RECLAMATION PLANS FOR ABANDONED MILL TAILING IMPOUNDMENTS IN THE SOUTH FORK COEUR D'ALENE RIVER BASIN

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ABSTRACT

Water pollution resulting from nearly a hundred years of continuous mining activity along the South Fork of the Coeur d'Alene River continues to be a problem. Although recent efforts by local mining companies and government agencies have greatly reduced contaminant levels in streams throughout the valley, a perennial source of "background" pollution remains which is not associated with currently active mining operations.

This report presents the results of a study of potential water quality problems from abandoned flotation tailing impoundments and offers specific reclamation plans designed to minimize water quality degradation. A summary of current reclamation technology is presented, followed by field studies of three abandoned impoundment sites. An inventory of all abandoned tailing impoundments in the South Fork basin was conducted. Based on the field studies and inventory of all sites, a number of factors important in site abandonment were identified and categorized as either physical, chemical, or aesthetic. Classification of each site with respect to the identified factors was then possible.

A general reclamation plan was drafted which deals with each of the identified factors important in site abandonment. Application of the general reclamation plan to each of the sites listed in the abandoned impoundment inventory ends the report. It is concluded that the major problems posed by the abandoned tailing impoundments are physical rather than chemical. Movement of fine-grained tailing material directly into the surface streams appears to be a more serious problem than chemical leaching of heavy metal ions from the abandoned tailing impoundments into ground water flow systems.

INTRODUCTION

Water quality problems associated with mining activity in the watershed of the South Fork of the Coeur d'Alene River in northern Idaho have been of public concern for nearly a century (Ellis, 1940). Advances in milling techniques and increasingly stringent federal water quality regulations have combined to reduce the concentrations of heavy metals and high sediment loads in area streams significantly in recent years. Recent improvements in quality are the result of concentrated efforts at eliminating point source pollution from active mine and mill sites. A "background" level of heavy metals and sediments carried by the South Fork remains a problem, however, and this paper is part of an attempt to formulate reclamation plans to treat the diverse sources of this relatively low-level water quality problem.

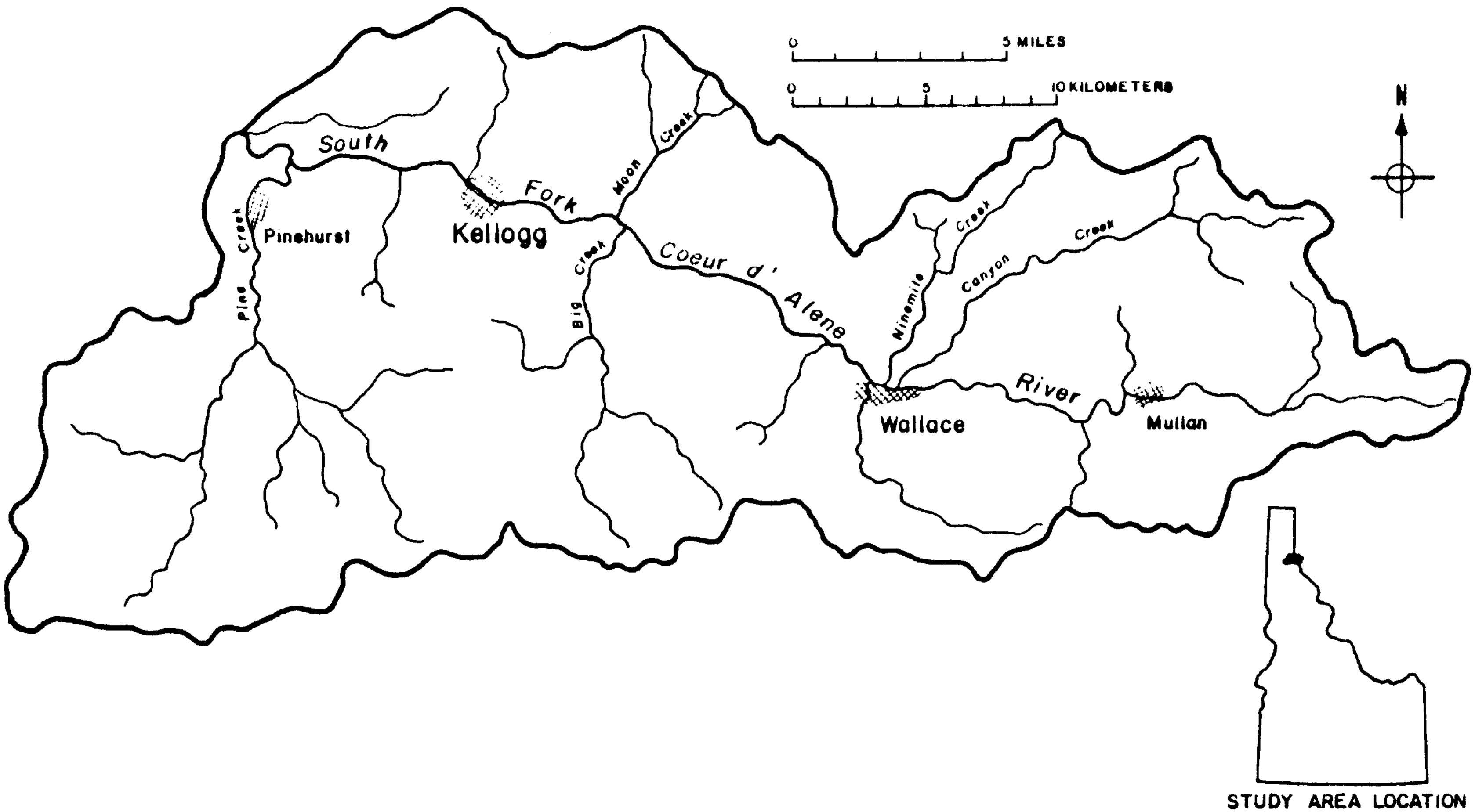
Authorization

This paper is part of a final report prepared for the Idaho Department of Health and Welfare, Division of the Environment, as the technical portion of their "Demonstration Control Program for Reclamation of Abandoned Mine Tailings." Research was financed through a grant from the U.S. Environmental Protection Agency under Contract No. 68-01-4352.

Scope

This report examines the extent of water quality degradation resulting from abandoned tailing impoundments in the basin of the South Fork of the Coeur d'Alene River (Figure 1). A survey of current technology in abandoned tailing reclamation is presented, followed by a

Figure 1.
South Fork Coeur d'Alene River Basin



description of detailed field studies of several abondoned tailing sites which were selected with the cooperation of representatives of the mining industry. Data from these detailed studies and a basin-wide inventory of abandoned tailing impoundments were used to identify factors which control physical and chemical transport mechanisms for pollutants after site abandonment as well as certain esthetic factors important in reducing the visual impact of a tailing dewatering facility. Each site is then classified according to the factors identified in the detailed investigations. Individual descriptions of sites and chemical analysis of tailing samples are compiled in the Appendices. Presentation of a general reclamation plan follows the site classification section.

Previously identified factors important in preventing water quality degradation after abandonment are used in the formulation of alternative reclamation procedures for a wide range of abandoned tailing site conditions within the basin. Each identified tailing site is then examined relative to the general plan and specific reclamation procedures are recommended on a site-by-site basis. A brief summation and conclusions complete the report.

Definitions

Several terms in this report require stated definitions. They are listed below.

1. The word tailing is a plural noun referring to the solid portion of the slurry waste product discharged by an ore concentrating mill. It is used with an ending s only when reference is made to the waste products of two or more milling operations.

2. The _slime_ portion of a tailing slurry is that fraction of solid material which would pass through a size 200 U.S. Standard Sieve. This corresponds to a maximum grain size of 0.074 millimeters.
3. _Controlled_ tailing is mill waste material which originally was deposited behind protective embankments or discharged in some other manner designed to keep the waste material from being carried away by stream erosion.
4. A tailing _impoundment_ is a facility to contain the tailing material for dewatering purposes. Generally these are settling basins with a structure to decant clarified water.
5. _Abandoned_ tailing impoundments, for the purpose of this study, are those dewatering facilities which have not received tailing from a mill on a regular basis for at least one year.
6. After abandonment, water gradually leaves the impounded tailing material. Such a dewatered mass of tailing material is often termed a tailing _pile_.

PURPOSE AND OBJECTIVES

The purpose of this study is to develop reclamation plans to minimize water quality degradation from abandoned tailing piles in the Coeur d'Alene Mining District. This is to be accomplished through the formulation and evaluation of reclamation plans for selected "controlled" tailing piles within the South Fork, Coeur d'Alene River basin. Specific objectives for the study are:

1. To use field studies of selected individual abandoned tailing sites to develop criteria for formulating a general reclamation plan for abandoned tailings in the District;
2. To determine the physical factors controlling the transportation of contaminants from abandoned tailing piles;
3. To determine the chemical factors controlling the transportation of contaminants from abandoned tailing piles;
4. To delineate esthetic factors pertaining to the over-all reclamation of abandoned tailing piles;
5. To compile an inventory list of all abandoned "controlled" tailing sites in the South Fork basin and classify sites according to identified physical, chemical and esthetic factors;
6. To develop a general reclamation plan for abandoned tailing sites in the Coeur d'Alene District;
7. To apply the general reclamation plan to specific sites selected for detailed study; and
8. To apply the general reclamation plan to other abandoned tailing sites throughout the South Fork basin.

STATEMENT OF THE PROBLEM

History of Mining Activity Along the South Fork

Initial development of the great silver and lead deposits in the Coeur d'Alene Mining District began in 1884 with the opening of the Tiger-Poorman Mine at Burke on Canyon Creek. New discoveries along the South Fork, particularly the Bunker Hill and Sullivan properties on Milo Creek, caused a rapid increase in the population of the basin and ushered in an era of mining development which has continued uninterrupted to the present. Concentrators were rapidly put into service. By 1887, both the Tiger-Poorman and the Bunker Hill mills were operating, followed closely by major concentrators at the Standard, Morning, Helena and Frisco, Mammoth, and Last Chance properties. A number of smaller concentrators were also in service and supported thriving communities at places like Burke, Frisco, Black Bear, Wardner, Gem, Wallace and Mullan (Hawley, 1920). The total number of mines and concentrators operating in the District fluctuated greatly over the years according to the many factors which govern the economics of hard-rock mining. The number of operating mills reached a maximum of 30 in 1943, when demands for metals to aid the war effort were at a peak (Campbell, 1943). Mining and milling activity in the South Fork basin (See Figure 1.) was divided geographically into five districts: Evolution (at Osburn), Hunter (at Mullan), Lelande (Canyon Creek, Burke), Placer Center (at Wallace and Ninemile Creek) and Yreka (at Kellogg and Pine Creek). The East Fork of Pine Creek was the scene of intense development in the 1940's and early 1950's.

Milling Practices

From the beginning of development of the Coeur d'Alene Mining District in the 1880's to 1928, the "jig" method of ore concentration was used almost exclusively (Mink, 1971). A mechanical gravity concentration process, jigging was a relatively inefficient method and produced waste rock particles ranging from microscopic to one inch in size (Norbeck, 1974) which were discharged into local streams and ultimately mixed with alluvium along all major streams in the basin. Zinc was not recovered at all in the early years of the District, but passed through the milling process as waste. High concentrations of the metal in valley floor alluvium are present in several locations (Williams and others, 1973).

Selective froth flotation, the successor to jigging as the prominent ore separation process, made an appearance in the Coeur d'Alene District around 1916 (Mink, 1971). The process involves fine grinding of ore, the formation of slurry with water, and subsequent treatment with a series of chemical reagents to "float" various metals from the ore. Remaining slurry material is then discharged as mill tailing (Fuerstenau, 1962). This flotation tailing is much finer and more uniform in size than that from the primitive jig process. A large percentage of the material discharged directly into streams was carried as suspended sediment and deposited on the Coeur d'Alene River delta in Coeur d'Alene Lake (Maxfield and others, 1974).

Awareness of a Pollution Problem

The heavy sediment load in the Coeur d'Alene River system was the first pollution problem from mining activity to receive attention. As early as 1904, pressure from downstream water users caused the mining companies to erect several piling-and-plank dams across the South Fork or its tributaries in an attempt to reduce suspended solids (Zeigler, 1943). Ellis (1932) found that sediments deposited near Medimont (approximately 15 miles (25 kilometers) below the confluence of the North and South Forks) had reduced channel depths from 50 feet (15 meters) to 12 feet (3.7 meters) in the first fifty years of mining activity.

Ellis also performed various experiments attempting to reintroduce aquatic life to the Coeur d'Alene River, discovering that the silt-laden waters of the South Fork and several tributaries were extremely toxic. Savage (1970) described the effects of pollution on invertebrate bottom life in the South Fork. She concluded that siltation was the main limiting factor preventing the establishment of macro-invertebrate colonies in the South Fork and that zinc ion concentrations during low flows were high enough to be toxic.

SUMMARY OF CURRENT TECHNOLOGY IN ABANDONED TAILING RECLAMATION

Recent water quality legislation and regulations directly affecting mining operations have fostered a number of research efforts dealing with physical and chemical stabilization of mining-impacted areas. Use of mill tailing impoundments became mandatory in 1968 following water-quality legislation. Many of the original tailing impoundments have reached design capacity, and several mining companies are facing decisions regarding the ultimate abandonment and reclamation of these original impoundments.

Four major types of action are considered in dealing with tailing pile abandonment: (1) physical stabilization to prevent erosion of tailing material; (2) chemical stabilization of tailing deposits to reduce acid formation and/or leaching and transport of metals; (3) remedial measures which may be conducted away from the tailing site to correct adverse effects of the tailing; and (4) alternative uses of tailing material which either remove the problem source or render it insignificant.

Physical Stabilization

Martin and Mills (1976) describe the various options available in stabilizing milling wastes, including covering with rock or less easily eroded soil, application of chemical compounds which harden to form impermeable crusts, and vegetative stabilization. Crust-forming chemicals are not as permanent a solution as rock cover or vegetation, but are effective in reducing erosion by wind and water in regions with harsh climatic conditions or deposits containing toxic materials.

Vegetative stabilization of tailing piles has received much attention in the past ten years, as can be seen by the number of articles on that subject included in the two volumes of Tailing Disposal Today by Alpin and Argall (1973) and Argall (1979). Various soil treatments and vegetation species are examined in these publications. Williams (1975) also deals with specific costs of reclamation techniques. Perhaps the most comprehensive source available for information on plant species and their success on tailing surfaces is provided by Donovan and others (1976). Their section on lead-zinc tailing is not completely applicable to the Coeur d'Alene Mining District, however, because the soil properties described represent tailing from ores found in limestone and dolomitic limestone in Missouri and Tennessee. These tailings are described as containing abundant calcium, which makes them valuable agricultural soil conditioners. The predominant host rock in the Coeur d'Alene District is quartzite, and the calcium content of tailing is very low compared to that exhibited by the Missouri lead-zinc ores.

Normal vegetative stabilization procedures begin with some type of soil conditioning to insure plant survival, then hydroseeding or hand planting of species native to the area or known to succeed in similar environments. Irrigation may be necessary to encourage initial plant growth, but species requiring continued application of irrigation water are contrary to the objective of maintenance-free abandonment. Bengson (1979) discusses the advantages of drip irrigation in vegetative stabilization. Poor control of irrigation facilities can result in erosion of the fine-grained tailing by escaping water.

Chemical Stabilization

Current technology for the chemical stabilization of mill wastes which have potential for metals leaching and acid formation is limited to three alternatives: (1) infiltration control, or surface sealing; (2) diversion of surface or ground waters around the site; or (3) placement of the wastes in an oxygen-free environment.

Infiltration control is accomplished through the use of a number of different sealing agents such as chemical soil sealants, synthetic membranes and clay blankets (Martin and Mills, 1976; Williams, 1975). These materials also retard or prevent erosion by wind and precipitation, but are not always adequate to provide maintenance-free protection for an abandoned tailing site. Clay blankets and chemical soil sealants tend to crack, reducing their effectiveness, and synthetic membranes are subject to puncture and possible deterioration because of solar radiation.

Diversion of surface and ground waters around a dangerous tailing pile removes the transport mechanism which is responsible for the continued supply of poor-quality water to surface streams. This procedure cannot prevent oxidation of pyrite or other sulfide ores, but can prevent the oxidation products from leaving the source area. Martin and Mills (1976) describe several alternate methods for preventing contact with tailing by surface waters, including: (1) stream channel relocation; (2) use of conveyance structures such as culverts or channels; and (3) construction of diversion ditches on hillsides similar to those used to protect highway cuts from erosion.

Isolation of acid-forming material in pits to be backfilled is a common technique in surface coal mine reclamation (Doyle, 1976). Spoil containing pyrite is placed in a portion of a pit which will be below the water table after abandonment. This saturated environment severely retards oxidation of the iron sulfide molecules (Marcy, 1979). This technology could be applied to abandoned tailing piles, but would involve relocation of the acid-forming material to a site which would be (1) located below the water table permanently, or (2) lined with impervious material to prevent leakage and maintain a saturated condition throughout the pile.

There appears to be no developed technology for the application of chemical buffering agents to an abandoned tailing pile to permanently prevent acid formation and metals leaching.

Alternative Uses

Clearly the best reclamation alternative for abandoned mill tailings is the use of such material in a beneficial way. Much research has been done on the application of tailing material as mine backfill. Williams (1975) describes the mechanisms and benefits of using tailing as backfill, and several articles in Alpin and Argall (1973) relate using both the coarse and fine fractions of tailing as backfill. Most work in this area has involved only the coarse (sand) fraction of tailing from active mills due to the ease of dewatering the coarser material and the convenience of installing cyclones for size separation at the mill outflow point. A truly abandoned, flooded mine could provide a safe repository for much abandoned tailing material, but valid arguments over the "abandoned" or "orphaned" status of any mine usually make such a proposal unfeasible.

Use of tailing as a construction material is another beneficial use for former waste products. Pettibone and Kealy (1972) reported on the application of lead-zinc mill tailing in highway embankment construction in the Kellogg area. Guerra (1973) reports other uses of tailing with proper engineering properties.

Using an abandoned tailing pile itself as a location or base for a secondary land use is a concept which has not received much attention. In steep mountain valleys where level land is at a premium, tailing disposal sites can be expensive to acquire as well as construct. Combining two such large-scale land uses on one site has obvious advantages. A regional waste water treatment plant was recently constructed on a 70-acre (28 hectares) abandoned tailing pile along the South Fork, Coeur d'Alene River, thus combining two esthetically displeasing land uses which require much flat land. Hitt (1974) describes properties of the abandoned pile relative to its suitability as a base for the treatment facility. Other second-generation uses for sufficiently stabilized and chemically safe abandoned piles might include parks, commercial building space, or even housing projects.

Remedial Measures

Reclamation procedures which are designed to treat the effects of tailing site abandonment rather than attack the cause of those effects are typically expensive and require periodic maintenance. Sedimentation basins can be constructed to reduce the turbidity of runoff water from one or more abandoned tailing sites (EPA, 1975), but these basins must be dredged periodically to remove accumulated sediment, and this collected sediment itself presents a disposal problem.

Collection and treatment of poor-quality surface water is an expensive alternative and should be avoided if possible. Williams (1975) discusses a variety of treatment schemes for acid water and high metals concentrations resulting from mining and milling activities.

FIELD STUDIES OF SELECTED SITES

Site Selection

During the planning stages of this project, representatives of the mining industry who served as a technical advisory committee were asked to suggest abandoned tailing sites which could be used for detailed study. Sites were requested which would be available for piezometer installation, water quality sampling, and chemical analysis of tailing materials during the summer of 1977. The Lucky Friday Impoundment No. 1 near Mullan and the Galena Impoundment No. 3 on Lake Creek near Wallace were offered as study sites. Both were constructed in 1968 and represent the first tailing sites of the modern type to be abandoned in the Coeur d'Alene District. A third site, the Page tailing impoundment, is presently under the ownership of the South Fork Coeur d'Alene River Sewer District. This pile had been the subject of previous studies by Galbraith (1971), Hitt (1974) and Morilla (1975) at the University of Idaho, and much data on the pile's hydrology and chemistry had already been gathered. Field study of the three sites began in June of 1977 with the measurement of water levels in existing piezometers and the installation of piezometers in the sites which lacked ground water monitoring equipment.

The Lucky Friday and Galena sites are more characteristic of the modern active tailing sites than of the remainder of the abandoned sites identified in the basin-wide inventory. They exhibit compacted mine waste-rock embankments, perimeter tailing discharge points, and decant systems. Both are constructed against hillsides, with ponded water kept against the hill and away from embankments. Both are considered for further tailing deposition, and are capable of being expanded. The Page impoundment is located on level ground, has embankments on all sides, and serves as a base for a modern sewage treatment plant.

The Page site had a central tailing discharge point and no embankments for at least the first 10 years of its existence. The majority of abandoned controlled tailing sites inventoried were smaller in volume, less protected from weathering and erosion agents, and much less carefully designed and constructed than the sites selected for detailed study. Utilizing the benefit of hindsight, it would perhaps have been better to substitute an example of this more primitive construction for one of the modern sites studied.

Luck Friday Impoundment No. 1

Location

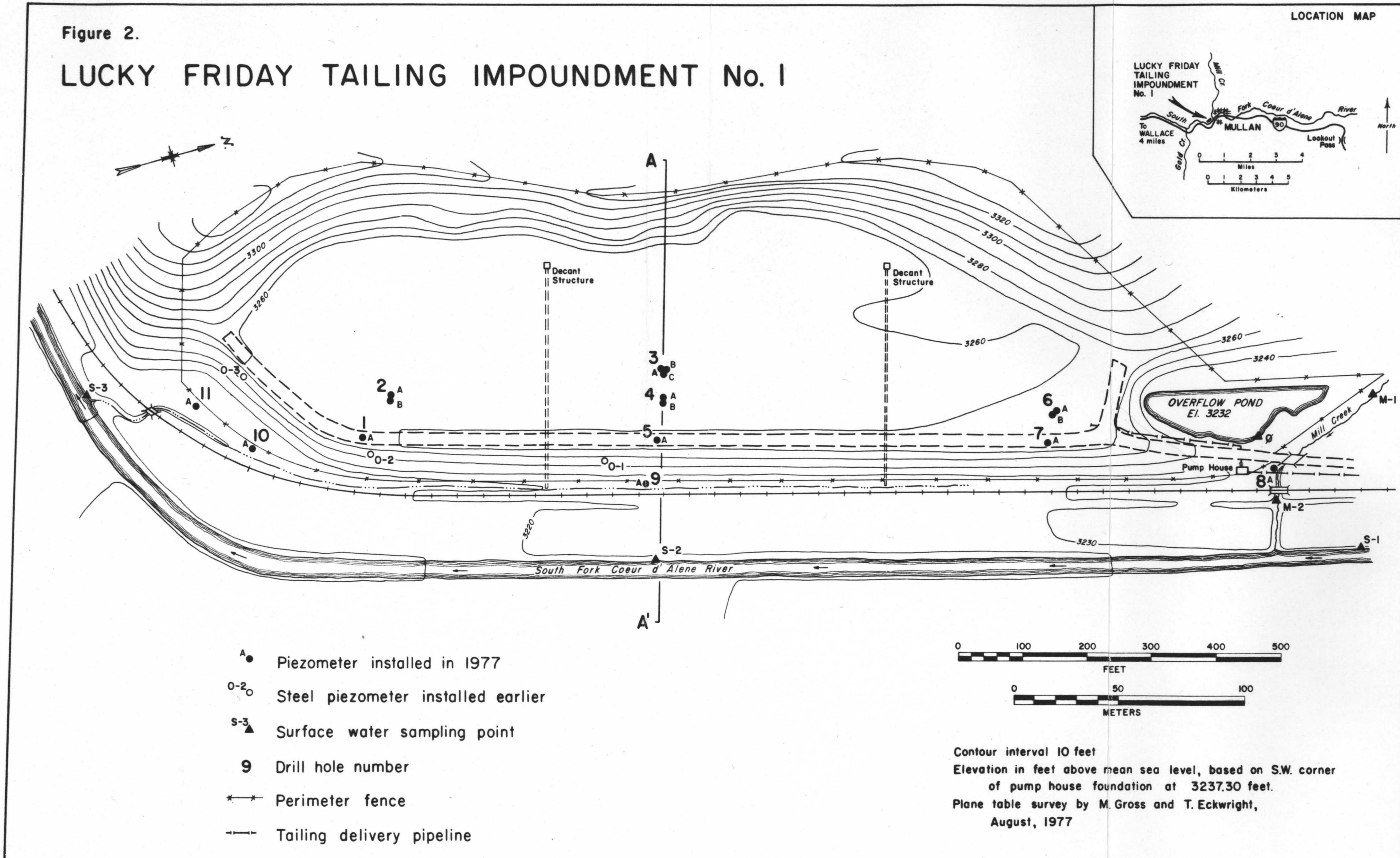
The Lucky Friday No. 1 tailing impoundment is located approximately 1/4-mile (0.4 kilometer) west of the town of Mullan near the mouth of Mill Creek (Figure 2). The Burlington Northern Railroad track runs the length of the pile and separates it from the South Fork of the Coeur d'Alene River, which flows parallel to the tracks. The pile is easily visible from Interstate Highway 90 west of Mullan and from the town itself.

History

Mining Operation. The history of the Lucky Friday mine began in 1899 with registration of several mining clams just east of the town

Figure 2.

LUCKY FRIDAY TAILING IMPOUNDMENT No. 1



of Mullan. The property went through a period of unsuccessful development attemps prior to 1938, and twice was sold to satisfy labor or tax claims, once for the meager sum of $120. The formation of the Lucky Friday Silver-Lead Company in 1939 signalled the beginning of a program of construction and property acquisition which made the Lucky Friday one of the District's top silver and lead producers. In 1958, Hecla Mining Company took over management of the mine and immediately began construction of a new mill, surface plant, sand-fill system and various underground improvements, all of which were completed by 1961. Prior to completion of the Lucky Friday mill, all ore from the mine had been processed at the Golconda custom mill, which ceased operation as soon as the new facility was ready (Featherstone, 1963). Shipments to the Golconda had been averaging 180 tons per day, and the new mill, which is still in operation, has a capacity of 500 tons per day. Tailing sand-fill has been used in the mine since completion of the mill in 1960, and was estimated in 1977 to be in operation approximately 70 percent of the operating time of the mill (McKee, 1977).

Tailing Pile. Lucky Friday Tailing Impoundment No. 1 was constructed in 1968 to satisfy water quality standards for point-source discharges which were put into effect by Environmental Protection Agency regulations. It was conceived as a settling pond to remove the majority of suspended solids from the tailing being discharged from the mill before releasing it ultimately into the South Fork just below Mullan. The original embankments were constructed of compacted basin scrapings to a maximum height of approximately 25 feet (8 meters). Two decant lines ran perpendicular to the long axis of the impoundment from decant towers near the hillside and exited the impoundment beneath the embankments. These pipes discharged into a ditch between the embankment toe and the railroad tracks.

Capacity of the impoundment was enlarged in 1972 with the raising of the embankments 10 feet (3 meters). Construction material was compacted mine waste rock. Another raising of the embankments using the upstream technique (McKee, 1977) and compacted waste rock was accomplished in 1975, resulting in the present maximum embankment height of 45 feet (15 meters) (Dames and Moore, 1977).

Because the tailing site is located approximately 1.5 miles from the mill a wood-stave pipeline was used to carry tailing through the town of Mullan to a pumping station at the east end of the pile, where it was lifted to the embankment and discharged from a moveable pipeline. An overflow pond at the east end of the pile was constructed to contain reverse flow in the tailing delivery line when pumping was halted.

Discharge of tailing onto the pile was made from the embankment, keeping ponded water as near the adjoining hillside as possible. Tailing near the embankments are therefore relatively more coarse than the material near the hillside, and hydraulic conductivity of the pile is also expected to be much higher near the embankments. During periods in which no sand-fill was being used in the mine, all tailing discharged from the mill was deposited on the pile. This resulted in the interbedding of layers of coarse material with thicker slime units in the zone between the discharge points and decant towers. The presence of these coarser layers supports the theory that the horizontal hydraulic conductivity in the middle portion of the pile is higher than the vertical.

Maximum capacity of the site at the present embankment height was reached in the summer of 1976, and the pile was considered inactive. A new impoundment had been constructed nearer the mill, and no plans then existed for an extension of the No. 1 embankments. Irrigation pipe and sprinklers were installed on the embankment, and hay was spread on portions of the tailing surface to aid the growth of grasses which were planted there in an effort to reduce the problem of blowing dust. Trees had already been established along the toe of the embankment, and a good growth of varied vegetation was present on the lower half of the slope and on top of the compacted-rock embankment.

The upper half of the slope was essentially unvegetated, and represented the most recent dam extension. Sand-size tailing had apparently been dumped down the slope to provide soil to cover the bare mine waste rock. This tactic was not successful because of the non-cohesive nature of the sandy tailing, which immediately began to move downslope and could not provide a stable footing for plant growth.

Construction began in the fall of 1977 on a ten-foot (3 meters) embankment lift of the Lucky Friday Tailing Impoundment embankment. Two future lifts of similar size are proposed and will be constructed when the recently enlarged tailing storage space is exhausted. This illustrates the temporary nature of "abandonment" as it relates to the mining industry. Although the impoundment had not received tailing on a regular basis for over a year, other sites for tailing disposal became filled or unavailable, leaving the enlargement of an existing older facility as the only economically feasible action available.

Geology

Mine Geology. Precambrain Belt series matamorphosed sediments of the St. Regis and Revette formations compose the rocks of the Lucky Friday mine. These rocks are mostly quartzitic in the vicinity of the ore body, which is predominantly high-grade galena, with subordinate amounts of tetrahedrite, sphalerite, pyrite and chalcopyrite (Hutchinson, 1961).

Tailing Pile Area. Lucky Friday tailing impoundment No. 1 is constructed on alluvium of recent age, composed of gravel, boulders, sands and clays deposited and reworked by the South Fork and Mill Creek. The pile is situated against a small ridge of St. Regis Formation which projects into the floodplain of the South Fork and constricts the valley just west of the town of Mullan, Idaho. Mill Creek joins the South Fork near the east end of the pile. "Jig" tailings and other milling wastes are present in the alluvium beneath the pile and therefore in the initial embankment.

Hydrology

Surface Hydrology. The Lucky Friday No. 1 tailing impoundment is located in a steep mountain valley at an elevation of 3,200 feet (975 meters). Much of its approximately 50 inches (127 cm) of annual precipitation falls as winter snow. The tailing pile has a surface area of approximately 8.5 acres (3.4 hectares), and the southeast slope of the ridge above the pile adds another 4 acres (1.6 hectares) to the closed catchment basin formed by the pile's embankment. Two decant towers provide the only outlet for ponded surface water, but evaporation and infiltration rates have been high enough to prevent accumulation of sufficient precipitation and runoff to allow discharge through the decant structures.

Railroad tracks and a buried municipal sewer line separate the pile from the South Fork of the Coeur d'Alene River. Mill Creek flows near the overflow pond embankments and then under the railroad tracks, joining the South Fork 300 feet (90 meters) east of the pile. Mill Creek was apparently diverted away from a southerly course along the low ridge to allow construction of the tailing pile.

Subsurface Hydrology. A series of test holes were drilled at the Lucky Friday site in June of 1977 to investigate the feasibility of raising the embankments and using the pile for further tailing disposal. Hecla Mining Company contracted with Dames and Moore to perform the necessary studies. The 8-inch (20 cm) boreholes drilled in the investigation were made available to the University of Idaho for installation of piezometers at various depths below the tailing surface. Additional piezometers were constructed at the Lucky Friday site as part of this investigation. Borehole and piezometer locations are indicated on Figures 2 and 3.

Dames and Moore placed one piezometer in each of the seven boreholes. These piezometers consisted of 2-inch (5 cm) diameter polyvinyl chloride (PVC) pipe with horizontal slot perforations approximately 3 inches (7.6 cm) apart along the lower twenty feet (6.1 meters) of the tube. Piezometers installed by this researcher consisted of 3/4-inch (1.9 cm) PVC pipe perforated with drilled holes along the lower foot (30 cm) of the tube and wrapped with several thicknesses of fiberglass window screening. Clean washed silica sand was used as backfill from one foot (30 cm) below the screened section to a foot (30 cm) above. Approximately six inches (15 cm) of bentonite was placed immediately above the sand backfill and again at the tailing pile surface. Three steel piezometers (designated O-1, O-2 and O-3) were already in place on the outside slope of the compacted embankment (Figure 2). A list of piezometers used in this investigation is presented as Table 1.

Comparison of static water level elevations in piezometers soon after installation revealed the presence of a ground-water mound within

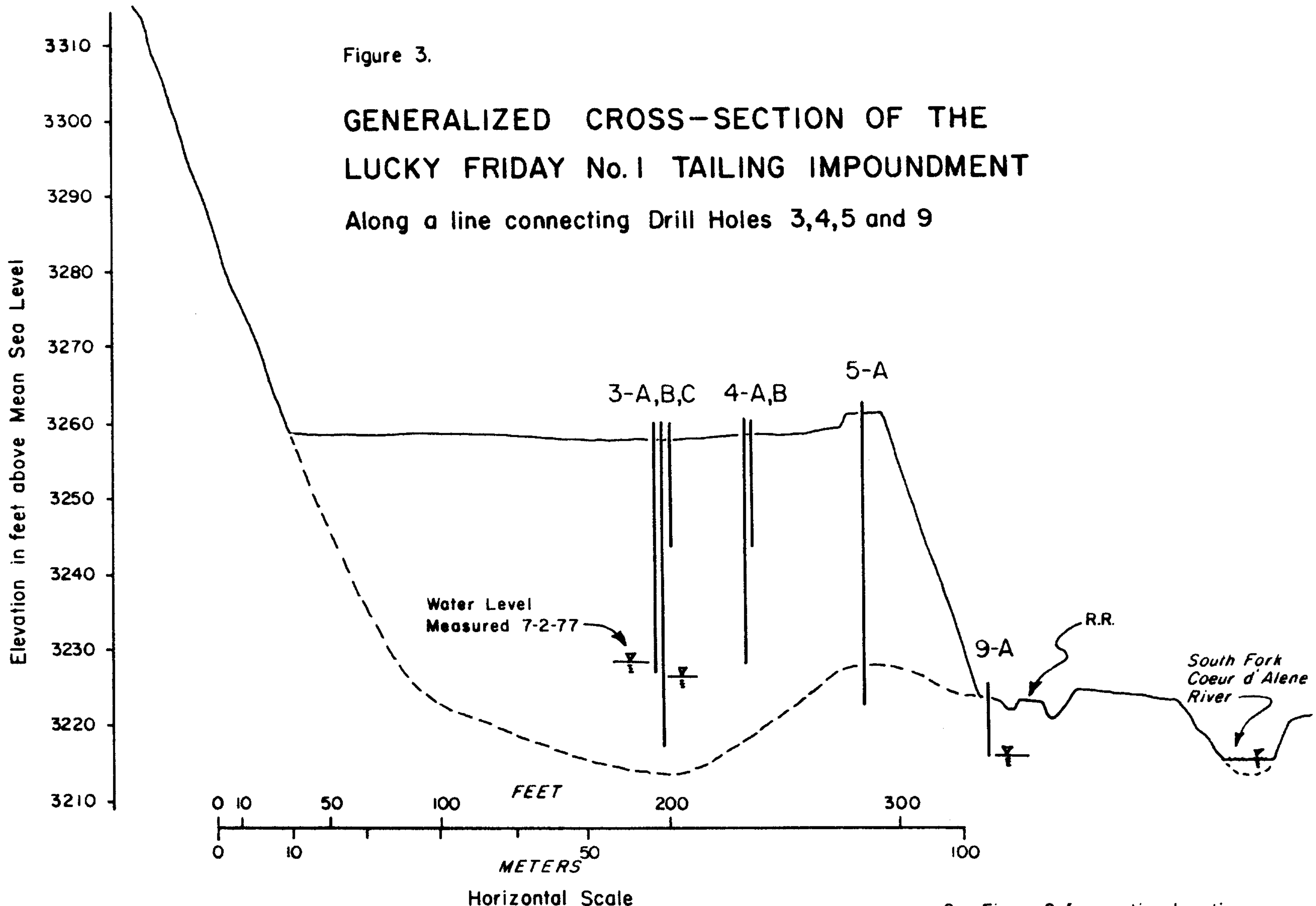


Figure 3.

GENERALIZED CROSS-SECTION OF THE LUCKY FRIDAY No. I TAILING IMPOUNDMENT

Along a line connecting Drill Holes 3,4,5 and 9

See Figure 2 for section location.

Table 1

Piezometers Installed at Lucky Friday Tailing Impoundment No. 1

Piezometer Tube No.	Date Installed	Date Lost	Tube Diameter, Material	Tube Length (feet)	Tube Bottom Elevation (feet above sea level)
0-1	?		2" steel	22.0	3228.4
0-2	?		2" steel	22.0	3226.3
0-3	?		2" steel	24.9	3221.5
1-A	6-19-77		2" PVC	49.6	3211.8
2-A	6-19-77		2" PVC	46.0	3216.3
2-B	6-19-77		3/4" PVC	21.1	3242.0
3-A	6-20-77		2" PVC	39.8	3221.5
3-B	6-20-77		3/4" PVC	45.8	3216.0
3-C	6-20-77		3/4" PVC	19.2	3242.1
4-A	6-20-77		2" PVC	34.2	3226.3
4-B	6-20-77		2" PVC	19.4	3242.1
5-A	6-21-77		2" PVC	39.6	3222.6
6-A	6-21-77		2" PVC	51.9	3214.2
6-B	6-21-77		3/4" PVC	39.8	3224.9
7-A	6-21-77	11-26-77	2" PVC	42.4	3221.1
8-A	8-14-77	10-1-77	3/4" PVC	7.3	3228.6
9-A	8-15-77	10-1-77	3/4" PVC	11.2	3213.9
10-A	8-16-77	10-1-77	3/4" PVC	9.4	3205.2
11-A	8-16-77	10-1-77	3/4" PVC	6.9	3206.2

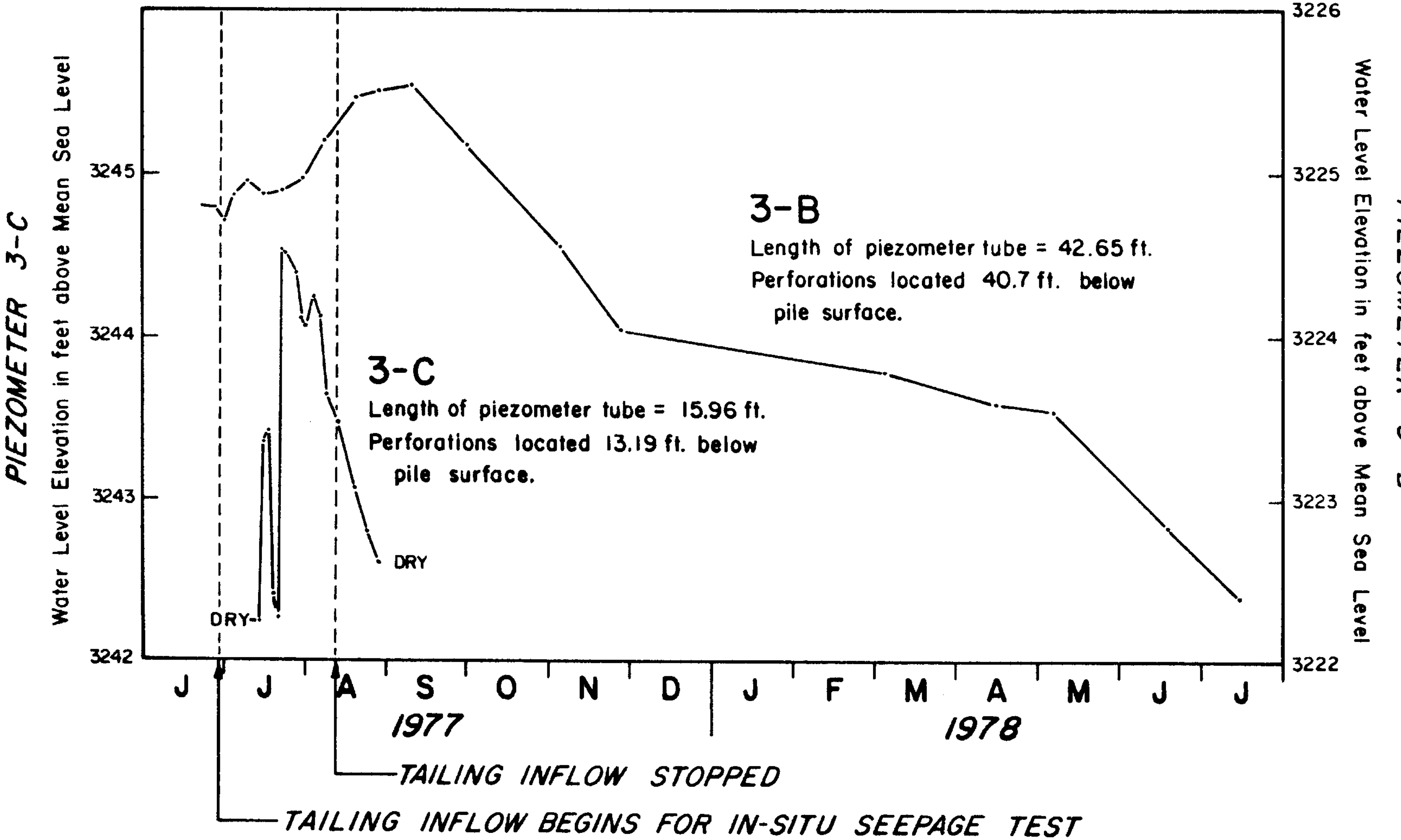
the abandoned tailing impoundment. Piezometers placed nearer the interior of the tailing pile surface exhibited depths to water of 31 feet (12 meters) to 41 feet (16 meters) below ground surface. Boreholes 1, 5, and 7 were in the dike material and penetrated beyond the bottom of the original 1968 embankment to depths between 42 feet (16.5 meters) and 50 feet (19.7 meters) below ground surface. None of the piezometers installed in these holes (1A, 5A, and 7A) reached the phreatic surface in the underlying alluvium. The position of the water table within and surrounding the tailing pile is shown diagrammatically in Figure 3.

Dames and Moore conduced an in-situ test for seepage at the pile by resuming tailing disposal and maintaining a pool water level near the ground surface elevation at Borehole 3. This test was begun on June 30, 1977 and rendered further collection of data on "abandoned" condition ground water levels impossible. Water level data for all piezometers continued to be gathered under an agreement with Hecla Mining Company and Dames and Moore. Water level data were collected in all available piezometers at varying frequencies from June 16, 1977 through July 14, 1978. Daily measurements were recorded during the in-situ seepage test mentioned above.

Figure 4 shows responses in two piezometers at borehole 3 to the renewal of tailing disposal activity on the pile. Piezometer 3-B reaches the alluvium beneath the tailing pile and shows a delayed response to the flooding of half the tailing pile surface. Piezometer 3-C exhibits a much faster response and some irregularity which can probably be explained by the erratic movement of the tailing slurry as it meandered across the tailing surface toward the pool.

By ignoring the hydrograph peak caused by the in-situ test, a

Figure 4. GROUND-WATER HYDROGRAPHS FOR TWO PIEZOMETERS IN DRILL HOLE No. 3, Lucky Friday No. 1 Tailing Impoundment



general downward trend can be seen in the data from piezometer 3-B, indicating water continued to drain from the tailing pile after its abandonment. A muted seasonal water level fluctuation can be seen, with a high in April and lowest levels in December and January.

If the pile had remained truly abandoned, this cyclic downward trend would continue until the maximum gravity drainage of the tailing pile occurred. Seasonal fluctuation would have occurred, reflecting the small amount of annual recharge from precipitation to the pile and the general water level fluctuation in the underlying alluvium.

Analysis of early data indicates that much of the tailing in the pile was very wet even after a year of abandonment. Slimes brought to the surface by the auger were usually wet a few feet below the tailing surface, but some piezometers penetrating twenty feet (6 meters) of tailing slimes remained dry until well into the in-situ seepage test.

The presence of water within the pile does not pose structural or horizontal seepage problems. No evidence of post-abandonment seeps were found around the embankments, and the large percentage of sand-size tailing deposited along the compacted rock-fill embankment seems to keep the phreatic surface low in the dike area. Movement of water ponded on the surface would be down through the pile and toward the embankments, then into the permeable alluvial gravel and boulders underlying the site.

Water Quality. Sampling for water quality was accomplished at all piezometer sites containing water and six surface locations on August 21, 1977 and again on May 5, 1978. Samples were taken from piezometers by dipping with either plastic test tubes or a weighted aluminum cylinder. Readings of temperature, pH, and electrical conductivity were taken at the piezometer site prior to filtration and acidification. Surface-water samples were collected by dipping from a freely-flowing portion of the stream. Temperature, electrical conductivity and pH were measured in the stream at the sample site. Environmental Protection Agency suggested procedures were followed in the sampling and analysis of data from this and all other sites. Marcy (1979) provides a more detailed description of sampling and chemical analysis procedures.

Examination of surface water samples from streams above and below the tailing pile area showed no significant increases in metals as a result of the abandoned pile. Table 2 shows concentrations of zinc and manganese to be higher in ground water just outside the tailing impoundment than in ground water within the tailing material or in a stream adjacent to the site. These higher concentrations may be attributable to the

Table 2: Mean element concentrations in water, 8-21-77, Lucky Friday Tailing Impoundment No. 1
All figures in parts per million

Location	Fe	Mn	Ca	Mg	Cu	Zn	Cd	Pb	No. of samples
Surface water in adjacent streams	*	.05	14.7	4.3	*	.01	*	*	5
Ground water within tailing pile	*	.65	27.6	2.9	*	.26	*	*	6
Ground water in alluvium near pile	*	.48	48.6	4.9	*	.68	*	*	2

*Below detectable limits

presence of older "jig" tailing present in alluvium beneath and around the Lucky Friday No. 1 impoundment. No measureable amounts of iron were found in water within or surrounding the abandoned tailing site. Very little pyrite is found in waste rock on the embankments, and the weathered surface of the pile is clean and white. Chemical analysis of tailing and alluvium samples taken during drilling indicates that lead, zinc and cadmium concentrations in the alluvial material on which the impoundment was constructed are more than double the concentrations of those metals in tailing within the impoundment. Further data on tailing composition are given in Appendix C.

Evaluation of Abandoned Site Reclamation

Physical Conditions. The abandoned Lucky Friday No. 1 tailing impoundment is well protected against direct erosion by surface streams. Protective embankments of the pile are complete and structurally sound. The small tributary area above the pile surface and the relatively higher hydraulic conductivity of material closer to the embankments greatly reduce any danger of dike overtopping by collected surface runoff. Blowing silt is a problem on the unvegetated pile surface, and the dust reaches residences in Mullan.

Chemical Conditions. Tailing composition and water quality within the abandoned tailing impoundment and in nearby surface streams indicate that leaching of metals from tailing material is probably occurring at a rate which does not pose a threat to water quality in the South Fork. Ground water is moving down through the pile and into the alluvium, but the metals load is very small. Complete gravity drainage of the pile has not occurred. Nutrients necessary for adequate plant growth are apparently lacking on the pile surface. Growth of grasses has been successful where mulch, fertilizer, and irrigation have been applied.

Esthetic Conditions. The impoundment is highly visible, both to residents of Mullan and travelers on the interstate highway. Trees planted along the embankment toe have been very successful, and good vegetation is present on the lower half of the slope. Establishing plants on the section of embankment constructed in 1975 has not worked as well. It appears that there is not enough moisture-retaining topsoil to keep the grasses healthy.

Galena Tailing Impoundment No. 3

Location

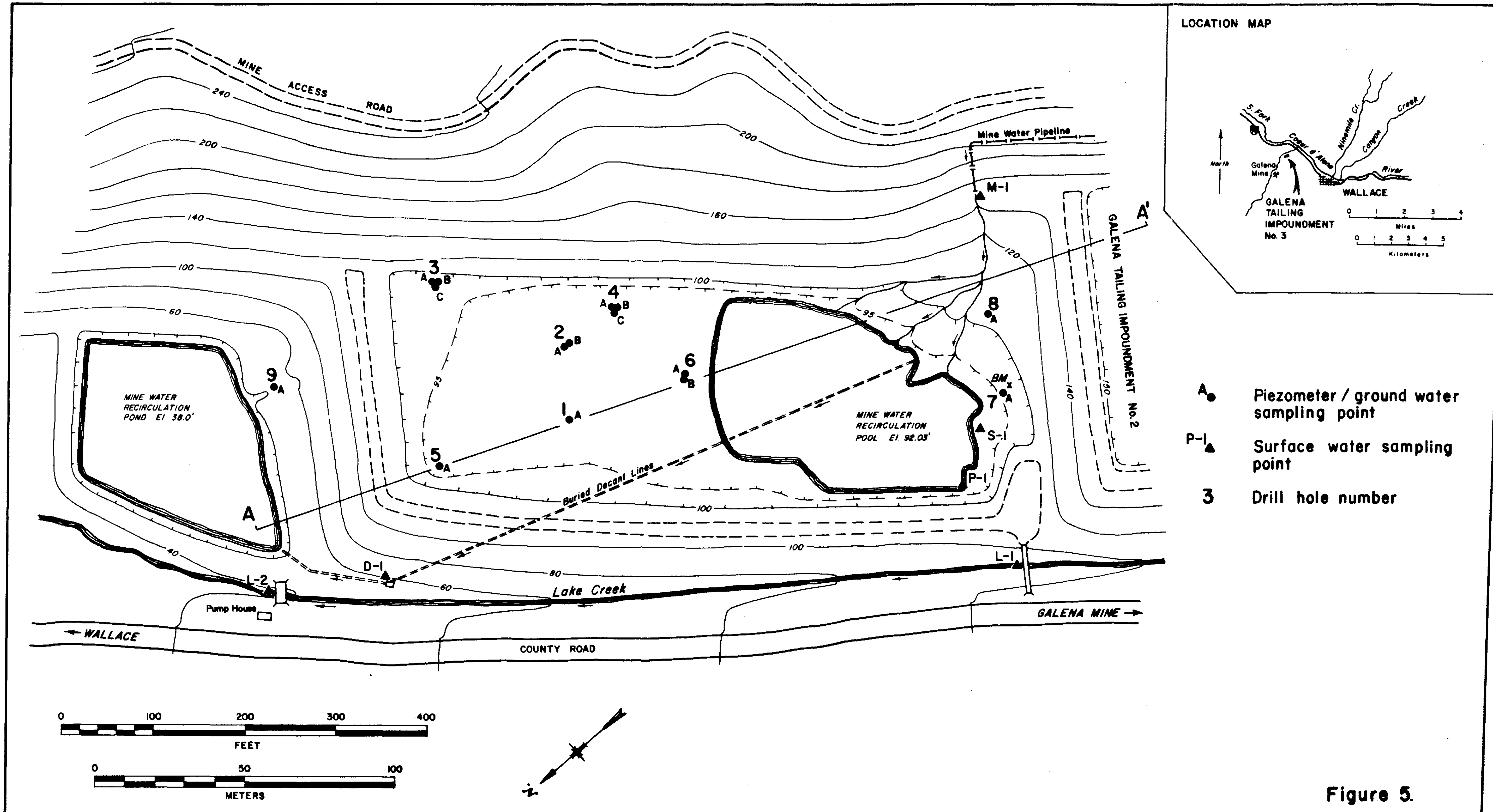
The Galena Tailing Impoundment No. 3 is the lowest in a series of three abandoned tailing impoundments constructed in the narrow valley of Lake Creek, a tributary of the South Fork Coeur d'Alene River. It lies approximately 1900 feet (580 meters) above the mouth of Lake Creek, 2.5 miles (4.2 kilometers) by road from Wallace and 3600 feet (1100 meters) downstream from the Galena mine and mill. See Figure 5.

History

Mining Operation. The Galena mine is one of the oldest mines in the Coeur d'Alene District, beginning near the end of the 19th century with numerous claims, but not showing any significant production until 1917. By 1946 the available resource had seemed exhausted, and a major program of shaft sinking and crosscutting was undertaken. Major ore bodies were discovered in 1951 and 1953. The property is owned by the Callahan Mining Corporation and is under long term lease to the American Smelting and Refining Company and Day Mines. ASARCO is the manager and operator of the facilities (Visnes, 1963).

Tailing Pile. The construction of Galena Tailing Impoundment No. 3 was described by McKinney (1977) as follows:

> Number three tailing dam was constructed in August 1968. All vegetation, timber and debris was removed from the area and a keyway 14 feet wide, 8 feet deep the length of the dike was excavated. The keyway was backfilled with plus 2-inch minus 10-inch rock. The dike was constructed in 12-inch lifts using run of mine waste rock, which is approximately 50 percent minus 2-inch, 100 percent minus 10-inch. A D-6 cat towing a grid roller was used to spread the fill and along with 10 yard dump trucks compacted the fill.



Topographic contour interval 20 feet
Elevations in feet above datum, defined as 100 feet below Bench Mark (nail in tree near Drill Hole No. 7)
Plane table survey by M. Gross, T. Eckwright, and M. Hall, October 1977.

Figure 5.

GALENA TAILING IMPOUNDMENT No. 3

> After the initial dike was built in 1968, ten-foot lifts were added in September 1970, October 1972, May 1973 and July 1976. Each lift was built in the same manner as the original dike. To insure proper decantation, two pipelines were placed through the dike and lengthened as the dam was filled with tailing. The decant lines are made from sections of 12" X 5' class III reinforced concrete pipe. The pipe has a bell on one end which is used for joining the pipe. In an effort to guard against leaking at the joints, each joint is filled with oakum, wrapped with twelve courses 2-feet wide of ten ounce burlap and finally wrapped with twelve gauge galvanized wire to secure the burlap.

The tailing piles along Lake Creek sustained heavy damage during the flooding on January 15, 1974 that caused $31 million in damages in northern Idaho (North Idaho Press, 1974). Major failures of several compacted waste-rock embankments occurred, including those of Impoundment No. 3, and tailing material was spread across the lower portion of the Lake Creek valley to the highway which parallels the South Fork. Direct cause of the failure was the overtopping of a temporary diversion dam near the mill site by rapidly rising flood waters. The channel beside tailing impoundment No. 1 was insufficient to control the sudden volume of water released when the temporary dike failed, and a large portion of the flood entered the series of tailing structures. This surge of flood waters and tailing destroyed a large section of the county road along Lake Creek, and the Galena mine was isolated for several days (Erskine, 1977).

No tailing has been deposited in Impoundment No. 3 since the last ten-foot lift of the embankment was accomplished in July 1976. A constant-level pool of mine drainage water has been established on the pile surface using the existing decant system to carry water to another reservoir below the pile.

Topsoil was placed on the embankment top and outside slope. The area was seeded with a variety of grasses and clover, then covered with

¼-inch (6.5 mm) mesh erosion control netting. Also, 800 pine and fir seedlings were planted around the area (McKinney, 1977).

Geology

Mine Geology. The Galena mine produces ore from two distinct ore body types within the Revett and St. Regis formations of the Belt series metasediments. The Lead Zone yields mostly argentiferous galena, with quartz as the principal gangue material. Most production from the Galena mine, however, has been from the Silver Vein, which contains argentiferous tetrahedrite, chalcopyrite and pyrite. Siderite is the most abundant vein gangue, with some quartz. Both zones of mineralization are closely associated with the Polaris Fault which is roughly parallel to the dominant Osburn Fault and bisects the property (Keston, 1963).

Tailing Pile Area. Galena Tailing Impoundment No. 3 is constructed against the east wall of the steep and narrow valley of Lake Creek. It is the lowest of a series of three tailing impoundments constructed in the valley, and consists primarily of two mine waste-rock embankments set at right angles to each other and behind which tailing was deposited against the hillside. The base of the pile rests on recent-age alluvium, probably mixed with older mill wastes from the early years of development at the Galena property. Valley walls and bottom are composed of lower Wallace Formation metamorphic sediments of the Precambrian Belt series, mostly dolomitic and calcareous quartzite (Hobbs and others, 1965). Lake Creek has been channelized along the tailing area and is confined between the rip-rapping on the embankment toe and the county road foundation, which occupies the west side of the narrow floodplain.

Hydrology

Surface Hydrology. Lake Creek flows along the western toe of the compacted rockfill embankment. Flow is perennial, with significant seasonal fluctuation resulting from snowmelt in higher portions of the drainage. Gradient of the stream channel along the pile averages 6 percent. This channel has been entirely relocated and straightened to allow construction of the tailing piles, and is heavily rip-rapped on both sides. The channel bottom is composed mostly of boulders and cobbles.

Precipitation in the Wallace area averages 41 inches (104 cm) annually, with approximately 50 percent falling as snow. Summer precipitation is typically very slight (Ross and Savage, 1967). The tailing pile surface forms a closed basin, relying on the two decant pipes to remove excess water. The pile surface itself has an area of 3.5 acres (1.4 hectares), and that portion of the hillside tributary to the pile and supplying runoff to its surface adds another 13.5 acres (5.5 hectares) to the total catchment area.

A pool of water exists on the southern end of the pile surface which covers from thirty to forty percent of the total surface area. This pool has its origin in water draining from and being pumped out of the Galena mine. Mine drainage water is piped down to the hillside above tailing pile No. 3, where it is discharged from a single 8-inch (20 cm) pipe. A channel has been gouged in the hillside below this discharge point, and a delta of organic material and alluvium has been built up in the pool. Twin decant pipes are used to regulate the pool's surface elevation. These decants are in constant use, since the mine water inflow does not stop. The decant lines run diagonally beneath the tailing pile from southeast to northwest. A concrete drop box is located at the northwestern toe of the tailing embankment, from which the water is diverted to a holding pond before being pumped back to the mine.

Subsurface Hydrology. Piezometers were installed using either a portable 4-inch (10 cm) diameter auger or 2¼-inch flush-coupled casing with machined plastic drive points as described by Morilla (1975) and Norton (1979). All piezometers were constructed of 3/4-inch PVC with screened perforations along the bottom twelve inches (30.5 cm). Clean washed sand was used to backfill holes around screening, and bentonite seals were placed on top of each sand pack and at the ground surface. Figure 5 indicates piezometer positions on the pile surface and below the embankment toe. Water levels were measured using steel tape and chalk on twelve occasions during the summer and fall of 1977 and in the spring and summer the following year. See Figure 6 and Table 3.

Examination of piezometers in drill hole No. 6 show that the pool of mine water at the southwestern end of the pile is quite possibly perched above an unsaturated tailing zone. Piezometer 6-A penetrates the tailing pile to a depth of 21.3 feet (6.5 meters) and was only 27 feet (8.2 meters) from the pool's edge. This piezometer never showed a water level higher than 18.3 feet (5.6 meters) below the pool's water surface elevation. Even when the pool's water surface was raised two feet (61 cm) in the winter of 1977 until it reached and surrounded the bases of piezometers 6-A and 6-B, the water levels in those piezometers failed to show any rise. The higher pool water level was maintained throughout the rest of the measuring period, and no piezometers showed any rise in water level which could be attributed to any such constant source of recharge.

Seasonal fluctuations are evident in all piezometers. Melt water from the winter snowpack on the pile surface and on the hillside tributary

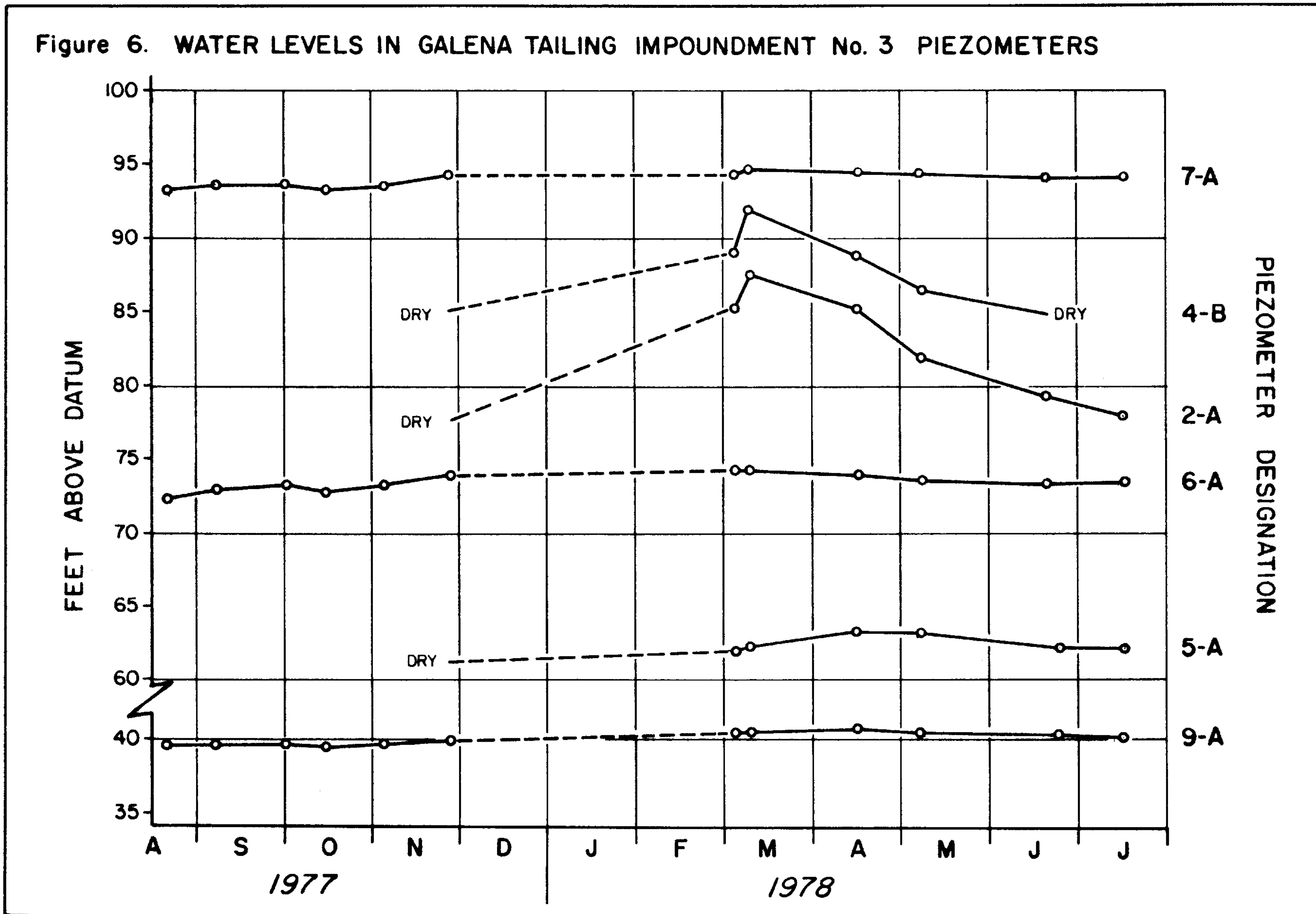


Figure 6. WATER LEVELS IN GALENA TAILING IMPOUNDMENT No. 3 PIEZOMETERS
100
95
90
85
80
75
70
65
60
40
35
FEET ABOVE DATUM
DRY
DRY
DRY
DRY
7-A
4-B
2-A
6-A
5-A
9-A
PIEZOMETER DESIGNATION
A
S
O
N
D
J
F
M
A
M
J
J
1977
1978

Table 3

Piezometers Installed at Galena Tailing Impoundment No. 3

Piezometer Tube No.	Date Installed	Ground Surface Elevation* (feet)	Tube Length** (feet)	Tube Bottom Elevation* (feet)
1-A	7-27-77	94.0	27.0	70.2
2-A	7-28-77	94.0	19.1	77.1
2-B	7-28-77	94.0	13.9	82.1
3-A	8-05-77	95.3	17.0	80.6
3-B	8-05-77	95.3	13.4	84.2
3-C	8-05-77	95.3	7.0	90.3
4-A	8-09-77	93.7	17.4	80.0
4-B	8-09-77	93.7	12.2	84.9
4-C	8-09-77	93.7	5.6	91.3
5-A	8-10-77	94.7	36.5	61.2
6-A	8-11-77	92.8	24.9	71.5
6-B	8-11-77	92.8	11.0	84.1
7-A	8-15-77	95.5	7.1	91.6
8-A	8-15-77	101.7	7.3	97.6
9-A	8-17-77	40.6	8.3	36.2

Notes:

* Elevations given are in feet above datum, defined as 100 feet below a nail in the tree nearest Drill Hole No. 7.

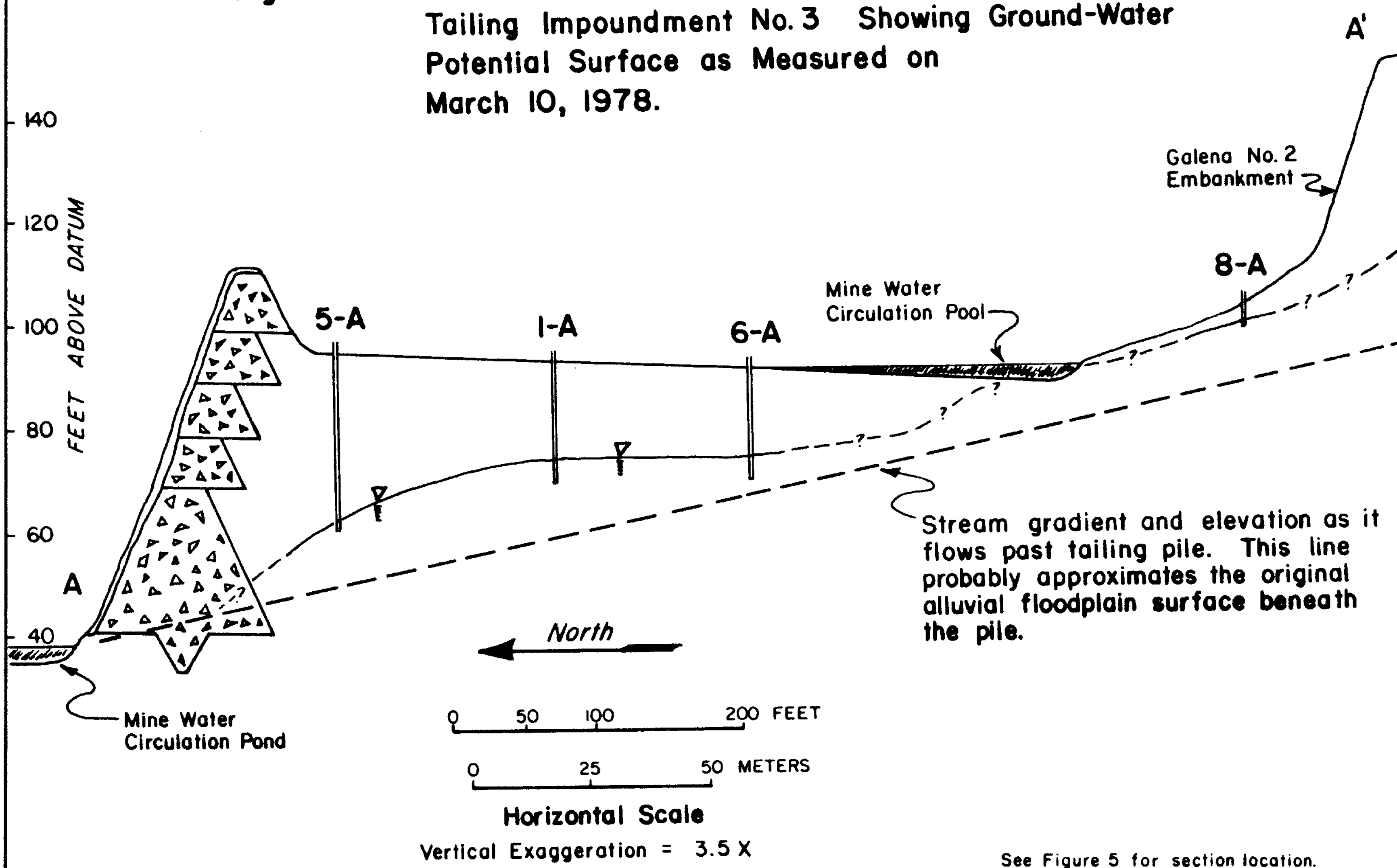
** All piezometers are constructed of 3/4-inch diameter PVC pipe.

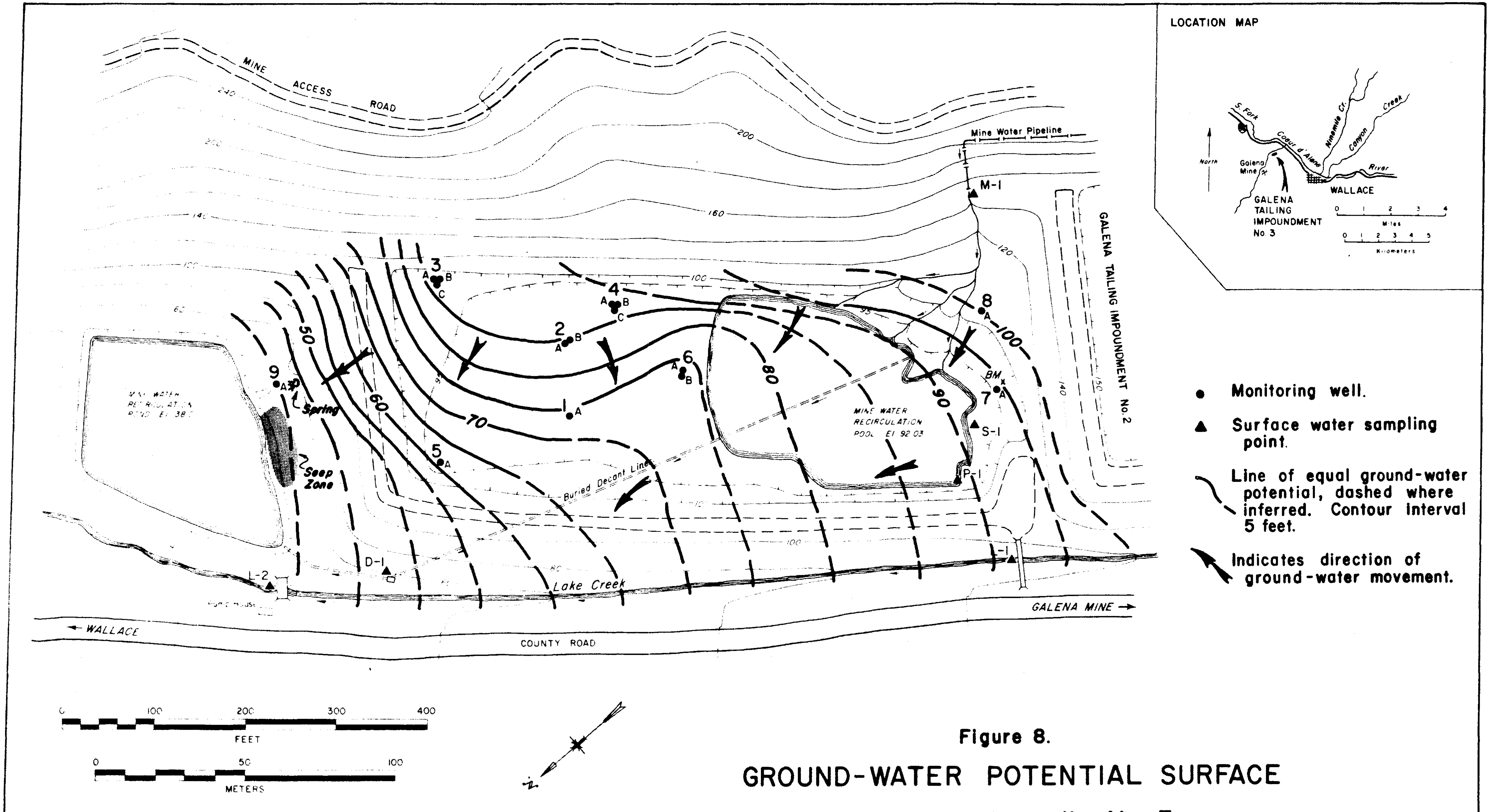
to the pile appears to move along the bedrock/tailing contact and into the tailing. The pile surface slopes toward the mine water pool, so much of the melt water from the pile surface may enter the mine water recirculation system and be separated from ground water moving through the tailing pile. Snowmelt near the embankments, where the more permeable fraction of tailing material has been deposited, probably moves downward and out of the bottom of the pile.

Some water probably enters the tailing pile as ground water recharge from Lake Creek as it reaches the pile. The permeable nature of the embankments allows movement of water into the less permeable tailing material within the pile, where ground water levels respond to seasonal changes in the flow of Lake Creek as well as to vertical recharge from precipitation. Figure 7 illustrates how this could occur. The position of Lake Creek as it flows past the tailing pile is indicated by a dashed line roughly parallel to the indicated phreatic surface. Lake Creek was displaced from the valley center when the tailing dikes were constructed, so a high-permeability zone of gravel and boulders can be expected somewhere under or inside the embankments. Ground water would be free to move along such a channel, and probably is recharged by infiltration losses from the upper section of Lake Creek along and above Impoundment No. 3. Ground water movement probably occurs from beneath Impoundment No. 2 as well.

No springs are visible along Lake Creek, but the coarse rip-rap lining the channel could allow ground-water discharge to occur undetected. Seeps are present along the downstream toe of the pile, discharging into the lower mine water circulation pond. Figure 8 shows a partly hypothetical view of ground water flow through the pile.

Figure 7. North-South Diagonal Section through Galena Tailing Impoundment No. 3 Showing Ground-Water Potential Surface as Measured on March 10, 1978.





Topographic contour interval 20 feet
Elevations in feet above datum, defined as 100 feet below Bench Mark (nail in tree near Drill Hole No 7)
Plane table survey by M. Gross, T. Eckwright, and M. Hall, October 1977

Figure 8.

GROUND-WATER POTENTIAL SURFACE

Galena tailing pile No. 3

AS MEASURED APRIL 14, 1978

Infiltration of snowmelt and rainfall have caused the mound in the northeast section of the pile, and water from Lake Creek is shown as moving beneath and within the pile from southwest to northeast.

Water Quality. Samples were collected from all piezometers containing enough water to allow sample recovery, plus two sites on Lake Creek, the mine water inflow stream and the concrete drop box below the pile. These sampling sites are identified in Figure 5. Sampling and chemical analysis procedures were conducted in the same manner as described for the Lucky Friday tailing pile. Results of chemical analysis for all samples are given in Appendix B. Samples were taken on August 21, 1977 and May 5, 1978.

August data show good quality water throughout the system. Very low concentrations of heavy metals were noted both inside and outside the tailing pile. Piezometers 7-A and 8-A show slightly higher concentrations of manganese, but this is not a serious threat to basin water quality. Zinc concentrations appear slightly higher within the pile than in either mine drainage water or Lake Creek. No siginificant change in the quality of Lake Creek was detected between stations above and below the tailing pile. Lead and cadmium concentrations were below detection limits in all samples taken in August.

May 5, 1978 chemical data from piezometers, surface streams and the mine water circulation system show low ion concentrations for all elements except cadmium. Samples taken the previous August showed no measureable amounts of cadmium, but May samples had concentrations from 19 to 40 micrograms per liter ($\mu g/l$). Other elements appear to be diluted with the rise in ground water levels and increased discharge of surface streams, but cadmium concentrations increased significantly. (See Table 4.)

Table 4: Cadmium concentrations in water samples from Galena Tailing Impoundment No. 3

Sample No.	Location	Cadmium Concentration (μg/1) 8-21-77	5-5-78
GP-L-1	Lake Creek above pile	*	26
GP-L-2	Lake Creek below pile	*	28
GP-M	Mine Water Inflow	*	26
GP-D	Mine Water Decant	*	19
Mean of 11 Piezometer Samples		*	31

* Below detectable limits (2μg/1.)

The higher concentrations were not limited to a single source, but appeared in Lake Creek, mine water inflow, mine water pool, piezometers in tailing and alluvium, and the decant mine water.

No reasonable explanation of the cadmium anomaly has been found. Cadmium concentrations in tailing material deposited in Galena Impoundment No. 3 were the lowest found in any tailing site sampled. (See Tailing Analysis Data for Site 10, Appendix C.) This would tend to indicate the possibility of sampling or analysis error for that element on one of the two sampling dates. Further testing would certainly be necessary before declaring the site a chemical hazard. None of the other elements analyzed appear to pose threats to water quality.

Evaluation of Abandoned Site Reclamation

Physical Conditions. Direct erosion of tailing by moving surface water is not a serious problem at the Galena No. 3 site. Heavy riprapping at the embankment toe and channelization of Lake Creek between the pile and road effectively protect the site. Wind erosion of the fine-grained tailing surface does occur, but the remoteness of the site makes public impact minimal. High embankments of the last ten-foot (3.3 meter) lift tend to keep blowing tailing material confined to the pile area and away from surface streams. Major failure of the pile after abandonment is not considered a serious problem; the existing decant system is adequate to carry both mine drainage water and surface runoff reaching the pile. If use of the pile for mine water circulation were discontinued, the decant system could serve as a drain for ponded surface runoff.

Chemical Conditions. Ground water moves through the tailing pile, with the phreatic surface exhibiting the expected seasonal fluctuations. This would provide a mechanism for the movement of oxidation products from heavy metal leaching into ground and surface waters below the pile. The spring-time rise in water levels within the tailing is due to recharge from snowmelt originating on the hillside above the pile and appears to be unrelated to the pool of mine drainage water maintained on the pile surface. Some ground water in the pile appears to originate as surface water farther upstream along Lake Creek.

Water quality and tailing material composition data gathered as part of this study were inconclusive in determining the site's potential for chemical problems. Should further sampling indicate that remedial action is necessary, isolation of the pile from ground water moving down the Lake Creek valley is not likely to be a recommended procedure. Steepness of the valley in the vicinity of the pile and the perennial source of recharge in Lake Creek will continue to support movement of ground water through buried channels and porous alluvium beneath the tailing deposit.

Esthetic Conditions. Although Galena tailing pile No. 3 is less than ½ mile (0.8 km) from a major interstate highway, it is visible to most travelers for only a few seconds as they pass the mouth of Lake Creek valley. Good results from an active revegetation program on the pile's outside embankments also lessens visual impact to travelers. No residences exist within view of the pile, and the most frequent users of the nearby county road are employees of the mine and mill. No vegetation has been introduced onto the tailing surface inside the dikes, but some species seem to be moving down from the hillside, and aquatic plants are evident at the edges of the mine drainage pool. Application of erosion control netting and a variety of grasses and clover have provided good slope stability and vegetative cover.

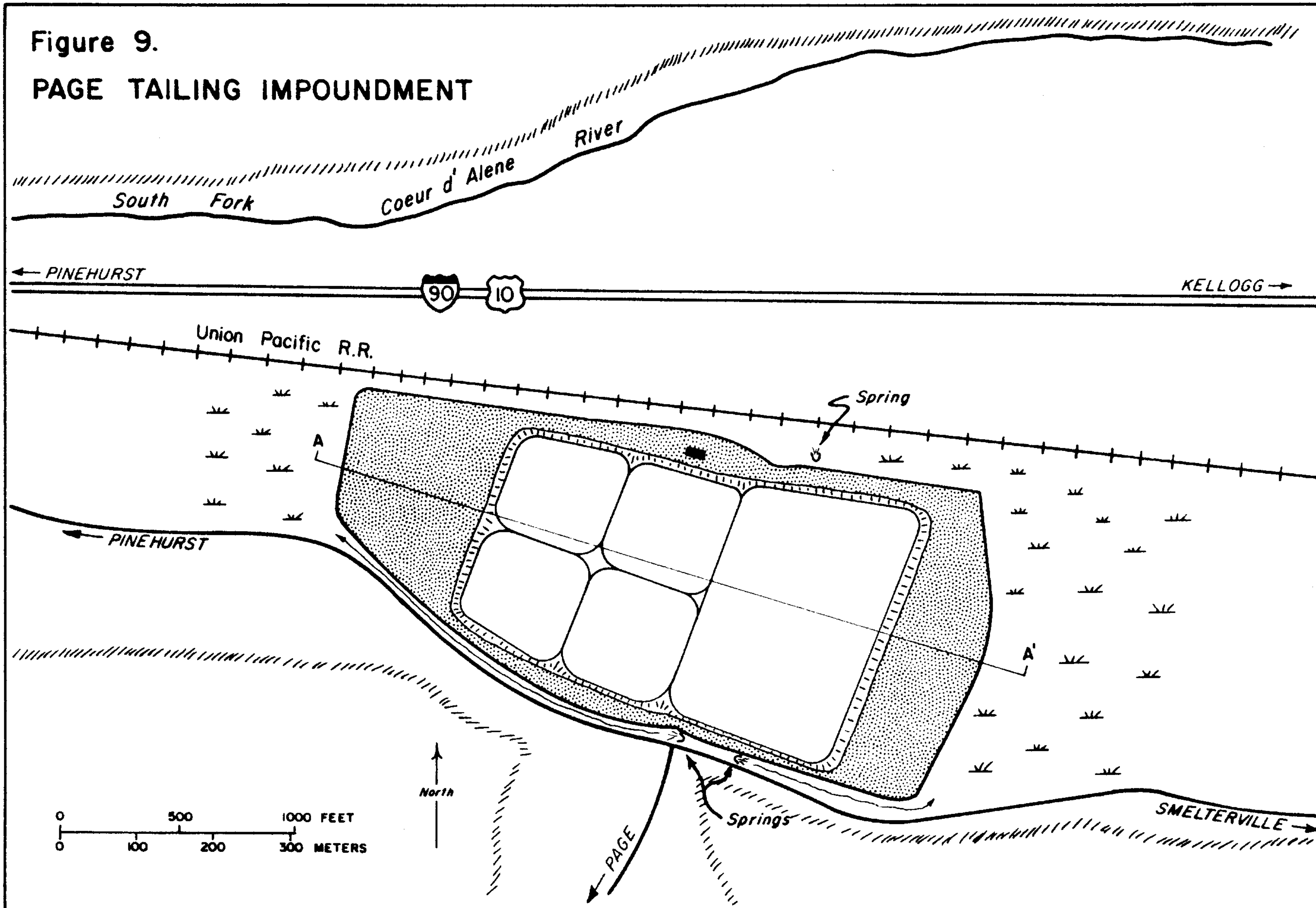
Page Tailing Impoundment

Location

The Page tailing impoundment, the oldest abandoned tailing pile in the district, is located one mile (1.6 km) west of Smelterville, one-half mile (0.8 km) south of the South Fork of the River, and about one and one-quarter miles (2 km) east of the confluence of Pine Creek and the South Fork. The Pinehurst highway (old U.S. 10) runs the length of the pile on the south side (Figure 9). The Page mine, now abandoned, is located at the head of the draw containing the town of Page, Idaho, approximately one mile (1.6 km) south of the tailing pile.

Figure 9.

PAGE TAILING IMPOUNDMENT



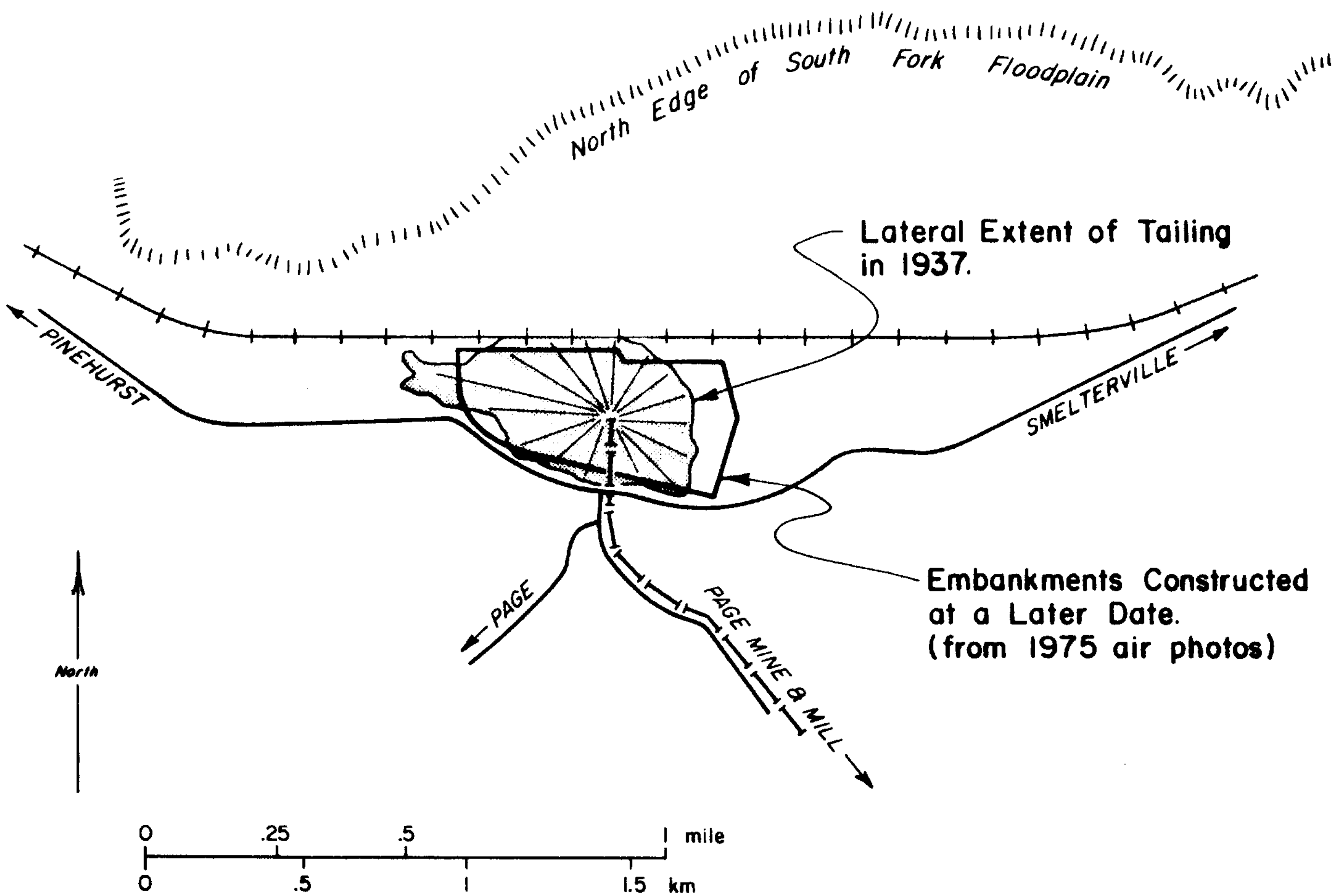
History

Mining Operation. Considerable work had been done before 1906 on the Page mine which was then known as the Corrigan-Blackhawk-Wyoming properties (Timken, 1936). In 1906 the Corrigan was renamed the Page mine. Gravity concentration of the ore was used by the mine prior to 1911. Work at the mine was discontinued in 1911 because of the inefficient method of ore dressing and the prevailing low metal prices. The mine was dewatered in 1925 with the introduction of the flotation method of ore separation and the desire of the company to do additional development. A 30-ton flotation concentrator was constructed and put into operation in December, 1926. Before 1926, all waste material was used as fill in the mine. With the employment of flotation, the waste was discharged as a slurry into a tailing pile. The mine continued in operation up to 1969 using the flotation process. The sandfill technique was initiated in the Page mine during 1956 for a new source of backfill.

Tailing Pile. Early air photographs have shown that the first method of tailing deposition on the Page pile consisted of a single pipe supported by wood scaffolding. From 1926 to 1939 tailing was discharged in an uncontrolled condition between the railroad grade and roadway which followed the south margin of the floodplain. Embankment construction with mine waste rock was in progress in 1939, and it appears that these embankments were built at least in part on top of slimes which existed at the edges of the early pile. (See Figure 10.)

The Page tailing pile, as it was abandoned in 1968, can be divided into two parts, east and west. A road separates the sections and forms the west embankment of the east pile. In 1948 embankments for enlarging

Figure 10. Location and Extent of Page Mill Tailing Prior to Embankment Construction.



the west portion of the pile had been completed, and that section was used almost exclusively. The center embankment corresponds with the earlier location of the slurry pipeline and single-point discharge in 1939. Because sandfill was not used until 1956, it seems likely that the center portion of the entire Page tailing site is underlain by relatively permeable sand-size tailing. The dividing embankment and road were apparently built across this material.

Sand backfill was initiated in the operation of the mine in 1956. The tailing slurry reaching the impoundment since 1956 has been primarily a slime mixture as compared to the sandy slime mixture deposited earlier. Most of the east part of the pile and the bottom of the west pile are believed to be composed of coarser materials than the top of the west pile because of deposition prior to the initiation of sandfill operation (Morilla, 1975).

The Page mine and mill operations were terminated along with the filling of the Page pile in 1968. Air pollution from blowing tailing has been a problem since abandonment of the pile. Trees were planted in 1971-1972 in an attempt to establish wind breaks. In 1972, the American Smelting and Refining Company transferred title to the Page tailing pile to the South Fork Coeur d'Alene River Sewer District for use in the construction of a collection and treatment system. The sewer district constructed five sewage lagoons on the surface of the pile. Construction of the lagoons eliminated much of the air pollution problem.

Geology

Mine Geology. Belt Supergroup rocks of Precambrian age comprise the rocks of the Page mine. The three formations intersected by the Page mine are the Burke, Revette, and St. Regis. The principal ore mineral is galena, followed by sphalerite. The galena is mostly fine-grained. Other minerals of importance are tetrahedrite, chalcopyrite, and pyrite. The gangue minerals in order of abundance are quartz, ankerite and siderite, sericite, and lencoxene (Timken, 1936).

Tailing Pile Area. The Page tailing pile is located on alluvial deposits of recent age. These deposits consist of rounded pebbles, boulders, sand and clay from erosion of the Belt series rocks plus reworked glacial terrane deposits. The alluvial deposits are 90 feet (27 meters) thick (Norbeck, 1974). Jig tailings from mineral recovery operations during the 19th and 20th centuries are interworked with the upper portion of the alluvium and glacial deposits. The jig tailings range from microscopic size to about one inch (2.5 centimeters).

Hydrology

Surface Hydrology. Morilla (1975, page 16) described surface-water conditions around the abandoned Page Tailing Impoundment as follows:

> The Page tailing pile is located in a marsh and bog area underlain by valley fill. Depth to ground water in the valley fill near the pile is usually between two and four feet below the surface. A perennial swamp is located on the east side of the pile with a seasonal swamp on the west end.
>
> Two tributary valleys supply surface water to the Page pile area. Grouse Creek flows into the main valley near Smelterville. The creek meanders across the flat east of the pile and enters the swamp ponded against the east bank of the east pond. During high water, water flows between the north bank of the pile and the tracks of the Union Pacific Railroad and discharges into the swampy area west of the pile.
>
> Humboldt Creek enters the main valley near the center of the Page pile and then flows eastward along the south bank of the west pond. The stream also discharges into the swamp area west of the pile. Surface water discharges from the west swamps only during high flow periods. Both Grouse Creek and Humboldt Creek recharge the ground-water system in the valley fill.

The Page Pile area receives nearly 31 inches (79 cm) of precipitation annually, much of it as winter snowfall. Summer months are usually very dry; strong westerly winds result in a problem with blowing tailing.

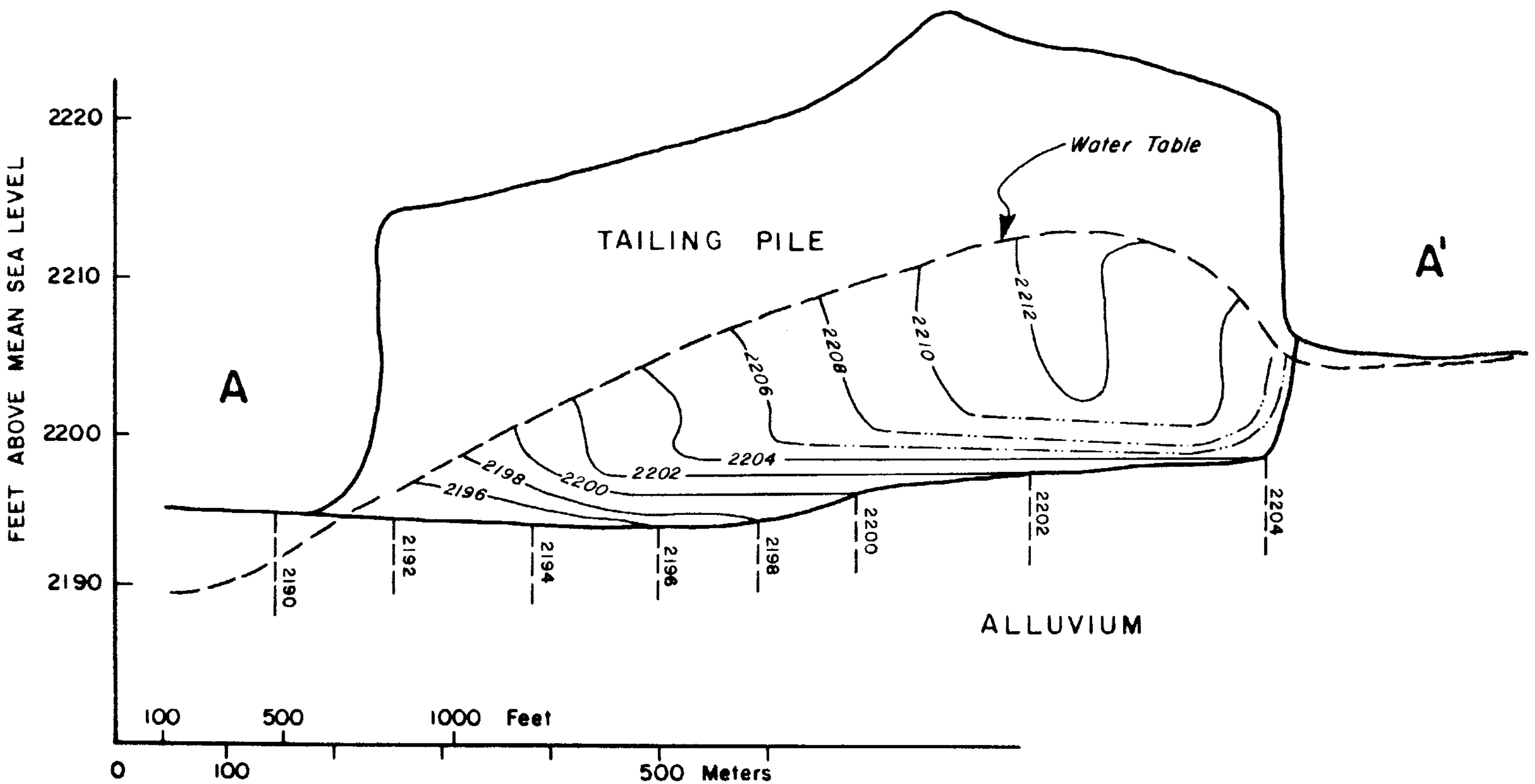
A major source of surface water which directly affects the tailing pile is the wastewater treatment plant constructed on the pile surface in 1974. Hitt (1974) gives the design inflow as between 1.4 and 4.4 million gallons per day, all of which circulates through the four unlined aeration lagoons and the 17-acre (6.8 hectares) stabilization pond.

Subsurface Hydrology. Morilla (1974) installed a number of piezometers in both the tailing pile and surrounding alluvium. He identified a ground water mound beneath the east portion of the pile, described the ground water flow system in the surrounding alluvium, and conducted laboratory tests for hydraulic conductivity on samples from several locations within the pile. The hydrologic data was used to construct a finite-element mathematical model of the tailing pile and underlying alluvium. Figure 11 shows the distribution of hydraulic potential in tailing and alluvium as measured before construction of the sewage treatment facility.

Hitt (1974) examined the suitability of the abandoned tailing pile as a site for the treatment plant. He measured discharge at several springs along the south embankment of the pile and one along the north embankment. More piezometers were installed as the lagoon dikes were raised. Although initial design specification called for a clay-type lining material in each of the five lagoons, the consulting firm engaged to coordinate construction decided that the tailing material itself was sufficient, and no liner was installed. Rises in water level in both the pile and surrounding alluvium accompanied the filling of lagoons in July

Figure 11.

Ground-Water Potential Distribution within and below the Page Tailing Impoundment, 1974
Along East-West cross-section A—A'



Vertical exaggeration 50:1
See Figure 9 for section location.

AFTER MORILLA, 1975

1974. This was explained as the result of weight loading on the pile surface rather than seepage from the lagoons. A mass water balance was attempted, but measurement inaccuracies at sewage inflow and effluent discharge points forced abandonment of the idea.

Piezometers remaining on the pile surface and surrounding area were reexamined in June of 1977, and water levels were recorded. An inspection of ditches to the south and north of the pile revealed ground water discharges. Springs in the southern ditch contained fine tailing material which "boiled" at the discharge point and created underwater mounds. (See Figure 9.) Seeps were noted at and above the toe of the southern tailing embankment. These seeps contain some gray tailing and have precipitated an iron stain at the embankment toe just east of the access road and gate. Red stain also appears at the single spring below the north embankment. Figure 12 shows the potential surface as measured in June of 1977, reflecting the changes made by the construction of the treatment plant. The phreatic surface within the pile rose between 12 and 16 feet (3.7 meters and 4.9 meters) from 1974 to 1977. The potentiometric surface of water in the alluvium beneath the tailing pile rose a maximum of 20 feet (6.1 meters) during the same period.

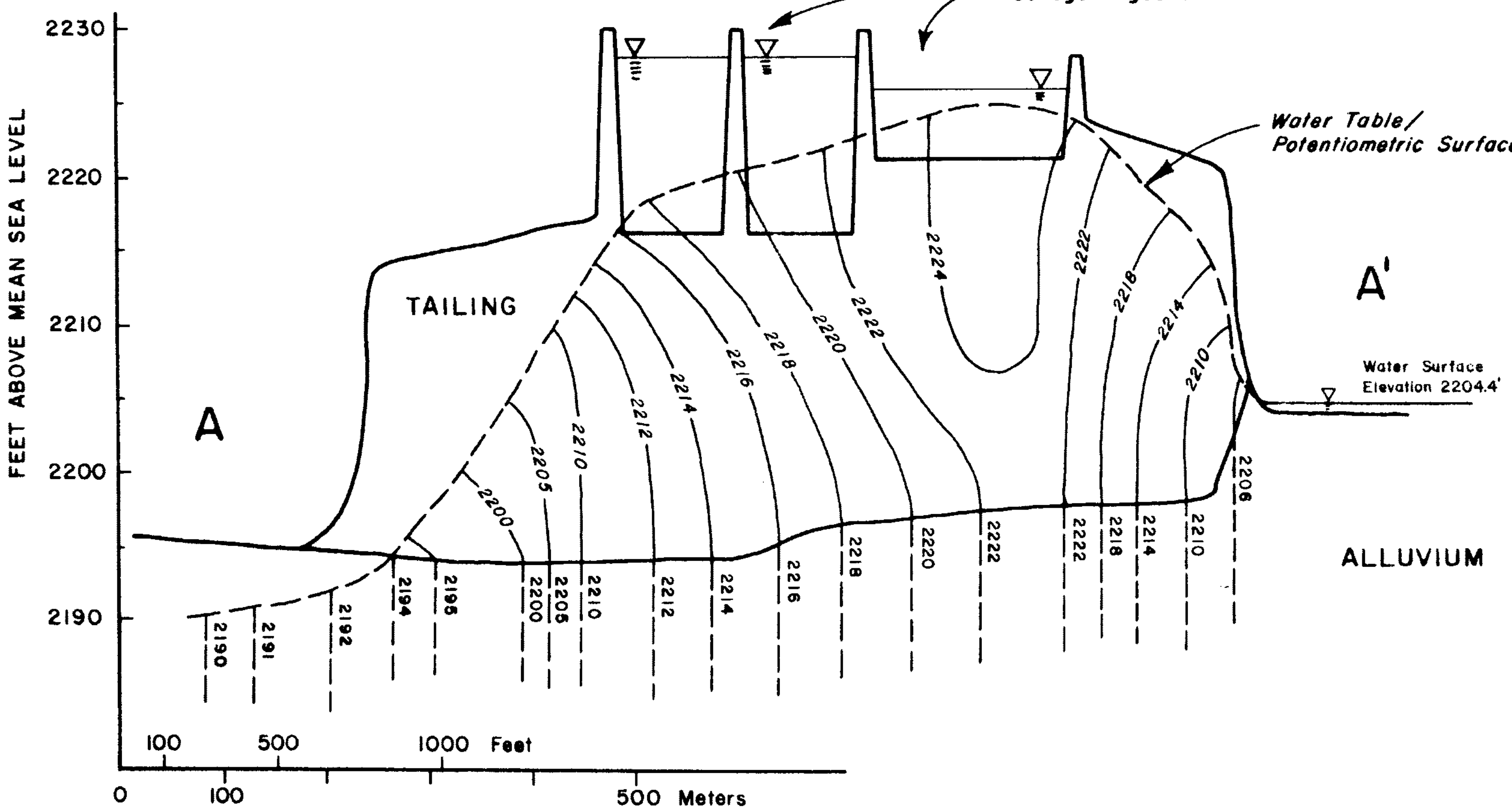
The higher water levels measured in 1977 seem to indicate that some leakage is occurring from one or more of the lagoons. If all water level changes noted by Hitt (1974) were due exclusively to loading, there should have been a subsequent fall in those water levels as a new equilibrium between infiltration and ground water discharge was achieved. No such decline seems to have occurred. In fact, the number of seeps and springs south of the pile seems to have increased, and seepage is now appearing on the outside face of the compacted waste-rock embankment.

Figure 12.

Ground-Water Potential Distribution within and below the Page Tailing Impoundment

Along East—West cross-section A—A'

As measured in June 1977



Vertical exaggeration 50:1
See Figure 9 for section location.

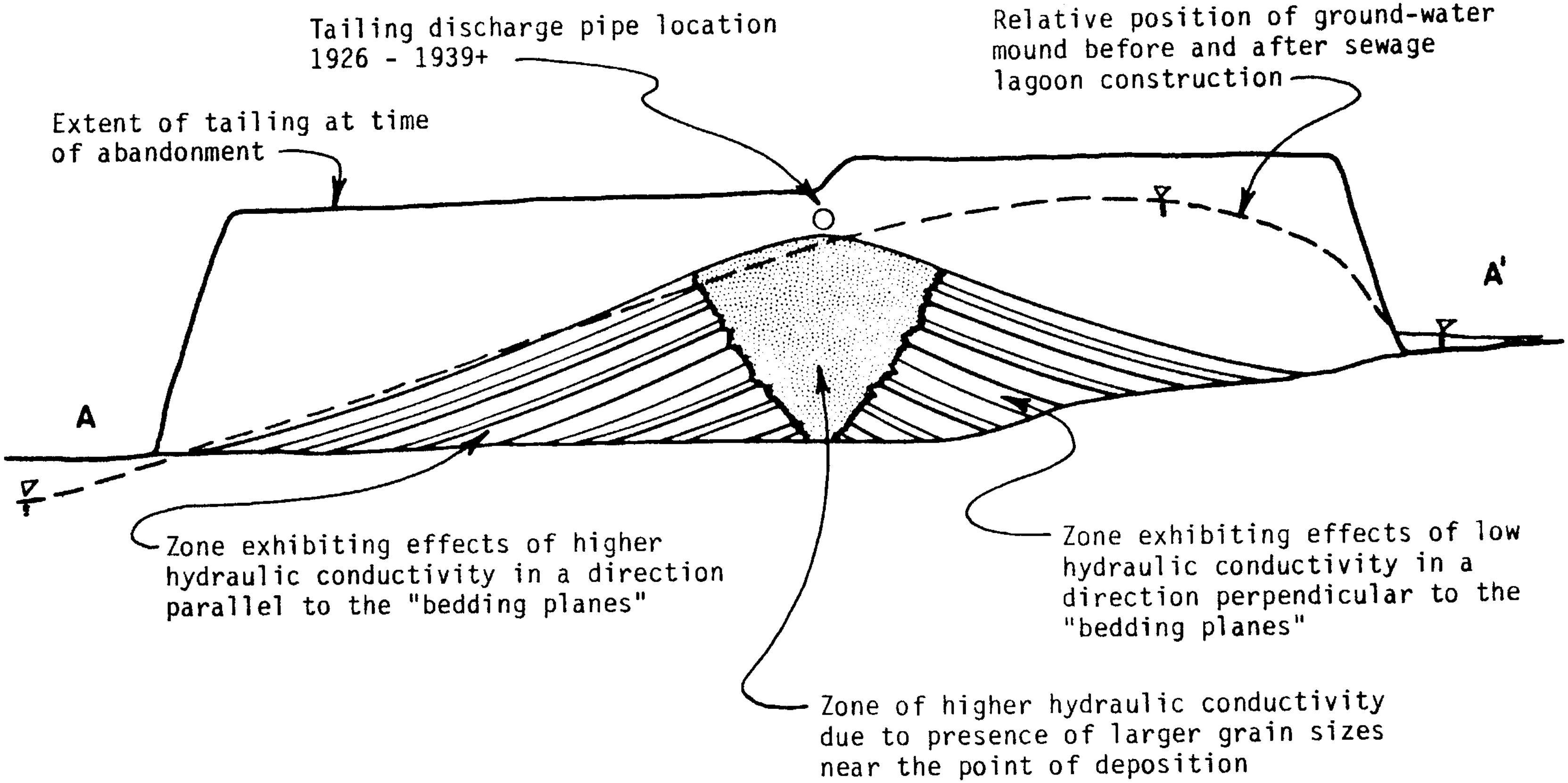
Base data from Morilla (1975)
Lagoon locations from Hitt (1974)

The ground water mound noted by Morilla (1974) in the eastern section of the pile still exists, and has increased in height following construction of the treatment facility. Examination of early (1937 and 1939) air photographs has revealed new information regarding the tailing pile's history and a possible explanation for the presence of this mound.

Because of the technique of deposition of tailing in the early years of the pile's history, a mound of coarser tailing exists within the center of the present pile structure and exhibits some unusual hydraulic characteristics. (See Figure 13.) A cone of tailing was built up with a series of deltaic deposits which originated at the single-pipe discharge point. This would have resulted in a decrease in sediment grain size with distance in all directions from the apex, and probably in a "layering" effect as the cone grew. Alternating thin (1 cm to 10 cm) layers of fine sand and slimes (minus 200-mesh), if deposited in a flat environment, would tend to exhibit a horizontal hydraulic conductivity which may be much greater than the vertical hydraulic conductivity. Transferring this concept to the mounded tailing situation, the hydraulic conductivity in a direction normal to the "bedding planes" in the mound would be expected to be lower than the hydraulic conductivity of tailing in a direction parallel to the dip, or along any line drawn from the slurry discharge point. Morilla (1974) only measured vertical hydraulic conductivity using laboratory techniques, and assumed a constant value for this parameter throughout the pile.

The ground water mound under the eastern portion of the pile may be explained as a "ponding" of water against the relatively low-vertical-conductivity outside the slope of the original tailing cone. As the water reaches an elevation where coarser materials are encountered, the "ponded"

Figure 13. Generalized West-East Cross-section through the Page Tailing Pile Showing Changes in Hydraulic Conductivity.



SKETCH MAP — NO SCALE
PILE SHAPE AND WATER TABLE DATA FROM MORILLA, 1975.

See Figure 9 for section location.

ground water could move more freely through the central part of the cone and farther west along the "bedding planes" of the early tailing deposit.

Water Quality. A number of researchers, including Galbraith (1971), Mink (1971), Hitt (1974), Morilla (1974), and Norbeck (1974) have dealt with quality of surface and ground water at the Page tailing pile since its abandonment in 1968. Galbraith (1971) obtained samples of the mounded water within the tailing pile which contained up to 105 ppm zinc and 1.0 ppm lead. The following table shows mean concentrations of elements in the mounded water.

Table 5: Mean concentrations (ppm) of elements in mounded water from eleven samples from the Page tailing pile. (From Galbraith, 1971)

Element	Mean Concentration (ppm)
Zn	40
Pb	0.3
Mn	40
Fe	0.7
Cu	0.03
Ca	260
Mg	95
Na	25
K	40

Morilla found similar zinc concentration in a more extensive sampling program. He reported no pattern of zinc concentration either horizontally or with depth and assumed an over-all mean of 15.16 ppm for all ground water in the tailing pile. This figure was used in calculating an estimated total zinc discharge of 17.8 pounds per day (8 kilograms per day) (Morilla, 1974). A figure of 2000 gallons per day per acre (18,900 liters per day per hectare) was used as the ground water discharge from the pile. Mean zinc concentrations in the 52 piezometers located in the surrounding alluvium were calculated at 28 ppm. Norbeck (1974) determined a mean of 33 ppm for three wells in the alluvium up-gradient from the Page tailing pile.

Zinc is the heavy metal element found in greatest concentration within and around the Page tailing pile (Morilla, 1974 and Marcy, 1979). It is quite toxic to many fish species (EPA, 1976) and is the most prevalent metal in the South Fork Basin. Sphalerite (Zn S) is easily broken down in the presence of water and oxygen (Marcy, 1979). The reaction is spontaneous, making zinc one of the more soluble metals found in the South Fork Basin. Sceva and Schmidt (1971) calculated the zinc load of the South Fork at Smelterville to be near 11,800 pounds per day, making it by far the most common pollutant.

Data collected by March (1979) and Norton (1979) from piezometers in alluvium near the Page tailing pile show significantly higher concentration of zinc than were present in ground water within the pile. Jig tailings mixed with alluvium are believed to be the source for the high zinc concentrations. This suggests that the portion of the metals load carried by the South Fork which can be attributed to the Page tailing pile may be insignificant when compared to contributions from the larger Smelterville Flats area.

Using zinc concentrations in ppm and flow measurements of the U.S. Geological Survey at Smelterville, Morilla (1974) concluded that the discharge of zinc from the Page tailing pile amounted to approximately 0.1 percent of the total daily amount of zinc carried by the South Fork. This would tend to suggest that the impact to water quality from metals moving out of the abandoned Page tailing pile is insignificant when compared to modern background concentrations of metals in the South Fork. Expensive chemical reclamation procedures for the pile may therefore be unfeasible if the objective of a limited-funding project would be the enhancement of water quality in the basin's main water course.

Evaluation of Abandoned Site Reclamation

Physical Conditions. The Page tailing impoundment is not in danger of suffering direct erosion by surface streams. Humbolt Creek and Grouse Creek do not pose threats, and the site is separated from the South Fork by a railroad embankment and an interstate highway. Sheet wash erosion is not a problem, since the catchment basin of the pile is limited to its surface area, and precipitation tends to be ponded briefly before being evaporated or infiltrating the tailing pile. Wind erosion remains a problem, even though 60 percent of the pile surface is now covered by the regional waste water treatment plant. Essentially no vegetation exists on the flat surfaces east and west of the sewage lagoons, and the typical hot, dry summers with prevailing westerly winds result in a wind-carried dust problem for the community of Smelterville.

Failure of a mine waste-rock embankment due to a reduction in shear strength because of a rise in ground water levels within the tailing pile may be a problem at this site.

Use of the unlined sewage lagoons have raised ground water levels within and below the tailing pile. Because the lagoons were built on top of the existing tailing pile surface, the hydrostatic head obviously must be higher now than at any time while the pile was used for tailing disposal. The resulting rise of the phreatic surface within the tailing has increased the chances for piping of water through the waste rock embankment. The presence of gray tailing slimes in the springs in the ditch south of the pile does not mean that piping is occurring. As indicated earlier in this section, embankments for the Page tailing impoundment were placed on a floodplain containing an abundance of tailing material. It is quite possible that the origin of the tailing "boils" in the ditch is the tailing/alluvium between the ditch and the embankment.

Of more concern is the presence of a very wet zone within the embankment approximately 3 feet (1 meter) above the toe in the vicinity of the springs south of the pile (Figure 9). This could signal a rise in the phreatic surface within the embankment.

Chemical Conditions. Heavy metals, especially zinc, have been identified in previous investigations both within the tailing pile and dissolved in ground water in the pile. Morilla (1974) found water emerging from springs north and south of the pile to contain high concentrations of zinc and other metals, showing that leaching and subsequent transport by ground water was taking place. The chemical effects of higher water levels in the pile due to the seepage from the lagoons has not been adequately investigated. The higher phreatic surface may be beneficial in preventing oxidation of sulfide ores present in that lower portion of the tailing pile which was deposited prior to the beginning of zinc recovery efforts.

Infiltration of surface water and subsequent movement of ground water through the tailing has been increased by the addition of the unlined seweage treatment ponds. The mechanism for transporting oxidation products from within the tailing pile has therefore been strengthened. The question of whether the introduction of relatively basic water from the lagoons and the establishment of a more constant phreatic surface has reduced the over-all rate of oxidation within the tailing is yet to be answered.

Esthetic Conditions. The combination of two esthetically displeasing land uses at one site should be commended and encouraged. Although visual quality and public visibility of the pile are not changed through the construction of the treatment plant, more valuable flat land is reserved for higher uses.

Visual quality of the Page tailing pile area could be improved greatly over present conditions while helping reduce the dust problem. A program of irrigation with water from the stabilization pond could result in grass cover on those portions of the original pile surface not presently reclaimed as well as the outer embankments. More trees could be planted around the pile perimeter to reduce the visual impact of the waste rock embankment as it appears from the old U.S. Highway 10 and the new interstate highway.

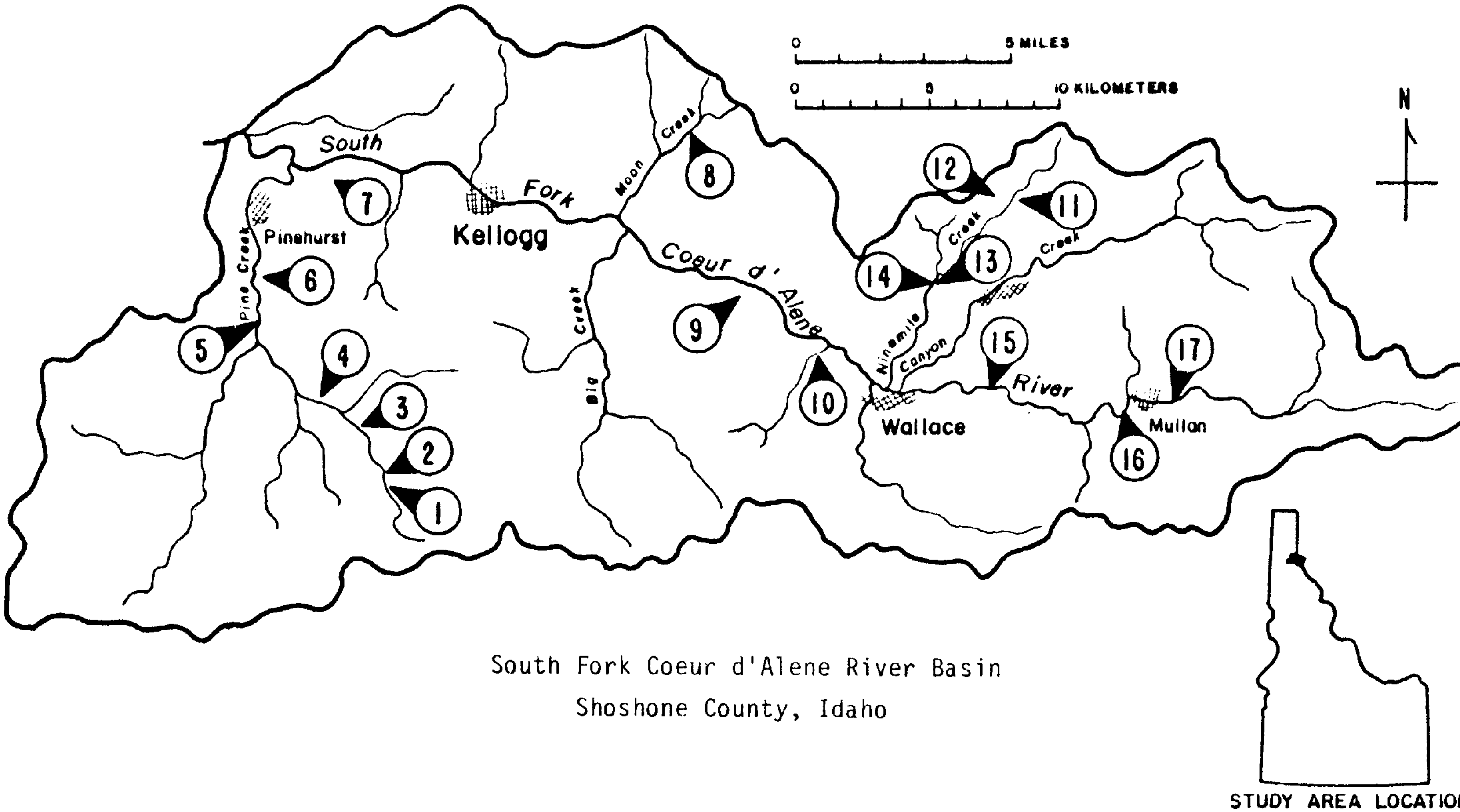
INVENTORY OF ABANDONED "CONTROLLED" TAILING IMPOUNDMENTS IN THE SOUTH FORK BASIN

For the purposes of this study, a controlled tailing site consisted of an area where slurried tailing material from a single mill was impounded for the purpose of dewatering the sediment. A site was considered "controlled" if evidence could be found of constructed embankments or of a tailing deposition procedure which served to confine the material to a distinct area.

Whether an inactive tailing impoundment is "abandoned" or not is a difficult question. Because all mining activities are governed so strictly by economics, an "active" mine or mill is likely to have intervals in which the operator finds it necessary to remain closed and inactive. Duration of the "inactive" status is also related closely to economics, and may be so extended that the property appears "abandoned". Tailing piles were considered abandoned if no tailing had been deposited on the site for at least a year prior to June 1977. This figure is necessarily arbitrary. The site selected for detailed examination and the remaining inventoried sites fit these criteria. At least one tailing impoundment of each of the operating mills in the basin was effectively excluded from the inventory.

An examination of the South Fork of the Coeur d'Alene River and its tributaries was conducted during the summer of 1978 to locate and identify all abandoned controlled tailing sites. Ground transportation, old air photographs and aircraft were employed to locate a total of seventeen sites (See Figure 14). These sites are examples of various degrees of site

Figure 14.
Location of Abandoned "Controlled" Tailing Sites



South Fork Coeur d'Alene River Basin
Shoshone County, Idaho

abandonment. Sites 10 (Galena No. 3) and 16 (Lucky Friday No. 1), which were selected for detailed study, have recently raised embankments and are ready to receive tailing. Both serve active mills which have alternate tailing disposal sites, but neither had received tailing on a regular basis for at least a year prior to June 1977. These sites remain "abandoned" only until the mining companies require their use. Representing the other end of the spectrum is Site 4, which is a small accumulation of tailing in the braided floodplain of the East Fork of Pine Creek. Whatever mill produced the tailing no longer stands, and only faint remnants of embankments have survived the series of seasonal floods from which the site has no protection. This site is not likely to be of any use for future tailing disposal, due to its precarious location. The tailing would be of little economic interest to a mining company, even if metals concentrations were high, because of the small volume involved.

Remaining sites vary widely in size, color of material, slope stability, proximity to actively eroding streams, vegetative cover, potential for structural failure, and evidence of water quality degradation. Detailed descriptions and locations for each site included in the inventory are given in Appendix A.

IDENTIFICATION OF PHYSICAL, CHEMICAL AND ESTHETIC FACTORS IMPORTANT IN TAILING SITE ABANDONMENT

Introduction

Before outlining a general reclamation plan, it is necessary to identify the factors which control physical and chemical transport mechanisms for movement of pollutants from a tailing site after abandonment. Data gathered during the detailed field studies and basin-wide inventory of abondoned tailing impoundments were used in identifying those physical and chemical factors which are important considerations in the abandonment of tailing impoundments in the South Fork basin. This section contains a description of each of these physical and chemical factors, plus a discussion regarding esthetic factors which should be considered in reclamation of abandoned tailing impoundments.

Physical Factors

Physical problems associated with abandoned tailing piles are closely related to the physical mechanisms involved in the dislodging and subsequent movement of tailing material into surface streams. These mechanisms for sediment loading of streams for abandoned "controlled" tailing piles can be viewed as three distinct types as follows: (1) major failure of the site which would result in a massive single-event contribution of tailing in a stream drainage; (2) direct stream erosion of tailing, where natural erosion processes of established streams act to dislodge and remove tailing from a site; and (3) wind and sheet wash erosion, in which wind action or overland flow serves to move tailing into adjacent streams.

Major Failure

Site 12 in the Ninemile Creek drainage is the most obvious entry in this category due to its location across the head of a steep valley tributary to the East Fork of Ninemile Creek. A steep and unvegetated waste rock embankment is constructed across the valley. Approximate maximum height of the embankment is 60 feet (18 meters). The resulting pond is filled with tailing. Diversion facilities for storm runoff apparently consist of a single culvert and two decant structures.

Site 8 represents a different kind of massive failure threat. Nearly 2,000 feet (600 meters) of the valley of the East Fork of Moon Creek is effectively filled with abandoned tailing piles which have breached embankments and a number of incised channels. The potential for massive failure is dependent on the probability for flooding in the headwaters of Moon Creek. Much of the channel of the East Fork is located in tailing material. Due to the choked condition of that portion of the valley, a flood of any magnitude could result in a massive amount of tailing being carried as a single event.

Control factors for massive failure must include the high energy potential associated with the location of a tailing dewatering facility high in a steep valley. Construction of an impoundment in such an environment may minimize the total erosive power of adjoining streams, but presents the threat of sudden release of a great mass of tailing. Much care must be given to the sizing of runoff diversion facilities and the design of embankments which will continue to provide protection to the site in an abandoned condition. Seismic stability of embankments and partially saturated tailing is also a consideration which should not be ignored.

Storm runoff control is the key factor involved in the Moon Creek example, since embankments there are no longer functional. Floods on the East Fork must be anticipated and appropriate modifications made to the stream channel to minimize tailing erosion.

Stream Erosion

All identified sites on Pine Creek are threatened by streams. Sites 1 and 3 are particularly susceptible to direct erosion by the East Fork due to the absence of embankments and their postion in the floodplain. Both piles originally had alluvium/waste rock embankments which have been removed by stream erosion. Site 3 has a vertical bank of tailing 12 feet (4 meters) high which is continually being undercut by the East Fork. Dislodged tailing falls directly into the stream.

The primary control factors of physical transport by stream erosion are: (1) the presence or absence of an adequate protective embankment and (2) the location of a tailing site within the floodplain of a given duration flood. A strong embankment and adequate treatment of a displaced stream channel to prevent damage to embankment during flooding can make a site suitable for abandonment. Site 10 is an example of effective tailing site placement, embankment construction, and stream channelization.

Wind and Sheet Wash Erosion

Wind erosion of fine-grained tailing material is a problem at every site, but is especially serious when tailing sites are located near and upwind of communities. Sites 7 and 16 are examples. This wind-carried material can be deposited directly in surface streams or fall as dust on the entire landscape, finding its way into streams during the next runoff event. Size of the particles carried by the wind depends on wind velocity. Apparently much of the tailing slime (minus-200 mesh material) often contains enough moisture to keep it from blowing. The fine-sand fraction of a dry tailing pile surface is often subject to much movement by wind, commonly forming dunes. A lack of surface-stabilizing vegetative cover can result in significant reductions in visibility when summer westerly winds blow across the dry, barren tailing surfaces.

Erosion by falling precipitation and unchannelled runoff from slopes above a tailing site is a problem at most abandoned tailing piles. Site 11 has no compacted embankment, but was constructed using the upstream technique with discharge points around the perimeter. Coarser material settled near the edges of the pile, while ponded water was kept against the adjoing hillside. The site supports no vegetation. Maximum height of tailing above the floodplain is approximately 25 feet (7.6 meters). An erosion channel has been cut deeply in the pile, presumably along a former decant line. The source area for runoff to erode such a channel appears to be only the top of the tailing surface and a small section of thickly wooded hillside. Each precipitation or snowmelt event results in movement of tailing into the nearby East Fork of Ninemile Creek.

Lack of vegetation and the existence of runoff channels on the tailing surface are the important control factors in wind and sheet wash erosion. A healthy growth of grass would virtually eliminate movement of tailing by wind. Vegetation would also reduce erosion from sheet wash by reducing the velocity of overland flow, also aiding infiltration and thereby keeping moisture available for plant growth. Runoff channels tend to collect precipitation and sheet wash runoff into high-velocity, rapidly-eroding miniature streams. These channels are incised rapidly into the fine-grained unconsolidated tailing. Sites 1, 3, 4, 5, 6, 8, and 11 exhibit problems with runoff channels.

Chemical Factors

The chemical problems associated with abandoned controlled tailing sites are controlled by two separate mechanisms: (1) oxidation of the sulfide ores containing heavy metal ions and (2) subsequent "flushing" of the free ions from their oxidation sites by movement of ground water. Galbraith (1971), Reece (1974), and Marcy (1979) have all done work specifically related to acid production and leaching of metals from tailings in the Coeur d'Alene mining district. Morilla (1975) examined heavy metal pollution from an abandoned controlled tailing site referred to in this study as site 7.

Oxidation of Sulfides in Tailings

The major processes which would result in the liberation of heavy metal ions from abandoned tailing piles include: (1) oxidation of a sulfide ore by molecular oxygen, (2) oxidation of sulfide ore in the presence of water and oxygen, (3) oxidation by trace amounts of hydrogen peroxide formed by water and free oxygen, (4) oxidation by ferric iron produced in a series of reactions in which pyrite (FeS_2) is oxidated and acid drainage results (Marcy, 1979) and (5) the action of aerobic sulfide-oxidizing bacteria (Galbraith, 1971).

The factors which are important in allowing these processes to occur are: (1) the presence of pyrite and other metallic sulfide ores in the tailings, (2) the availability of water and free oxygen and (3) the presence of neutralizing agents within the tailings. The conditions favorable for oxidation and subsequent leaching are present in the unsaturated, or vadose, zone in all the abandoned controlled tailing sites. The saturated condition of the lower portions of the piles effectively inhibits oxidation of sulfide ores in the phreatic zone (Marcy, 1979). A number of carbonate minerals, calcite in particular, have been shown to have neutralizing effects in acid water formed by pyrite oxidation (Reece, 1974). If the carbonates are present in sufficient quantity, even a pyrite-rich abandoned tailing site may present no chemical threat to water quality.

Fortunately the seriousness of the chemical threat to water quality is dependent on the concentration of metallic ions present in the tailings, and most modern mineral recovery operations are efficient enough to make such concentrations very small. Also, tailing from a particular mill reflect the mineralogy of the ore body being mined. Because pyrite is present in varying quantities in all ore bodies which contributed to the controlled tailing piles now abandoned, and since the pyrite is discarded as waste from the mill and ultimately reaches the tailing impoundments, it has been considered the chief source of oxidizing agents in the leaching of heavy metals from abandoned controlled tailing piles. Oxidation of pyrite also results in acid water production within the tailings. The resulting acid enviornment further aids oxidation of the metallic sulfides (Marcy, 1979).

Transport of Oxidation Products

Water is the transporting agent for metal ions and acid salts produced within tailings. Oxidation occurs in the unsaturated zone, where sufficient quantities of water and free oxygen are present. When water movement occurs in this area, whether by infiltration of precipitation from above or because of a general rise in water table, the oxidation products are released from the crystal faces and go into solution. This results in a period of high metal concentration in ground water while the oxidation sites are being "flushed" by the first rise of water levels in spring and probably after each significant precipitation event.

Control factors for metal ion transport are those which would effectively prohibit downward percolation of moisture from precipitation and keep ground water levels constant throughout the year. A sealant applied to the pile surface would prevent infiltration, and a series of cut-off trenches and diversion ditches would provide more control on water levels within a tailing pile. Other solutions include a healthy plant cover which would retard infiltration and permanent flooding of the tailing site, eliminating the unsaturated zone necessary for oxidation and acid production.

Esthetic Factors

Esthetic impacts are difficult to assess. People do not all feel threatened by the same things, and abandoned tailing piles evoke quite different reactions from different individuals. Any listing of factors important in the esthetic impacts of abandoned tailings is therefore bound to be subjective and open to argument. In this study, it was determined that the public visibility and visual quality of a site were sufficient measures of its esthetic impact (EPA, 1975).

Public visibility refers to a site's proximity to residents of an area and to travelers. A site such as #16 (Lucky Friday Impoundment

No. 1), which is in plain view and upwind of the town of Mullan as well as adjacent to the interstate highway, would have a more severe esthetic impact than site 8, which is located in the remote tributary valley of Moon Creek. Even though the Moon Creek site exhibits far more serious physical problems than the Mullan site, its impact from a public visibility standpoint is significantly lower.

Visual quality is a more subjective measure of esthetic impact, and deals more directly with the appearance of a site than with the number of persons likely to veiw it. Of prime importance in this category is the physical form of the tailing pile itself. An impoundment constructed along a hillside, using that hillside as an embankment, is less disturbing to the continuity of the landscape than is a free-standing structure built in the middle of a flat floodplain. Some tailing sites were constructed nearly completely filling narrow valleys, such as site 8 on the East Fork of Moon Creek. Such sites become the dominant features of their landscapes, and the esthetic impact is great. Vegetation on embankments or tailing surfaces is also important to a site's over-all visual quality.

CLASSIFICATION OF ABANDONED "CONTROLLED" TAILING IMPOUNDMENTS

Criteria for classification of the abandoned controlled tailing sites can be divided into three categories representing the identified factors important in site abandonment. Physical, chemical, and esthetic factors were considered separately in examining each site, and final criteria for classification were chosen as follows:

Physical Factors

(1) the potential for an immediate and massive physical failure of the tailing pile, thereby releasing all previously impounded sediments into a stream drainage area;

(2) the potential for direct erosion of tailing by seasonal flood waters from established streams, controlled primarily by the site's location within the floodplain and the structural integrity of whatever protective embankments exist;

(3) a site's potential for sediment contribution to surface streams due to sheet wash from hillsides, wind erosion, or direct precipitation on the tailing surface, reflecting the amount and effectiveness of vegetative cover on the site, and the presence of incised drainage channels which facilitate movement of sediment into nearby streams;

Chemical Factors

(1) acid production potential for the site, based on the presence of pyrite in the ore body, quantity of iron evident from chemical analysis of sediment, presence of acid neutralizing agents within

tailing, and historic water quality data;

(2) presence of a fluctuating ground water flow system within the tailing material;

Esthetic Factors

(1) public visibility of the site, reflected in its proximity to public roads and communities; and

(2) an assessment of the visual quality of the site, especially the presence or absence of vegetation and the over-all shape and orientation of the site with respect to surrounding topography.

Table 6 illustrates the results of site classification on the basis of chemical and physical factors. The hazard classes shown in the table correspond to classification criteria mentioned previously. Movement of water through tailing material, both as a result of local rises in ground water levels and infiltration of precipitation, was assumed to be a factor at every site, and would provide a chemical transport mechanism for whatever pollutants were available due to acid leaching. Because the transport mechanism existed at every site, the classification system deals only with the source of pollutants in hazard class A.

The remaining hazard classes represent the physical transport mechanisms governing the contribution of fine-grained sediment by the tailing piles. Massive failure of a site is seen as either the breakdown of an embankment or large-scale slumping of unprotected tailing, either of which would result in the introduction of massive amounts of fine-grained tailing material into a stream. Other hazard classes related to erosion deal with seasonal erosion potential rather than large single-event failures. Seasonal erosion problems generally could be prevented with some earthwork and revegetation.

Table 6. Tailing site classification according to hazard type and potential for pollution*

Site	Drainage	No. of Piles	HAZARD CLASS: A Potential for Acid Production; Long Term Water Pollution Problem — Sufficient Data Available	A — Insufficient Data Available	B Potential Physical Hazard (Massive Failure)	C Potential for Erosion by Surface Streams	D Potential for Sheet Wash and Wind Erosion
1	Pine Creek	2	I		III	IV	V
2	Pine Creek	1	I		I	IV	III
3	Pine Creek	2		-	III	V	IV
4	Pine Creek	2	I		I	IV	IV
5	Pine Creek	1	I		I	IV	IV
6	Pine Creek	2		-	I	III	III
7	South Fork	1	V		II	I	III
8	Moon Creek	6		-	III	V	IV
9	South Fork	2		-	I	I	III
10	Lake Creek	3		-	II	II	III
11	Ninemile Creek	1		-	III	IV	V
12	Ninemile Creek	1		-	V	III	III
13	Ninemile Creek	1		-	II	I	II
14	Ninemile Creek	3		-	I	II	II
15	South Fork	1	I		I	II	III
16	South Fork	1	I		II	I	III
17	South Fork	2		-	I	I	III

* I. No significant potential for physical movement of wastes regardless of reclamation condition.
II. Potential exists, but present reclamation procedures are adequate to control any physical problems.
III. Potential exists, reclamation is inadequate.
IV. High potential exists, no reclamation attempted.
V. Very high potential exists, need for corrective measures obvious.

In rating individual sites, five levels of pollution potential were used. Roman numberals I-V signify the levels, ranging from "no significant potential, regardless of reclamation condition" to "very high potential, need for corrective measures obvious". The suitability of the site for maintenance-free abandonment of a tailing pile was of prime importance.

A further classification of sites according to esthetic factors was attempted in Table 7. The usual problems with rendering a sensitive and subjective topic in strictly objective terms were encountered; however, it is hoped that the composite esthetic rating assigned to each site will provide a useful guide in assigning priorities for reclamation. It can be seen that sites such as 16, which is considered physically and chemically safe, may rank low in esthetics due to a location near a highway or town. Others, such as 1 and 2, may present more severe physical problems, but rank higher in esthetics due mostly to isolation. This information on esthetic factors is not intended as a separate category of pollution problems equal to the physical and chemical transport of pollutants. The esthetic ratings should be used in assigning reclamation priorities among sites exhibiting equal hazards.

Table 7: Tailing site classification according to esthetic factors important in abandonment.

	PUBLIC VISIBILITY		VISUAL QUALITY		
Site	Proximity to Public Roads	Proximity to Communities and Residences	Landscape Continuity	Presence of Vegetation	Composite Esthetic Rating
1	B	[illegible]	C	C	B-
2	B	A	B	D	B
3	C	A	C	C	C
4	C	A	C	C	C
5	C	C	D	C	C-
6	C	B	B	B	B
7	D	C	D	D	D
8	B	B	D	C	C+
9	A	C	B	C	B-
10	C	A	C	B	B-
11	B	A	C	D	C+
12	B	A	B	D	B-
13	C	B	B	B	B
14	C	B	B	C	B-
15	D	B	C	C	C
16	D	D	B	B	C
17	C	C	A	B	B-

Explanation of Symbols:

A . . . Most esthetically favorable condition
- far from public view or hidden by vegetation or landforms, or
- in harmony with landscape, or
- covered by a sustained growth of vegetation.

B . . . Less esthetically favorable condition
- visible from unpaved Forest Service or county road, or
- residences nearby, but not within sight, or
- pile placed along hillside, not occupying entire valley, or
- vegetation is successful on embankments, some present on tailing surface.

C . . . Esthetically unfavorable condition
- visible from paved, well-traveled road, or
- visible from at least one residence, or
- occupying a large portion of the valley and dominating the visual scene, or
- vegetation beginning to encroach on site without modification.

D . . . Most esthetically unfavorable condition
- visible from major interstate highway, or
- visible from an established community, or
- an obvious contradiction to natural landscape, or
- no vegetation on the site.

GENERAL RECLAMATION PLAN

Reclamation Objectives

Three major objectives are addressed in the formulation of the general reclamation plan:

(1) to minimize ground and surface water pollution by heavy metal ions from abandoned tailing impoundments;

(2) to minimize the contribution to surface waters of fine-grained sediments from abandoned tailing impoundments; and

(3) to enhance, where possible, the visual esthetics of the basin.

Guided by these objectives, a series of general alternative reclamation procedures has been prepared. Site-specific reclamation procedures are to be chosen from the list of alternatives comprising the General Reclamation Plan, and are presented in the succeeding chapter.

Selection of Reclamation Procedures

Four major factors control the selection of a reclamation procedure for a specific abandoned tailing site: (1) the type and intensity of the problems, (2) volume of waste, (3) recoverable metal value within the tailing or suitability of the mill wastes as construction material, and (4) potential uses of the reclaimed area. A site-specific reclamation plan must be based upon the identified physical, chemical and esthetic problems of that particular site in relation to the general reclamation objectives. The volume of wastes at each site controls the economics of individual reclamation procedures. For example, physical removal may be the best plan for a small tailing pile that has major chemical problems. Reclamation of an abandoned tailing pile generally involves large expenditures with no direct monetary return. Recoverable metal values in abandoned flotation tailing are normally very low, but there may be potential for use of the material in construction. Revenues from this type of application may help offset the over-all cost of reclamation in the basin. Finally, reclamation of a given site must include consideration of anticipated future land uses. Foundation stability, for example, may be a more important factor at selected sites in the South Fork Valley than effective revegetation. The land value gain in the creation of stable industrial building property could also aid in funding the reclamation effort.

Alternative Reclamation Procedures

Physical Removal of Tailings

This reclamation alternative would be viable only where: (a) there are high recoverable metal values in the mine wastes or (b) the site includes only a small volume of wastes. Recovery of metal values would result in the ultimate disposal of most of the wastes in the active tailing pile associated with the mill doing the reprocessing. Physical removal of wastes without reprocessing would require purchase of space in an existing tailing pile facility, construction of a new and more permanent controlled tailing site, or redeposition in a protected and isolated environment, such as an abandoned mine designated by the mining industry for such a purpose. Removal of tailings could be by loader and truck or slurry pipeline.

Physical Stabilization of Tailings

The method of physical stabilization of tailings selected for a specific site could range from stream channel construction to slope revegetation. In most cases, the stream channel work could include stream alignment and bank erosion control. Protection of tailing pile embankments from stream erosion would be required at a number of individual sites. This could be accomplished by rip rap or similar erosion protection measures.

Diversion of overland flow around or across the wastes would be required at a number of sites. Such diversions could be open ditches or french drains dependent upon site conditions. Diversion of overland flow would probably be accompanied by surface stabilization of the wastes by either revegetation or rock cover. Reclamation will in some cases simply include slope regrading to eliminate drainage channels that have developed due to embankment failures or grading to lessen slope angles to reduce the potential for slope failures. Vegetative cover established on sites for sheet or wind erosion should be of varied types to provide year-round protection and both shallow and deep root development.

Chemical Stabilization of Tailings

One alternative for the chemical stabilization of tailings is the removal of acid-producing wastes to a more controlled environment. This alternative is viable only for small piles unless a large-scale waste reclamation project is implemented in a safe environment, such as a flooded, abandoned mine. On-site reclamation must be based on limiting the acid production or limiting the transport of the acid salts.

The availability of oxygen can be used to control the acid production by either flooding the site or by limiting oxygen movement into the site. The flooding of abandoned tailing piles involves raising the ground water level above the acid producing zones. This alternative is difficult at most controlled tailing sites. Flooding these sites increases the potential for slope failure and makes effective embankment design much more difficult. Most abandoned sites also readily drain out the bottom into the underlying coarse alluvium. Because of these complications, flooding of abandoned tailing piles may not be a viable alternative at any of the sites identified. Bacterial utilization of oxygen has been suggested as a technique for acid control. The overall impacts from this alternative are not known.

Most movement of oxygen into the wastes occurs through the unsaturated zone. Sealing of the surface is one method of limiting the availability of oxygen for the acid production process. Sealing of the surface can be accomplished with construction on the waste material, especially the application of an asphalt paving surface. Air movement must be limited over a large area if this alternative is to be successful in limiting acid production.

Transport of acid salts is accomplished by either water migration down through the wastes or by fluctuations of the saturated zone. Sealing of the surface can be used to prevent downward movement of both oxygen and water. The ground water level can be lowered to prevent fluctuations in the zone of acid production in the tailings. This lowering could be accomplished by either gravity drains or by pumping shallow wells.

Esthetic Improvement of Tailing Sites

Visual improvement of the tailing sites can be accomplished by reshaping and vegetating the sites where necessary and disposing of wood and metal debris. A "pick-up" campaign is needed at many of the abandoned sites. The best alternative for many of the sites along the valley floor of the South Fork is the development of the land for other uses. This may involve regrading and backfilling areas to provide a suitable base for buildings.

APPLICATION OF THE GENERAL RECLAMATION PLAN

After considering the factors important in site abandonment and the reclamation objectives of the general reclamation plan, recommendations are offered for each of the seventeen abandoned controlled tailing sites identified in the basin-wide abandoned tailing inventory. The data available for decision-making at individual sites varies widely. Site 10 has been sampled and analyzed for ground-water quality, surface water quality and tailing composition, while Site 4 was only measured to determine the volume and extent of tailing remaining.

Data are most seriously lacking in the determination of the acid-producing potential of most sites. No sure indicator of such a property of tailing piles has been found. Where data on acid production and leaching were not available, a recommendation for reclamation was based on the presence of iron precipitate in surrounding surface waters and/or the similarity of ore type to a site which either exhibited or did not exhibit acid production or leaching problems.

System for Assigning Reclamation Procedures

Each inventoried controlled abandoned tailing pile was assigned a seven number/letter designation to indicate a recommended reclamation procedure. This system for organizing tailing sites by reclamation requirements was developed as a part of this study and a similar effort by Ioannou (1979) in which reclamation plans were developed for abandoned uncontrolled tailing piles. The key to recommended procedures is given on the following page.

Number---This indicates the relative magnitude of the required reclamation program. The number 1 indicates a minor reclamation program while 10 indicates that extensive work needs to be done.

Letter

Column 1 -- Physical Removal
- A--Physical removal is not an alternative.
- B--Physical removal and reprocessing.
- C--Physical removal and relocation at a new or existing site.

Column 2 -- Stream Erosion Control
- A--No action required.
- B--Channel relocation and construction.
- C--Major channel control.
- D--Improved embankment protection.

Column 3 -- Control or erosion due to overland flow
- A--No action required.
- B--Construction of diversion channel(s) around site.
- C--Construction of drainage channel(s) across site.

Column 4 -- Control of Wind and Sheetwash Erosion
- A--No action required.
- B--Revegetation of the tailing surface.
- C--Revegetation of the protective embankments.
- D--Revegetation of both the tailing surface and the protective embankments.
- E--Rock cover for the tailing surface and the protective embankments.
- F--Stabilization of the tailing surface as a result of secondary uses.

Column 5 -- Control of Chemical Processes
- A--No action required.
- B--Raising or lowering of ground water levels to limit acid production or removal.
- C--Reducing movement of water and oxygen through the tailing to limit acid production or removal.
- D--Placement of buffering materials above or near the tailing to limit acid production.
- X--Data are not available on the chemical processes within the tailing site or are not adequate to make a definite recommendation.

Column 6 -- Other Considerations
- A--No further action required.
- B--Removal of abandoned equipment and structures on the tailing pile.
- C--Reshape the tailing for better landscape continuity and revegetate.
- D--Remove abandoned equipment and structures and reshape and revegetate the tailing pile.

Reclamation Recommendations

Recommended reclamation procedures for each site are shown in Table 8. Each site is identified by number, and a reclamation procedure number/letter designation is given for each. It can be seen that Site 16, which has a procedure number of 1AAABAA, requires very little additional work for effective reclamation, while Site 8 (8ABBDXE) requires an extensive reclamation program.

An important exception to the reclamation procedure recommendation procedure occurs with Site No. 7 (Page tailing impoundment). Improved embankment protection is recommended in Column 2, but the danger is not from outside stream erosion. The construction of a waste water treatment plant on top of the abandoned tailing site may have caused a rise in the phreatic surface within the original tailing embankments, increasing the possibility of an embankment failure.

Table 8

Recommended Reclamation Procedures for Abandoned Controlled Tailing Piles in the Drainage of the South Fork of the Coeur d'Alene River, Idaho

Site Number	Basin Location	Problem Magnitude Number	Procedure Number					
			Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1	East Fork Pine Creek	5	A	D	C	D	A	B
2	East Fork Pine Creek	2	C	A	A	A	A	B
3	East Fork Pine Creek	5	A	C	A	B	X	A
4	East Fork Pine Creek	2	C	A	A	A	A	A
5	Pine Creek	4	C	A	A	B	A	A
6	Pine Creek	4	A	D	C	B	X	D
7	South Fork at Smelterville	6	A	D	A	D	C	A
8	East Fork Moon Creek	8	A	B	B	D	X	D
9	South Fork at Osburn	1	A	A	A	B	X	A
10	Lake Creek	1	A	A	A	B	X	A
11	East Fork Ninemile Creek	5	A	D	B	D	X	A
12	East Fork Ninemile Creek	6	A	A	B	D	X	A
13	Ninemile Creek	1	A	A	A	B	X	A
14	Ninemile Creek	1	A	A	A	A	X	A
15	South Fork above Wallace	3	A	A	A	D	A	A
16	South Fork at Mullan	1	A	A	A	B	A	A
17	South Fork at Mullan	1	A	A	A	B	X	A

SUMMARY AND CONCLUSIONS

Summary of Findings

1. Abandoned tailing impoundments resulting from nearly sixty years' use of the froth flotation process for ore concentration can be found throughout the South Fork drainage. These piles of fine-grained tailing exist in various stages of abandonment and differ widely in the degree of potential for pollution.
2. Hydrologic and physical examinations of three abandoned tailing piles provided the basis for the selection of factors important in site abandonment. Physical, chemical and esthetic factors were identified as being important in site abandonment.
3. A total of seventeen uncontrolled abandoned tailing sites were identified. These abandoned tailing impoundments have been classified according to the following potential hazards to the environment:
   (a) massive structural failure of pile;
   (b) erosion by surface streams;
   (c) erosion by wind and sheet wash;
   (d) acid production and metals leaching;
   (e) transport of pollutants by ground water;
   (f) public visibility of the site; and
   (g) visual quality and vegetative cover at the site.
4. A general reclamation plan was drafted. It was designed to minimize the degradation of water quality in the South Fork drainage as a result of physical and chemical processes which act on the piles of abandoned tailings distributed throughout the basin. Esthetic

improvement of the tailing sites is a secondary objective of the reclamation plan. Reclamation can usually be achieved through the application of physical and chemical stabilization procedures and some simple clean-up activities.

5. The general reclamation plan was applied to each of the seventeen abandoned controlled tailing sites identified in the inventory portion of the study. Alternative reclamation procedures were chosen from those outlined in the general reclamation plan, resulting in a recommended reclamation plan for each of the seventeen sites.

Conclusions

1. The major water-quality problem with abandoned "controlled" tailing piles in the South Fork of the Coeur d'Alene River basin is physical rather than chemical. Nearly all identified sites are threatened by active streams, sheet wash and wind. Old failures along decant lines at a number of sites tend to concentrate runoff from precipitation and thereby increase sediment loads of nearby streams. Two sites present a potential for massive failure due to a position high in a watershed and inadequate diversion facilities. Only one site is a documented chemical problem, probably due to the relatively high concentrations of zinc and lead contained in tailing deposited as early as 1926. Chemical data were not available for most of the controlled sites.

2. A long-term solution is needed for the tailings now being produced in the valley and for the abandoned tailing impoundments identified in this study. A comprehensive plan for tailings disposal could greatly reduce the continuing problem of finding flat land for

building tailing piles and the subsequent problems associated with the safe abandonment of those piles. This solution should involve the maximum use of mill tailings as mine backfill, the designation of an orphaned underground mines as a tailing disposal site, the construction of carefully designed tailing landfills in the valley to serve as foundations for building construction, or a combination of these or as yet undetermined alternatives. This study is intended as a guide for implementing reclamation procedures on abandoned tailing impoundments. It is hoped that the reclamation plans identified in these theses will serve as guidelines in reducing water quality degradation from tailing impoundments to be abandoned in the future, as well as those already abandoned.

3. Potential chemical problems with abandoned controlled tailing piles are difficult to diagnose due to some significant problems in data collection and analysis. Procedures exist for sampling ground water within tailing and for measuring metal ion concentrations in nearby surface waters, but no clear indicator has been found which would indicate the acid-production potential of a pile of tailing, given a sample of the mill waste material itself. Because of the seasonal "flushing" action of rising water tables within tailing material and the oxidation which tends to occur in the unsaturated zone of the piles, timing of ground-water samples and sampling depth become very important in establishing a reasonable data base from which to assess the chemical potential for water pollution.

4. Reclamation procedures for the abandoned "controlled" tailing sites are generally simple, most requiring only some reshaping of the pile

surface, some rip-rapping of adjoining stream banks, and revegetation. Unfortunately, there is no economic incentive to aid implementation of the procedures. Reduction in suspended sediment loads of area streams and the over-all esthetic improvement of the valley are the only present rewards.

5. The primary need for further research in abandoned tailing impoundment reclamation is in the area of large-volume tailing disposal methods in mountain environments. The nation's need for metals will continue, and lower-grade ore bodies will become economically mineable. Improvements in ore recovery processes will also make possible the processing of larger volumes of rock for a given amount of concentrate. This will ultimately result in an increasingly serious mill waste disposal problem. Level land is already scarce in the steep mountain valleys of the South Fork basin. Mining companies presently are pumping tailing long distances at great expense, and every new tailing impoundment competes with a growing population for the little flat land available. This study has identified ways to avoid problems presented by abandoned tailing impoundments, but more work is necessary to deal with the volumes of tailing expected to be produced as mining continues in the South Fork basin.

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APPENDIX A

INVENTORY OF ABANDONED CONTROLLED MILL TAILING SITES

South Fork Coeur d'Alene River Basin, Idaho

Site number: 1

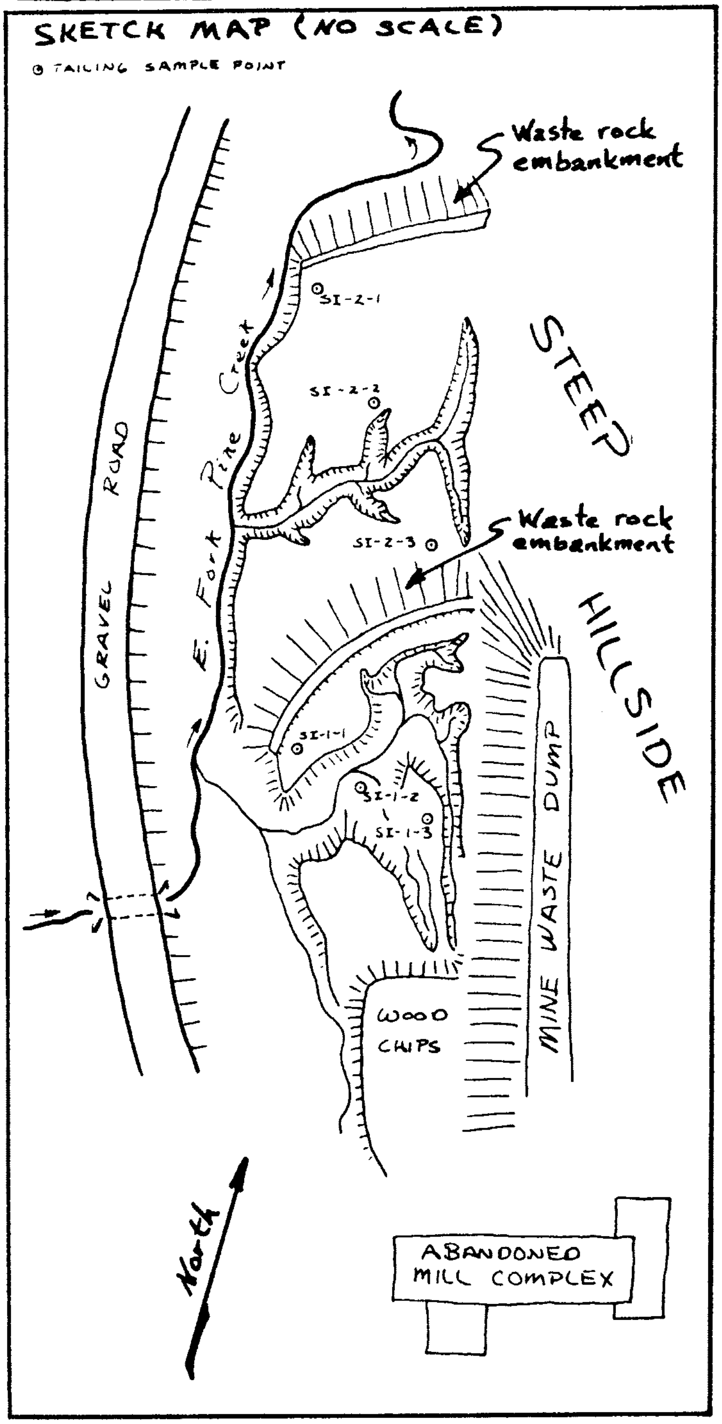
Basin location: East Fork of Pine Creek above Gilbert Creek

Map location: NE¼, NW¼, Sec. 11, T.47N., R.2E.

Approximate surface area: 2 acres

Approximate volume of tailing: 25,000 cubic yards

Description of the site: Abandoned tailing site No. 1 is a crescent-shaped deposit of flotation tailing approximately 500 feet long and 180 feet wide between a steep hillside and the East Fork of Pine Creek. The nearest dwelling is 3 miles downstream. A gravel county road just west of the East Fork confines the flow of the stream between the road embankment and the tailing pile. Two distinct impoundments are present, both of which exhibit remnants of crushed-rock embankments constructed to impound the tailing for dewatering. Both imoundments have failed structurally, apparently along the original wooden decant structures. The lower embankment and tailing deposit has been eroded extensively by the creek, as well as through runoff from the hill-side tributary to the pile surface.



Flotation tailing material was deposited behind constructed embankments along the east margin of the floodplain. Clarified water was decanted through wooden conduits laid beneath the embankments. Both sand-size tailing and slimes are dark gray in color when wet, weathering to a nearly white color when exposed on land surface. Chemical analysis of tailing samples (see Appendix B) reveals no unusually high concentrations of dangerous elements. Iron concentrations are unusually low, indicating that pyrite oxidation may not be a problem.

Only a few grasses have been established on the tailing surface, mostly where some organic material has been mixed with the sandy portion. A few bushes and trees are growing in the extreme northern embankment. At least 90% of the remaining pile surface is unvegetated.

Erosion by streams, wind and sheet wash appears to be the major problem affecting water quality at this site. Failure of the embankments and subsequent encroachment on the site by flood flows of the East Fork of Pine Creek have resulted in a situation where a large amount of fine-grained sediment is completely open to erosive forces. Deep channels have been carved into the tailing surface by runoff from the site itself as well as the hillside above. These channels add sediment to the stream with every precipitation event.

Recommended reclamation: 1) Embankment protection should be increased to prevent direct erosion by the adjoining stream. 2) Reshaping the tailing surface and providing safe drainage channels across the tailing is required to prevent erosion of tailing through runoff channels. 3) Revegetation is necessary to stabilize tailing surfaces. 4) Removal or burial of discarded chemical drums and other debris would make the site more esthetically pleasing.

Site number: 2

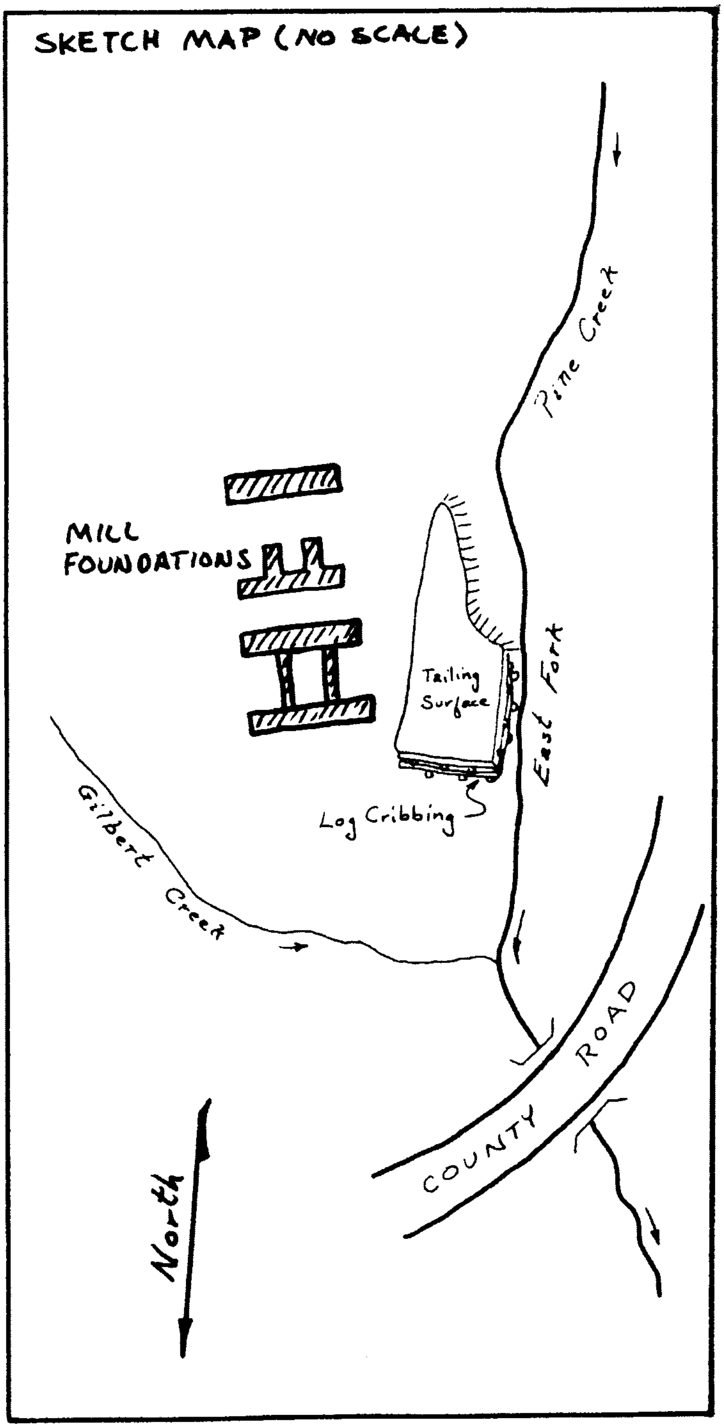
Basin location: East Fork of Pine Creek at Gilbert Creek

Map location: SW¼, Sec. 2, T.47N., R.2E.

Approximate surface area: 540 square yards

Approximate volume of tailing: 900 cubic yards

Description of the site: Abandoned controlled tailing impoundment No. 2 is located on the east bank of the East Fork of Pine Creek, just above the mouth of Gilbert Creek. Part of the remaining tailing material is still protected by its original embankment of log cribbing. The southernmost section of the site has been eroded so that a vertical bank approximately 8 feet high of tailing sands and slimes is exposed at the stream's edge.



Tailing material at Site No. 2 varies from gray slimes to dark brown and orange sand. No chemical analysis was made at this site. Reddish stain was present on rocks in the lower reaches of Gilbert Creek, but the source for low-quality water is probably mine drainage higher in that watershed. Almost no vegetation is established on the tailing surface.

The major problem presented by Site No. 2 appears to be that of potential sediment contribution to the Pine Creek drainage. No data on chemical problems from the site are available. Without remedial action, erosion by the East Fork of Pine Creek will continue, the rate dependent on the severity of flooding.

Recommended reclamation: 1) Due to the relatively small size of this site, the most reasonable reclamation alternative seems to be complete removal of the tailing to a more easily controlled site. 2) A variety of abandoned equipment, structures, and other debris could be buried or removed to improve site esthetics.

Site number: 3

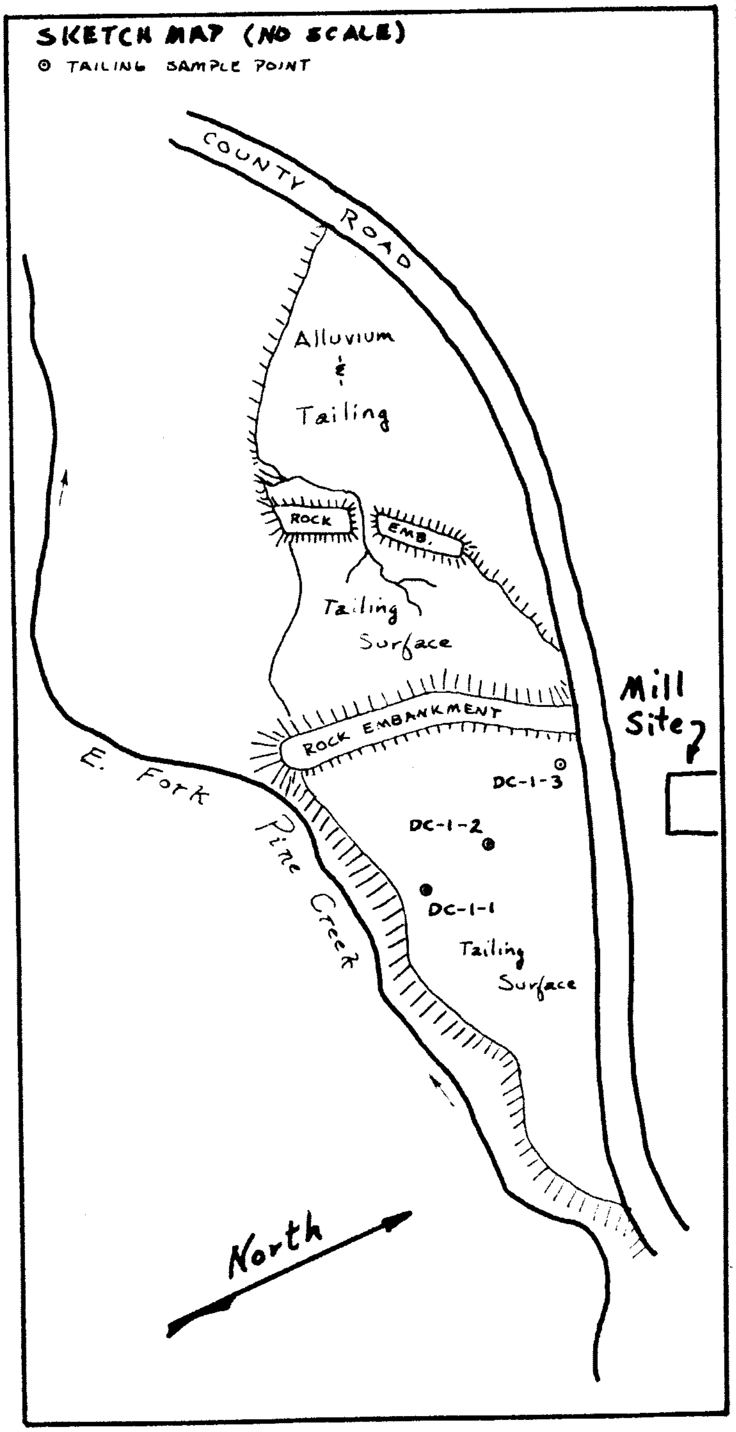
Basin location: East Fork of Pine Creek, 300 feet above Dry Creek

Map location: SE¼, Sec. 34, T.48N., R.2E.

Approximate surface area: 2.4 acres

Approximate volume of tailing: 31,000 cubic yards

Description of the site: Site No. 3 lies just north of the East Fork of Pine Creek and is confined between the creek and county road, which appears to have been built at least partially on the tailing surface. Remnants of mine waste rock/alluvial gravel embankments are present at two locations on the site, dividing the tailing pile into two distinct segments. Both embankments have failed, and a vertical bank of tailing up to 15 feet high is immediately available for stream erosion along 500 feet of the pile's south edge.



Tailing material impounded at this site is mostly brown, ranging in size from slimes to sand. Chemical analysis of tailing composition (See Appendix C) indicates moderate iron content and relatively high concentrations of zinc. Tailing in the upper (east) pile averages approximately 12 feet in thickness and has no vegetative cover. Trees, shrubs, and grasses have been established on both embankments and on the lower tailing surface.

Recommended reclamation: Assuming that further chemical analysis does not show significant leaching of metals, recommended reclamation involves reconstruction of the embankment along the East Fork and revegetation of the pile surfaces.

Site number: 4

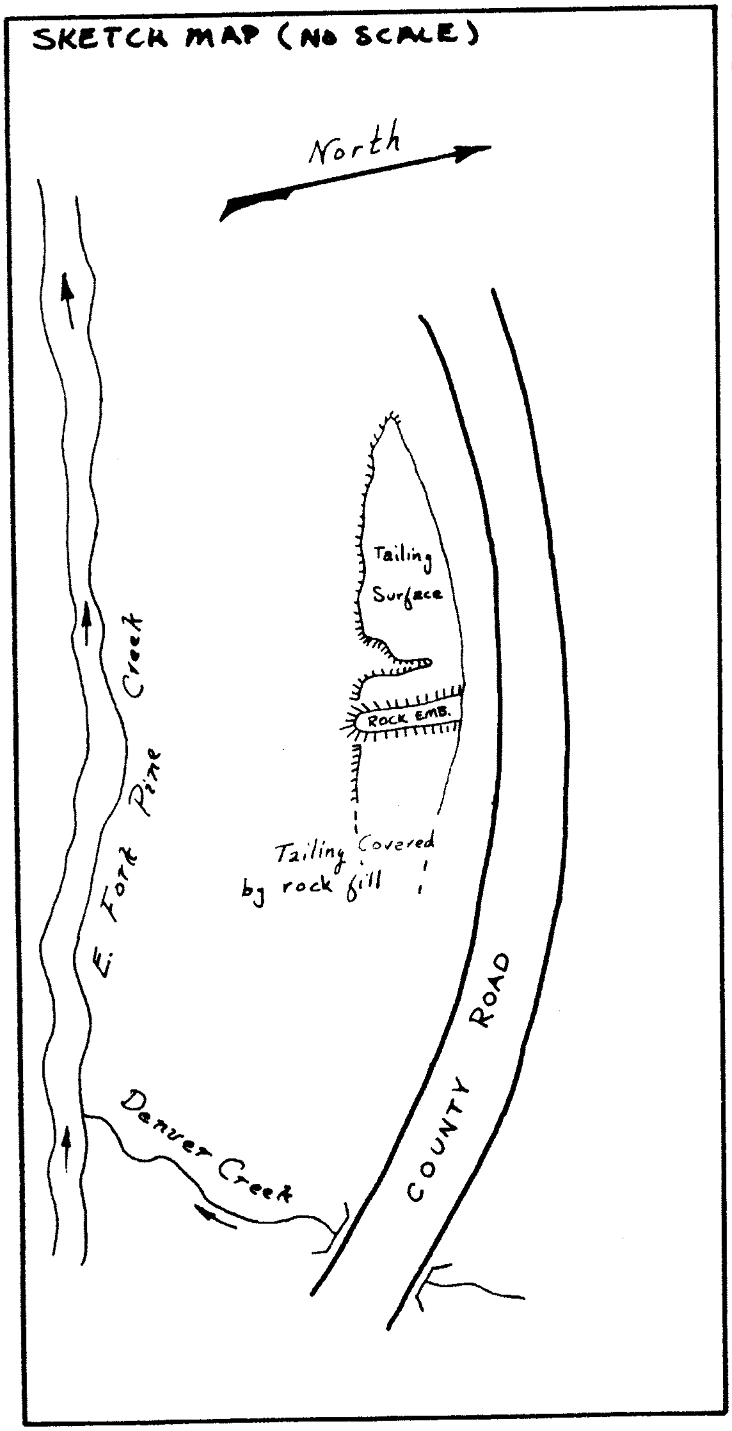
Basin location: East Fork of Pine Creek, 300 feet below Denver Creek

Map location: SE¼, Sec. 28, T.48N., R.2E.

Approximate surface area: ¼ acre

Approximate volume of tailing: 1,600 cubic yards

Description of the site: Site No. 4 lies between the East Fork of Pine Creek and the county road. Only a small remnant of an embankment still exists, and the tailing is completely unprotected from wind, sheet wash, and stream erosion. The pile has high visibility, being located on the inside of a curve in the county road.



Tailing in the pile is yellow to gray in color, and ranges in size from coarse sand to slimes. Maximum thickness of the pile is estimated to be 4 feet. A few varieties of short grass exist on the tailing surface, and a single pine tree is established on the old embankment.

Recommended reclamation: The relatively small volume, high visibility, and exposure to erosion exhibited by Site 4 lead to a recommendation that the tailing material be removed to another site.

Reprocessing with disposal in an active tailing impoundment should be explored as an alternative.

Site number: 5

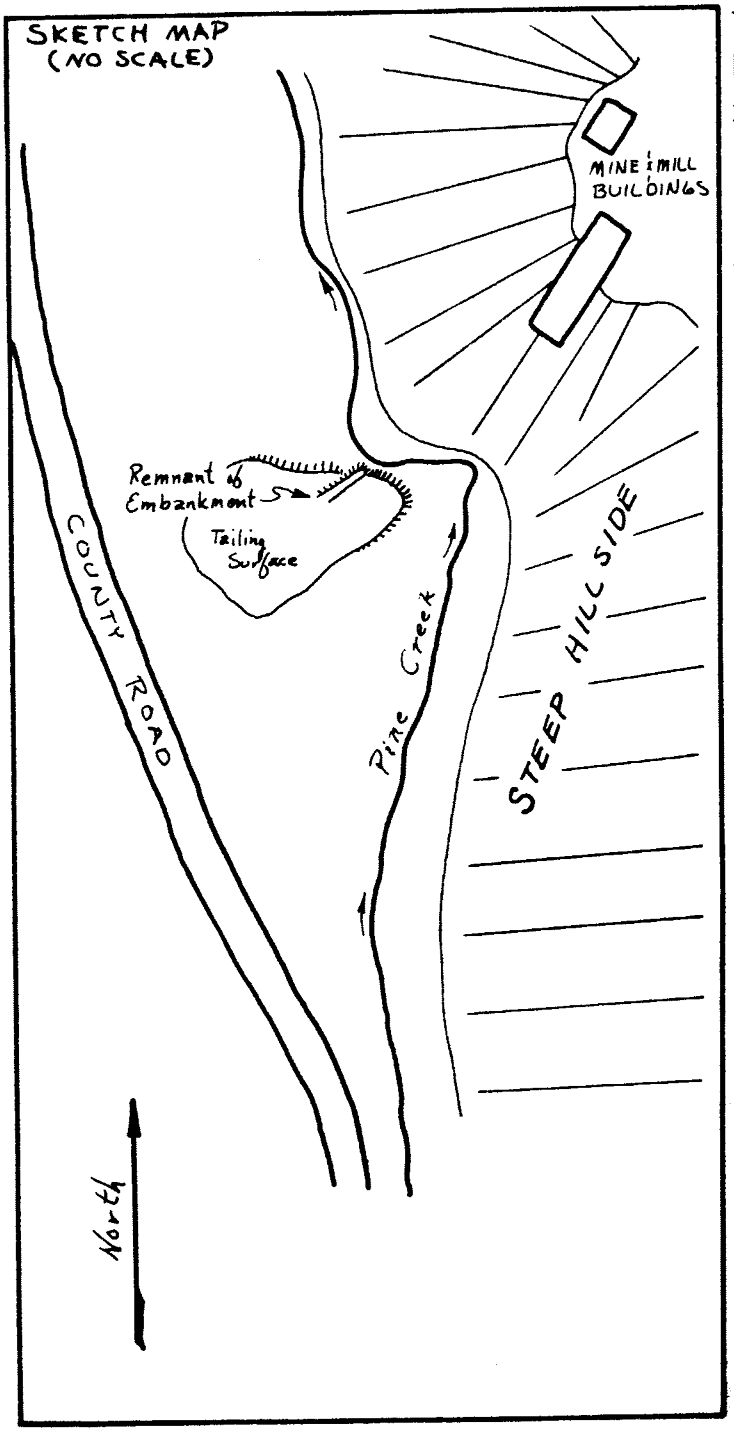
Basin location: Pine Creek above Klondike Gulch

Map location: NW¼, Sec. 20, T.84N., R.2E.

Approximate surface area: 2.5 acres

Approximate volume of tailing: 9,000 cubic yards

Description of the site: Controlled Tailing Site No. 5 is located in the Pine Creek floodplain behind an auto salvage yard 3 miles south of Pinehurst. Erosion by wind and water (and apparent bulldozer activity) has destroyed all but a small remnant of the controlling embankment. The remaining tailing material is yellow, ranging in size from fine sand to slimes. The deposit is oval, approximately 500 feet in length, with a maximum thickness of about 2.5 feet.



There is no protection from flood waters of Pine Creek, although grasses and small trees are reclaiming the south and east portions of the tailing surface.

Recommended reclamation: Because of the small volume and high potential for erosion, removal is recommended for this site. Complete recovery will probably not be possible, so revegetation of the remaining tailing material is suggested.

Site number: 6

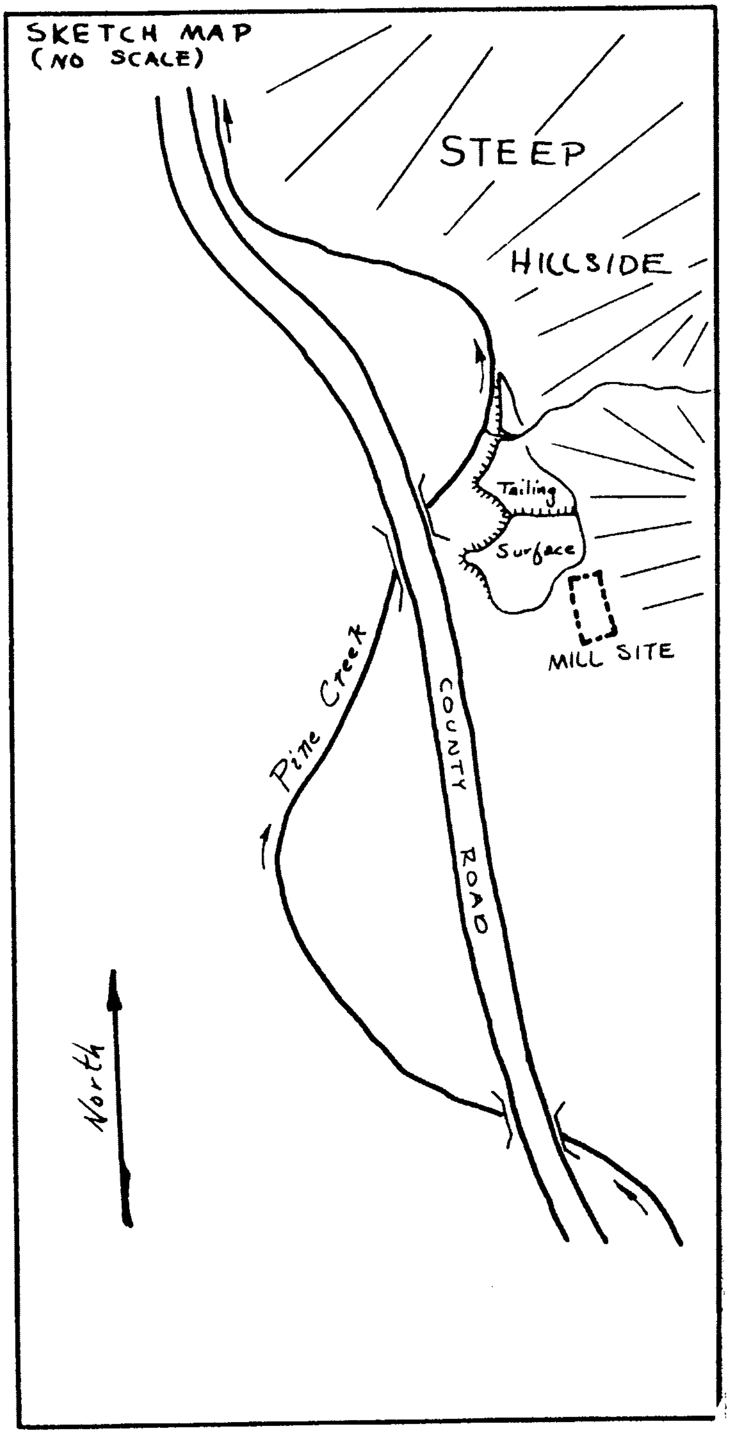
Basin location: Pine Creek below Hauck Gulch

Map location: SE¼, NW¼, NW¼, Sec. 17, T.48N., R.2E.

Approximate surface area: ¼ acre

Approximate volume of tailing: 1,200 cubic yards

Description of the site: Site No. 6 is located just east of Pine Creek at the second county road bridge south of Pinehurst (approximately 2 miles south of Pinehurst). The recently-constructed bridge abutments and riprap serve to protect most of the site from encroachment by Pine Creek. The northernmost section is vulnerable to erosion both by Pine Creek and the perennial tributary stream which crosses the tailing surface.



Much of the tailing surface now supports vegetation, especially the section nearest the mill site and roadway. Both jig and flotation tailing are found at the site, and pieces of abandoned structures and equipment litter the area.

Recommended reclamation: Relatively little additional riprap protection would be necessary to prevent erosion of the tailing material. Some earth-moving will be necessary to insure that the tributary stream does not cross the tailing surface, and removal or burial of the abandoned equipment would make the area more esthetically pleasing.

Site number: 7

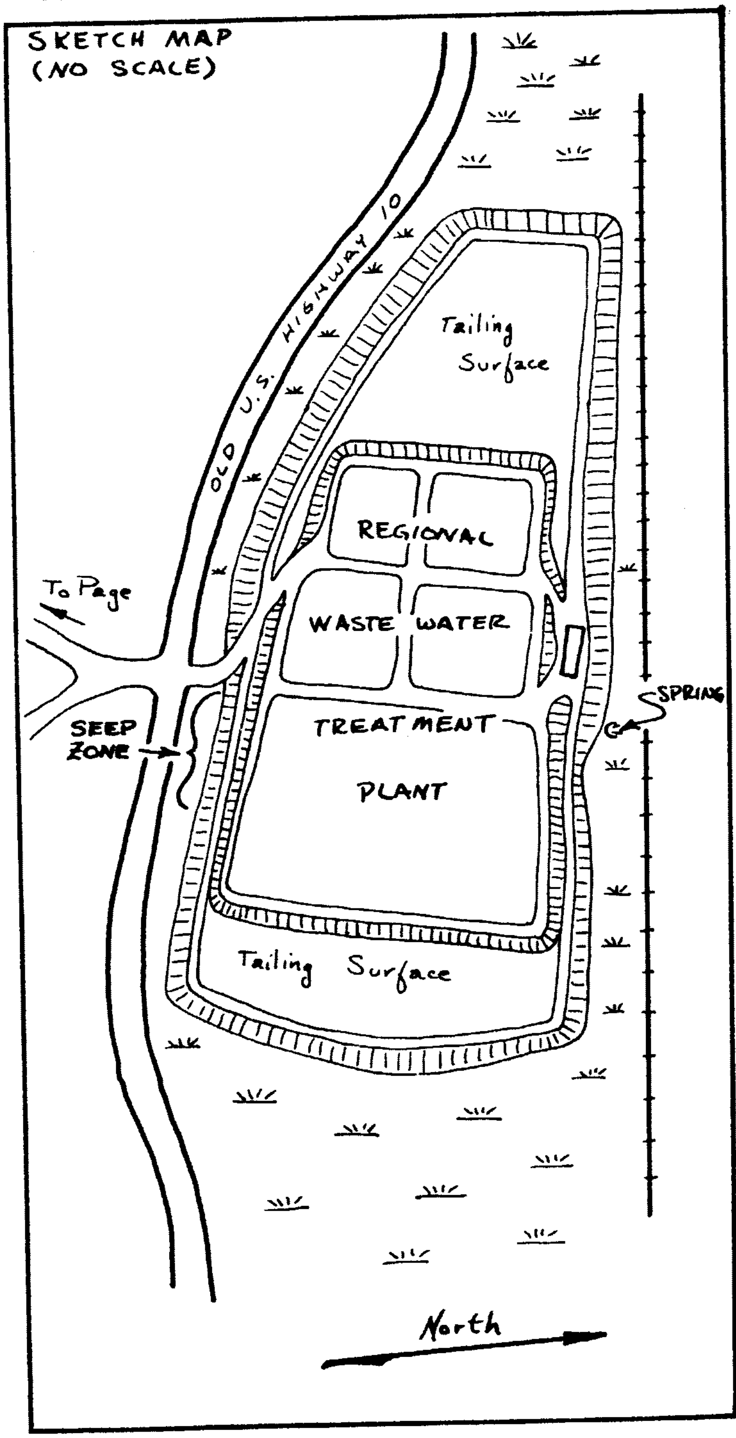
Basin location: South Fork Coeur d'Alene River near Humboldt Gulch

Map location: SE¼, Sec. 33, T.49N., R.2E.

Approximate surface area: 70 acres

Approximate volume of tailing: 2.8 million cubic yards

Description of the site: A detailed description of Site No. 7, the Page tailing pile, has been included in the text, pages 43 - 59.



Recommended reclamation:

1) Improve the condition of waste-rock embankments on the north and south sides of the pile parallel to the treatment plant dikes. 2) Introduce vegetation to the bare pile surface using imported topsoil or a secondary nutrient source, such as sewage sludge. Irrigation volume and frequency should be closely monitored.

3) Line the wastewater ponds with an impermeable material to reduce the chance of embankment failure and to slow the movement of metals from within, under, and around the pile toward the South Fork of the Coeur d'Alene River.

Site number; 8

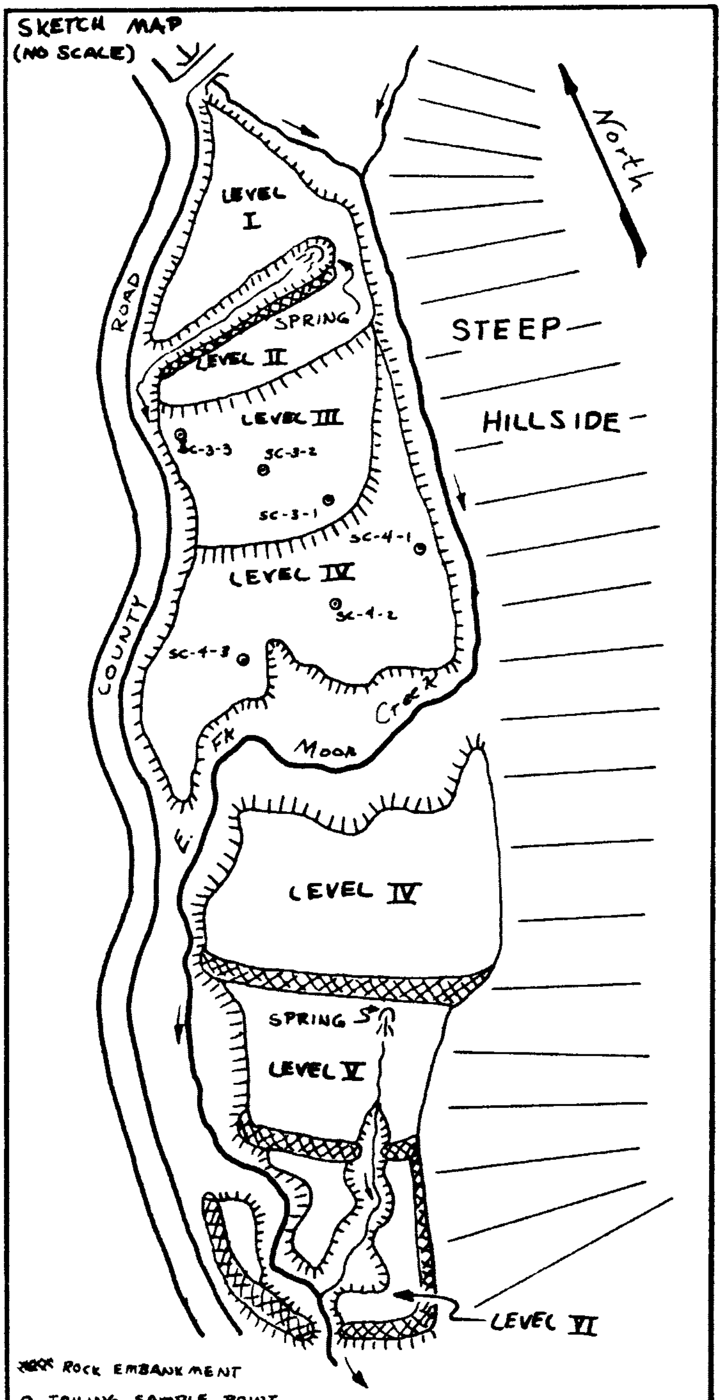
Basin location: East Fork of Moon Creek

Map location: E½, SW¼, Sec. 25, T.49N., R.3E.

Approximate surface area: 5 acres

Approximate volume of tailing: 42,000 cubic yards

Description of the site: Site 8 is located on the East Fork of Moon Creek 3 miles above its confluence with the South Fork of the Coeur d'Alene River. The remnants of tailing piles and embankments are deeply eroded by streams and exhibit six distinct levels of tailing, as shown at left. Erosion is active on all levels, and vertical banks 6 feet high are sloughing into the stream with each runoff event. At least three embankments in the series have failed, providing a path for the stream directly across tailing surfaces.



Two major ground-water discharge points exist at the site. One is in an apparent former stream channel now blocked by tailing between levels I and II, and the other is on the surface of level V just below the toe of the level IV embankment.

Tailing material discharged at the site was produced by a "custom" mill, and the different colors of oxidized tailing on the various levels indicate a variety of ore and tailing types. Chemical analysis (Appendix C) of the tailing also shows the complexity of the site. The highest lead and zinc concentrations encountered in the study were from Site 8.

Recommended reclamation: The first step in reclaiming this site should be the isolation of all tailing material from the stream. Detailed chemical data for the site is not available, but preliminary information indicates the possibility of a metals-leaching problem. It will be important to reduce ground-water movement through and beneath the piles along buried stream channels and to create a safe channel for the East Fork of Moon Creek. Vegetation is already established on some of the piles, and should be encouraged when the stream erosion problem has been solved.

Site number: 9

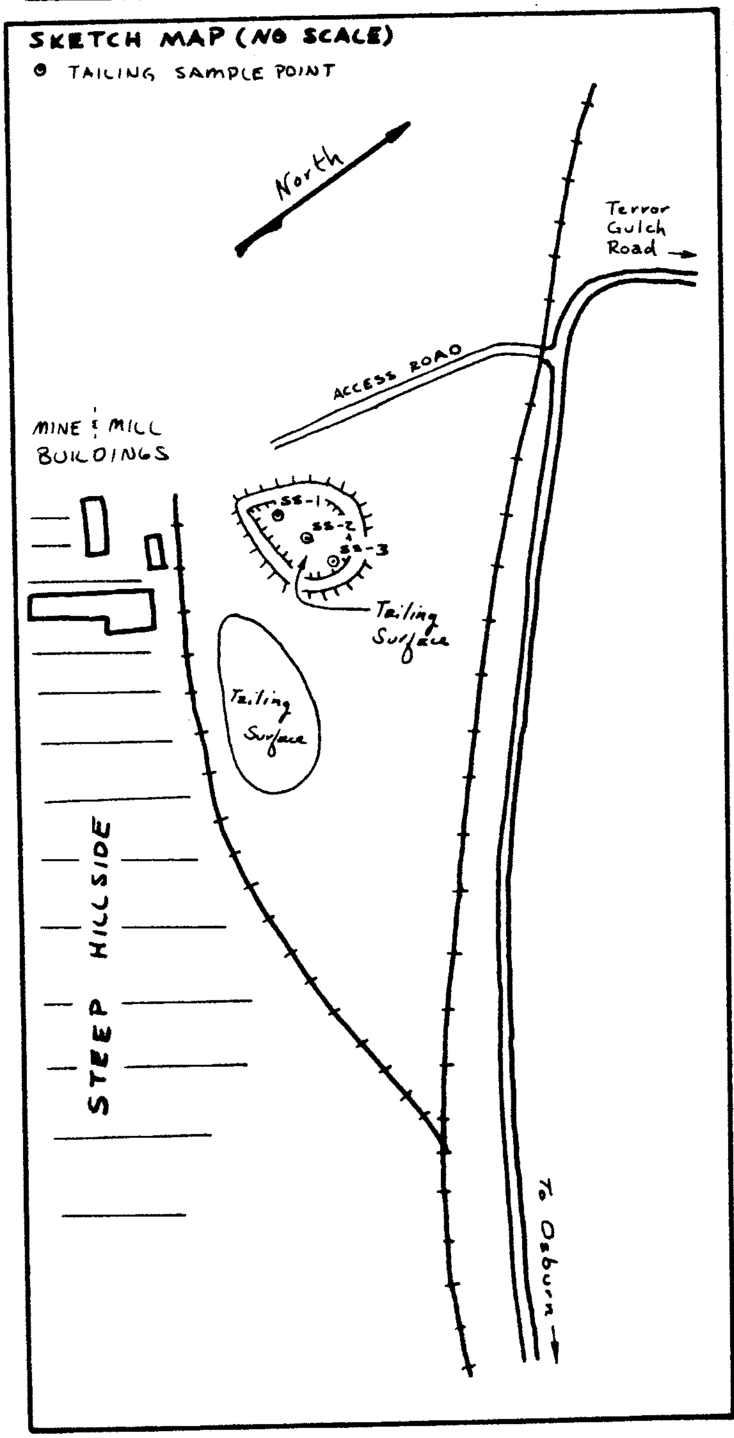
Basin location: South Fork Coeur d'Alene River above Rosebud Gulch

Map location: NW¼, Sec. 13, T.48N., R.3E.

Approximate surface area: 1 acre (total for two sites)

Approximate volume of tailing: not available

Description of the site: Site No. 9 consists of two tailing piles south of Interstate Highway 90 at the edge of the community of Osburn. The western pile has obvious embankments and a decant system. Deposition has been by means of a single-pipe discharge near the pile's center. The second site has been graded flat and is used informally as a motorcycle racetrack. The area surrounding the piles has very little relief, and neither site is in any danger from stream erosion or overtopping from storm runoff. Chemical analysis results are given in Appendix C. Tailing samples show high iron and manganese concentrations, but very little lead, zinc, or cadmium.



Recommended reclamation:
Revegetation is the only reclamation procedure necessary at this site. Visibility is low due to the low reflief of the area and good vegetation growth everywhere

except the tailing surface. Establishing vegetation on these surfaces should solve the wind erosion problem.

Site number: 10

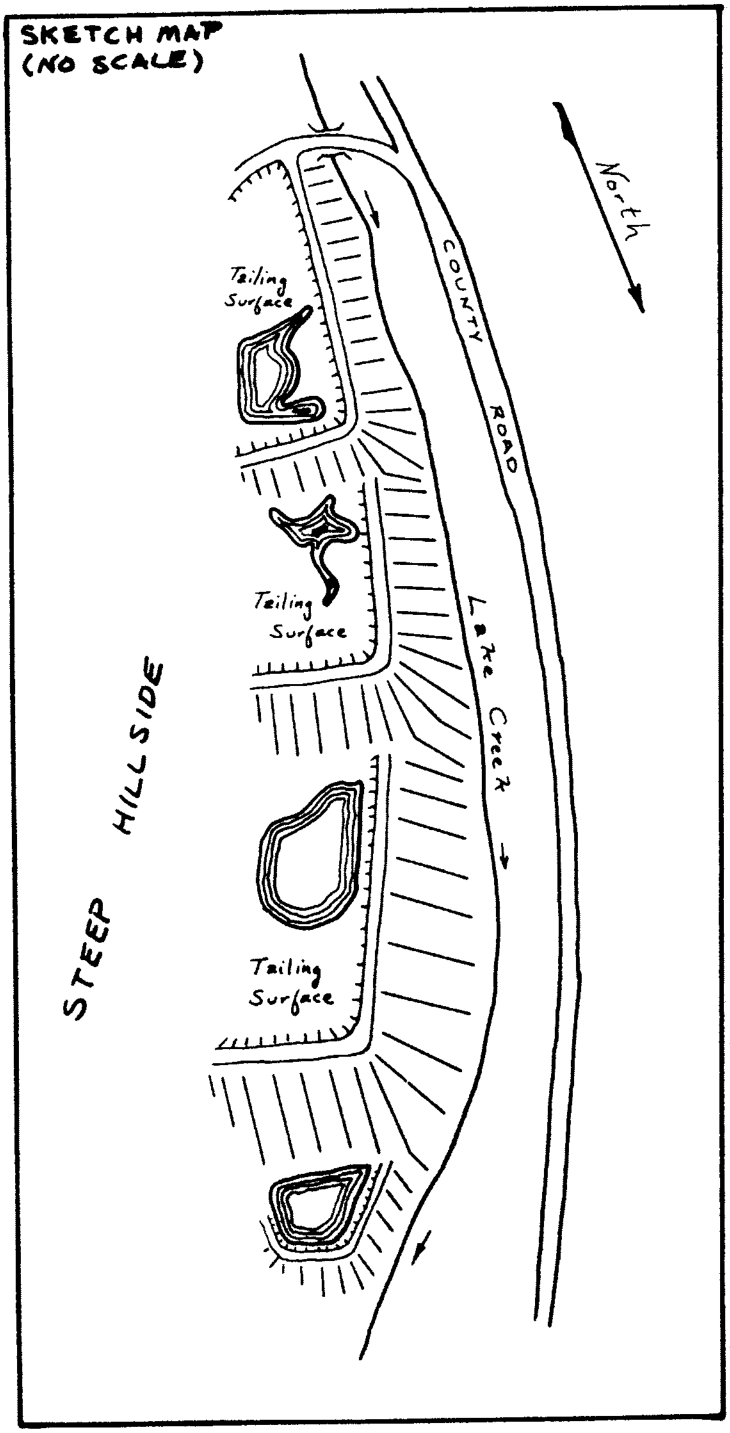
Basin location: Lake Creek

Map location: NW¼, Sec. 28, T.48N., R.4E.

Approximate surface area: 9 acres (total for three piles)

Approximate volume of tailing: not available

Description of the site: This site was one of three selected for detailed examination in this study, and is described on pages 30 - 43 of the text. Only the lowest pile (Galena tailing Impoundment No. 3) has been studied. The other two piles can be expected to have similar chemical composition and hydrologic properties. All three are being kept ready to receive additional tailing. New embankment lifts were constructed prior to 1977, and the decant systems are in constant use as mine drainage water is circulated.



Ground-water quality data are available for the downstream pile, but are not conclusive regarding the site's potential for providing pollutants to the Lake Creek drainage. More frequent monitoring will be necessary to adequately assess the site's need for chemical stabilization or isolation procedures. Vegetation has been established on all rock embankments, and is having some success on the tailing surfaces.

Recommended reclamation: Revegetation is the only procedure necessary at this site. Stream erosion has been prevented with riprap, and all embankments appear to be in good shape for abandonment.

Site number: 11

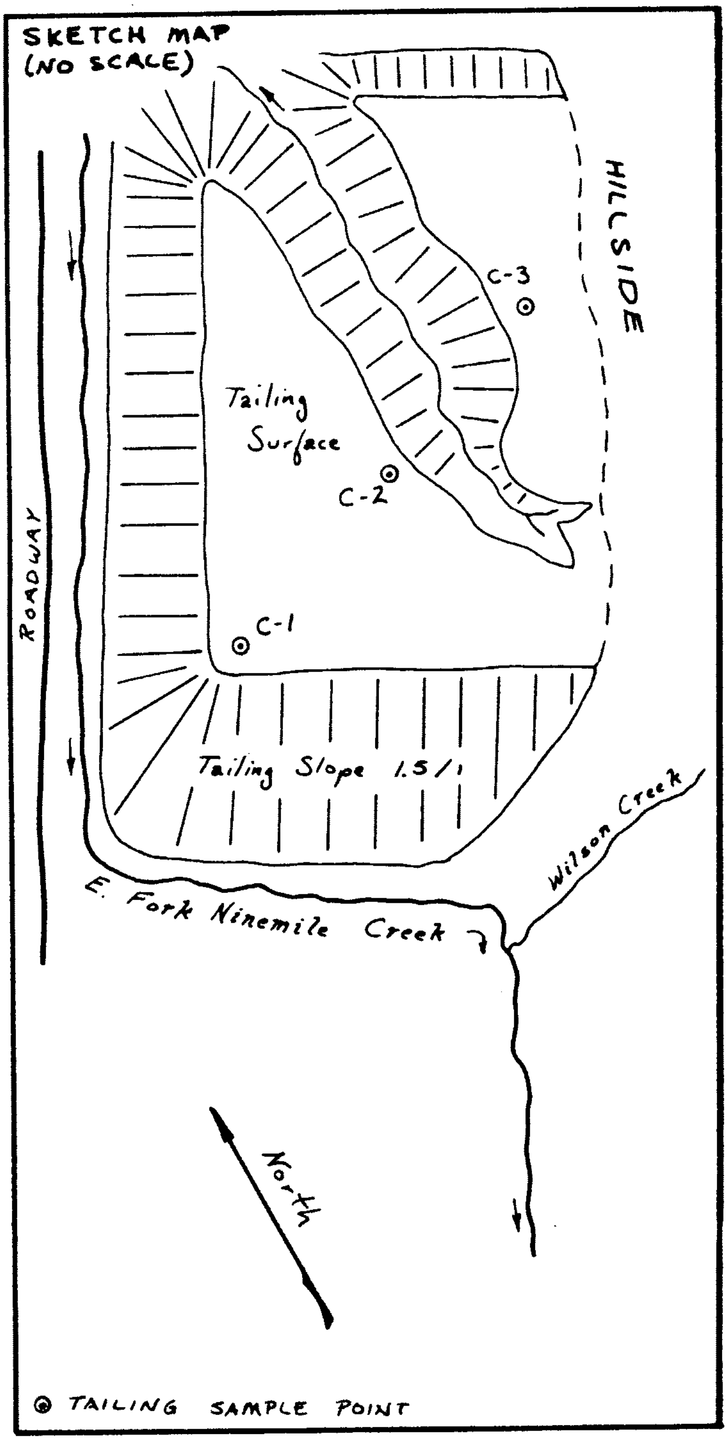
Basin location: East Fork of Ninemile Creek above Wilson Creek

Map location: SE¼, NE¼, Sec. 6, T.48N., R.5E.

Approximate surface area: 1 acre

Approximate volume of tailing: not available

Description of the site: Site No. 11 is immediately adjacent to the East Fork of Ninemile Creek approximately 6 miles north-east of Wallace. It is the only site in the basin with no rock embankment. Tailing was deposited using the upstream method, with coarser material forming the steep outside surface. The remaining pile has side slopes of 1.5:1 and has failed along a decant line. A major erosion channel is cut into the pile's center, and the toe of the northwest-facing slope is being cut by stream erosion.



Chemical analysis of tailing samples shows moderately high concentrations of lead, zinc, and iron, but very little calcium. No water quality data is available.

Recommended reclamation: Channel stabilization and slope protection are needed along the East Fork of Ninemile Creek. Slopes of the pile are steep, and re-shaping should be done prior to revegetation. An additional diversion channel is recommended to control hillside runoff above the pile.

Site number: 12

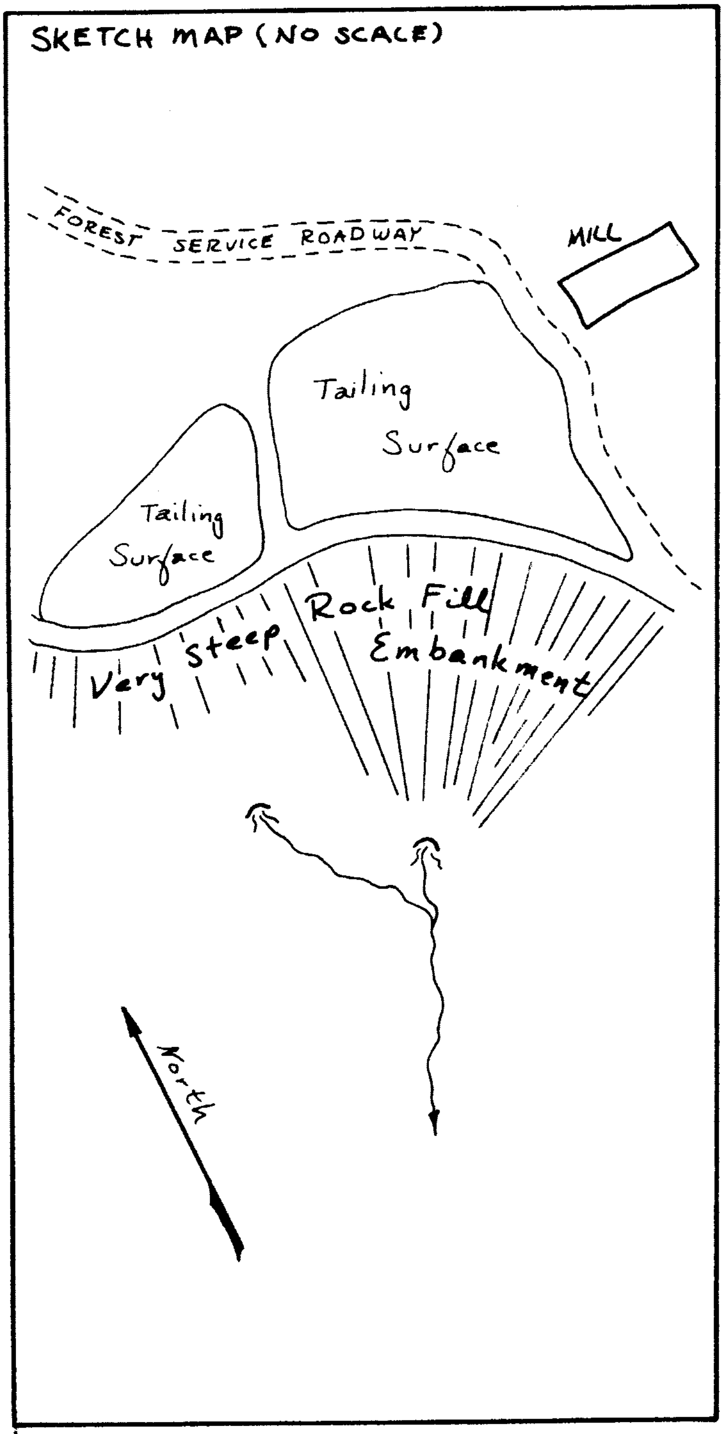
Basin location: Unnamed tributary to East Fork of Ninemile Creek

Map location: SE¼, NW¼, Sec. 6, T.48N., R.5E.

Approximate surface area: not available

Approximate volume of tailing: not available

Description of the site: Site No. 12 is constructed across a steep, narrow valley high in the Ninemile Creek watershed. A steep rock-fill embankment over 100 feet high (slope distance) has no vegetation cover and appears to be discharging water at the toe. Flotation tailing (sands to slimes) fills the area above the embankment, and a single pipe through the embankment is the only protection from overtopping in a severe precipitation event. Runoff diversions to by-pass the impoundment surface are inadequate.



Chemical analysis was not performed on ground water or tailing at this site.

Recommended reclamation: Successful reclamation at this site will depend on the effectiveness of permanent surface-water control structures to prevent massive failure of the embankments.

Site number: 13 and 14

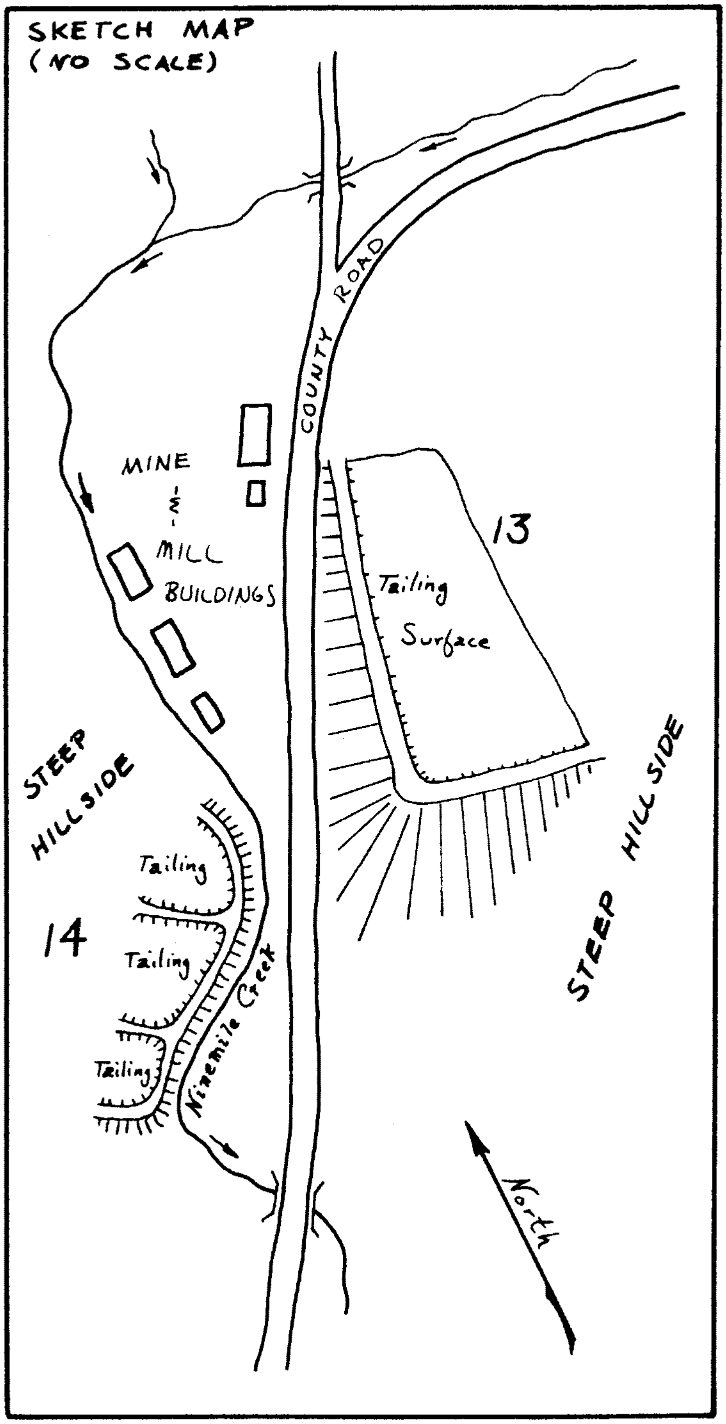
Basin location: Ninemile Creek above Blackcloud Creek

Map location: SW¼, NW¼, Sec. 13, T.48N., R.4E.

Approximate surface area: 6 acres

Approximate volume of tailing: not available

Description of the site: Site 13 consists of a single tailing impoundment built against a steep hillside across the county road from Ninemile Creek approximately 3 miles NE of Wallace. The L-shaped rock-fill embankment has good vegetation growth and appears quite stable, with a small tributary area and low visibility of the tailing surface. No tailing composition date are available.



Site 14 contains three small ponds just west of Ninemile Creek, all of which appear to have adequate embankment protection and good vegetation growth both on the embankments and tailing surface. Some standing water is present, but flow conditions have not been investigated. No chemical data is available.

Recommended reclamation: Site No. 13 exhibits good vegetative stability on the embankments and is safe from stream-channel encroachment.

Further recommendations for reclamation procedures, based on a brief examination, call only for vegetation to be established on the tailing surface.

Site 14 is very small and well protected from Ninemile Creek by stable embankments. As long as no chemical problems are attributed to this site by future investigations, no further reclamation is necessary.

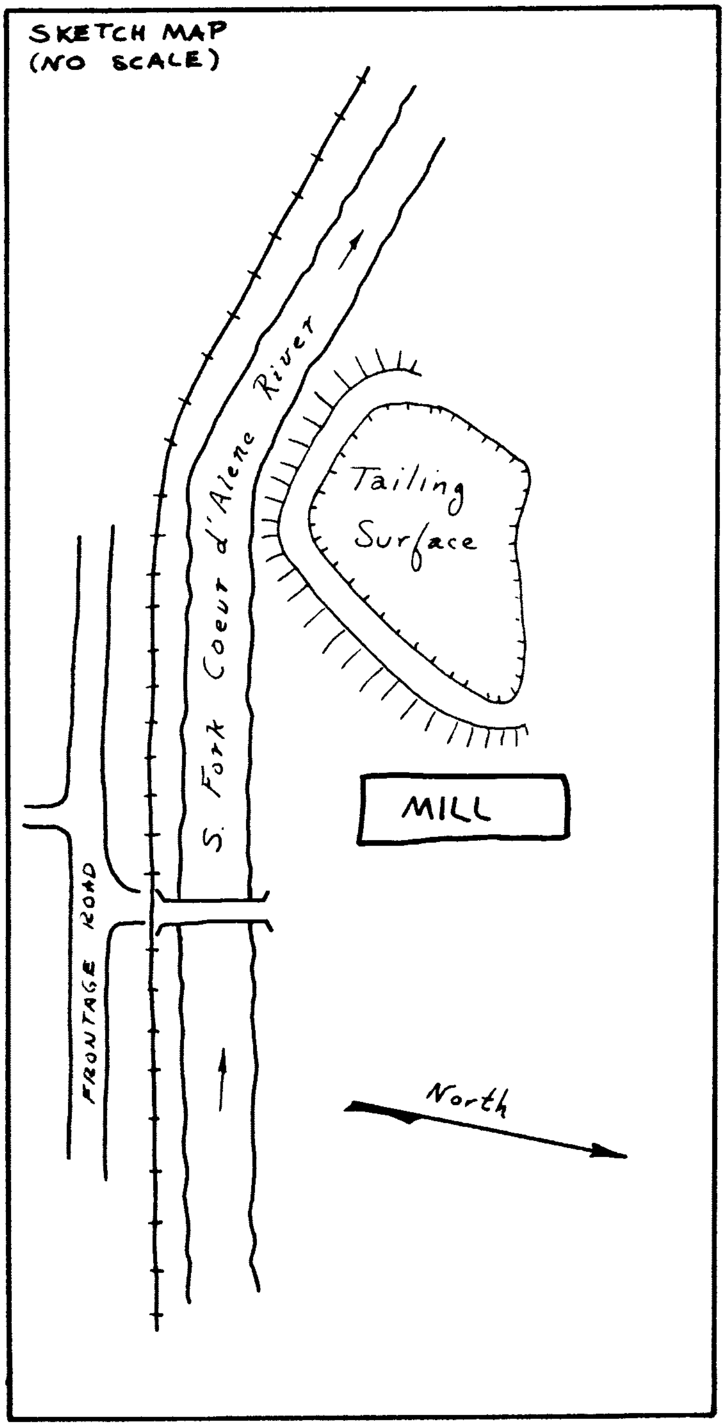
Site number: 15

Basin location: South Fork of the Coeur d'Alene River below Trowbridge Gulch

Map location: SW¼, Sec. 30, T.48N., R.5E.

Approximate surface area: 1 acre

Approximate volume of tailing: not available



Description of the site:

Site No. 15 consists of a small impoundment with adequate embankments and small tributary drainage area. It is located just north of the South Fork of the Coeur d'Alene River approximately 3 miles east of Wallace. The embankments and tailing surface are visible from Interstate Highway 90. An abandoned mill stands near the impoundment. Material within the impoundment includes sandy brown tailing at the surface with gray sands and slimes below. No samples of ground water or tailing material were collected at this site.

The mill supplying tailing to site 15 was a "custom" mill, processing ore from a number of mines in the district. It last operated in 1960.

Recommended reclamation:

In the absence of any chemical

data indicating a metals-leaching problem at the site, revegetation of embankments and tailing is the only reclamation effort required.

Site number: 16

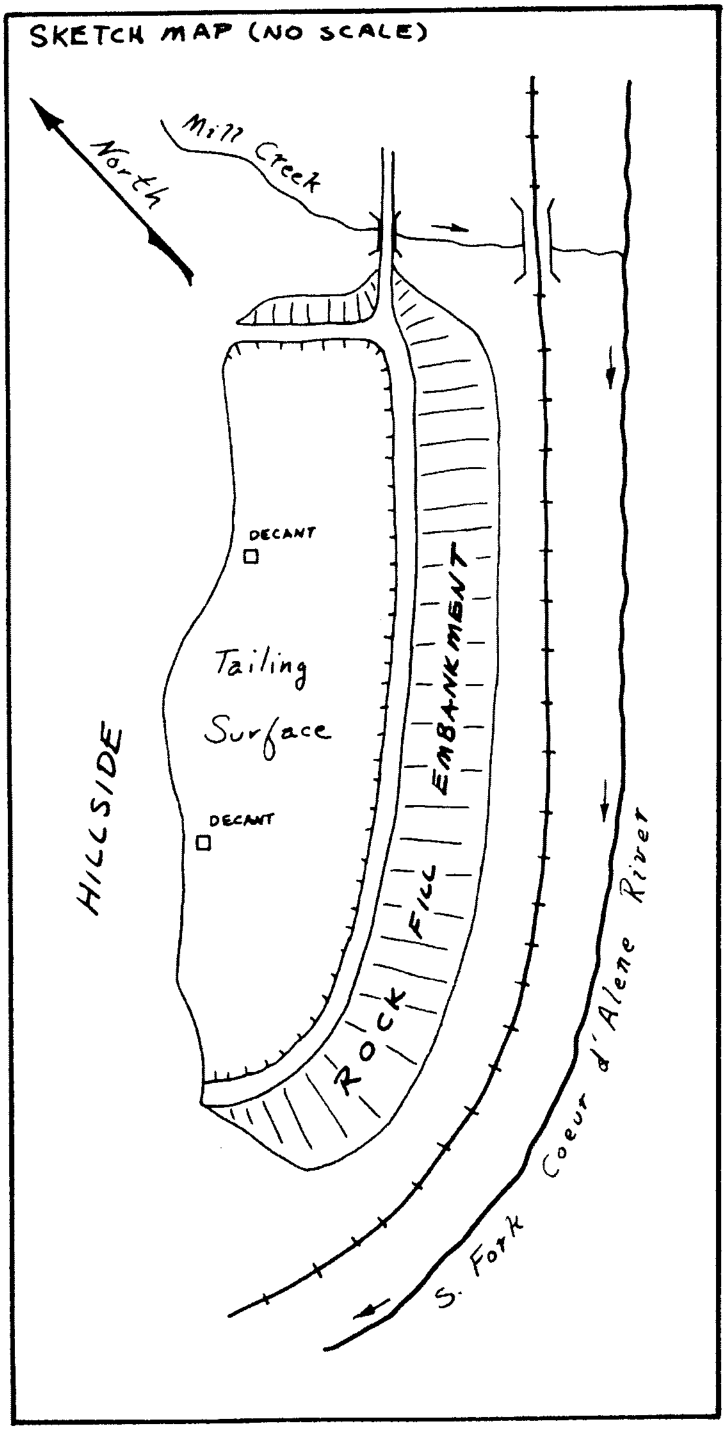
Basin location: South Fork of the Coeur d'Alene River below Mullan

Map location: NE¼, SE¼, Sec.34, T.48N., R.5E.

Approximate surface area: 7 acres

Approximate volume of tailing: 400,000 cubic yards

Description of the site: Site No. 16 was selected for detailed study and is covered in the text, pages 16 - 29. It is constructed against a hillside just west of the town of Mullan and has recently been enlarged to permit re-activation of the tailing disposal system.



Recommended reclamation: Water quality and tailing sample analysis has shown that this site does not represent a chemical hazard. Erosion by surface streams is not a problem, and the catchment basin above the pile surface is limited. Revegetation of the top half of the embankment and the entire tailing surface is the only reclamation procedure recommended.

Site number: 17

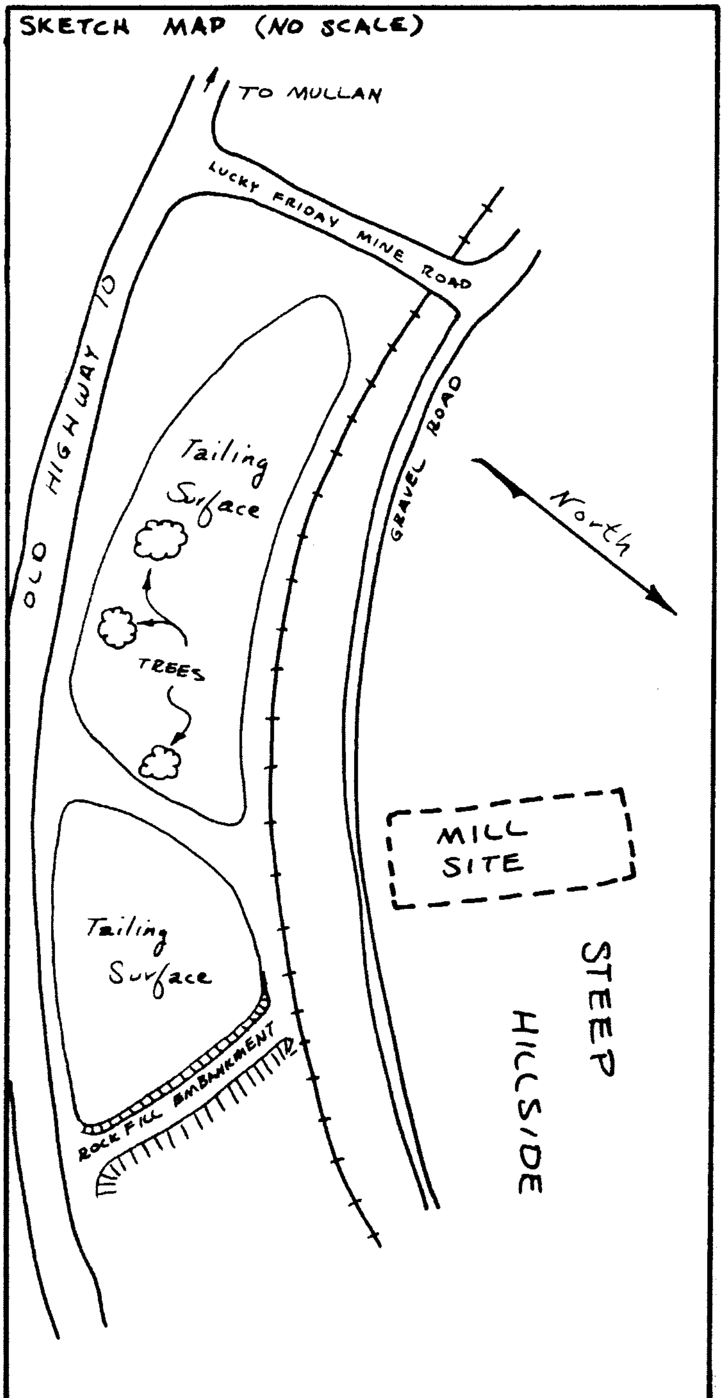
Basin location: South Fork of the Coeur d'Alene River above Mullan

Map location: W½, NE¼, Sec.35, T.48N., R.5E.

Approximate surface area: 1.5 acre

Approximate volume of tailing: not available

Description of the site: This tailing deposit is confined between the railroad tracks and the Shoshone Park Road just east of Mullan. An obvious embankment exists at the east end of the site, but all that remains of the mill is a foundation on the steep hillside to the north. The tailing surface is composed of black and brown sandy material which has been subject to wind erosion. Natural reclamation by trees, shrubs, and grasses is taking place on the tailing, and the site is not subject to stream erosion.



No chemical analysis was performed for this site. The dark appearance and apparent age of the tailing at this site probably warrant chemical testing. The original mill may have been a copper concentrator, in operation early in the District's history, and may have produced tailing unlike any other examined in this study. The site is small, so any chemical problems would have to be major to justify an expensive clean-up campaign.

Recommended reclamation:

The only reclamation procedure recommended at this site is the establishing of more vegetative cover on the tailing surface to prevent wind erosion.

APPENDIX B

Water Quality Data

WATER QUALITY SAMPLE ANALYSIS

Samples Taken August 21, 1977

SAMPLE* #	TEMP. (°C)	pH	E.C.	Fe	Mn	Ca	Mg	Cu	Zn	Cd	Pb
LF-M-1	17	7.8	117	-	<0.02	17.6	4.54	-	-	.021	-
LF-M-2	14	7.8	111	-	0.014	16.7	4.33	-	.010	-	-
LF-Ø	21	7.7	143	-	0.28	19.0	4.19	-	.087	-	-
LF-S-1	17	7.8	118	-	0.054	12.7	4.18	-	-	-	-
LF-S-2	18	7.9	113	-	0.042	13.0	4.13	-	.010	-	-
LF-S-3	18	7.7	115	0.044	0.10	13.3	4.18	-	.015	-	-
LF-2A	13	7.6	189	-	0.71	15.7	1.33	-	.58	-	-
LF-3A	13	7.5	384	0.058	0.99	61.6	3.55	-	.38	-	-
LF-3B	13	8.3	208	-	0.03	18.0	0.61	-	.30	-	-
LF-3C	15	8.3	241	-	0.30	17.6	3.49	-	.028	-	-
LF-4A	15	7.6	460	-	0.31	21.3	3.84	-	.081	-	-
LF-6A	13	7.4	271	-	1.56	31.3	4.66	-	.21	-	-
LF-8A	19	7.4	222	-	2.3	63.3	5.5	0.023	1.3	-	-
LF-10A	13	7.3	252	0.069	7.4	34.0	4.35	-	.056	-	-
GP-L-1	17	7.7	405	-	0.15	46.4	27.0	-	0.038	-	-
GP-L-2	18	8.0	424	-	0.11	45.4	25.4	-	0.021	-	
GP-M-1	22	7.4	222	-	-	22.9	12.1	-	-	-	-
GP-P-1	19	8.0	161	-	0.36	20.3	8.40	-	-	-	-
GP-D-1	20	8.0	175	0.052	0.20	19.6	8.79	-	-	-	-
GP-6A	14	7.0	441	.03	0.66	40.9	10.5	.03	0.37	-	-
GP-7A	11	6.7	497	-	4.0	81.4	25.0	.02	0.33	-	-
GP-8A	16	7.1	339	-	3.8	34.5	9.6	.012	0.29	-	-
GP-9A	13	7.1	345	-	1.61	50.4	19.5	.014	0.25	-	-

*LF = Lucky Friday Tailing Impoundment No. 1

GP = Galena Tailing Impoundment No. 3

Remaining number/letter designations refer to sampling locations

See Figures 2 and 5 for sampling sites.

WATER QUALITY SAMPLE ANALYSIS

Samples Taken May 5, 1978

SAMPLE* #	TEMP. (°C)	pH	E.C.	Fe	Mn	Ca	Mg	Cu	Zn	Cd	Pb
LF-M-1	5.5	7.6	60	-	-	11.0	2.8	-	.065	-	-
LF-M-2	6.0	7.4	60	-	-	10.5	2.8	-	-	.029	-
LF-Ø	10.	7.2	95	-	.92	16.8	4.2	-	.47	.012	-
LF-S-1	6.0	7.4	37	-	-	6.7	2.2	-	.020	-	-
LF-S-2	6.0	7.4	45	-	-	6.8	2.1	-	.028	-	-
LF-S-3	6.0	7.5	43	-	.03	6.0	2.1	-	.024	-	-
LF-2A	10.0	7.35	128	.26	.22	11.9	15.8	-	.053	-	-
LF-3A	10.5	7.3	145	-	.12	16.8	1.6	-	.13	-	-
LF-3B	9.5	7.65	130	-	.08	42.0	.8	-	.015	-	-
LF-6A	8.5	7.2	550	-	.99	109.	20.4	-	0.90	-	-
LF-0-1	9.0	6.75	290	2.2	8.4	26.2	8.1	-	-	.038	-
GP-L-1	6.5	7.3	57	-	.03	8.08	2.7	-	.016	.026	-
GP-L-2	5.5	7.5	150	-	.03	7.6	2.8	-	.059	.028	-
GP-M	11.0	7.6	210	-	.24	17.8	11.0	-	.019	.026	-
GP-D	9.0	7.3	160	-	.42	20.0	10.5	-	.11	.019	-
GP-1A	10.0	7.6	405	-	.45	48.3	7.4	-	.019	.036	-
GP-2A	8.0	7.5	355	-	.22	49.4	1.9	-	.019	.020	-
GP-3A	7.0	7.3	220	0.63	.74	36.8	8.7	-	0.24	.042	-
GP-3B	11.0	7.6	245	-	.19	15.3	7.7	-	.021	.034	-
GP-4A	6.5	6.85	237	-	2.3	37.5	14.3	-	.018	.035	-
GP-4B	7.0	7.2	550	-	1.8	105.	34.2	-	.036	.028	-
GP-5A	10.0	7.3	550	.44	.38	88.7	17.1	-	.032	.040	-
GP-6A	10.0	7.6	317	-	.06	46.0	6.1	-	.024	.024	-
GP-7A	10.0	6.3	378	-	77.7	63.8	17.8	-	.36	.028	-
GP-8A	10.0	6.8	160	.63	.94	28.1	4.6	-	.039	.032	-
GP-9A	9.0	7.2	340	-	6.3	51.8	16.3	-	.057	.026	-
GP-S-1	13.5	6.7	700	5.8	13.4	109.2	38.8	-	.028	-	-

*LF = Lucky Friday Tailing Impoundment No. 1

GP = Galena Tailing Impoundment No. 3

Remaining number/letter designations refer to sampling locations

See Figures 2 and 5 for sampling sites.

APPENDIX C

Tailing Analysis Data

ELEMENT CONCENTRATIONS IN TAILING, SITES 1, 3, 8, 9, 11

(PARTS PER MILLION)

DATE	SITE	SAMPLE #	DEPTH (meters)	Fe	Pb	Cd	Zn	Ca	Mn	Mg	Cu	DESCRIPTION
9/29/78	1	SI-1-1	.73	18,450	2,240	12.6	2,830	9,960	920	2,770	36	Gray, sandy, dry
9/29/78	1	SI-1-2	.73	25,720	1,130	11.4	3,450	13,020	1,200	3,850	297	Gray-green slimes, wet
9/29/78	1	SI-1-3	.73	22,720	4,620	9.8	2,270	13,540	1,100	3,690	40	Gray slimes, wet
9/29/78	1	SI-2-1	.73	29,560	5,910	21.8	4,550	9,460	1,260	2,640	268	Gray slimes, wet
9/29/78	1	SI-2-2	.73	23,660	3,670	22.9	6,850	7,480	1,200	2,520	212	Dark gray very fine sand, dry
9/29/78	1	SI-2-3	.73	25,900	4,140	16.2	5,920	12,440	1,400	2,800	143	Dark gray fine sand, dry
9/29/78	3	DC-1-1	.73	46,770	2,570	9.5	3,040	350	2,340	3,680	107	Dark brown, sandy, dry
9/29/78	3	DC-1-2	.73	40,780	1,090	18.6	7,340	76	1,030	1,960	190	Brown, very fine sand, dry
9/29/78	3	DC-1-3	.73	38,920	2,200	21.7	3,550	410	2,060	4,630	245	Brown, slimes, moist
9/30/78	8	SC-3-1	.73	106,490	24,240	5.2	3,000	<70	610	1,030	372	Red-brown sand dry
9/30/78	8	SC-3-2	.73	100,370	1,800	67.8	5,580	5,860	7,860	6,690	177	Yellow-brown, very fine sand, dry
9/30/78	8	SC-3-3	.73	20,390	1,080	34.5	8,050	32,700	9,980	13,520	150	Gray slimes, wet
9/30/78	8	SC-4-1	.73	26,520	16,540	17.1	1,710	<70	620	750	174	Brown, fine sand, dry
9/30/78	8	SC-4-2	.73	37,930	16,960	39.5	3,360	<70	570	830	238	Brown, very fine sand, some slimes, dry
9/30/78	8	SC-4-3	.73	54,030	29,180	91.3	2,830	<70	1,200	1,630	681	Brown slimes, wet
9/30/78	9	SS-1-1	.73	127,600	<130	1.8	<50	2,100	11,160	4,240	260	Gray slimes, wet
9/30/78	9	SS-1-2	.73	131,500	160	2.4	66	2,140	11,180	4,490	198	Red-yellow, very fine sand, dry

ELEMENT CONCENTRATIONS IN TAILING, SITES 1, 3, 8, 9, 11 (continued)

(PARTS PER MILLION)

DATE	SITE	SAMPLE #	DEPTH (meters)	Fe	Pb	Cd	Zn	Ca	Mn	Mg	Cu	DESCRIPTION
9/30/78	9	SS-1-3	.73	92,630	180	2.6	73	110	7,450	2,330	560	Red-brown, slimes, dry
9/30/78	11	C-1	.73	39,270	3,840	2.5	390	120	700	3,060	110	Dark brown, sandy, dry
9/30/78	11	C-2	.73	57,690	6,200	2.1	1,150	<70	580	1,990	168	Red-brown, fine sand, dry
9/30/78	11	C-3	.73	37,900	7,070	6.9	1,400	<70	580	2,330	40	Light brown, slimes, very fine sand, moist
DETECTION LIMITS FOR ANALYSIS (ppm)				105	130	0.5	50	70	30	100	10	

ELEMENT CONCENTRATIONS IN TAILING, SITE 10

(PARTS PER MILLION)

DATE	SITE	SAMPLE #	DEPTH (meters)	Fe	Pb	Cd	Zn	Ca	Mn	Mg	Cu	DESCRIPTION
8/11/77	10	GP-1-1	.09	239,000	127	< 0.5	35	1,780	17,400	6,000		Near Drill Hole #1 (Oxidized)
8/12/77	10	GP-1-2	.80	233,000	2,750	< 0.5	62	2,120	17,800	5,860		Gray slimes
8/12/77	10	GP-1-3	1.3	264,000	117	< 0.5	48	2,080	18,800	6,780		Sandy tailing
7/26/77	10	GP-3-1	.08	229,000	217	< 0.5	69	1,710	16,700	5,690		Sandy tailing, (Oxidized)
7/26/77	10	GP-3-2	1.6	254,000	196	< 0.5	63	2,410	19,100	6,660		Fine sandy tailing, hard packed
7/26/77	10	GP-3-3	3.0	257,000	177	< 0.5	51	2,000	18,600	6,690	NOT TESTED	Former oxidized surface (mostly sandy, some slimes)
		+80*	3.0	57,200	104	< 0.5	22	500	4,630	1,740		
7/26/77	10	GP-3-4	3.4	271,000	123	< 0.5	45	2,040	20,200	7,020		Sandy, oxidized tailing
		+80*	3.4	57,200	104	< 0.5	22	500	4,630	1,740		
8/9/77	10	GP-5-1	.12	280,000	167	< 0.5	48	2,150	20,800	7,170		Sandy surface (oxidized)
		+80*	.12	149,000	102	< 0.5	46	1,040	11,600	3,790		
8/9/77	10	GP-5-2	.30	276,000	175	< 0.5	48	2,360	21,300	7,200		Sandy tailing (gray)
		+80*	.30	80,800	111	< 0.5	28	810	6,180	2,310		
8/9/77	10	GP-5-3	3.0	248,000	135	< 0.5	47	2,220	18,900	6,540		Dry slimes
8/11/77	10	GP-6-1	.06	227,000	229	< 0.5	78	1,890	17,500	5,770		Sandy tailing, (Oxidized)
8/11/77	10	GP-6-2	.80	221,000	94	2.13	45	1,700	17,400	5,740		Sandy tailing, (Oxidized)

*ENTRIES MARKED "+80" REPRESENT THAT PART OF A SAMPLE WHICH DID NOT PASS A SIZE 80-MESH SIEVE. ALL OTHER SAMPLES CONSIDER ONLY MINUS 80-MESH MATERIAL.

	Fe	Pb	Cd	Zn	Ca	Mn	Mg
DETECTION LIMITS FOR ANALYSIS (ppm)	0.04	0.05	0.01	0.01	0.003	0.04	0.05

ELEMENT CONCENTRATIONS IN TAILING, SITE 16 (PARTS PER MILLION)

DATE	SITE	SAMPLE #	DEPTH (meters)	Fe	Pb	Cd	Zn	Ca	Mn	Mg	Cu	DESCRIPTION
6/18/77	16	D.H. 1-F	13.4	118,000	14,000	39	4,500	1,700	10,500	2,800	NOT TESTED	Sand, gravel from alluvium beneath pile
6/19/77	16	D.H. 2-A	1.5	91,200	4,100	16	2,100	2,500	8,600	2,700		Wet slimes
6/19/77	16	D.H. 2-B	2.3	63,000	1,500	9	1,500	2,800	6,600	2,300		Wet slimes
6/19/77	16	D.H. 2-C	5.2	85,500	3,400	13	2,100	2,600	8,100	2,700		Wet slimes
6/19/77	16	D.H. 2-D	8.4	92,000	3,300	16	2,200	2,600	8,900	2,800		Very fine sand, some slimes
6/19/77	16	D.H. 3-A	13.4	72,000	2,500	13	1,600	2,200	7,600	2,700		Gravel, some yellow clay
DETECTION LIMITS FOR ANALYSIS (ppm)				0.04	0.05	0.01	0.01	0.003	0.04	0.05		

APPENDIX D

Water Level Elevations in Piezometers

Lucky Friday Tailing Impoundment No. 1

June 1977 - July 1978

Lucky Friday #1 Water Level Elevations, in ft. (Add 3200 for MSL elevations)

Date	0-1	0-2	0-3	1-A	2-A	2-B	3-A	3-B
6-22-77	30.87	26.92	Dry	Dry	22.3	Dry	25.9	24.8
6-23-77	31.03	26.89	"	"	20.4	"	25.9	24.8
6-27-77	30.49	26.74	"	"	20.4	"	26.2	24.8
6-30-77	30.34	26.63	"	"	20.4	"	26.8	24.8
"	-	-	-	"	20.4	"	26.0	24.68
"	30.27	26.72	Dry	"	20.4	"	26.1	24.67
7-01-77	30.25	26.69	"	"	21.29	"	26.08	24.70
"	30.23	26.70	"	"	21.30	"	26.11	24.78
7-02-77	30.20	26.71	"	"	21.25	"	26.11	24.78
7-03-77	-	-	-	"	21.31	"	26.12	24.86
7-04-77	30.22	26.69	Dry	"	21.37	"	26.14	24.90
7-05-77	30.13	26.70	"	"	21.27	"	26.16	24.94
7-06-77	-	-	-	"	21.37	"	26.14	24.67
7-07-77	29.77	26.65	Dry	"	21.42	"	26.19	24.97
7-08-77	29.64	26.63	"	"	21.47	"	26.19	24.95
7-11-77	-	-	-	"	21.48	"	26.19	26.42
7-12-77	29.17	26.61	Dry	"	21.45	"	26.19	24.87
7-13-77	-	-	-	"	21.48	"	26.17	24.84
7-14-77	28.96	26.56	Dry	"	21.56	"	26.21	24.88
7-16-77	-	-	-	"	21.60	"	26.21	24.89
7-18-77	28.79	26.55	Dry	"	21.60	"	26.20	24.88
7-19-77	-	-	-	"	21.62	"	26.19	24.85
7-20-77	28.69	26.43	Dry	"	21.67	"	26.22	24.87
7-21-77	28.72	Dry	"	"	21.64	"	26.21	24.89
7-22-77	-	-	-	"	21.68	"	26.22	24.90
7-26-77	Dry	Dry	Dry	"	21.76	"	26.25	24.90
7-29-77	"	"	"	"	21.79	"	26.31	24.94
7-30-77	-	-	-	"	21.84	"	26.34	24.96
8-03-77	Dry	Dry	Dry	"	21.94	"	26.46	25.10
8-05-77	-	-	-	"	22.00	"	26.52	25.18
8-07-77	Dry	Dry	Dry	"	22.04	"	26.55	25.20
8-08-77	-	-	-	"	22.11	"	26.59	25.21
8-12-77	Dry	Dry	Dry	"	22.33	"	26.70	25.32
8-14-77	-	-	-	"	22.27	"	26.76	25.36
8-16-77	Dry	Dry	Dry	"	22.41	"	26.79	25.41
8-18-77	"	"	"	"	22.50	"	26.86	25.46
8-21-77	-	-	-	"	22.52	"	26.84	25.49
8-23-77	-	-	-	"	22.65	"	26.94	25.46
8-27-77	-	-	-	"	22.70	"	26.96	25.50
9-09-77	Dry	Dry	Dry	"	23.08	"	26.92	25.55
10-01-77	"	"	"	"	23.09	"	26.45	25.16
10-14-77	-	-	-	"	22.98	"	26.17	24.89
11-04-77	-	-	-	"	22.80	"	25.65	24.53
11-26-77	-	-	-	"	21.52	"	24.86	24.04
3-03-78	31.79	27.52	Dry	"	21.19	"	24.36	23.78
3-10-78	31.75	27.50	"	"	21.09	"	24.51	23.71
4-14-78	31.55	27.56	"	"	20.68	"	24.32	23.57
5-05-78	31.29	27.31	"	"	20.51	"	24.24	23.54
6-17-78	29.80	26.93	"	"	20.22	"	22.96	22.83
7-14-78	29.37	26.58	"	"	19.85	"	23.52	22.41

Lucky Friday #1 Water Level Elevations, in ft. (Add 3200 for MSL elevations)

Date	3-C	4-A	4-B	5-A	6-A	6-B	7-A	8-A
6-22-77	Dry	Dry	Dry	Dry	18.14	Dry	Dry	
6-23-77	"	"	"	"	19.02	"	"	
6-27-77	"	"	"	"	19.93	"	"	
6-30-77	"	"	"	"	19.96	"	"	
"	"	"	"	"	19.95	"	"	
"	"	"	"	"	19.81	"	"	
7-01-77	"	"	"	"	19.89	"	"	
"	"	"	"	"	19.93	"	"	
7-02-77	"	"	"	"	20.02	"	"	
7-03-77	"	"	"	"	20.14	"	"	
7-04-77	"	"	"	"	20.31	"	"	
7-05-77	"	"	"	"	20.43	"	"	
7-06-77	"	"	"	"	20.52	"	"	
7-07-77	"	"	"	"	20.52	"	"	
7-08-77	"	"	"	"	20.46	"	"	
7-11-77	"	"	43.63	"	20.16	"	"	
7-12-77	"	"	43.79	"	20.14	"	"	
7-13-77	"	"	43.97	"	20.08	"	"	
7-14-77	43.35	"	44.48	"	20.10	"	"	
7-16-77	43.43	"	44.76	"	20.13	"	"	
7-18-77	42.42	26.99	Dry	"	20.11	"	"	
7-19-77	42.26	26.87	"	"	20.13	"	"	
7-20-77	44.51	26.89	"	"	20.09	"	"	
7-21-77	44.54	26.91	"	"	20.10	"	"	
7-22-77	44.50	26.94	"	"	20.12	"	"	
7-26-77	44.39	26.93	"	"	20.11	"	"	
7-29-77	44.11	26.92	42.88	"	20.01	"	"	
7-30-77	44.06	26.92	Dry	"	19.97	"	"	
8-03-77	44.25	26.91	"	"	20.02	"	"	
8-05-77	44.11	26.87	"	"	20.03	"	"	
8-07-77	43.64	26.90	"	"	19.99	"	"	
8-08-77	43.68	26.90	"	"	19.97	"	"	
8-12-77	43.48	26.86	"	"	19.85	"	"	
8-14-77	43.42	26.86	"	"	19.83	"	"	28.90
8-16-77	43.18	26.84	"	"	19.83	"	"	28.90
8-18-77	43.07	26.89	"	"	19.82	"	"	28.91
8-21-77	-	26.89	"	"	19.77	"	"	28.92
8-23-77	42.80	27.02	"	"	19.54	"	"	28.94
8-27-77	Dry	27.03	"	"	19.63	"	"	29.19
9-09-77	"	26.99	"	"	19.56	"	"	29.11
10-01-77	"	Dry	"	"	20.85	"	"	Lost
10-14-77	"	"	"	"	20.44	"	"	
11-04-77	"	"	"	"	21.99	"	"	
11-26-77	"	"	"	"	19.80	"	"	
3-03-78	"	"	"	"	23.74	"	"	
3-10-78	"	"	"	"	24.07	"	"	
4-14-78	"	"	"	"	24.51	"	"	
5-05-78	"	"	"	"	24.66	"	"	
6-17-78	"	"	"	"	24.42	"	"	
7-14-78	"	"	"	"	24.06	"	"	

Lucky Friday #1 Water Level Elevations, in ft. (Add 3200 for MSL elevations)

Date	9-A	10-A	11-A
6-22-77			
6-23-77			
6-27-77			
6-30-77			
"			
"			
7-01-77			
"			
7-02-77			
7-03-77			
7-04-77			
7-05-77			
7-06-77			
7-07-77			
7-08-77			
7-11-77			
7-12-77			
7-13-77			
7-14-77			
7-16-77			
7-18-77			
7-19-77			
7-20-77			
7-21-77			
7-22-77			
7-26-77			
7-29-77			
7-30-77			
8-03-77			
8-05-77			
8-07-77			
8-08-77			
8-12-77			
8-14-77			
8-16-77	14.21	6.70	Dry
8-18-77	14.06	6.65	"
8-21-77	14.12	6.65	"
8-23-77	14.12	6.61	"
8-27-77	Dry	6.63	"
9-09-77	14.10	6.57	"
10-01-77	14.31	Lost	Lost
10-14-77	Lost		
11-04-77			
11-26-77			
3-03-78			
3-10-78			
4-14-78			
5-05-78			
6-17-78			
7-14-78			

APPENDIX E

Water Level Elevations in Piezometers

Galena Tailing Impoundment No. 3

August 1977 - July 1978

Galena #3 Water Level Elevations, in feet above datum (see Figure 5).

Date	1-A	2-A	2-B	3-A	3-B	3-C	4-A	4-B
8-21-77	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
8-22-77	"	"	"	"	"	"	"	"
9-10-77	"	"	"	"	"	"	"	"
10-01-77	"	"	"	"	"	"	"	"
10-14-77	"	"	"	"	"	"	"	"
11-04-77	"	"	"	"	"	"	"	"
11-26-77	"	"	"	"	"	"	"	"
3-03-78	73.82	85.41	85.95	87.05	88.83	"	88.12	88.97
3-10-78	74.09	87.50	87.84	89.46	89.52	"	91.51	91.91
4-14-78	74.07	85.41	85.83	86.69	88.67	"	88.24	88.73
5-05-78	73.16	81.88	82.82	83.29	85.97	"	83.34	86.32
6-19-78	72.12	79.16	Dry	Dry	Dry	"	Dry	Dry
7-14-78	71.57	77.97	"	"	"	"	"	"

Galena #3 Water Level Elevations, in feet above datum (see Figure 5).

Date	4-C	5-A	6-A	6-B	7-A	8-A	9-A	Pond
8-21-77	Dry	Dry	71.92	Dry	93.11	99.50	39.49	-
8-22-77	"	"	72.30	"	-	99.51	39.49	-
9-10-77	"	"	72.80	"	93.28	99.81	39.55	90.54
10-01-77	"	"	73.14	"	93.64	99.86	39.71	90.88
10-14-77	"	"	73.09	"	93.21	99.80	39.49	90.39
11-04-77	"	"	73.42	"	93.40	99.86	39.87	90.26
11-26-77	"	"	73.70	"	94.11	100.50	39.95	91.43
3-03-78	"	61.96	74.15	85.70	94.24	100.29	40.52	92.76
3-10-78	93.05	62.32	74.51	86.62	94.53	100.59	40.60	Lost
4-14-78	Dry	63.26	74.07	85.42	94.42	100.42	40.70	
5-05-78	"	63.24	73.61	84.71	94.36	100.19	40.66	
6-19-78	"	62.57	73.48	84.65	94.21	99.90	40.53	
7-14-78	"	62.15	73.58	85.34	94.12	99.86	40.34	

APPENDIX F

Piezometer Locations and Water Level Measurements

Page Tailing Pile

Single Measurement on June 10, 1977

PAGE TAILING PILE PIEZOMETERS

Order of Meas-urement	Number Marked on Tube	Location Coordinates* X	Y	Measuring Point Elevation* (feet)	Length of Tube (feet)	Water Level Elevation (feet)	Remarks
East Pile Piezometers							
1	EP-7-16	5474	3227	2225.34	18.30	2213.92	
2	EP-7-23	"	"	2225.33	24.80	2213.81	
3	EP-57-	5343	2908	2225.44	17.80	2220.96	
4	EP-56-30	5560	2335	2224.20	32.00	2203.85	through pile
5	EP-56-	"	"	2223.73	16.50	2220.22	
6	EP-6-23	5743	2188	2222.71	24.79	2203.71	through pile
7	EP-6-?	"	"		15+		elev. unknown
8	EP-6-20	"	"	2221.94	21.65	2212.6	
9	EP-6-?	"	"		10+		elev. unknown
10	EP-2-20	5754	2704	2223.76	23.40	2212.67	through pile
11	EP-2-17	"	"	2224.24	18.50	2215.28	
12	EP-2-13	"	"	2223.43	14.67	2214.65	
13	EP-2-30	"	"	2223.94	27.60	2207.41	through pile
West Pile Piezometers							
14	WP-7-25	3237	1600	2214.80	26.65	2192.23	NW corner
15	WP-7-22	"	"	2214.91	23.40	2194.77	"
16	WP-7-21	"	"	2215.70	24.05	2193.99	"
17	WP-4-30	3211	1859	2214.13	26.90	2194.24	through pile
18	WP-4-24	"	"	2214.84	25.65	2193.92	through pile
19	WP-4-19	"	"	2214.71	20.64		dry
20	WP-6-18	3181	2142	2215.47	19.90	2197.22	SW corner
21	WP-6-21.5	"	"	2215.25	22.70	2197.14	"
22	WP-6-25	"	"	2215.10	26.25	2196.43	"
23	WP-6-20	"	"	2214.90	20.70	2198.03	"
24	WP-13-20	3472	2380	2216.37	21.85	2202.16	
25	WP-13-?	"	"	2216.34	19.80	2202.12	
26	WP-13-16	"	"	2216.26	17.50	2202.21	
27	WP-1-18	3730	2590	2218.72	20.90	2208.64	SW of lagoon
28	WP-16-28	3760	2090	2217.85	26.40	2209.88	through pile
29	WP-16-15	"	"	2217.81	19.55	2212.98	through pile
30	WP-16-30	"	"	2217.52	18.02	2212.74	through pile
31	WP-45-30	3542	1965	2216.20	21.40	2194.93	
32	WP-45-16-G	"	"	2216.20	17.35	2200.79	
33	WP-45-21	"	"	2216.27	25.30	2199.12	
34	WP-45-18	"	"	2215.75	19.95	2199.77	
35	WP-14-G	3695	1672	2216.73	24.14	2197.48	through pile
36	WP-14-20	"	"	2216.25	21.75	2198.97	
37	WP-14-24	"	"	2216.76	25.25	2195.59	through pile
38	WP-15-	4060	2784	2223.05	14.80	2211.58	S of lagoons

PAGE TAILING PILE PIEZOMETERS

Order of Meas- urement	Number Marked on Tube	Location Coordinates* X	Location Coordinates* Y	Measuring Point Elevation* (feet)	Length of Tube (feet)	Water Level Elevation (feet)	Remarks
Perimeter Piezometers							
39	O-1	4410	3012	2208.79	6.40	2207.05	
40	P-1	3450	2489	2198.76	7.50	2197.50	
41	P-2	3431	2504	2199.72	6.80	2197.33	
42	D-1	3762	1608				broken
43	D-2	3786	1577	2197.74	7.20	2194.13	
44					4+		origin unknown
45	NP-5	4175	1640	2200.37	4.91	2197.53	
46	A-1-G	3050	2110	2197.28	8.30	2194.8	West swamp
47		3095	1843		2+		origin unknown
48		"	"		6+		origin unknown
49	B-2	3026	1824	2196.16	9.05	2191.90	
50		"	"		2+		elev. unknown
51		"	"		3+		dry, plugged
52	Steel pipe; W.S. 3.56' below M.P.						elev. unknown
53	Steel pipe; W.S. 5.55' below M.P.						elev. unknown
54	B-3	2886	1794	2194.99	8.00	2191.43	
55	B-4	2714	1791	2196.20	9.18	2191.25	
56	C-11	2742	1557	2196.13	10.25	2188.83	
57	C-3	2969	1494	2194.23	10.60	2186.93	
58					5+		origin unknown
59	C-10	3230	1255	2199.26	12.90	2190.15	
60	A-4	2994	2152	2195.70	7.30	2194.28	
61	A-2	2988	2095	2196.03	7.40	2194.62	
62	A-3						not found
63	A-6						not found
64	Steel pipe; W.S. 6.00' below M.P.						origin unknown
65	NP-2	5300	1890	2205.76	5.00	2203.71	
66	NP-1	5528	1940	2206.82	5.00		dry
67	J-1	5890	2000	2206.12	5.00	2204.00	NE of pile
68	J-2	5926	1919	2207.29	8.50	2203.83	"
69	J-3	5953	1851				broken
70					2.7+		origin unknown
71	J-5	6028	1908	2205.15	6.20	2204.51	
72	K-1	5930	2470	2205.76	8.00	2204.28	East swamp
73	M-1	5556	3382	2211.07	11.90	2205.89	
Treatment Plant Piezometers							
74	EP-5A-12	5260	2573	2226.84	17.40	2225.13	
75	EP-5A-15	"	"	2226.81	18.65	2224.60	
76	EP-5A-27	"	"	2226.87	29.40	2223.89	through pile
77		"	"		13.25		submerged
78	EP-45A	4979	2510	2226.77	17.20	2224.60	
79	EP-4A	4776	2479	2226.84	19.55	2222.67	
80	EP-8A	5000	1971	2226.94	22.00	2224.20	
81	EP-59A	4956	2796	2227.76	18.35	2225.78	

PAGE TAILING PILE PIEZOMETERS

Order of Meas- urement	Number Marked on Tube	Location Coordinates* X	Location Coordinates* Y	Measuring Point Elevation* (feet)	Length of Tube (feet)	Water Level Elevation (feet)	Remarks
Treatment Plant Piezometers (continued)							
82	A-1-14	3940	2091	2229.95	28.00	2218.03	
83	1½" PVC pipe 24' long; W.S. 9.79' below M.P.						origin unknown

*Coordinates, measuring point elevations, and some tube lengths from Morilla (1975) and Hitt (1974). Other tube lengths and all water levels were measured by M. Gross and T. Eckwright in June 1977.