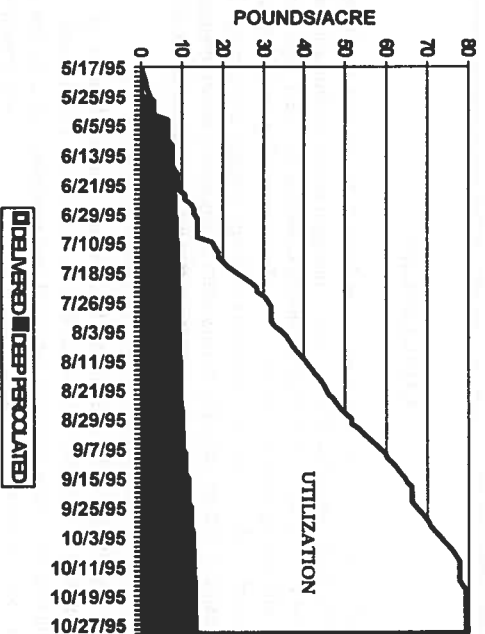


Fig. 7. 1995 Cumulative Nitrogen Utilization

TABLE 1. LAD PERFORMANCE SUMMARY

WATER				
	1994 PIVOT #1	1995 PIVOT #1	1995 PIVOT #2	1995 TOTAL
Delivered to LAD, af (ha-m)	107 (13.2)	78 (9.6)	47 (5.8)	125 (15.4)
Delivered to LAD, in (mm)	66.14 (1,680)	47.82 (1,215)	25.82 (656)	36.16 (918)
Applied to ground, af (ha-m)	80 (9.9)	65 (8.0)	46 (5.7)	111 (13.7)
Applied to ground, in (mm)	48.93 (1,243)	40.03 (1,017)	28.37 (721)	33.85 (860)
Precipitation, in (mm)	13.80 (351)	12.50 (318)	12.50 (318)	12.50 (318)
Deep percolation, in (mm)	25.13 (638)	29.06 (738)	13.39 (340)	20.76 (527)
Evaporation, in (mm) (Calculated)	31.01 (788)	20.30 (517)	9.95 (253)	14.81 (376)
Crop uptake, in (mm) (Calculated)	24.75 (629)	10.96 (278)	14.98 (380)	13.09 (332)
Water Utilization Eff (%)	62%	39%	48%	43%
NITROGEN				
	1994 PIVOT #1	1995 PIVOT #1	1995 PIVOT #2	1995 TOTAL
Delivered to LAD, lbs (kg)	2,386 (1,085)	2,060 (936)	1,230 (559)	3,290 (1,496)
Delivered to LAD, lbs/ac (kg/ha)	122 (137)	106 (119)	56 (63)	79 (89)
Applied to ground, lbs (kg)	1,152 (524)	623 (283)	462 (210)	1,084 (493)
Applied to ground, lbs/ac (kg/ha)	59 (66)	32 (36)	21 (24)	26 (29)
Precipitation, lbs (kg)	0 (0)	0 (0)	0 (0)	0 (0)
Deep percolation, lbs (kg)	53 (24)	413 (188)	134 (61)	548 (249)
Evaporation, lbs (kg) (Calculated)	1,233 (560)	1,438 (654)	768 (349)	2,206 (1,003)
Crop uptake, lbs (kg) (Calculated)	1,099 (500)	209 (95)	328 (149)	537 (244)
Nitrogen Utilization Eff (%)	98%	80%	89%	83%

## CONCLUSIONS

A successful, state-of-the-art land application disposal system and monitoring program was implemented at SMC to utilize nitrogen and to reclaim chromium tailings. The LAD systems at Stillwater Mining Company had very high nitrogen utilization efficiencies during 1994 and 1995. The surrounding environment has been enhanced by significant improvements in forage quantity and quality. This project illustrates that an inter-disciplinary team of engineers, environmental specialists, and state and federal regulatory personnel can successfully work together to protect and enhance the environment.

Montana's Department of Environmental Quality calls land application "a preferred method of ultimate wastewater disposal" (MDEQ, 1995). Land application systems, when designed, managed, and operated correctly, may be an important tool in wastewater treatment and disposal. LAD systems should be considered in future planning and for remediating existing water quality problems.

**REFERENCES**

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