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Project Summary

Reclamation of Toxic Mine Waste Utilizing Sewage Sludge—Contrary Creek Demonstration

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Three abandoned pyrite mines in central Virginia that have been inactive since 1923 contained about 12 denuded hectares (ha) and caused severe acid mine drainage (AMD) in a small stream known as Contrary Creek. The AMD which included heavy metals made the stream virtually void of aquatic life. The Virginia State Water Control Board (SWCB) was prompted to seek a solution to this problem when plans were announced in 1968 to construct a reservoir for a nuclear power plant downstream from Contrary Creek. Two of the mine sites comprising about 8 ha were reclaimed with a U.S. Environmental Protection Agency (EPA) demonstration grant in which the SWCB contributed matching funds through in-kind services and the Soil Conservation Service (SCS) provided technical assistance. Reclamation began in 1976 and included the use of sewage sludge as a soil conditioner. Severe droughts in 1976 and 1977 and the highly toxic nature of the mine waste required a continuing maintenance program to establish vegetation. By the fall of 1980 approximately 90 percent of the reclaimed areas supported fair to good grass cover.

A comprehensive monitoring program has indicated little improvement in the water quality of Contrary Creek since reclamation began. There appeared to be slight decreases in concentrations and loads of acidity and some metals in 1979 and 1980, but it is too early to tell if a remedial trend is beginning. Significant improvement is expected as infiltration and AMD formation are reduced by the development of a soil layer and vegetative cover. Biologic surveys have revealed negligible improvement in the biota.

In late 1980 the EPA approved a request from the SWCB to extend the project until mid-1982 to provide continued maintenance and evaluation.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Contrary Creek Project is located in Louisa County, Virginia, approximately 65 km northwest of Richmond and 129 km southwest of Washington, D.C. Contrary Creek is approximately 8 km in length with an average annual flow of 197 l/s (7.3 cfs) at its mouth where it empties into Lake Anna, an impoundment completed in 1972 as a source of cooling water for a nuclear power plant. The lake also has important recreational and fishing values.

The area is in the so-called pyrite-gold belt of the Piedmont physiographic province and was the scene of extensive mining activity in the 19th century. Between 1880 and 1923 three deep shaft pyrite mines known as the Arminius, Boyd Smith, and Sulphur were operated along Contrary Creek. Over six million tons of pyrite ore were produced from the mines during their operation. It was during this period that large volumes of wastes were dumped indiscriminately along Contrary Creek, denuding about 12 ha at the three sites and creating an AMD problem. The sources of AMD are shown in Figure 1. The worst conditions prevailed at the Sulphur Site where about 6 ha were seriously affected.

The area remained essentially in this condition for over 50 years after the mines were closed until plans were announced to build the reservoir on the North Anna River into which Contrary Creek drained. There was concern that the continued influx of AMD would eventually cause a buildup of contaminants in the reservoir and could create major fish kills. Pre-impoundment biologic studies had shown aquatic life to be adversely affected in the North Anna River for about 9 km below the confluence of Contrary Creek.

The SWCB conducted a cursory water quality study of Contrary Creek in 1971 and determined that the heavy metals, copper, iron, lead, manganese, and zinc, were present in excessive amounts. In 1973 the SWCB applied for an EPA demonstration grant to perform abatement measures under the provisions of Section 107 of PL-92-500. In conjunction with a feasibility study by a consultant to support the grant request, the SWCB initiated a preliminary monitoring program in 1974 to more accurately define the AMD problem. Table 1 shows average concentrations of approximately 20 samples collected at the mouth of Contrary Creek and indicates the magnitude of the AMD problem.

An EPA grant to reclaim the two downstream mine sites known as the Boyd Smith and Sulphur was awarded to the SWCB in 1975. The provisions of the grant were for 60 percent Federal funding to cover construction costs with the SWCB providing 40 percent matching funds through in-kind services including project administration, monitoring, and preparing reports. A mining company assumed responsibility for reclaiming the third mine site known as the Arminius. To save the cost of retaining an engineering consultant, the SWCB asked the SCS to provide technical assistance. The SCS had done some earlier experimental vegetative studies at one of the Contrary Creek mine sites and agreed to assist. The SWCB obtained easements from all affected property owners before reclamation began.

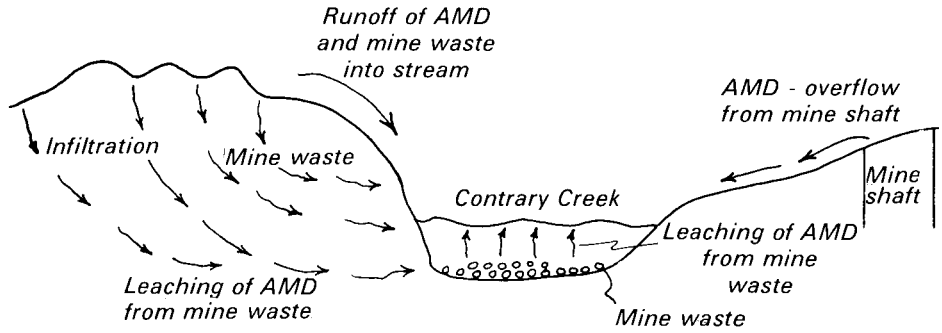

Figure 1. *Sources of mine drainage into Contrary Creek. (Not to scale).*

Table 1. *Average composition of water at mouth of Contrary Creek (mg/l)**

pH	Acidity as $CaCO_3$	SO_4	Fe	Cu	Zn	Pb	Mn
3.3	169	267	23.1	1.20	3.5	0.05	1.5

**Average of approximately 20 samples collected in 1974.*

Reclamation of the Boyd Smith and Sulphur Sites began in April 1976 and consisted essentially of clearing debris, regrading and smoothing wastes, constructing diversions, excavating stream channels, riprapping stream banks, applying fertilizer and lime, incorporating wastewater sludge as a soil conditioner, seeding and mulching, and placing erosion controls.

Arrangements were made with the Government of the District of Columbia to deliver wastewater sludge from the Blue Plains Sewage Treatment Plant (STP). The plant generates approximately 275 wet tonnes of anaerobically digested sludge daily which is concentrated to approximately 20 percent solids. Because of the high cost of sludge disposal in the Washington, D.C. area, the District agreed to deliver all sludge needed at no cost to the SWCB which resulted in a tremendous cost saving.

The 1976 reclamation work was completed in early July, but the late seeding at the onset of hot weather coupled with meager rainfall for the remainder of the summer resulted in very sparse seed germination. A complete reseeding was done the following spring, but 1977 proved to be one of the driest years of the century which made the effort almost a complete failure. The dry summers of 1976 and 1977, both followed by abnormally cold winters, led to the development of the following semi-annual maintenance program that is still in progress:

(1) applying additional fertilizer, lime, and sludge
(2) spot-seeding persistent problem areas
(3) placing straw bales for erosion control
(4) periodic irrigation of a small portion of the Sulphur Site.

A total of 2118 dry tonnes (2335 tons) of sludge was applied to the two mine sites from 1976 through 1979. Seventy-five percent of this amount was applied during the major reclamation work of 1976 with lesser amounts applied each successive year. Application rates in 1976 ranged from 200 to 260 dry tonnes/ha (90 to 116 tons/ac).

During the initial reclamation work, lime was applied to all areas at the rate of 8.9 tonnes/ha (4 tons/ac). Lime application rates for subsequent maintenance were determined on the basis of pH and lime titration analyses of composite soil samples collected from various areas of the reclaimed sites and ranged from 4.5 tonnes/ha (2 tons/ac) to 33.4 tonnes/ha (15 tons/ac).

Fertilizer application rates have generally been 1121 kg/ha (1000 lbs/ac). Initially, 10-10-10 fertilizer was applied to all areas with 38-0-0 (ureaform) added at the rate of 448 kg/ha (400 lbs/ac) to unsludged areas. Beginning in 1979, 6-6-12 and 6-0-12 fertilizers were used to increase potash availability.

Conclusions

Vegetation and Soil Conditions

The first real successes in the revegetative effort did not occur until 1978 and 1979 when near normal seasonal rainfall returned, but even then irrigation water had to be applied periodically to critical parts of the Sulphur Site. Another dry summer in 1980 impeded vegetative growth. Despite the abnormal weather conditions that have plagued this project and the very harsh conditions that existed before reclamation, about 90 percent of the Sulphur Site had a fair to good cover of vegetation by late 1980. However, some highly toxic portions of the Sulphur Site remained practically barren, especially the streambanks. Much of this site has a very thin soil layer supporting vegetation and the susceptibility to drought is quite high. About 98 percent of the Boyd Smith Site had a dense mat of grass established by late 1980, and appeared well on its way to reverting back to the natural wildlife habitat of the surrounding areas. It is doubtful that a fraction of the vegetative cover would have been attained in this project without the use of sludge.

The most successful planting has been KY-31 fescue grass which has proved to be the mainstay of the vegetation. Weeping lovegrass exhibited high tolerance for drought and always made its best showing during the hot months when the KY-31 became dormant. Korean and sericea lespedeza have both been used in the seed formula, but neither of these legumes has shown any appreciable success.

Regular soil analyses conducted by the SCS and SWCB have shown significant increases in pH and nutrient availability in the top layer of soil as the project has progressed. However, there has been little improvement in the deeper layers below the root zone. The heavy application of lime has undoubtedly been a factor in raising the pH. Fertilizer formulas have been adjusted according to nutrient requirements. A high potash fertilizer was used after soil tests began to show a relationship between potash deficiency and difficult areas to vegetate. Soil was also analyzed for acid-extractable heavy metals, and there have been sharp reductions in metal concentrations within the top few cm over most of the reclaimed areas. Table 2 shows pH and metals analyses of composite soil samples collected between 1975 and 1980 from the east and west sides of the Sulphur Site.

Reclamation of the Arminius Site, which has been under the direction of a private consultant, has progressed similarly to that at the other two mine sites. A wide variety of plant species has been tried and soil additive application rates generally have been less. Sludge from the Blue Plains STP was used at this site also.

Water Quality

A comprehensive water quality program to evaluate the success of the project was implemented in October 1975 prior to reclamation. The program involved semi-monthly samplings and flow measurements at five stream stations and sampling of two stations at surface, middle, and bottom depths in the Contrary Creek arm of Lake Anna. A stream monitoring station was established below each mine site with an additional one at the mouth of Contrary Creek and another above the Arminius Site for control. Water samples from both stream and lake stations were analyzed for the following parameters: pH, acidity, sulfate, copper, iron, lead, manganese, zinc, suspended solids, turbidity, BOD (5-day), and fecal coliform.

BOD and fecal coliform were included to determine if adverse effects of the wastewater sludge were occurring. Additional parameters including some of the less common metals present were analyzed at least once annually. The regular monitoring program continued until early 1980 when the lake stations were eliminated and the stream sampling was reduced to once monthly. Other monitoring included pH and conductivity transects along selected reaches of Contrary Creek and periodic analyses of tributaries.

Concentration and load data from the regular stream stations are presented in the Project Report. The data show that the water quality of Contrary Creek steadily deteriorates downstream and that there has been little change in water quality since reclamation began. The Sulphur Site is the major contributor of AMD, but certain heavy metals appear peculiar to each site. Erosion and surface runoff of AMD have been reduced. However, the continual leaching of AMD from the stream banks, the sudden flushouts during heavy rainstorms following extended dry periods, and the mine wastes remaining in the stream channel downstream from the Sulphur Site are serious problems.

The monitoring program has shown that the Contrary Creek arm of Lake Anna is degraded by AMD, but the main body of the reservoir apparently has been unaffected. No adverse effects on water quality and no health hazards are known to have resulted from the extensive use of sludge in this project. In view of the very toxic nature of the AMD emanating from these mine sites and unfavorable weather that has occurred since reclamation began, it is concluded that rapid changes in the water quality of Contrary Creek cannot be expected. It will probably be several

Table 2. *pH and Metals Content in Soil at Sulphur Site (mg/kg-dry weight basis)**

Area and Date	*pH*	*Cu*	*Fe*	*Mn*	*Zn*
Sulphur East					
11-76	*5.5*	*8.6*	*4.2*	*31*	*18.8*
3-78	*7.3*	*0.3*	*6.2*	*0.5*	*0.1*
3-79	*5.9*	*0.3*	*3.6*	*1.9*	*1.2*
2-80	*5.2*	*0.2*	*0.8*	*1.7*	*3.4*
Sulphur West					
11-76	*4.1*	*50*	*30*	*74*	*262*
6-77	*3.1*	*62*	*34*	*17*	*82*
3-78	*5.1*	*0.1*	*7.8*	*6.8*	*6.6*
6-78	*5.9*	*1.0*	*24*	*3.6*	*1.5*
3-79	*4.5*	*3.2*	*7.6*	*6.4*	*28*
2-80	*4.9*	*0.2*	*0.4*	*2.6*	*3.4*

**Each analysis is for one composite sample collection. All samples were collected at depth of about 5 cm.*

years before any appreciable improvement in water quality is realized.

Biologic Studies

As part of the monitoring program, the SWCB conducted spring and fall biologic surveys annually to determine the status of aquatic life in Contrary Creek. The studies to date indicate that the virtual sterility of the stream existing for nearly 100 years has remained essentially unchanged within the relatively short time interval that has elapsed since reclamation began. There have been slight improvements in the benthic communities between the Boyd Smith and Sulphur Sites, but much of the stream in the affected area remains highly toxic to all but the most tolerant organisms.

Costs

The total cost of the project through the end of June 1980 was $295,334. A breakdown of cost figures appears in Table 3. On the basis of the total cost of reclamation and maintenance of 8 ha (19.8 acres) at the Boyd Smith and Sulphur Sites the cost of reclamation through June 1980 was $5,875/ac or $14,518/ha.

Due to the need for continued maintenance and project evaluation, a request was made to EPA to extend the project until 1982; the request was approved in October 1980.

Recommendations

A project of this type will require several years of maintenance to assure permanent survival of vegetation. Regular inspections are necessary to determine maintenance needs including reseeding of problem areas and placement of erosion controls. Soil tests should be conducted at least once annually to evaluate progress and to determine soil additives needed.

Whenever feasible, wastewater sludge should be used in the reclamation of lands severely affected by mine wastes. The positive effects that sludge has in promoting vegetative growth on highly toxic areas have been well demonstrated in this project. Large urban areas that generate huge volumes of sludge and have problems obtaining disposal sites are the likeliest sources.

The ongoing water quality monitoring program associated with this project should continue with stream stations sampled monthly for at least one year, and then on a quarterly or semi-annually basis for a few more years. Biologic studies should continue at least biennially.

Table 3. *Summary of Project Costs-July 1975 through June 1980*

Federal funds		Costs, $
Reclamation-1976		*65,709*
Maintenance-1977-80 (inclusive)		*47,888*
Water quality study by University of Virginia		*16,465*
Aerial photography		*1,006*
Survey work		*890*
Draft of construction plans		*80*
	Subtotal	*132,038*
SWCB matching funds		Costs, $
Personnel		*98,109*
Fringe Benefits		*22,565*
Travel		*8,229*
Lab Analyses		*28,023*
Lab Equipment		*5,105*
Photo Supplies		*361*
Miscellaneous Supplies		*683*
Bid Advertisement		*194*
Easement Recording		*27*
	Subtotal	*163,296*
Grand Total		*295,334*

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R. D. Hill *was the EPA Project Officer (for information contact* ***R. C. Wilmoth,*** *see below).*

The complete report, entitled "Reclamation of Toxic Mine Waste Utilizing Sewage Sludge—Contrary Creek Demonstration," (Order No. PB 82-227 521; Cost: $25.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

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