GROUP II,

# Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the

# COAL MINING

## Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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# DEVELOPMENT DOCUMENT
# for
# INTERIM FINAL EFFLUENT LIMITATIONS GUIDELINES
# and
# NEW SOURCE PERFORMANCE STANDARDS
# for the
# COAL MINING POINT SOURCE CATEGORY

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# ABSTRACT

This document presents findings of an exhaustive study of the coal mining and coal preparation industries for the purpose of developing effluent limitations guidelines and standards of performance for new sources to enable implementation of Sections 304, 306, and 307 of the Federal Water Pollution Control Act Amendments of 1972.

Effluent limitations guidelines contained herein set forth the degree of reduction of pollutants in effluents achievable by application of the "best practicable control technology currently available" and the "best available technology economically achievable." These standards must be attained by existing point sources by July 1, 1977 and July 1, 1983, respectively. Standards of performance for new sources contained herein set forth the degree of reduction of pollutants in effluents which is achievable through application of the "best available demonstrated control technology, processes, operating methods, or other alternatives."

This report details findings, conclusions, and recommendations on control and treatment technology relating to waste water from coal mines and coal preparation plants. Supporting data and rationale for development of the proposed effluent limitations and standards of performance are contained herein.

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# SECTION I

# CONCLUSIONS

Based on the findings of this study, the following conclusions have been made:

The coal industry point source category was divided into two subcategories - coal production and coal preparation - for the purpose of establishing effluent limitations and standards of performance.

Pollutant parameters whose concentrations most frequently exceed acceptable levels in waste water from coal production facilities are: acidity, total iron, dissolved iron, manganese, aluminum, nickel, zinc, total dissolved solids, total suspended solids, sulfates, ammonia, fluorides, and strontium.

Concentrations of fluoride, strontium, ammonia, and sulfate, although occasionally above accepted standards, are not normally high enough to have deleterious effects. In addition, the cost of technology for reduction of these constituents in the concentrations observed is not considered feasible. Total dissolved solids pose a similar problem as the cost of the technology does not warrent the reduction obtained.

Pollutant parameters whose concentrations most frequently exceed acceptable levels in waste water from the coal preparation subcategory of the industry include: total iron, dissolved iron, total dissolved solids, total suspended solids, and sulfates.

Subcategorization of the coal production portion of the industry is limited to differentiation between acid or ferruginous drainage and alkaline drainage, which in turn reflects local or regional coal and overburden conditions; and is directly related to the treatment technology required. Alkaline drainage is most frequently found in the Interior and Western coal fields and is generally characterized only by total dissolved and suspended solids in excess of acceptable levels. Acid or ferruginous drainage, typically found in Northern Appalachia, exhibits high concentrations of all critical parameters defined in this report (see Section VI).

Generally, water quality analyses indicated no significant differences between untreated waste water from surface and underground mining operations in similar geologic settings. Several parameters namely total and dissolved iron and total suspended solids did vary within the classes of mine drainage, however, this is believed to be the result of precipitation patterns. (heavy rainfall on surface mines).

The most serious water related mining problem associated with development of western coal fields appears to be disruption of aquifers resulting in lowered water tables and well levels.

The coal production segment of the industry has already developed technology to solve its most serious waste water problem: neutralization of acidity with concurrent reduction of other pollutants to safe concentrations. This is usually achieved with lime neutralization followed by aeration and sedimentation.

Other reagents occasionally utilized by the coal industry for neutralization include limestone, caustic soda, soda ash, and anhydrous ammonia. Anhydrous ammonia can result in eutrophication of receiving waters if used for prolonged time periods or relatively high mine drainage volumes.

Mine drainage neutralization treatment plants can successfully control acidity, iron, manganese, aluminum, nickel, zinc, and total suspended solids.

While neutralization successfully controls most acid mine drainage pollutant parameters, final effluents frequently contain suspended solids in excess of those exhibited by unneutralized settling pond effluent (alkaline mine drainage). This occurs for two reasons: 1) physical addition of solids (neutralizing agents) during the treatment process; and 2) the increased pH resulting from the neutralization process initiates precipitation of previously dissolved constituents.

Operating costs of mine drainage neutralization plants are a function of the volume treated. As a result, operating costs were found to vary from 3 to 10 cents per thousand liters (11 to 40 cents per thousand gallons).

Neutralization plant construction costs were found to have an inverse relationship to the volume of drainage being treated. All plants must provide the same essential equipment including lime storage, feeders, control facilities, and housing regardless of the flow encountered.

Associated facilities such as aeration basins and settling ponds have a proportional increase in cost with an increase in flow. Settling ponds construction cost for alkaline mine drainage have a direct relationship to flow or volume treated.

The coal production portion of the industry has also controlled a second serious waste water problem - the presence of excessive total suspended solids in both alkaline drainage and acid or ferruginous drainage - through utilization of settling basins and coagulants prior to the discharge of mine waters. The concentrations of suspended solids in the final effluent can be further reduced through deep bed, mixed media filtration. Although such filtration techniques have not been demonstrated in the coal industry, the technology has been used extensively in other industries for removal of total suspended solids.

The only adverse nonwater quality environmental factors associated with treatment of waste waters from the coal industry are occasional monopolization of otherwise productive land for treatment facility siting and disposal of solid waste (sludge) generated during the treatment process.

Routine maintenance and cleaning of sedimentation basins is essential to efficient operation. Accumulated sludge can actually increase effluent suspended solids concentrations above influent concentrations, particularly in surface mining operations during periods of heavy rainfall.

Sedimentation ponds installed for "polishing" otherwise acceptable drainage can result in increased total suspended solids loadings as a result of carry-over of algae blooms in the final effluent. Such basins are not installed unless warranted by degraded water quality, or for flow equalization.

Control of waste water pollution from surface mines is successfully achieved by implementation of effective mining, regrading, water diversion, erosion control, soil supplementation and revegetation techniques. These control techniques may be augmented with treatment techniques including neutralization plants or sedimentation basins during mining and reclamation.

Infiltration control can occasionally reduce the volume of waste water discharged from active underground mines and is achieved by implementation of mine roof fracture control including the design of the mine's pillars and barriers, sealing of boreholes and fracture zones, and backfilling of overlying abandoned surface mines. Concentration of pollutants is also significantly reduced by limiting the contact time of the waste water within the mine workings, control of waste water pollution on closure of underground mines can be affected with proper mine sealing.

Through a combination of efficient plant design, inprocess controls and end-of-process treatment, coal preparation plants can utilize a closed-water circuit and, therefore, achieve zero discharge of waste water. This was demonstrated at the majority of the coal preparation plants visited during this study.

Waste water from coal preparation plant ancillary areas, including coal storage areas and refuse storage areas, is controlled and treated with techniques similar to techniques employed by surface mines.

Dust presents a temporary nonwater environmental problem during mining and reclamation in western coal fields. The impact of this temporary aspect is reduced by the fact that most western mine developments are in sparsely populated regions. Dust problems also occur in Eastern and Interior coal fields where dust occasionally blows from trucks and railroad cars.

Waste loads from coal production are unrelated, or only indirectly related, to production quantities. Therefore effluent limitations are expressed in terms of concentration rather than units of production.

# SECTION II

## RECOMMENDATIONS

Extensive study of all existing methods for the treatment of coal industry waste water indicates that the best practicable control technology currently available is in widespread use by the coal industry.

Based upon the information obtained in the study and presented in this report, the following effluent limitations guidelines are recommended for the major categories of the coal industry. Since data analyzed during this study indicated no significant differences in each of the raw mine drainage categories, bituminous and lignite mining and anthracite mining categories are combined, as are bituminous and lignite mining services and anthracite mining services. Separate standards are proposed for suspended solids limitations in alkaline mine drainages since lower concentrations can be achieved in unneutralized alkaline drainages.

EFFLUENT LEVELS ACHIEVABLE THROUGH APPLICATION OF THE
BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | | | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | No Discharge of Process Water | No Discharge of Process Water | 3.5 | 7.0 | 3.5 | 7.0 | 3.5 | 7.0 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 35 | 70 | 35 | 70 | 25 | 50 |

*All values except pH in mg/l.

BAT effluent limitations are based on implementation of the best control or treatment technology employed by a specific point source, or readily transferable from one industry process to another. Although economically achievable technology does not exist for significant reduction of additional pollutant parameters, design refinements and better control of the treatment operation can result in lower concentrations of those parameters controlled with BPT technology. Also, the state-of-the-art has been developed and is in use in other industries for further reduction of suspended solids concentrations. Based upon the information presented in this report, a determination has been made that the reduction of pollutants attainable through application of the best available control technology economically achievable is presented below.

EFFLUENT LEVELS ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | | | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | No Discharge of Process Water | No Discharge of Process Water | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 20 | 40 | 20 | 40 | 20 | 40 |

*All values except pH in mg/l.

The filtration technology upon which BAT suspended solids limitations were based has not been applied in a coal industry operation, thus its adaptability, suitability, and economics have not yet been fully demonstrated. It is recommended that New Source Performance Standards for the coal industry be the same as those identified for BAT, except for suspended solids which shall be the same as for BPT.

NEW SOURCE PERFORMANCE STANDARDS

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | No Discharge of Process Water | No Discharge of Process Water | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | | | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 35 | 70 | 35 | 70 | 25 | 50 |

*All values except pH in mg/l.

In order to assure maximum efficiency and continual operation, it is recommended that adequate safeguards be incorporated at critical locations throughout each mine drainage treatment plant. These safeguards should consist of automatically pH-adjusted feed controls and effluent monitors equipped with emergency alarms and shutdown features. Turbidity meters should continually monitor settling pond effluent drainage to reduce the possibility of accidental discharge of excessive concentrations of suspended solids. Such instrumentation requires attention to plant maintenance to assure effective operation.

An inventory should be maintained of critical or hard to locate parts, and emergency auxiliary units should be readily available. Storage should be provided for adequate supplies of raw materials (neutralizing reagents), and alternative sources of supply should be identified.

Operating schedules should include adequate time for preventive maintenance, including routine cleaning of sludge ponds and basins, to insure adequate detention and to prevent carryover of accumulated solids.

# SECTION III

# INTRODUCTION

## PURPOSE

The Federal Water Pollution Control Act Amendments of 1972 require the United States Environmental Protection Agency to establish effluent limitations which must be achieved by point sources of discharge into the navigable waters, or tributaries of navigable waters of the United States.

Specifically, Section 301 (b) of the Act requires achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on implementation of the "best practicable control technology currently available" as defined by the administrator pursuant to Section 304 (b) of the Act. Section 301 (b) further requires achievement by not later than July 1, 1983, of effluent limitations for point sources which are based on application of the "best available technology economically achievable". This will result in further progress toward the National goal of eliminating discharge of all pollutants. Section 306 of the Act requires achievement by new sources of control of discharge reflecting the application of the "best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants."

Within one year of enactment, the Administrator is required by Section 304 (b) of the Act to promulgate regulations providing guidelines for effluent limitations setting forth:

1. The degree of effluent reduction attainable through application of the best practicable control technology currently available.
2. The degree of effluent reduction attainable through application of the best control measures and practices achievable (including treatment techniques, process and procedure innovations, operation methods, and other alternatives).

The regulations proposed herein set forth effluent limitation guidelines pursuant to Section 304 (b) of the Act for coal industry point sources in anthracite mining and mining services and bituminous and lignite mining and mining services.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306 (b) (1) (A) of the Act, to propose regulations establishing Federal standards of performance for new sources within such categories. The Administrator published, in the Federal Register of January 16, 1973 (38FR 1624) a list of 27 source categories. Publication of an amended list will constitute announcement of the Administrator's intention of establishing under Section 306 standards of performance applicable to new sources within the coal mining industry. The list will be amended when interim final regulations for the coal mining industry are published in the Federal Register.

The guidelines in this document identify in terms of chemical, physical, and biological characteristics of pollutants, the level of pollutant reduction attainable through application of the best practicable control technology currently available. The guidelines also consider a number of other factors, such as the costs of achieving the proposed effluent limitations and nonwater quality environmental impacts (including energy requirements) resulting from application of such technologies.

## SUMMARY OF METHODS USED FOR DEVELOPMENT OF EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and standards of performance proposed herein were developed in a series of systematic tasks. The Coal Industry was first studied to determine whether separate limitations and standards are appropriate for different segments within the point source category. Development of reasonable industry categories and subcategories, and establishment of effluent guidelines and standards requires a sound understanding and knowledge of the Coal Industry, the processes involved, waste water generation and characteristics, and capabilities of existing control and treatment methods.

Initial categorizations and subcategorizations were based on the suggested Standard Industrial Classification Groups (SIC) which categorize the mining and preparation segments of the industry and on such factors as type of mining operation (surface mine/underground mine), geographic location, size of operation, and rank of coal mined (anthracite/bituminous/lignite).

On-site visits and interviews were made at selected surface mines, underground mines, and coal preparation plants throughout the United States to gather new data and to confirm and supplement compiled data. All factors potentially influencing industry subcategorization were represented at the selected sites. Detailed information on production, water use, waste water control practices, and waste water treatment practices was obtained. Flow diagrams were prepared indicating the course of waste water streams. Control and treatment plant design and cost data were compiled. Raw and treated waste water streams were sampled and analyzed and historical effluent quality data was obtained wherever possible. Duplicate samples were analyzed by the National Coal Association to confirm the analytical results.

Raw waste characteristics were then identified for each category or subcategory. This included an analysis of all constituents of waste waters which may be expected in coal mining or preparation plant waste water.

Each of these constituents found to be present was initially evaluated against maximum concentrations recommended for agriculture and livestock, public water supply, and aquatic life and wildlife. Based on this evaluation constituents which should be subject to effluent limitations and standards of performance were identified.

Raw waste characterization was based on a detailed analysis of samples collected during this study and historical effluent quality data supplied by the coal industry and Federal and State regulatory agencies.

Based on a critical review of the waste water characteristics of the initial industry subcategories, it was determined that there are generally two types of untreated waste water for the mining segment of the industry - alkaline, and acid or ferruginous - determined largely by regional and local geologic conditions and not by mine size or type of mine. Water quality within a particular class (acid or ferruginous/alkaline) is reasonably uniform, and the class of raw mine drainage determines the treatment technology required. For the most part, the quality of discharge effluent from acid mine drainage treatment plants did not exceed the standards initially established for reference. The quality of untreated alkaline mine drainage was found to be commonly superior to effluent quality from acid mine drainage treatment plants.

It was therefore determined that the initial industry subcategorization was not warranted and categorization was based on SIC Code and the two classes of raw mine drainage.

It was also determined after review of coal preparation plant visits and review of information supplied by the industry that the existing practice and standard of the industry was closed water circuits in the wet cleaning of coal in coal preparation plants. This practice obtains no discharge of pollutants for the actual cleaning of coal.

Waste water from coal preparation plant yards, coal stock piles, and refuse disposal areas was either treated in the same treatment facility as the mine drainage, or was treated in a separate facility using similar techniques and methods as used for the mine drainage from the mine served by the preparation plant.

It was therefore determined that the mining services category (coal preparation plants) should be subcategorized as to the actual coal cleaning process itself (coal preparation) and ancillary areas (coal stock piles, refuse disposal areas, and coal preparation plant yards).

The full range of control and treatment technologies utilized within the major SIC industry categories was identified. The problems, limitations and reliability of each treatment and control technology and the required time, cost, and energy requirements of implementing each technology were also identified. In addition, this report addresses all nonwater quality environmental effects of application of such technologies upon other pollution problems, including air, solid waste, noise and radiation.

All data was then evaluated to determine what levels of treatment constituted "best practicable control technology currently available," "best available technology economically achievable," and "best demonstrated control technology, processes, operating methods, or other alternatives." Several factors were considered in identifying such technologies. These included the application costs of the various technologies in relation to the effluent reduction benefits to be achieved through such application, engineering aspects of the application of various types of control techniques or process changes, and nonwater quality environmental impact.

The data and effluent limitation guideline recommendations presented in this report were developed based upon an exhaustive review and evaluation of raw waste water and treated effluent sample data, available literature, and visits to more than two hundred individual mine sites or coal preparation facilities in twenty-two coal producing states. The recommended effluent limitation guidelines represent an analysis of these facilities, and a detailed analysis of seven selected AMD treatment facilities and six surface mine settling basins for 90 consecutive days to verify historical data.

## DESCRIPTION OF AMERICAN COAL FIELDS

The process of coal formation entails the accumulation and compaction of organic materials beneath layers of sediments. Such materials can accumulate in either fresh water or marine environments, particularly where water levels are subject to fluctuation and subsequent sediment influx. The degree of compaction plays an extremely important role in the classification of coals by rank. Coals are classified according to relative percentages of fixed carbon, moisture and volatile matter. Depending on the specific classification system, this categorization can be general or extremely detailed. Four general categories are discussed.

Minimal compaction of accumulated organic materials results in formation of peat, which is not considered to be a type of coal. The first major stage of compaction of peat produces lignite, the lowest coal rank. The following average characteristics are typical of lignite: 1) 30 percent fixed carbon; 2) 25 percent volatiles; 3) 45 percent moisture; and 4) 6500 BTUs.

Compaction of lignite produces a higher rank of coal (subbituminous), which is still considered to be low quality. Average characteristics of subbituminous coal are: 1) 42 percent fixed carbon; 2) 34 percent volatile matter; 3) 23 percent moisture content; and 4) 9700 BTUs.

Bituminous coal is produced by the continued increase of pressure and compaction on the organic materials. Bituminous coal as described here encompasses a large majority of all coal mined today. Characteristics of bituminous coal vary widely, and this rank can consequently be extensively subcategorized. The range of general characteristics for bituminous coal are: 1) 47 to 85 percent fixed carbon; 2) 22 to 41 percent volatiles; 3) 3 to 12 percent moisture; and 4) 9,700 to 15,000 BTUs.

The highest coal rank - anthracite, requires extreme amounts of heat and compaction for formation. The extremes required seldom occur in nature and, as a result, anthracite coal is not common. Locally or regionally-confined areas of intense folding or igneous intrusion, where they occur in coal-bearing strata, may result in the development of anthracite coal. General characteristics of anthracite coal follow: 1) greater than 85 percent fixed carbon; 2) less than 3 percent moisture; 3) less than 12 percent volatile matter; and 4) 12,000 to 15,000 BTUs.

Sulfur content is another important constituent of coal, although it fluctuates greatly and cannot be related to coal rank. The fluctuations in sulfur content are attributable to variations in environmental conditions at the time of deposition, accumulation and initial compaction of the organic material. Sulfur content is discussed in greater detail in the description of each coal producing region.

Coal rank, geologic occurrence, estimated reserves, general mining procedures and economic conditions for the various American coal-producing regions and provinces are discussed in detail in the following section. Figure 1 illustrates the location of major coal deposits in the United States.

## Anthracite Coal

Although not a major fuel source for today's energy production, anthracite coal has been historically significant in the economic and industrial growth of the United States. The United States is completely self-sufficient in anthracite, with nearly all coal reserves and production centered in Northeastern Pennsylvania (see Figure 2). The coal lies within four individual fields - the northern, eastern-middle, western-middle, and southern - located in the Valley and Ridge Province of the Appalachian Highlands. These coal fields cover a total of 1240 square kilometers (480 square miles) and each consists of one or more small, U-shaped basins trending northeast-southwest between adjacent ridges.

The basins or synclines are structural in nature, resulting from downfolding of the rock units and coal seams. The extent or degree of this downfolding is directly related to the depths below the surface at which the coal seams lie - as deep as 1800 meters (6000 ft) in the southern field where folds are extremely tight.

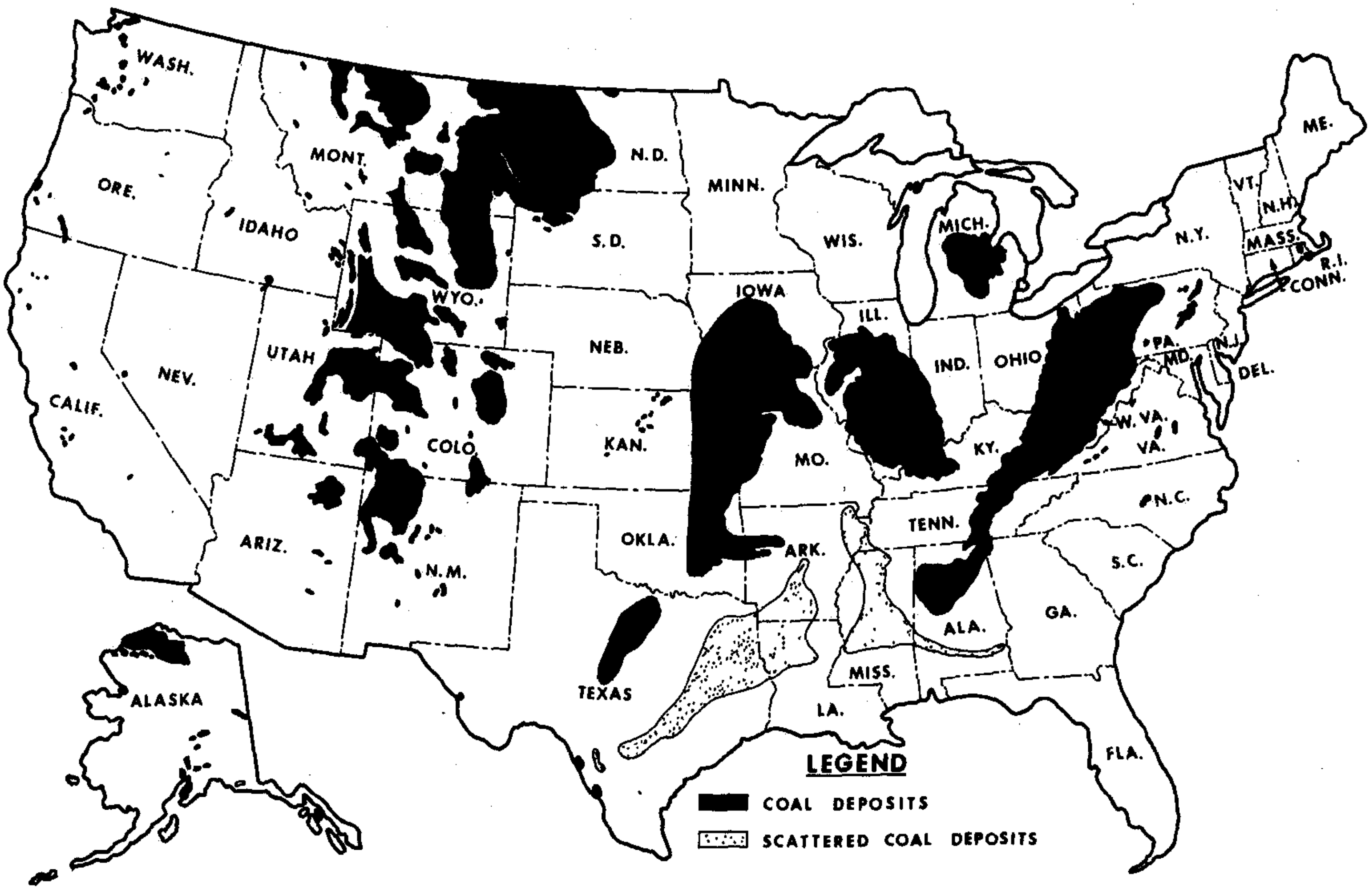
The northern coal field encompasses the Scranton and Wilkes-Barre region and underlies Lackawanna and Wyoming Valleys. Coal reserves occur in a curved, canoe-shaped syncline with a flat bottom and steep sides outcropping along the mountain ridges. There are 18 workable seams lying at depths up to

640 meters (2,100 ft), and the bulk of this field's reserves can only be recovered by underground mining techniques. The northern field has been extensively mined with interconnecting workings that are largely inundated today. As a result, the threat of massive water handling problems due to seepage or flow from adjacent abandoned mines prohibits economic extraction by deep mining of any of this field's reserves. All current production in this field is from bank recovery and strip mining operations, which do not have prohibitively high pumping and mine drainage treatment costs.

The eastern-middle field is centered around the Hazleton area and consists of numerous long, narrow, east-west trending coal basins. Mined portions of this field generally lie above drainage along mountain ridges and are gravity drained by specially driven tunnels. Total stratigraphic thickness of the coal bearing formation in this field is approximately 610 meters (2000 ft). The major coal seam, Mammoth, ranges in thickness from 9 to 15 meters (30 to 50 ft) and is one of Pennsylvania's most economically important anthracite seams.

The western-middle anthracite field encompasses the Mahanoy-Shamokin region and contains the same major seams found in the eastern-middle field. All coal seams in the western-middle field are contained stratigraphically within 760 meters (2,500 ft) of rock. Seams are flat-lying in some areas and steeply pitching in others. Coal seams in the Shenandoah and Mahanoy basins, including the Mammoth, are folded over upon themselves, doubling the thickness of mineable coal and locally achieving thicknesses of 60 meters (200 ft). Coal basins in this field are almost totally beneath natural drainage channels. Consequently, the abandoned mines are inundated and mine pool overflows account for most of the mine drainage pollution.

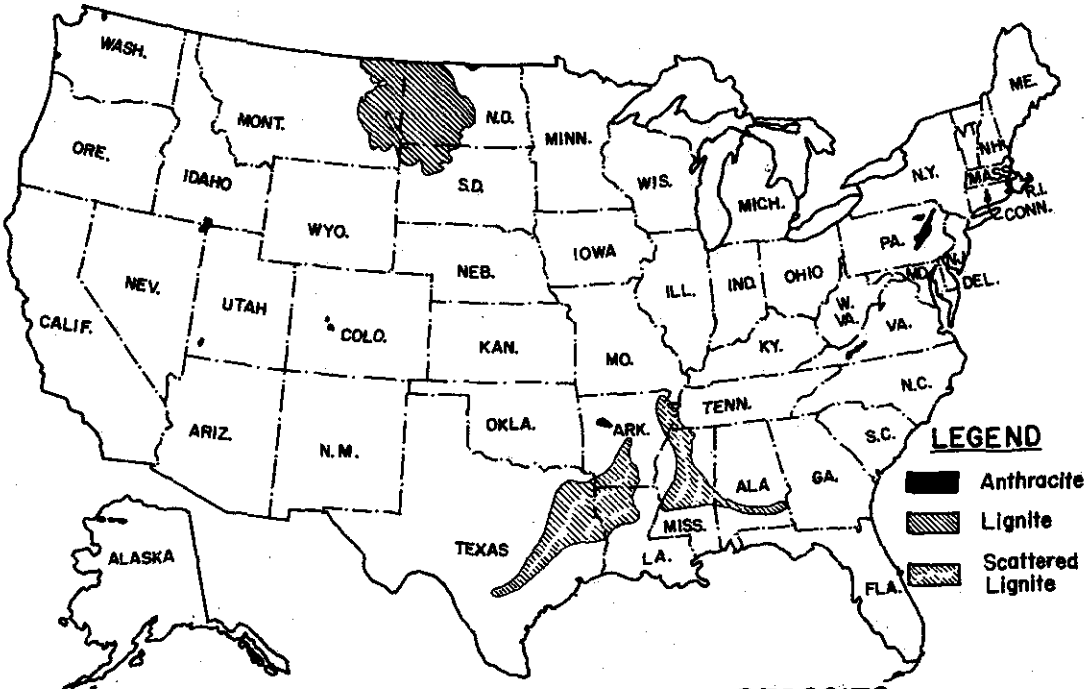
The southern field is the largest of the four coal fields with an area of 520 square kilometers (200 square miles). This field is extremely long, extending from the Lehigh River Valley westward almost to the Susquehanna River. The 26 workable coal seams in the southern field lie within a 670 meter (2200 ft) rock section. Coal seams dip very steeply to depths of nearly 1800 meters (6000 ft). Deep mine workings in the southern field occupy positions both above and below natural drainage. Consequently, mine drainage emanates from both mine pool overflows and drainage tunnels.



Adapted from illustration
in KEYSTONE COAL
INDUSTRY MANUAL (1974)

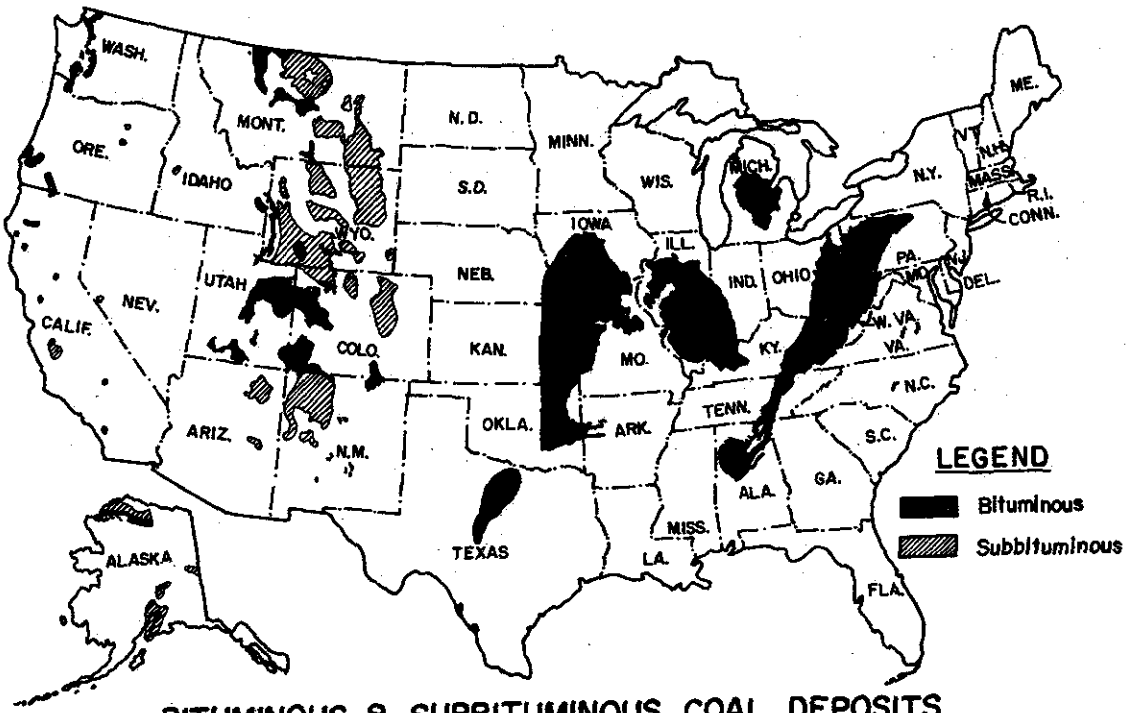
COAL DEPOSITS IN THE UNITED STATES

Figure 1



ANTHRACITE & LIGNITE COAL DEPOSITS

Figure 2



BITUMINOUS & SUBBITUMINOUS COAL DEPOSITS

Figure 3

Adapted from illustration
in KEYSTONE COAL
INDUSTRY MANUAL (1974)

Coal mining operations were present in nearly all of the major anthracite fields by the early 1800's. The use of shaft mining for extraction of deep-lying coal was first employed in these anthracite fields, and by 1870, total annual anthracite production by deep mine methods alone was about 13 million kkg (14 million tons). By the turn of the century, there was a four-fold increase in total production, still primarily by deep mine methods. World War I saw total annual production reach a high of 91 million kkg (100 million tons), with a rapid post-war decline until about 1930. Anthracite production then remained stable at 50 million kkg (55 million tons) annually until 1948. During this time strip mining gained importance, and production from surface mines reached a high of nearly 10 million kkg (11 million tons) in 1944.

Both surface and deep mine production of anthracite coal have steadily decreased since the 1940's, although production per square mile of coal field remains at least three times greater than that for bituminous mining. The Pennsylvania Department of Environmental Resources reported a total anthracite production of 8.4 million kkg (9.25 million tons) for 1970, and an annual production decline of about 10 percent annually in subsequent years. In 1973, anthracite production was estimated at 5.8 million kkg (6.4 million tons) from 37 surface and underground mines and 10 secondary recovery operations. At that time, underground, surface and bank mining accounted for approximately 0.6, 3.1 and 2.1 million kkg (0.7, 3.4 and 2.3 million tons), respectively.

Preliminary production figures for 1974 show, however, that despite the energy crisis and increasing demand for fossil fuels, anthracite production continues to decline. These figures show an increase of 6.9 percent in bituminous coal production and a decrease of 14.8 percent in anthracite coal production. Consumer demand for anthracite from public utilities and the iron and steel industry is limited, relative to the bituminous industry. As a result of these factors, anthracite production is not expected to increase greatly in the near future. In addition, production increases are limited by labor shortages, lack of investment incentive, high mining costs, lack of easily mineable coal and environmental considerations. Although a great number of problems affect the anthracite mining industry, the increased demand for cleaner burning fuels could revitalize the industry.

Total estimated coal reserves as of January, 1970, for the four anthracite fields, were about 15 billion kkg (14 billion tons). Recoverable anthracite reserves, those seams over 0.6 meters (2 ft) thick, were estimated at 7 billion kkg (8 billion tons). This figure indicates that 23 percent of Pennsylvania's total recoverable coal reserves lie within 3 percent of its coal land.

## Bituminous Coal, Subbituminous Coal and Lignite

Bituminous coal has been the major source of the Nation's energy for the past three centuries. Production and utilization of this resource has always been vitally linked to the economic and industrial growth of the nation and, as a result, trends in soft coal production have closely paralleled trends in nationwide industrial activity. Bituminous coal, until recent years, was the only soft coal product that was mined on a major scale. Its production has peaked during each major war in the last century - World War I, World War II, and the Korean Conflict - with an all-time high of 572 million kkg (630 million tons) in 1947. Production has also generally declined following each of those periods, recovering only gradually. Since 1947 bituminous production has climbed at a fairly steady rate, but has remained below 544 million kkg (600 million tons) annually, except for one year.

The slow recovery of the coal industry to World War II production levels has been in part caused by rapid, extensive changes in consumer utilization of coal between 1947 and the mid 1960's. During this period, the railroads converted from coal-fired to diesel locomotives and much of the domestic heating market converted from coal to oil or gas. These demand declines were partially offset, however, by steadily increasing use of coal in electrical generating plants. Demand for low sulfur coal has increased substantially with increasing concerns for cleaner stack emissions from generating stations. Low sulfur subbituminous and lignite coal production is rapidly expanding to meet these needs. Although these materials have lower heating capabilities than higher grade bituminous, large deposits of low sulfur material can be mined and sold to distant markets at costs competitive with higher grade low sulfur bituminous coal, which is much less common. Since deposits in several of the major producing areas contain bituminous coal, subbituminous coal, and lignite, all are discussed together in the following description of the Nation's major coal producing regions.

Appalachian Basin. The Appalachian or Main Bituminous Coal Basin is the easternmost, and currently most important, coal producing region in the United States. The basin extends from North-central Pennsylvania through portions of Ohio, Maryland, West Virginia, Virginia, Eastern Kentucky, Tennessee, and Northern Alabama. This bituminous coal producing region consists of a major, elongated depositional basin containing a series of local, parallel, northeast - southwest trending synclinal basins, occasionally offset by faulting.

The southern two thirds of the basin lies higher and has been more severely eroded than the northern section. As a result, many of the younger, stratigraphically higher seams were eroded away, and only the older, deeper coal remains. The younger, uneroded seams are generally limited to the north-central portion of the basin, lying in West Virginia and small adjacent portions of surrounding states. These younger seams are thicker and of above-average quality.

The thickest strata in the basin lie along its eastern edge, while the percentage of limestone and calcareous overburden material increases to the west and south. These trends are directly related to the depositional history of the strata in the basin. The exposed land surface, which was the source of sediments and coal-producing organic material, lay to the east of the inland sea in which the materials were deposited; and the deeper, marine portions of that sea were located to the south and west. These trends are also closely related to the pollution production potentials of the coal strata. Many of the coal seams in the basin are high sulfur and constantly produce acid during and after mining. The limestone and calcareous units, where they are present, have the ability to neutralize a substantial portion of the acid produced. As a result, there is generally a less serious acid mine drainage pollution problem in western and southern portions of the basin.

Broad regional variations within the basin have been an important factor in determining trends of coal extraction and resultant mine drainage patterns. Most major coal formations outcrop, at least intermittently, around the rim of the basin and lie at great depth at its center. Mining was initiated along coal outcrops, particularly in thicker seams in the northern portion of the basin - the Pennsylvania, West Virginia, Ohio region. Here, surface mining has been an extremely important extraction technique, since seams are thick and relatively shallow. Farther south in the basin, coal seams generally follow the basin's dip and lie at greater depths, necessitating slope or drift mining to maximize coal extraction. The bulk of Appalachian Basin coal resources lie at depth in or near its center. As a result, many newly opened or planned mines are being designed with shaft entrances to reach deeper seams.

The number of coal seams present in any single portion of the Main Bituminous Basin is determined by local depositional, structural and erosional conditions and, as a result, is highly variable. Much of the basin has a large number of seams, but many of those are local, discontinuous, or too thin to mine. There are generally about 5 to 10 commercially mineable seams in any portion of the basin. For example, Southeastern Ohio has over 50 identified coal seams, but only about 11 of those are commercially mineable. Coal quality also varies considerably according to the original depositional environment. Quality of a single seam can change quite drastically between geographic areas, and different coal seams may be even more dissimilar. Sulfur content of Appalachian coals ranges from 0.2% to 10%, and all other important parameters have equally large ranges.

One of the most important and valuable coal deposits in the Nation is the Pittsburgh seam, which underlies approximately 15,500 square kilometers (6000 square miles) in the north-central portion of the Main Bituminous Basin. This coal is characterized by a consistent average thickness of 2 meters (6 ft) and high quality. It was extremely important during the development of the early American steel industry.

Total coal reserves in the Appalachian Basin have been estimated at 238 billion kkg (262 billion tons), most of which is bituminous coal. This reserve figure is second only to that of the Western Region - the Northern Great Plains and Rocky Mountain Provinces - where vast untapped lignite deposits in North Dakota increase the total reserves to 787 billion kkg (868 billion tons).

Since this basin has been the primary source of American bituminous coal for many years, trends in national coal production have been those evidenced in Appalachia. Production declined following the Korean War and has slowly and steadily climbed since then. Recently passed environmental restrictions and more strictly enforced safety laws have significantly increased production costs, and, along with labor disputes, have slightly depressed production in the past few years. Bituminous coal production in this region far surpassed that from any other coal-producing region, but still decreased from 351 to 340 million kkg (387 to 375 million tons) between 1972 and 1973.

Interior Region. The Interior Coal Region consists of two major basins - the Eastern and Western - that underlie all or part of nine states. The coal seams in this province contain relatively high percentages of sulfur, but acid mine waters are not as common as in the Appalachian Basin.

Limestones and other calcareous rock units overlying coal-bearing strata produce naturally alkaline surface waters and neutralize any acid formed around the pyritic coal. Thus mine effluents are often of acceptable quality in many respects.

The Eastern Interior Coal Basin is a single, large basin which underlies flat or gently rolling farmlands in Illinois, Western Indiana, and Western Kentucky. Rock units are relatively flat-lying throughout much of the basin, but are found along the Ohio River in several overturned, severely faulted folds. The basin locally contains as many as 35 different bituminous seams, but only about eight high volatile, high sulfur seams are major coal producers. BTU content of the coals generally increases to the Southeast, but ash and sulfur are unsystematically variable throughout this field. Many of the economically important seams here are shallow, and a substantial portion of this basin's coal production is from large area-type surface mines utilizing high capacity stripping equipment.

The Western Interior Coal Basin is substantially larger than the eastern, extending from North-central Iowa southward through portions of Nebraska, Missouri, Kansas, Oklahoma and Arkansas. Coal seams in this basin are predominantly bituminous with high sulfur, moisture, and ash content, and have been correlated with seams found in the Eastern Interior Basin. In addition to these bituminous seams, there is also a small pocket of anthracite coal found in Arkansas.

Characteristics of coal and overburden material in the Western Basin show significant geographical variation. Coal seams in Iowa are generally thin, lenticular and discontinuous, and, as a result, mining operations are small and mobile. Much of the northern portion of the basin is overlain by glacial drift, which locally reaches depths of 150 meters (500 ft). Farther south, in Kansas, coals are flat-lying and persistent with little faulting, but are often too deeply buried to economically mine. The number of seams identified in this portion of the basin exceeds 50, but only seven are economically important. Overburden thicknesses decrease eastward in the basin, and much of the coal produced in Missouri can be surface mined. Area mining techniques and large strip mining equipment make the mines in this region highly productive. The Interior Region has been actively mined for many years and, as a result, production trends have been closely aligned with those observed in the Main Bituminous Basin. The conflicting needs of recently passed clean air requirements and the energy crisis have caused coal production to fluctuate in recent years, with a net production decline in this province. Production totaled 140 million kkg (154 million tons) in 1972 and dropped to 134 million kkg (148 million tons) in 1973. Western Interior operations, which are predominantly surface mines, showed an increase from 8.4 to 8.6 million kkg (9.25 to 9.5 million tons) during that period. Production from the Eastern Interior Basin, however declined from 132 to 126 million kkg (145 to 139 million tons).

The Interior Province contains an estimated 238 billion kkg (262 billion tons) of coal reserves, and will certainly be an extremely important factor in future coal production. As energy and fossil fuel demands continue to increase, production is expected to show a corresponding increase.

Western Region. The Western Region of the American coal field consists of three coal provinces - Northern Great Plains, Rocky Mountain, and Pacific Coast - underlying eight western states. These provinces are discussed in detail below.

The Northern Great Plains Province consists of a vast expanse of lignite and subbituminous coal deposits extending into portions of Montana, Wyoming and North Dakota. This coal province contains by far the largest coal reserve in the Nation. Strata are generally flat-lying, with steepened dips only along mountain flanks. The lignite fields are defined or subdivided according to type of overburden material above the mineral deposits - glacial drift in the north and poorly consolidated, fine-grained, nonglacial materials farther south. Due to the relatively recent deposition of these lignite and subbituminous beds and the lack of subsequent tectonic disturbance (folding or faulting), the rank of Northern Great Plains Province coals increases with depth of burial, which is in turn determined by age of the deposits. Sulfur contents are one percent or less and ash values are correspondingly low.

The Montana and Wyoming portions of this province contain more subbituminous coal than lignite. Seam thicknesses average 6.1 meters (20 ft), occasionally exceeding 30 meters (100 ft), and many of the deposits have unconsolidated overburden. Surface mining is therefore relatively inexpensive. The low rank and heating capabilities of the coal or lignite are effectively countered by the low costs at which that coal can be produced. Nearly all lignite currently produced is used for electrical generation, but future intended uses for this material include gasification.

The Rocky Mountain Coal Province consists of a large number of relatively small coal basins underlying portions of Arizona, New Mexico, Colorado, Utah, Wyoming and Montana. Coals in the northern and central portions of this province occur in broad, asymetric, synclinal folds lying between or paralleling various ranges of the Rocky Mountains. The coal seams here are relatively flat-lying and deep in central portions of the province, with steeper dips along basin flanks. In several instances, coal deposits have been warped upward by the regional tectonics that have formed the mountains. As a result, many of the seams in the central portion, particularly in Colorado and Utah, have steep dips, severely limiting the amount of strippable coal.

Many of the seams in the southern portion of the province are not persistent, extending only eight to 48 kilometers (five to 30 miles). Coal ranges from low rank bituminous to anthracite, depending on proximity to local igneous intrusions. One of the larger coal fields in this portion of the province is in Arizona's Black Mesa synclinal basin. The low sulfur (less than one percent) coals in this field have only recently been tapped on a large scale. Similar low sulfur coals are found in much of the Rocky Mountain Province, and account for its importance despite production difficulties.

The Pacific Coast Province is relatively small and unimportant, with widely scattered basins or deposits in Washington, Oregon and California. The deposits in Washington are the only ones mined to any extent, thus discussions here largely pertain to Washington. The coal deposits are approximately two thirds subbituminous, one third bituminous. Although BTUs are relatively low, the coal is of very high quality with low ash and sulfur contents. The coal reserves, which are largely unmined, underlie the foothills of the Cascade Mountains. Coal in these small basins has undergone considerable tectonism, as evidenced by folds, faults and vertical or steeply pitching seams. Deepest coal seams are, therefore, not necessarily oldest, and the vicinity of greatest deformity generally contains higher rank coals. Physical conditions of these coal seams also minimize underground mining and frequently restrict sizes of active mining operations.

Contrary to recent national declines in coal production, tonnage from each province of the Western Region has increased significantly in the past few years. This is mines, is the 1969 Federal Coal Mine Health and Safety Act. In 1969 the average kkg per man day for deep coal mines was 14.7 kkg/man (15.6 tons/man). In 1973 this dropped to 10.2 kkg/man (11.2 tons/man) with a corresponding increase in production cost. A marked increase in capital costs for equipment and cost of materials to meet the 1969 Act has also been experienced. These increased costs resulted in mine closures which are continuing even with the increased realization per ton of coal, and have discouraged the opening of small independent mines which can not absorb the increased costs. Since World War II the Nation's 50 top-producing companies have increased their share of national coal production from 42 percent to 69 percent. In 1972 the top 15 companies produced 51% of the bituminous tonnage. In 1972, 80 percent of all underground coal production was from mines with annual tonnages exceeding 181,400 KKG (200,000 tons). In 1973, 95 percent of total surface mined coal was from mines producing more than 90,700 KKG (100,000 tons) annually, and 70 percent was from mines producing over 181,400 KKG (200,000 tons) annually. This trend will apparently continue in the future, as small mining companies are gradually forced to close due to more stringent environmental and safety restrictions.

Coal is recognized as a major source of energy to meet the nation's increasing demand for energy.

A recent study by the National Academy of Engineering (NAE) concludes that, if the coal industry is to double production by 1985 to meet increased energy demands, it must:

1. Develop 140 new 1,814,000 kkg/yr. (2,000,000-ton-per-year) underground mines in the eastern states.

2. Open 30 new 1,814,000 kkg/yr. (2,000,000-ton-per-year) surface mines in the eastern states and 100 new 4,535,000 kkg/yr. (5,000,000-ton-per-year) mines in the western states.

3. Recruit and train 80,000 new coal miners in the eastern states and 45,000 coal miners in the western states.

4. Manufacture 140 new 25.2 cu m (100-cubic-yard) shovels and draglines.

5. Build 2,400 new continuous mining machines.

Also of interest are the NAE study's projections for expansion in the transportation area to haul a doubled coal output by 1985. They would entail the following:

1. Construction of 60 new 1,814,000 kkg/yr. (2,000,000-ton-per-year) eastern rail-barge systems of 161 km to 805 km (100 to 500 miles) each.

2. Construction of 70 new 2,721,000 kkg/yr (3,000,000-ton-per-year) western rail-barge systems of 1609 km to 1931 km (1,000 to 1,200 miles) each.

3. Building of four new 22,675,000 kkg/yr (25,000,000-ton-per-year) slurry pipelines of 1609 km (1,000 miles) each.

4. Installation of two new 70,000,000 cum (2,500,000,000-cubic-feet-per-day) gas pipe lines of 1609 km (1,000 miles) each to transport synthetic gas from coal.

5. Manufacture of 8,000 new railroad locomotives and 150,000 new gondola and hopper cars.

This last point is particularly important because the poor financial condition of the country's railroads will limit their ability to provide sufficient rolling stock (coal cars) to move the needed quantity of coal from the mines to the point of consumption.

## DESCRIPTIONS OF FACETS OF THE COAL INDUSTRY

As the major SIC categories imply, the Coal Industry can be divided into two segments - coal mining and coal mining services (coal cleaning or preparation). Each of these categories is discussed in detail in the following section.

## COAL MINING

### Mining Techniques

Coal mines are classified according to the methods utilized to extract coal. Methods selected to mine a coal seam in any specific area depend on a number of physical and economic factors: 1) thickness, continuity and quality of the coal seam; 2) depth of coal; 3) roof rock and overburden conditions; 4) local hydrologic conditions as they relate to water handling requirements; 5) topography and climate; 6) coal market economics; 7) availability and suitability of equipment; 8) health and safety considerations; and 9) any environmental restrictions which could affect the mine.

Surface or strip mining is employed where the coal is close enough to the land surface to enable the overburden (the rock material above the coal) to be removed and later attributable to the low ash and sulfur contents and the ease with which much of the coal can be mined. With increased demand for low sulfur power generating coal to decrease stack emissions, the subbituminous and lignite mining portions of the coal industry have mushroomed in recent years. Between 1972 and 1973 the following production increases were noted for the Western Region: 1) Pacific Coast Province - 2.4 to 3.4 million kkg (2.6 to 3.7 million tons), 2) Rocky Mountain Province 29.4 to 33.7 million kkg (32.4 to 37.2 million tons), and 3) Northern Great Plains Province - 42.8 to 49.5 million kkg (47.2 to 54.6 million tons). For the same basic reasons, the Western Region is also expected to show the greatest future production increases. The most comprehensive coal exploration and mine development programs are currently in progress here, and this region contains an extremely large reserve - an estimated 793 billion kkg (874 billion tons). These characteristics combine to make the Western Region a potential future leader in American coal production.

Future Production Trends. There are a number of factors that will be extremely important in determining future production trends of the coal industry. The energy crisis has produced a steady, dramatic increase in demand for coal, which in turn provides a strong incentive to increase production. The value of a ton of coal has significantly increased to the point where previously uneconomic or marginal coal deposits can now be profitably extracted and marketed. However, increased demands for coal and availability of economically mineable coal have not inspired increased production as they should have. These factors are tempered by several other important considerations which have actually reduced production slightly.

Environmental aspects of coal utilization have recently become critical in determining current mining trends, and will continue to gain importance in the future. Stringent clean air restrictions have been imposed on coal-burning electric generating plants, which used 90 percent of all coal produced in 1973. Most of these plants are located in the eastern United States, near major population and industrial centers, and the coal they burn is almost exclusively high-sulfur Appalachian Basin bituminous coal. Equipment has been developed to reduce the undesirable emissions caused by burning high-sulfur coal, but the technology has not yet been fully perfected and equipment is costly. At present, a financially feasible alternative to installation of this emission equipment is utilization of low-sulfur western coal or lignite. This coal is of lower rank and commonly has a lower BTU value than eastern bituminous coal, meaning that more lower rank material must be burned to obtain the same amount of heat. These low rank bituminous coals and lignite deposits are found in the western coal fields, where seams are thicker, overburden is thinner, and water problems are minimal. As a result, the coal can be more easily mined, shipped east, and sold at prices that are competitive with those for Appalachian high-sulfur coal. Western coal fields have been experiencing a rapid mining expansion, which should continue for some years. As these western fields achieve full production, annual tonnages for national surface mining of coal should increase significantly.

One of the major deterrents to expansion of the coal industry is availability of transport for the coal to the consumer. The present transportation system, particulary railroad systems, are operating at capacity. Alternatives suggested for railroad transportation include slurry pipe lines, mine mouth power plants, and mine mouth gasification and liquification plants.

The immediate demand for coal is not expected to greatly increase the percentage of coal produced from underground mines. Many active deep mines are already operating at maximum potential, with no practical way to increase production. The reserves of coal that can be extracted utilizing current underground mining technology at competitive costs is relatively small when compared to the total deep mine reserve. Large scale percent increases in underground mine production can only occur if the technology is perfected to enable economic, safe extraction of deeper lying coal seams which comprise the bulk of this country's reserves. If these technological breakthroughs occur, underground mine production can be expected to increase substantially not only on an annual basis, but also on the percent extracted by underground methods.

Economic considerations have also had an important role in establishing a trend toward the prominence of larger mines and mining companies. Environmental restrictions and regulations on surface mines have increased production and capital costs substantially. It is frequently impossible for smaller mining operations to comply. As a result, small operations are becoming scarce, because their owners are forced by economic conditions to close. Larger companies are more capable of absorbing these production costs.

A major effect on the productivity of individual deep mines, which has reflected in the number of mines and size of replaced or regraded while still realizing a profit from the coal sale. Extraction of coal with large augers, which can be accomplished without removing overburden material, is also occasionally utilized at surface mines. Where the coal is too deep to permit profitable strip mining, underground mining techniques are utilized. These major methods of extracting coal are discussed in detail in the following pages.

It should be noted that regardless of the method of mining, water use is generally limited to dust suppression, and in the United States is not used as an integral part of any major mining technique. Water removal is required as it is a nuisance and hinderance to mining. As such, mine dewatering and handling is a required part of the mining plan at most coal mines, and, as such, mine drainage is considered a waste water for the coal production segment of the industry.

Underground Mining. Underground mines are developed by driving entryways into a coal seam and are classified according to the manner in which the seam is entered. Drift mines enter the coal at an outcrop, the point at which the coal seam is exposed on the land surface. Drifts are the cheapest method of access to underground mines, where conditions are suited, and provide horizontal or nearly horizontal access to the mine workings. Slope mines are found where the coal is at an intermediate depth or where the coal outcrop condition is unsatisfactory or unsafe for drift entry. Slope mines employ an inclined slope entry driven to the coal from the land surface above. Slope entry use allows the coal to be entered from above while permitting continuous haulage of coal from the workings up the slope to the surface. Shaft mines are utilized where the coal lies too far below the surface to outcrop. The shaft itself is a vertical entry driven to a coal seam from the land surface above. Access to the workings and mined coal must then be transported via elevators in the mine's shaft or shafts.

The method of entry employed to gain access to a coal seam can be extremely important in development of an underground mine. Drift entries must be driven from the coal outcrop, regardless of where the remaining extractable coal lies. Slope entry locations are also restricted with relation to the remainder of a proposed mine by the thickness of overburden. A shaft entry can be located to facilitate entry and coal haulage while minimizing any anticipated problems. However, the cost of a shaft is directly related to the depth of the shaft.

The mining techniques employed in the mines themselves are not dependent on the type of entryway in use, and are fairly uniform in all underground mines. Most American coal mines utilize room and pillar extraction. Main tunnels, or headings, are first driven from points of entry. From these main headings, secondary headings are driven perpendicularly. Configuration of crossheadings, or crosscuts, must be carefully planned to permit adequate ventilation, support of headings, drainage of the workings, and to facilitate coal haulage. Blocks of coal are then extracted in some systematic pattern along both sides of the headings, and pillars of intact coal are left between the mined out rooms to support the mine roof and prevent surface subsidence above the workings. Configurations of rooms and pillars are designed to consider roof conditions, equipment utilized, depth of the seam and other physical factors. Room and pillar mining permits extraction of 40 to 60 percent of the coal in the mine, with the remainder left in the form of pillars.

Room and pillar mining is also effectively employed in extraction of very steeply dipping anthracite coal seams in northeastern Pennsylvania. In these mines, terminology differs but the technique is quite similar. The primary change required for steep dip mining is in the type of haulage employed, particularly from the coal face. Sufficiently steep workings are able to rely solely on gravity for haulage from the face to some collection point. Where other special haulage plans or equipment are required, mining costs may increase significantly, but the general mining system is still adaptable for use under these circumstances.

There are two predominant coal extraction procedures currently employed in American underground bituminous coal mines - conventional and continuous mining. Conventional mining consists of a repeated series of steps used to simultaneously advance a series of rooms. The procedure rotates a set of mining equipment from one room to another so that each piece of equipment in the set, or mine "unit", is always working somewhere. In this manner, no men or equipment in the unit sit idle waiting for their step of the procedure.

The sequence of events that lead to extraction of coal and advancement of the room is: 1) undercutting or overcutting the coal seam with a mechanized "cutter" as required to permit expansion of the coal upon blasting while minimizing damage to the roof rock; 2) horizontally drilling the coal at predetermined intervals to enable placement of explosives and blasting; 3) breakage of the coal by either explosives or high pressure air; 4) loading coal onto haulage vehicles or conveyor belts; and 5) roof bolting or timbering to support overburden material where the coal has been removed.

Conventional mining as described above is gradually being replaced by continous mining equipment. A "continous miner" is a single mechanized unit which breaks or cuts coal directly from the coal face and loads it onto haulage vehicles or belts. This eliminates equipment and operating personnel for cutting, drilling, and blasting. Secondary coal haulage from a coal face can be accomplished by rubber tired electric shuttle cars or by small conveyor systems. Primary haulage from these secondary systems to mine portals is generally accomplished by specially designed electric rail equipment or by conveyor systems.

Initial development in an underground mine may leave as much as 60 percent of the coal in pillars. Following development of entries, it is often possible to safely remove some of those pillars as the machinery retreats from an area of the mine. When pillars are "pulled" coal recovery for the mine significantly increases. However, resultant roof collapse and fracturing can greatly increase overburden permeability, facilitating mine water infiltration and subsequently increasing mine drainage problems. This is particularly true when operating under shallow cover or overburden.

Another deep mining technique, longwall mining, is relatively new to the American mining industry, although it is extensively used in Europe. An advantage of this technique is that it permits increased recovery of coal. Coal is extracted along a single "face" which is much longer than those used in room and pillar mining. The longwall can range from 30 to 200 meters (100 to 700 feet) in width and up to 2,000 meters (6,600 feet) in length.

Longwall mining equipment consists of hydraulic roof supports, traveling coal cutter, conveyors and power supply. Parallel headings of variable length are driven into the coal and a crossheading is driven between them at their maximum length. Equipment is installed in this third heading and working of the new face is initiated. Cutters move along the face and the cut coal falls onto a chain conveyor which parallels the face. Roof supports advance with the longwall face, restricting the size of the working area adjacent to the face, but permitting controlled roof collapse as the longwall progresses. Longwall mining generally increases percent of recovery over room and pillar methods.

From this brief description, it is obvious there is a wide range of mine types and equipment that can be utilized for underground coal extraction. Equipment and techniques employed at a particular mine are largely dependent on the physical and economic conditions at that site. Since these factors are subject to wide local variations, each existing or proposed mine must be carefully evaluated or re-evaluated periodically to determine applicability of the techniques discussed.

Surface Mining. Surface mining techniques are used to extract relatively shallow, or near surface coal seams. Where applicable, this techniques is generally favored over underground mining because: 1) less manpower is required to produce a ton of coal; 2) strip mines can be brought into productive operation generally faster with resultant expedient return on capital investments; 3) surface mining equipment is easily transferred to other operations when coal is exhausted; 4) safety considerations are less critical; 5) surface mining techniques can be utilized in shallow seams which can not be safely mined by underground techniques; and 6) coal recovery for surface operations is generally higher than recovery from underground operations.

Overburden material above a coal seam is removed or stripped using power shovels, draglines and other earthmoving equipment. This spoil material is cast to the side of the excavation or cut, the coal is removed, and the spoil is pushed back into the cut. This last step, the backfilling of a strip cut, has been required of strip miners only in recent years by relatively new reclamation laws. Prior to passage of those laws, spoil material was often either left where it was cast, slightly rounded, or partially pushed back into the cut. Recent reclamation laws generally require backfilling to the approximate original contour of the undisturbed site.

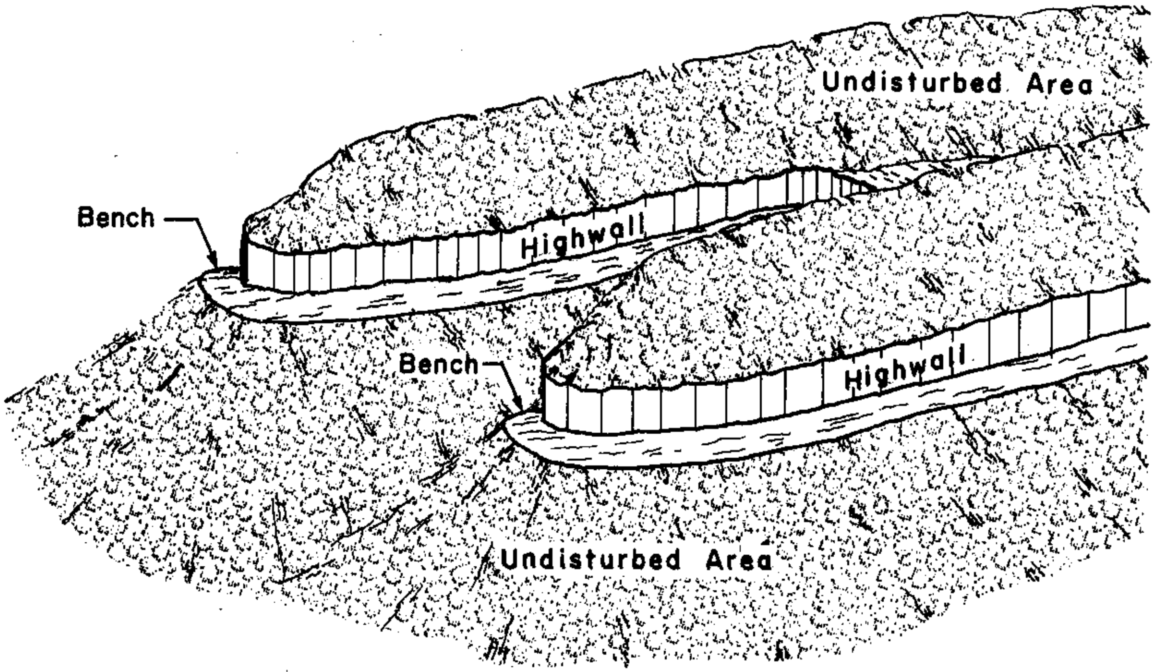
The amount of overburden that can be removed to enable profitable extraction of underlying coal is variable, depending upon the thickness, continuity, slope and quality of the coal seam, type and condition of overburden encountered, size of the property to be mined and return per ton of coal mined. The primary factor determining economy of strip mining and overburden removal is the ratio of overburden thickness to coal thickness. Depending upon conditions cited above, this ratio can be as high as 30:1 and still permit profitable stripping.

The sequence of operations that occurs in a typical surface mining operation is the mine site is cleared of trees and brush, overburden is vertically drilled from the surface, explosive charges - generally ammonium nitrate - are placed and the overburden is blasted or "shot". This sufficiently fractures the overburden material to permit its removal by earth moving equipment such as draglines, shovels or scrapers. Removal of this overburden generally takes the greatest amount of time and frequently requires the largest equipment. Specific sizes and types of equipment utilized vary according to conditions at each mine, with bucket capacities of the largest shovels and draglines currently exceeding 150 cubic meters (200 cubic yards).

Following removal of the overburden material, coal is loaded onto haulage trucks or conveyors for transport. Spoil backfilling follows coal extraction, and can be done with draglines, shovels, dozers, or scrapers depending on the conditions of the material and the amount that must be moved. The backfilled spoil is then regraded and seeded to establish vegetative growth and minimize erosion.

There are two general categories of strip mines which are defined largely by topography of the mined area - contour and area. The sequence of strip mining operations described above is utilized in both types of mines. Contour strip mining (see Figure 4) is most common where coal deposits occur in rolling or hilly country, and is widely employed in Pennsylvania, West Virginia, Virginia, Maryland, Ohio, Eastern Kentucky, Tennessee and Alabama. In contour stripping, an initial cut is made along a hillside, at the point where the coal outcrops, or is exposed at the land surface. Successive cuts are made into the hill until it becomes uneconomical to remove further overburden. In this manner, the strip cuts follow the contour of the coal outcrop around the hillside, generally resulting in a long, sinuous band of strip mined land around an entire hill. Contour strip mining results in a bench or shelf on the hillside where the coal has been removed, bordered on the inside by a highwall and on the outer, downslope side by the piled spoil material. Prior to recent passage of strict mining regulations, much of this spoil material remained on the natural slope below the bench, creating a spoil outslope much steeper than the natural land slope. Such unconsolidated spoil banks can create severe erosion and landslide problems.

The area strip mining technique is used extensively in relatively flat-lying lands of the Midwest and West. Area stripping, as the name implies, affects large blocks of



CONTOUR STRIPPING
Figure 4

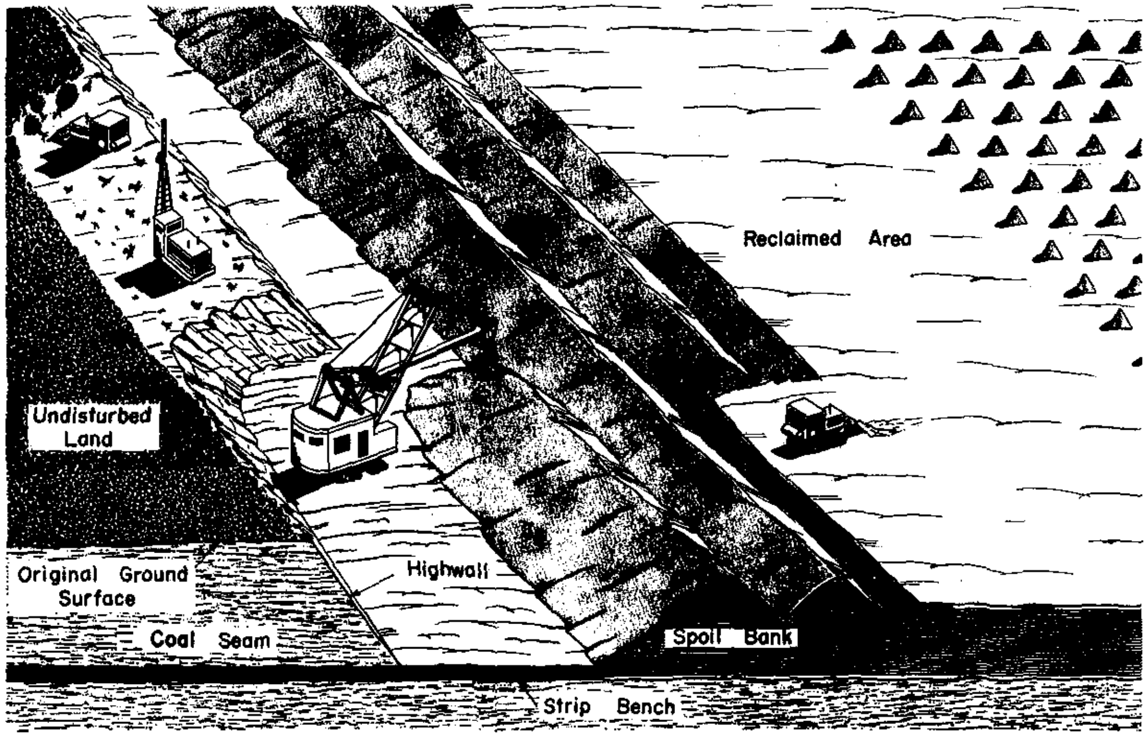
land, rather than the sinuous bands of contour stripping. The first cut in an area mine is generally made to the limits of the property to be mined. Coal is extracted from this cut and mining proceeds in a series of cuts, parallel to the first and adjacent to one another. Spoil from each new cut is placed in an adjacent completed cut, from which the coal has been removed. Thus the final cut in an area mine is the only one with either an exposed highwall or open cut, ridges. Until recently, the last cut was frequently developed into a large lake. However, with stricter reclamation laws, area mines must also be entirely regraded to approximate original contour. Figure 5 illustrates the sequence of operations in an area mine with concurrent regrading.

Auger mining is most commonly associated with contour strip mining, and is thus largely confined to eastern coal fields. Augering is one of the least expensive methods of extracting coal, but is limited to horizontal and shallowly dipping seams where easily accessible outcrops or highwalls exist. Large augers drill horizontally into a coal seam from the outcrop or the base of the highwall, after the overburden becomes too thick to remove economically. Auger heads range from 41 to 213 centimeters (16 to 84 inches) in diameter and can penetrate more than 60 meters (200 ft) into the coal. Depending upon the thickness of the coal and spacing of the holes, auger mining can recover 50 to 80% of the coal. Generally overburden collapses into the empty holes.

## COAL MINING SERVICES OR COAL PREPARATION

Coal cleaning has progressed from early hand picking practices for removal of gross refuse material to present technology capable of mechanically processing coal fines and slimes, permitting greater recovery of selected compositions. These technological advances were introduced with mechanization of the mines and were stimulated by more stringent market quality requirements and increased coal production rates. Approximately 49 percent of United States bituminous coal production (1971) is mechanically cleaned. Depending on the degree of preparation and nature of the raw coal, preparation can: produce a uniformly sized product; remove excess moisture; reduce ash content; reduce sulfur content; and increase calorific value. It can also enable effective coal composition management.

Coal markets have greatly influenced the degree of preparation required for coal produced from any particular mining operation. Traditionally, utility (steam) coal has been subject to less extensive preparation than has



AREA MINING WITH SUCCESSIVE REPLACEMENT

Figure 5

Adapted from drawing in
STUDY OF STRIP AND
SURFACE MINING IN
APPALACHIA (1966)

metallurgical coal. This is because the coke industry has the most stringent standards of all major coal consuming industries. Detailed preparation provides a uniform product with reduced sulfur and ash content important to coke plant, blast furnace, and foundry-cupola operations. Although utility coal must have relatively uniform size, economic benefits accrued from extensive cleaning have not been sufficient to offset additional preparation costs. However, more complete cleaning of utility coal may be required with increased enforcement of sulfur dioxide emission limitations for power generating plants. Responsibility for controlling stack emissions will be placed on electric and mining companies. Generating stations will eventually be required to install scrubbers or similar equipment for sulfur removal from gases, and the mining companies will be forced to supply a cleaner, lower sulfur coal.

## Coal Preparation Plants

Three general stages or extent of coal cleaning are practiced within the coal mining industry. Coal preparation plants are individually grouped in these stages according to degree of cleaning and unit operations. Transportation of raw coal from a mine site to a preparation plant, and transportation of clean coal and refuse from the plant are unit operations common to all stages of preparation. These transport operations do not enhance coal quality or affect the cleaning processes. Thus, coal and refuse transportation procedures and environmental controls are not delineated in the analysis of each stage of preparation.

Stage I: Crushing and Sizing - Basic Cleaning. This stage of coal cleaning is basic and involves only crushing and sizing. Preparation plants grouped in this stage always perform primary crushing, and in many instances secondary crushing is also employed to effect further size control. The two major objectives in Stage 1 preparation are: 1) a reduction of raw coal to uniform market sizes; and 2) segregation of refuse material which usually appears as reject from the first screening. Since these goals are accomplished with removal of only large refuse material, Stage 1 cleaning plants achieve maximum calorific recovery (approximately 95 percent clean coal) but minimal improvement in ash and sulfur contents.

Equipment used in this cleaning process is common to all stages of preparation. A variety of comminution units are employed, including single and double roll crushers, rotary breakers, hammer mill and ring crushers, and pick breakers.

Rotary breakers (Bradford breakers) serve a dual function by breaking coal to a predetermined top size and removing refuse and trap iron. Thus, this particular comminution unit receives wide use throughout the coal industry. Screens are usually employed in conjunction with crushers to provide additional segregation or sizing of coal. Moving and stationary screens are available to accomplish desired sizing. The most common screens are punched plate and woven wire vibrating screens.

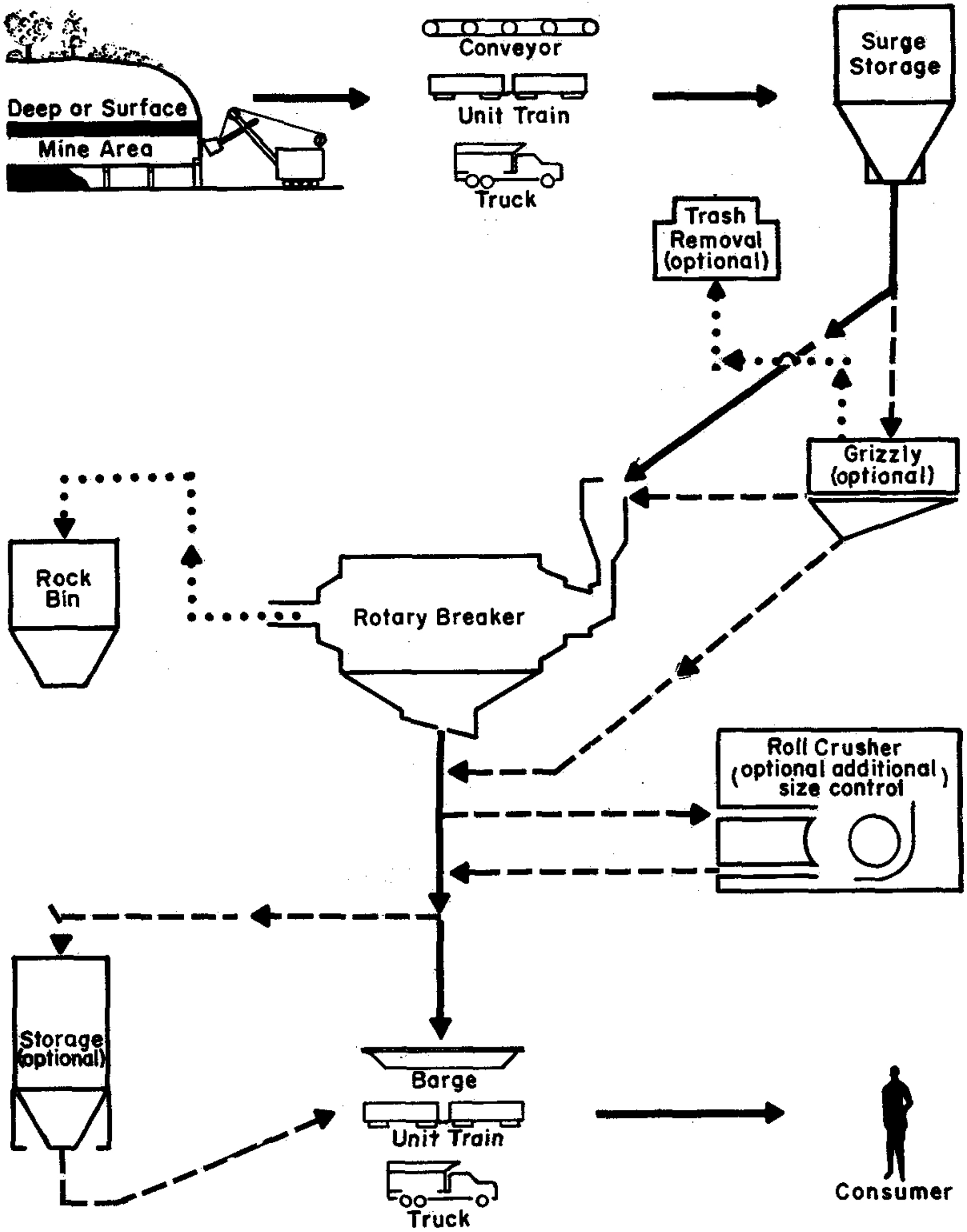
Flow paths of coal and refuse within a typical Stage 1 preparation plant are shown in Figure 6. This flow diagram illustrates the location of standard and optional equipment in an entire cleaning system.

A water circuit is not included in plant design because Stage 1 preparation is usually a dry process. Lack of plant process water limits water pollution potential to surface runoff near the plant and from refuse disposal areas.

Stage 2: Hydraulic Separation Standard Cleaning. Stage 2 coal preparation is a standard system that provides a clean coal product usually for the utility coal market. This process typically incorporates comminution and sizing to about 8 to 10 centimeters (3 to 4 inches) top size, and optional by-pass of minus 1 centimeter (3/8 inch) material. Coal cleaning is usually accomplished by jigs using a pulsating fluid flow inducing particle stratification via alternate expansion and compaction of a bed of raw coal. A density segregation is effected with dense impurities in bottom layers and clean coal in upper layers of the particle bed. A primary objective of Stage 2 preparation is removal of liberated mineral matter by cleaning at high gravity. This provides a uniform product with reduced ash and sulfur content. Coal preparation plants employing this system accrue a high calorific recovery with some inherent loss of combustible material (80 percent clean coal recovery).

Fine coal is usually not cleaned and is directly blended with coarse clean coal. However, Stage 2 preparation plants can be modified to include a fine coal circuit for cleaning minus 1 centimeter (3/8 inch) material. Cleaning of fine coal involves either wet or dry processing and provides additional quality control.

A very limited number of fine coal cleaning circuits utilize air cleaning tables. A thermal dryer may be incorporated to reduce moisture in advance of air cleaning because excessive moisture can lower the efficiency of air cleaning processes.



STAGE I - COAL PREPARATION PLANT
Figure 6

Most fine coal cleaning circuits employ shaking tables, hydrocyclones, or heavy media cyclones for cleaning fines, and extreme fines are by-passed to refuse or blended with coarse coal. Mechanical drying (centrifuge) is usually required with wet cleaning of fine coal. Thermal dryers are used for fine clean coal only when necessary.

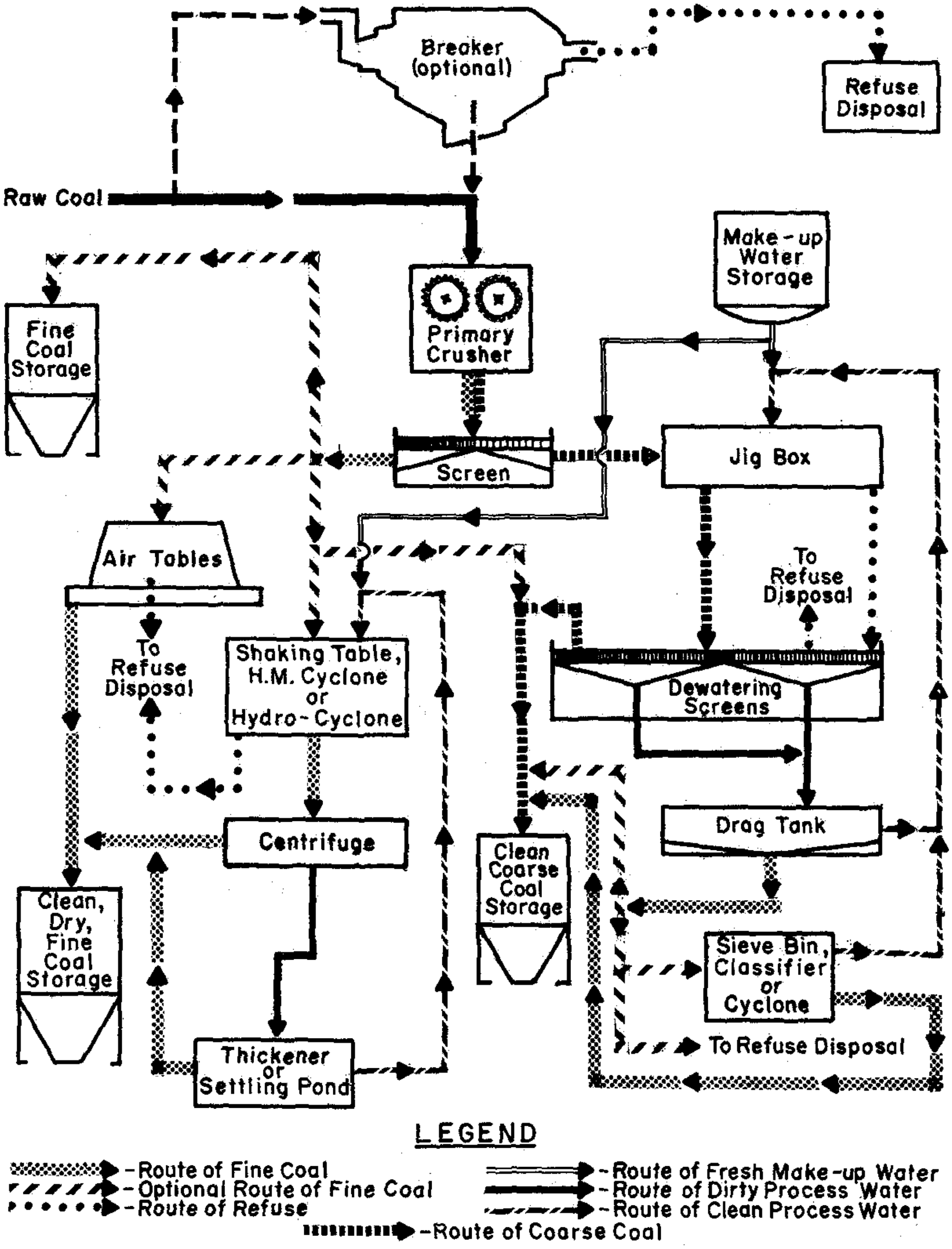
Unit operations in a Stage 2 preparation plant are: Primary crushing; sizing; gravity separation of coarse coal; dewatering of clean coal and refuse; and removal of fines from process waters. The following equipment is frequently employed to perform individual unit operations: single or double roll crushers and vibrating screens for comminution and sizing; jigs for gravity separation; vibrating screens for dewatering; and drag tanks and thickeners or settling ponds to remove coal fines.

Material transfer and equipment locations for a Stage 2 preparation plant are shown in Figure 7. Since Stage 2 coal preparation utilizes wet processing, degradation of process water will undoubtedly occur. Suspended solids are the greatest pollutant, and inclusion of a fine coal cleaning circuit intensifies this problem. Closed water circuits with either thickeners or settling ponds to remove fines will ameliorate most of the water pollution problems.

A majority of Stage 2 preparation plants surveyed during this study had closed water circuits. In addition, pH control was occcasionally used to limit acid concentration. This usually involves addition of lime to make-up water.

Stage 3: Dense Medium Separation - Complete Cleaning. Coal preparation plants grouped in Stage 3 provide complete and sophisticated coal cleaning. Most metallurgical coal is subject to this detailed preparation, resulting in a superior quality, uniform product having reduced ash and sulfur to meet prescribed specifications. Sized raw coal is cleaned in a Stage 3 preparation plant by immersing it in a fluid acting at a density intermediately between clean coal and reject. This produces a stratification of material according to specific gravity. Magnetite is the most common dense media employed for cleaning coal, although sand is still occasionally used.

These processes are predicated on a size reduction to attain the maximum liberation (freeing of particles) that can be economically justified. The resultant increase of fine particles requires additional processes to achieve maximum coal recovery (approximately 70 percent), meet moisture specification for the clean coal, and to close the water



STAGE 2-COAL PREPARATION PLANT

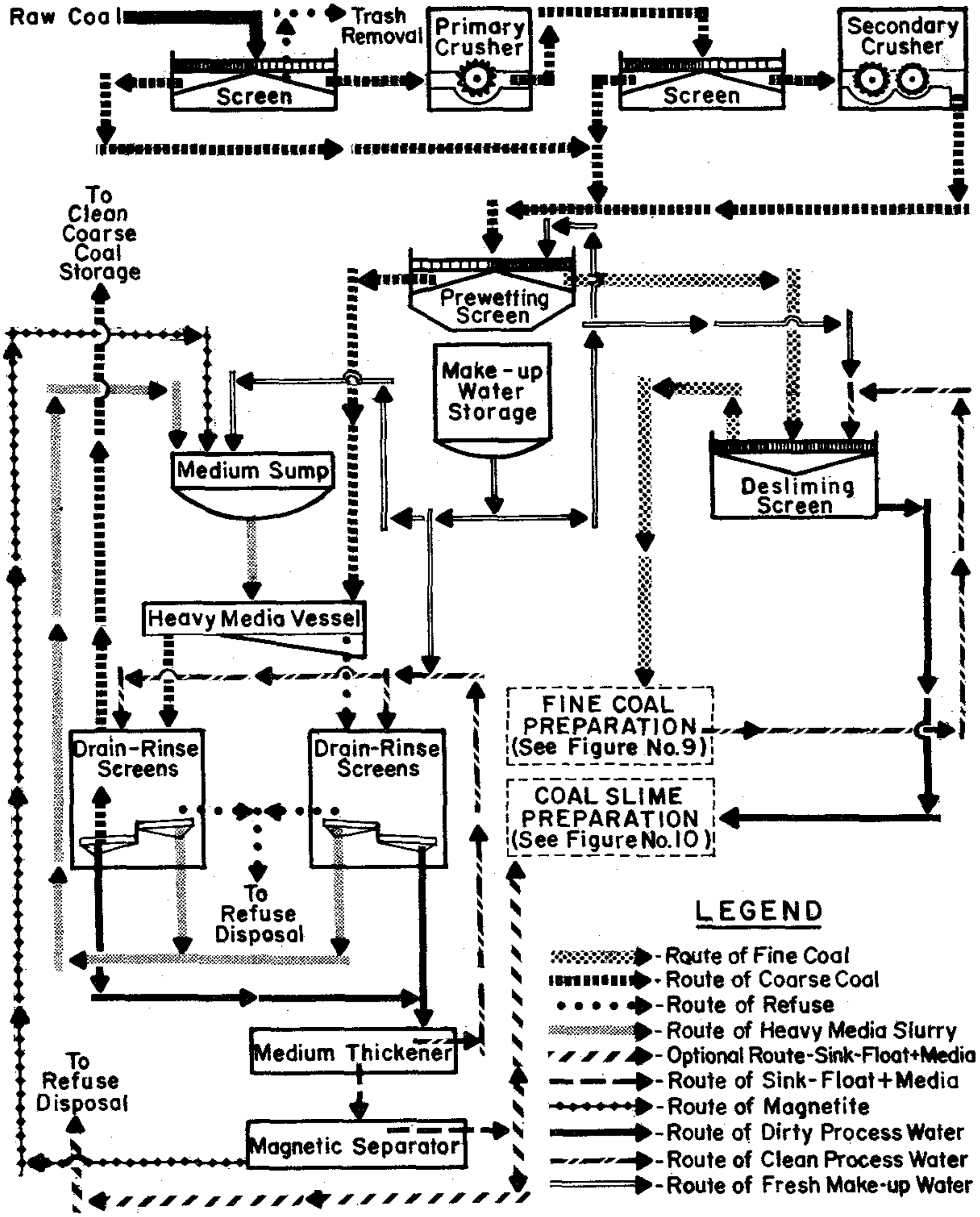
Figure 7

circuit. Major unit operations involved in the complexities of Stage 3 preparation are: comminution; sizing; gravity separation; secondary separation; dewatering; heavy media recovery; and water control.

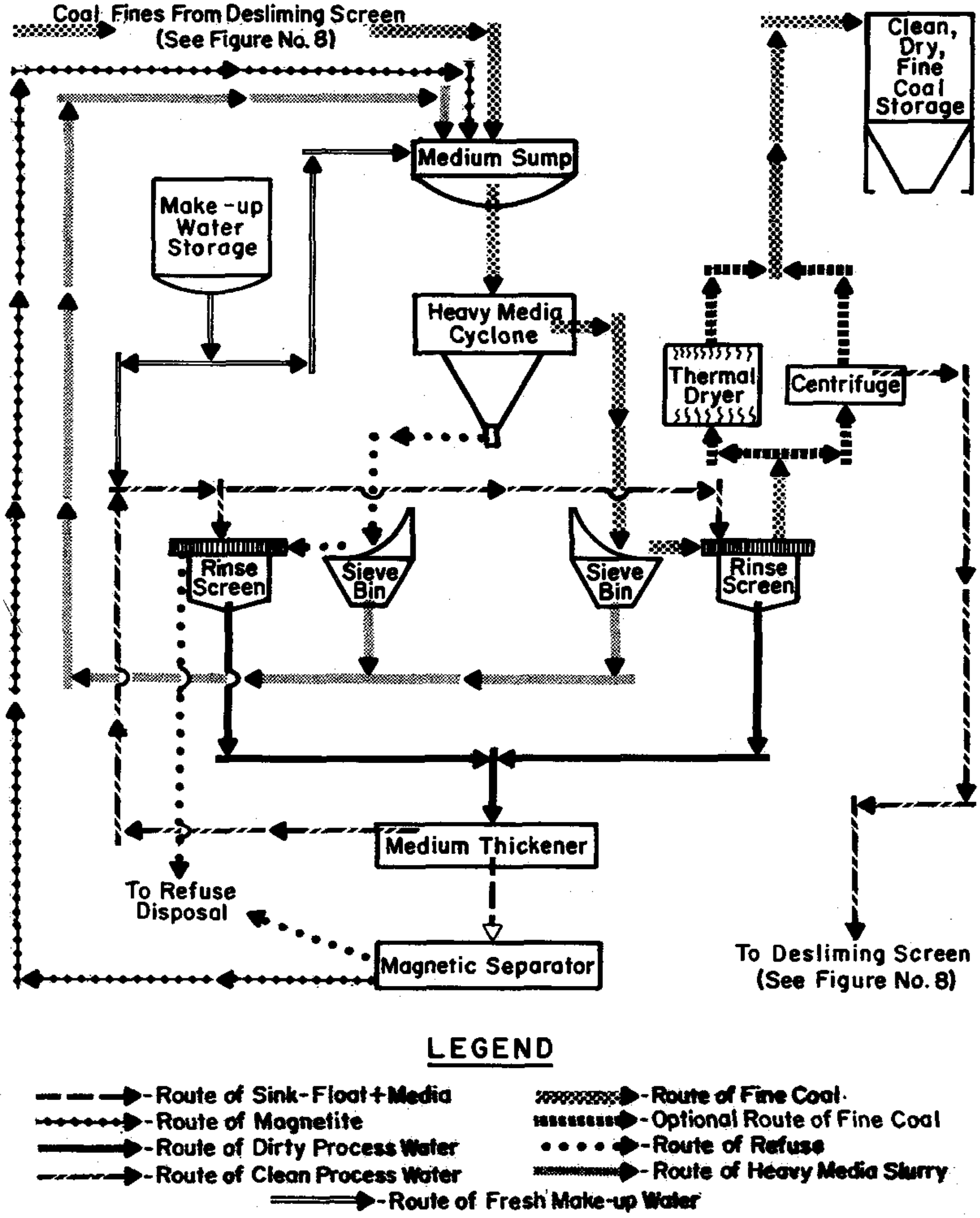
Equipment used in Stage 3 preparation plants varies according to product requirements and individual operator preferences based on raw coal characteristics. Comminution is primary crushing usually by a single roll crusher and secondary crushing using a double roll crusher. Material from the crushers is screened with topsize 3.8 to 1.9 centimeters (1 1/2 to 3/4 inches) going to coarse coal cleaning and undersize to fine coal and slimes cleaning. Coarse coal separation is generally accomplished with heavy media vessels (1.35 - 1.45 gravities), and fine coal separation by heavy media cyclones (1.32 - 1.45 gravities). Slimes cleaning usually involves hydrocyclones and froth flotation cells.

Clean coarse coal and refuse from heavy media vessels are dewatered on drain and rinse screens. Dewatering of the fine coal and refuse from heavy media cyclones includes sieve bends and centrifuges as well as drain and rinse screens. Proper dewatering of slimes usually requires filtering and thermal drying. Thermal dryers are also occasionally employed to dewater fine coal from centrifuges. Since magnetite is a common heavy media used for coal separation, recovery and reuse of media is an economic necessity. The last process in a Stage 3 cleaning plant is removal of particulate matter from process waters by thickeners (sometimes settling ponds) prior to recycling. Figures 8, 9, and 10 depict a typical Stage 3 coal preparation plant for coarse, fine, and coal slime recovery.

Most Stage 3 preparation plants have closed water circuits using thickeners to maintain acceptable loads of suspended solids in recycled water. Froth flotation commonly utilizes pH control because both product quality and recovery can be affected. Lime is often added to make-up water to maintain a pH between 6.0 and 7.5. Treatment of small quantities of make-up water is less costly than treatment of larger quantities of water not recycled.

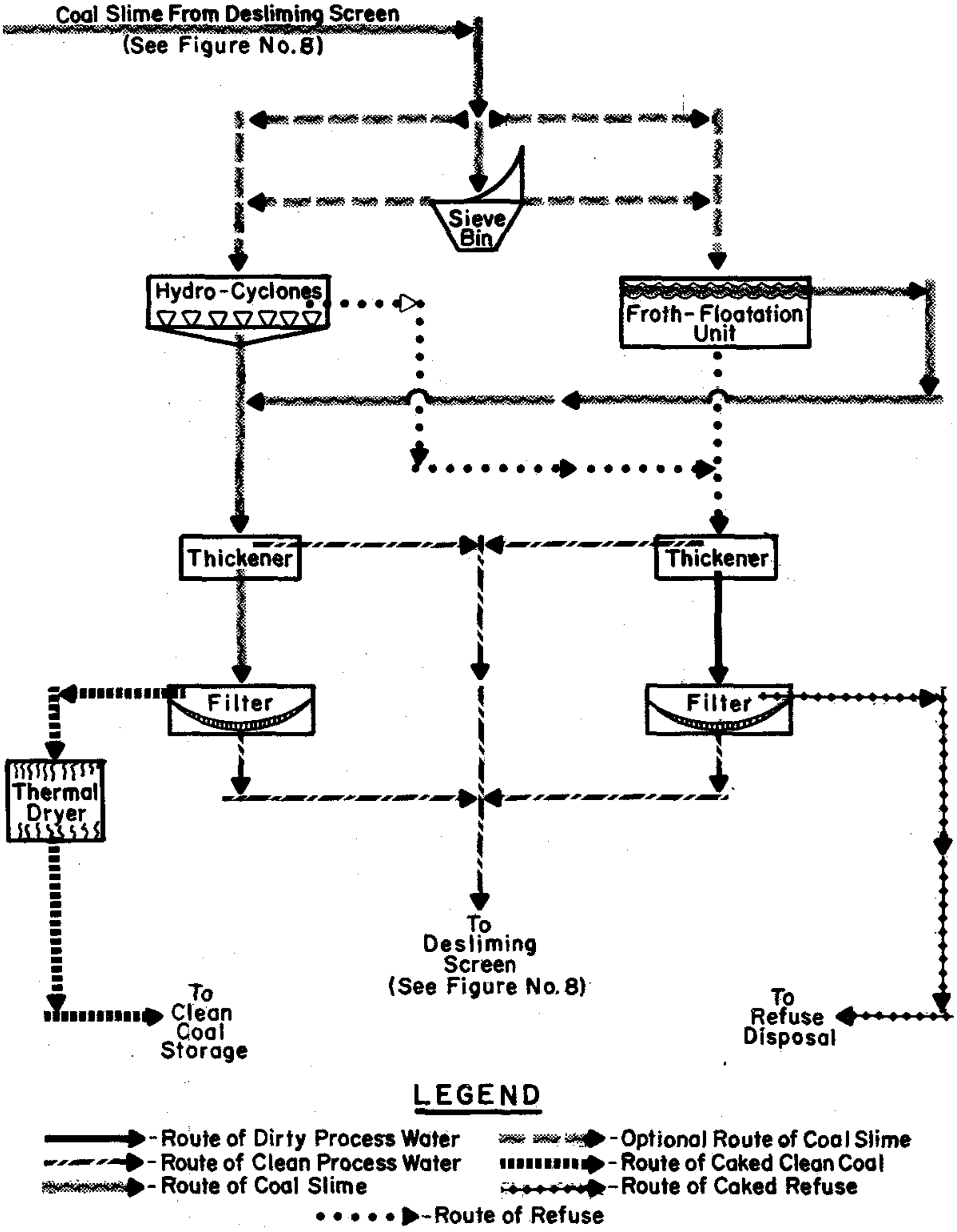


STAGE 3 - COARSE COAL PREPARATION PLANT
Figure 8



STAGE 3 - FINE COAL PREPARATION PLANT

Figure 9



STAGE 3-COAL SLIME PREPARATION PLANT

Figure 10

# SECTION IV

## INDUSTRY CATEGORIZATION

The development of effluent limitation guidelines can best be realized by categorizing the industry into groups for which separate effluent limitations and new source performance standards should be developed. This categorization should represent groups that have significantly different water pollution potentials or treatment problems.

In order to accomplish this task, initial coal industry categorization was based on four important characteristics: 1) rank of coal mined; 2) geographic location; 3) type of mine; and 4) size of mine. Categorization by rank of coal mined was based upon the following previously established Standard Industrial Classification (SIC) groups:

| | |
|---|---|
| SIC 1111 | Anthracite Mining |
| SIC 1112 | Anthracite Mining Services |
| SIC 1211 | Bituminous Coal and Lignite Mining |
| SIC 1213 | Bituminous Coal and Lignite Mining Services |

Bituminous and lignite mining was further subcategorized by geographic region, which was originally believed necessary, because of anticipated variations in raw mine drainage. These variations in mine discharges are determined by such factors as climate and chemical characteristics of the coal and overburden.

Anthracite, bituminous and lignite mining were subcategorized by mine type and size. Underground and surface mining operations were differentiated because of the obvious gross differences in mining techniques. These differences could result in significant variations in raw mine drainage. Mine size was also deemed important because economic considerations, particularly capital and operating costs of treatment facilities, could prohibit smaller operations from complying with proposed effluent limitations.

For the purpose of developing effluent limitation guidelines the term <u>coal mine</u> means an active area of land, and all property placed upon, under or above the surface of such land, used in or resulting from the work of extracting coal from its natural deposits by any means or method including secondary recovery of coal from refuse or other storage piles derived from the mining, cleaning, or preparation of coal.

A coal operation is considered as one mine if the pits are: owned by the same company, supervised by the same superintendent, and located in the same county.

The term mine drainage means any water drained, pumped or siphoned from a coal mine.

The preliminary industry categorization resulted in the following breakdown:

- I. Anthracite Mining - Pennsylvania only
    - A. Surface Mines
        - Large - greater than 136,000 KKG (150,000 tons) per year
        - 2. Small - less than 136,000 KKG (150,000 tons) per year
    - B. Underground Mines
        - 1. Large - greater than 136,000 KKG (150,000 tons) per year
        - 2. Small - less than 136,000 KKG (150,000 tons) per year
- II. Anthracite Mining Services (Preparation Plants)
- III. Bituminous Coal and Lignite Mining
    - A. Eastern and Interior Area - Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, Tennessee, Alabama, Illinois, Indiana, Iowa, Missouri, Kansas, Oklahoma, Arkansas
        - 1. Surface Mines
            - a. Large - greater than 136,000 KKG (150,000 tons) per year
            - b. Small - less than 136,000 KKG (150,000 tons) per year
        - 2. Underground Mines
            - a. Large - greater than 136,000 KKG (150,000 tons) per year
            - b. Small - less than 136,000 KKG (150,000 tons) per year
    - B. Western Area - Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado, Arizona, New Mexico, Washington, Alaska.
        - 1. Surface Mines
            - a. Large - greater than 136,000 KKG (150,000 tons) per year
            - b. Small - less than 136,000 KKG (150,000 tons) per year

2. Underground Mines
    a. Large - greater than 136,000 KKG (150,000 tons) per year
    b. Small - less than 136,000 KKG (150,000 tons) per year

IV. Bituminous and Lignite Mining Services (Preparation Plants)

One of the initial goals of this study was determination of the validity of this categorization. The primary source of data utilized for this evaluation was information obtained during the study's sampling program and mine visits. This information was supplemented with data obtained through personal interviews, literature review, and historical effluent quality data supplied by the coal industry and regulatory agencies.

Based upon an exhaustive data review, the preliminary industry categorization was substantially altered.

The data review revealed there are generally two distinct classes of raw mine drainage - Acid or Ferruginous and Alkaline - determined by regional and local geologic conditions. Raw mine drainage is defined as acid or ferruginous raw mine drainage if the untreated mine drainage has either a pH of less than 6 or a total iron of more than 10 mg/liter. Raw mine drainage is defined as alkaline raw mine drainage if the untreated raw mine drainage has a pH of more than 6 and with a total iron of less than 10 mg/liter.

It was determined that rank of coal (anthracite/bituminous/lignite), type of mine (surface/underground), and mine size did not significantly affect the categorization of mines by these two raw mine drainage classes.

Categorization by rank of coal has been maintained, since it is defined by the SIC classes that apply to the coal industry. However, mine size and type were dropped from consideration, and a revised industry categorization was developed.

This revised industry categorization consisted of the SIC classes and two large regions, determined by the predominance of Acid or Ferruginous raw mine drainage. Region I, states or areas characterized by Acid or Ferruginous raw mine drainage is comprised of Maryland, Pennsylvania, Ohio, and northern West Virginia. Isolated mines or areas in Western Kentucky and along the Illinois-

Indiana border also exhibit acid or ferruginous raw mine drainage. Region II includes all the remaining coal producing areas which exhibit predominantly Alkaline raw mine drainage.

Statistical analysis of all raw mine drainage obtained during the field program substantiated the revised categorization based on the chemical characteristics of the raw mine drainage. Based on this information, it was determined there was no need for further industry categorization of the coal mining segment of the industry other than by raw mine drainage characteristics.

Mining services were evaluated as to the process waste water from the coal cleaning process itself-coal preparation plant waste water. Drainage, or waste water, from a preparation plant's yards, coal storage areas, and refuse disposal areas was evaluated separately as, coal preparation plant ancillary area waste water.

### REVISED INDUSTRY CATEGORIZATION

I Anthracite Mining, Bituminous Coal and Lignite Mining
    A. Acid or Ferruginous Raw Mine Drainage
    B. Alkaline Raw Mine Drainage

II Anthracite Mining Services, Bituminous and Lignite Mining Services
    A. Coal Preparation Plant Waste Water
    B. Coal Preparation Plant Ancillary Area Waste Water

# SECTION V

## WASTE CHARACTERIZATION

The nature and quantity of pollutants discharged in waste water from surface and underground coal mining operations and coal preparation facilities varies significantly throughout the United States. The waste water situation evident in the mining segment of the coal industry is unlike that encountered in most other industries. Usually, most industries utilize water in the specific processes they employ. This water frequently becomes contaminated during the process and must be treated prior to discharge. In contrast, water is not utilized in the actual mining of coal in the U.S. at the present time except for dust allaying and fire protection. Waste water handling and management is required in most coal mining methods or systems to insure the continuance of the mining operation and to improve the efficiency of the mining operation. Water enters mines via precipitation, groundwater infiltration, and surface runoff where it can become polluted by contact with materials in the coal, overburden material and mine bottom. This waste water is discharged from the mine as mine drainage which may require treatment before it can enter into navigable water. The waste water from coal mining operations is unrelated, or only indirectly related, to production quantities. Therefore, raw waste loadings are expressed in terms of concentration rather than units of production.

In addition to handling and treating mine drainage during actual coal loading or coal production, coal mine operators are faced with the same burden during idle periods. Waste water handling problems are generally insignificant during initial start-up of a new underground mining operation. However, these problems continue to grow as the mine is expanded and developed and, unless control technology is employed may continue indefinitely as a pollution source after coal production has ceased. Surface mines can be somewhat more predictable in their production of waste water pollutants. Waste water handling within a surface mine can be fairly uniform throughout the life of the mine. It is highly dependent upon precipitation patterns and control technology employed, i.e.: use of diversion ditches, burial of toxic materials, and concurrent reclamation. Without the use of control measures at surface mines the problems of waste water pollution would also grow and continue indefinitely after coal production has ceased.

In light of the fact that waste water pollution does not necessarily stop with mine closure, a decision must be made as to the point at which a mine operator has fulfilled his obligations and responsibilities for waste water control and treatment at a particular mine site. This point will be discussed in detail in Section VII - Control and Treatment Technology.

The chemical characteristics of raw mine drainage is determined by local and regional geology of the coal and associated overburden. Raw mine drainage ranges from grossly polluted to drinking water quality. Depending on hydrologic conditions, water handling volumes at a mine can vary from zero to millions of cubic meters per day within a geographic area, coal field or even from adjacent mines.

Due to these widely varying waste water characteristics, it was necessary to accumulate data over the broadest possible base. Effluent quality data presented for each industry category includes minimum, maximum and average values. These were derived from historical effluent data supplied by the coal industry, various regulatory and research bodies, and from effluent samples collected and analyzed during this study.

There has been an extensive amount of historical data generated in the past 15 years on waste water quality from surface and underground coal mines and coal preparation plants. The principal pollutants that characterize mine drainage have, as a result, been known for many years. Consequently, most water quality studies have limited the spectrum of their investigations and analyses to those few key parameters.

The waste water sampling program conducted during this study had two primary purposes. First the program was designed to compensate for the wide diversity of geologic, hydrologic and mining conditions in the major producing coal fields by obtaining representative waste water data for every coal-producing state. Second, the scope of the waste water analyses was expanded to include not only the previously established group of important paramenters, but all elements which could be present in mine drainage. The resultant list of potential mine drainage pollutants for which analyses were performed is included in Table 6, Section VI.

Waste water analysis data obtained during the study as well as the historical data, indicated the following constituents commonly increased in concentrations over background water quality levels: acidity, total iron, dissolved iron, manganese, aluminum, nickel, zinc, total suspended solids, total dissolved solids, sulfates, ammonia, fluoride and strontium.

Data evaluation also revealed that there were only minor differences in the chemical characteristics of raw mine drainage from surface and underground mines in similar geologic settings.

Major differences were observed between the two classes of raw mine drainage which are generally representative of geographic areas. These differences reflect the nature of the coal and overburden material and are unrelated to mine type or size. To illustrate these differences, the raw mine drainage data utilized in this study for waste characterization is presented in Tables 1, 2, 3 and 4. This data represents all untreated mine drainage samples collected and analyzed during the initial study conducted in the summer and fall of 1974.

Evaluation of all waste water sample data from mines revealed that there were four basic types of effluent based on water analysis: 1) acid mine drainage - untreated mine drainage characterized as acid with high iron concentrations, definitely requiring neutralization and sedimentation treatment; 2) discharge effluent - untreated mine drainage of generally acceptable quality, i.e., not requiring neutralization or sedimentation; 3) sediment-bearing effluent -mine drainage which has passed through settling ponds or basins without a neutralization treatment; and 4) treated mine drainage - mine drainage which has been neutralized and passed through a sedimentation process.

Means and standard deviations were computed and assessed for treated, discharge, and sediment-bearing samples. In order to evaluate the need for regional variations in effluent limitations, additional statistical analyses were performed.

The analysis data for treated mine drainage indicated that, for the most part, waste water treatment techniques currently employed by the coal mining industry are capable of reducing the concentrations of constituents of raw mine drainage which are considered harmful to aquatic organisms or are objectionable as to taste, odor, or color to acceptable levels.

The data also indicated that discharge effluent and sediment-bearing effluent quality was commonly superior to the quality of treated mine drainage from the most efficient treatment plants, regardless of region. Based on this information, it was determined that there was no need for further waste categorization of the coal mining segment other than by raw mine drainage characteristics, which are in turn related to the type of treatment that is required.

The raw waste characteristics of coal preparation plant process water are highly dependent upon the particular process or recovery technique utilized in the operation. Since process techniques generally require an alkaline media for efficient and economic operation, process water does not dissolve significant quantities of the constituents present in raw coal. The principal pollutant present in coal preparation plant process water is suspended solids. In plants utilizing froth flotation (Stage 3 Preparation Plants) for recovery of coal fines (-28 mesh), process water typically contains less total suspended solids than plants which do not recover coal fines. Analyses of raw water slurry (untreated process water from the wet cleaning of coal) from several typical preparation facilities that do not employ froth flotation are summarized in Table 5.

It is important to note that of the more than 180 coal preparation facilities utilizing wet cleaning processes investigated during this study (either through site visits or industry supplied data), over 60% in varying terrain and geographic locations had or reported closed water circuits. Of the plants visited which did not use closed water circuits virtually all employed some form of treatment for solids removal prior to discharge.

The waste characteristics of waste water from coal storage, refuse storage and coal preparation plant ancillary areas is characterized as being generally similar to the raw mine drainage at the mine served by the preparation plant. Geologic and geographic setting of the mine and the nature of the coal mined affect the characteristics of these waste waters.

For the most part water usage and discharges from coal preparation facilities are similar to other industrial processes, i.e., water is used in the process, and upon plant shut-down water usage (and resultant discharge) is eliminated.

Drainage from a preparation plant's refuse disposal area is similar to a surface mine in that this waste water from a refuse disposal area can continue to pollute after the preparation plant is shut down or closed. Like a surface mine, waste water handling volumes for a preparation plant's refuse disposal area is highly dependent on precipitation patterns. Control technology employed to control pollution after shut down are similar to those employed at a surface mine to control pollution after the mine is closed.

Based on these considerations and the industry categorization the following waste characterization was established:

Waste Characterization

I Anthracite Mining, Bituminous Coal and Lignite Mining
    A. Acid or Ferruginous Raw Mine Drainage
        1. Treated Mine Drainage
    B. Alkaline Raw Mine Drainage
        1. Discharge Effluent
        2. Sediment-bearing Effluent

II Anthracite Mining Services, Bituminous Coal and Lignite Mining Services
    A. Coal Preparation Plant Waste Water
    B. Coal Storage, Refuse Storage, and Coal Preparation Plant Ancillary Waste Water

## TABLE 1

## RAW MINE DRAINAGE CHARACTERISTICS - UNDERGROUND MINES ALKALINE

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| Parameters | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) | Std. Dev. |
|---|---|---|---|---|
| pH | 6.6 | 8.5 | 7.9 | - |
| Alkalinity | 22 | 1,840 | 469 | 451 |
| Total Iron | 0.03 | 9.10 | 1.54 | 2.52 |
| Dissolved Iron | 0.01 | 0.95 | 0.25 | 0.33 |
| Manganese | 0.01 | 0.41 | 0.08 | 0.11 |
| Aluminum | 0.01 | 0.60 | 0.13 | 0.12 |
| Zinc | 0.01 | 0.30 | 0.06 | 0.07 |
| Nickel | 0.01 | 0.02 | 0.01 | 0.002 |
| TDS | 418 | 22,658 | 2,702 | 5,034 |
| TSS | 1 | 76 | 26 | 23 |
| Hardness | 52 | 1,520 | 455 | 445 |
| Sulfate | 10 | 1,370 | 495 | 426 |
| Ammonia | 0.02 | 4.00 | 0.94 | 1.17 |

## TABLE 2

## RAW MINE DRAINAGE CHARACTERISTICS - UNDERGROUND MINES ACID OR FERRUGINOUS

| Parameters | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) | Std. Dev. |
|---|---|---|---|---|
| pH | 2.4 | 8.2 | 4.0 | - |
| Alkalinity | 0 | 720 | 59 | 145 |
| Total Iron | 0.24 | 9,300 | 352 | 1,080 |
| Dissolved Iron | 0.05 | 5,000 | 268 | 613 |
| Manganese | 0.04 | 92 | 7.3 | 11.35 |
| Aluminum | 0.10 | 533 | 43.4 | 75 |
| Zinc | 0.02 | 12.7 | 1.47 | 2.22 |
| Nickel | 0.01 | 5.59 | 0.72 | 0.92 |
| TDS | 12 | 15,572 | 4,749 | 3,245 |
| TSS | 1 | 1,740 | 228 | 323 |
| Hardness | 142 | 5,000 | 1,218 | 686 |
| Sulfate | 300 | 9,711 | 2,370 | 1,643 |
| Ammonia | 00 | 57 | 12.03 | 13.58 |

## TABLE 3

## RAW MINE DRAINAGE CHARACTERISTICS - SURFACE MINES ALKALINE

| Parameter | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) | Std. Dev. |
|---|---|---|---|---|
| pH | 6.2 | 8.2 | 7.7 | |
| Alkalinity | 30 | 860 | 313 | 183 |
| Total Iron | 0.02 | 6.70 | 0.78 | 1.87 |
| Dissolved Iron | 0.01 | 2.7 | 0.15 | 0.52 |
| Manganese | 0.01 | 6.8 | 0.61 | 1.40 |
| Aluminum | 0.10 | 0.85 | 0.20 | 0.22 |
| Zinc | 0.01 | 0.59 | 0.14 | 0.16 |
| Nickel | 0.01 | 0.18 | 0.02 | 0.04 |
| TDS | 152 | 8,358 | 2,867 | 2,057 |
| TSS | 1 | 684 | 96 | 215 |
| Hardness | 76 | 2,900 | 1,290 | 857 |
| Sulfate | 42 | 3,700 | 1,297 | 1,136 |
| Ammonia | 0.04 | 36 | 4.19 | 6.88 |

## TABLE 4

## RAW MINE DRAINAGE CHARACTERISTICE - SURFACE MINES ACID OR FERRUGINOUS

| Parameter | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) | Std. Dev. |
|---|---|---|---|---|
| pH | 2.6 | 7.7 | 3.6 | |
| Alkalinity | 0 | 184 | 5 | 32 |
| Total Iron | 0.08 | 440 | 52.01 | 101 |
| Dissolved Iron | 0.01 | 440 | 50.1 | 102.4 |
| Manganese | 0.29 | 127 | 45.11 | 42.28 |
| Aluminum | 0.10 | 271 | 71.2 | 79.34 |
| Zinc | 0.06 | 7.7 | 1.71 | 1.71 |
| Nickel | 0.01 | 5 | 0.71 | 1.05 |
| TDS | 120 | 8,870 | 4,060 | 3,060 |
| TSS | 4 | 15,878 | 549 | 2,713 |
| Hardness | 24 | 5,400 | 1,944 | 1,380 |
| Sulfate | 22 | 3,860 | 1,842 | 1,290 |
| Ammonia | 0.53 | 22 | 6.48 | 4.70 |

## TABLE 5

## RAW WASTE CHARACTERISTICS - COAL PREPARATION PLANT PROCESS WATER

| Parameters | Minimum (mg/l) | Maximum (mg/l) | Mean (mg/l) | Std. Dev. |
|---|---|---|---|---|
| ph | 7.3 | 8.1 | 7.7 | |
| Alkalinity | 62 | 402 | 160 | 96.07 |
| Total Iron | 0.03 | 187 | 47.8 | 59.39 |
| Dissolved Iron | 0 | 6.4 | 0.92 | 2.09 |
| Manganese | 0.3 | 4.21 | 1.67 | 1.14 |
| Aluminum | 0.1 | 29 | 10.62 | 11.17 |
| Zinc | 0.01 | 2.6 | 0.56 | 0.89 |
| Nickel | 0.01 | 0.54 | 0.15 | 0.19 |
| TDS | 636 | 2,240 | 1,433 | 543.9 |
| TSS | 2,698 | 156,400 | 62,448 | 8,372 |
| Hardness | 1,280 | 1,800 | 1,540 | 260 |
| Sulfates | 979 | 1,029 | 1,004 | 25 |
| Ammonia | 0 | 4 | 2.01 | 1.53 |

# SECTION VI

# SELECTION OF POLLUTANT PARAMETERS

## CONSTITUENTS EVALUATED

As previously mentioned in Section V, the water quality investigation preceding development of effluent guideline recommendations covered a wide range of potential pollutants. The study was initiated with a compilation of chemical constituents which could be found in coal or its overburden material. A complete list of analyses performed on each water sample collected is presented in Table 6. The analytical procedures used are in accordance with the procedures published in the Federal Register, Vol. 38, number 199, October 16, 1973.

## GUIDELINE PARAMETER SELECTION CRITERIA

Selection of parameters for the purpose of developing effluent limitation guidelines was based primarily on the following criteria:

a. Constituents which are frequently present in mine drainage in concentrations deleterious to aquatic organisms.

b. Technology exists for the reduction or removal of the pollutants in question.

c. Research data indicating that excessive concentrations of specific constituents are capable of disrupting an aquatic ecosystem.

## MAJOR PARAMETERS - RATIONALE FOR SELECTION OR REJECTION

Evaluation of all available effluent analysis data indicated that the concentrations of certain mine drainage constituents were consistently greater than the concentrations considered deleterious to aquatic organisms or the concentration capable of disrupting an aquatic ecosystem.

The following were identified as the major pollutant constituents in coal mine drainage.

Acidity
Total Iron

Aluminum
Nickel

## TABLE 6

## POTENTIAL CONSTITUTENTS OF COAL INDUSTRY WASTEWATER

### Major Constituents - Total

Acidity
Alkalinity
Aluminum
Boron
Calcium
Chlorides
Dissolved Solids
Fluorides
Hardness
Iron
Magnesium
Manganese
Nickel
Potassium
Silicon
Sodium
Strontium
Sulfates
Suspended Solids
Zinc

### Minor Constituents - Total

Arsenic
Barium
Cadmium
Chromium
Copper
Cyanide
Lead
Mercury
Molybedenum
Selenium

### Major Constituents - Dissolved

Aluminum
Boron
Calcium
Iron
Magnesium
Manganese
Nickel
Silicon
Strontium
Zinc

### Minor Constituents - Dissolved

Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Mercury
Molybdenum
Selenium

### Additional Analyses

Acidity, net
Acidity, pH8
Ammonia
Color
Ferrous Iron
Oils*
pH
Specific Conductance
Turbidity

* Preparation Plants Only

Dissolved Iron
Manganese
Sulfates
Ammonia
Strontium
Zinc
Total Suspended Solids
Total Dissolved Solids
Fluorides

The major pollutant constituents identified in effluent drainage from coal preparation plants are:

Acidity
Total Iron
Dissolved Iron
Ammonia
Total Suspended Solids
Total Dissolved Solids
Fluorides
Sulfates

The parameters selected for establishing effluent limitation guidelines and standards of performance for the coal industry are presented, with the rationale for their selection, in the following discussion.

## pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Due to the significant impact of low pH's and high acidities on receiving streams and the fact that these parameters can be easily controlled, effluent limitations have been proposed for this parameter.

Total and Dissolved Iron

Iron is one of the major pollutants of coal mine drainage, and is frequently found in coal preparation plant drainage in objectionable concentrations. Precipitated iron, in the form of ferric hydroxide or ferric sulfate, blankets stream bottoms, destroying aquatic life and aesthetically degrading those streams. Both dissolved and suspended iron can precipitate on the gills of fish and can eventually accumulate to lethal concentrations. Industrial and municipal water supplies are affected by objectionable taste, staining, and encrustation resulting from iron deposition.

Natural waters may be polluted by iron-bearing industrial wastes such as those from pickling operations and by the leaching of soluble iron salts from soil and rocks, e.g. acid-mine drainage and iron-bearing ground water.

Although many of the ferric and ferrous salts such as the chlorides are highly soluble in water, the ferrous ions are readily oxidized in natural surface waters to the ferric condition and form insoluble hydroxides. These precipitates tend to agglomerate, flocculate, and settle or be absorbed on surfaces; hence, the concentration of iron in well aerated waters is seldom high. In ground water, the pH may be such that high concentrations of iron remain in solution.

Iron in trace amounts is essential for nutrition. Indeed, larger quantities of iron are taken for therapeutic purposes. The daily nutritional requirement is 1 to 2 mg, and most diets contain 7 to 35 mg per day, with an average of 16.

Instead of physiological reasons, therefore, the limit is based on esthetic and taste considerations. Iron and manganese tend to pecipitate as hydroxides and stain laundry and porcelain fixtures. It has also been reported that ferric iron combines with the tannin in tea to produce a dark violet color.

The taste threshold of iron in water has been given as 0.1 and 0.2 mg/l of iron from ferrous sulfate and ferrous chloride respectively. It has also been reported that ferrous iron imparts a taste at 0.1 mg/l and ferric iron at 0.2 mg/l.

Iron is an essential constituent of animal diets, but animals are sensitive to changes in iron conentration. Cows will not drink enough water if it is high in iron, and consequently, milk production is affected.

Most of the references dealing with this beneficial use are expressed in terms of specific iron salts. When iron is added to water in the form of chlorides, sulfates, or nitrates, the salt dissociates but the resulting ferrous or ferric ions combine with hydroxyl ions to form precipitates. Hence, very little of the iron remains in solution; but if the dosage is sufficient and the water is not strongly buffered, the addition of a soluble iron salt may lower the pH of the water to a toxic level. Furthermore, the deposition of iron hydroxides on the gills of fish may cause an irritation and blocking of the respiratory channels. Finally, heavy precipitates of ferric hydroxide may smother fish eggs. When testing the effects of wastes from nail-making plants on trout, stickleback, and perch with wastes containing concentrations of chloride, hydrogen, ferric and ferrous ions, concentrations of 1000 mg/l of these mixed salts killed most fish within a few hours, hardy stickleback were not killed until five hours exposure to 2500 mg/l. Much of the killing action was attributed to coatings of iron oxide or hydroxide precipitates on the gills. The toxicity of rion and iron salts depends on whether the iron is present in the ferrous or ferric state and whether it is in solution or suspension.

Crenothrix, Gallionella, and other iron bacteria utilize iron as a source of energy and store it in their microbial protoplasm. They may accumulate in wells, treatment plants, pipelines, and other water works structures; or they may pass into the distribution system and cause customer complaints. Trouble with this organism is experienced frequently when the iron exceeds 0.2 mg/l.

Total and dissolved iron parameters can be relatively easily controlled, since the same neutralization processes that control acidity and pH cause iron to precipitate from solution. As a result of these several factors, guidelines have been developed for the limitation of total and dissolved iron concentrations.

## Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

As a result of these serious effects on receiving streams, effluent limitations have been proposed for total suspended solids in this report.

## Manganese

The presence of manganese may interfere with water usage, since manganese stains materials, especially when the pH is raised as in laundering, scouring, or other washing operations. These stains, if not masked by iron, may be dirty brown, gray or black in color and usually occur in spots and streaks. Waters containing manganous bicarbonate cannot be used in the textile industries, in dyeing, tanning, laundering, or in hosts of other industrial uses. In the pulp and paper industry, waters containing above 0.05 mg/l manganese cannot be tolerated except for low-grade products. Very small amounts of manganese--0.2 to 0.3 mg/l may form heavy encrustations in piping, while even smaller amounts may form noticeable black deposits.

## Nickel

Elemental nickel seldom occurs in nature, but nickel compounds are found in many ores and minerals. As a pure metal it is not a problem in water pollution because it is not affected by, or soluble in, water. Many nickel salts, however, are highly soluble in water.

Nickel is extremely toxic to citrus plants. It is found in many soils in California, generally in insoluble form, but excessive acidification of such soil may render it soluble, causing severe injury to or the death of plants. Many experiments with plants in solution cultures have shown that nickel at 0.5 to 1.0 mg/l is inhibitory to growth.

Nickel salts can kill fish at very low concentrations. Data for the fathead minnow show death occurring in the range of 5-43 mg/l, depending on the alkalinity of the water.

Nickel is present in coastal and open ocean concentrations in the range of 0.1 - 6.0 ug/l, although the most common values are 2 - 3 ug/l. Marine animals contain up to 400 ug/l, and marine plants contain up to 3,000 ug/l. The lethal limit of nickel to some marine fish has been reported as low as 0.8 ppm. Concentrations of 13.1 mg/l have been reported to cause a 50 percent reduction of the photosynthetic activity in the giant kelp (Macrocystis pyrifera) in 96 hours, and a low concentration was found to kill oyster eggs.

## Zinc

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively for galvanizing, in alloys, for electrical purposes, in printing plates, for dye-manufacture and for dyeing processes, and for many other industrial purposes. Zinc salts are used in paint pigments, cosmetics, pharmaceuticals, dyes, insecticides, and other products too numerous to list herein. Many of these salts (e.g., zinc chloride and zinc sulfate) are highly soluble in water; hence it is to be expected that zinc might occur in many industrial wastes. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and consequently it is to be expected that some zinc will precipitate and be removed readily in most natural waters.

In zinc-mining areas, zinc has been found in waters in concentrations as high as 50 mg/l and in effluents from metal-plating works and small-arms ammunition plants it may occur in significant concentrations. In most surface and ground waters, it is present only in trace amounts. There is some evidence that zinc ions are adsorbed strongly and permanently on silt, resulting in inactivation of the zinc.

Concentrations of zinc in excess of 5 mg/l in raw water used for drinking water supplies cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals at high concentrations.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitivity of fish to zinc varies with species, age and condition, as well as with the physical and chemical characteristics of the water. Some acclimatization to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated to zinc-free water (after 4-6 hours of exposure to zinc) may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, but the presence of calcium or hardness may decrease the relative toxicity.

Observed values for the distribution of zinc in ocean waters vary widely. The major concern with zinc compounds in marine waters is not one of acute toxicity, but rather of the long-term sub-lethal effects of the metallic compounds and complexes. From an acute toxicity point of view, invertebrate marine animals seem to be the most sensitive organisms tested. The growth of the sea urchin, for example, has been retarded by as little as 30 ug/l of zinc.

Zinc sulfate has also been found to be lethal to many plants, and it could impair agricultural uses.

Effluent limitations have been proposed for aluminum, manganese, nickel and zine because of their presence in raw mine drainage in quantitites sufficient to seriously degrade receiving waters. Significant reductions of these constituents have been demonstrated in exemplary coal mine drainage treatment plants, where they are achieved in conjunction with simple acid neutralization.

Several additional parameters were identified in acid mine drainage and coal preparation plant waste waters in concentrations in excess of existing water quality standards, but were not recommended for effluent limitation guidelines. These parameters and the rationale for their rejection in guideline establishment, are discussed below:

## Total Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleaness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Although the level of total dissolved solids attributable to the coal mining industry sometimes exceeds accepted drinking water standards, it generally does not approach levels toxic to plants or animals. In view of this, and the fact that technology for economic dissolved solids reduction does not exist, effluent limitations have not been proposed for this parameter.

## Sulfates

Due to overburden characteristics, drainages associated with coal-producing and coal-processing facilities frequently contain significant amounts of sulfates. While excessively high concentrations of sulfates can affect the palatability of drinking water, the effects on aquatic organisms are minimal. Sulfates generally undergo little or no reduction in normal neutralization facilities. For these reasons, effluent limitations have not been proposed for this parameter.

## Fluorides

As the most reactive non-metal, fluorine is never found free in nature but as a constituent of fluorite or fluorspar, calcium fluoride, in sedimentary rocks and also of cryolite, sodium aluminum fluoride, in igneous rocks. Owing to their origin only in certain types of rocks and only in a few regions, fluorides in high concentrations are not a common constituent of natural surface waters, but they may occur in detrimental concentrations in ground waters.

Fluorides are used as insecticides, for disinfecting brewery apparatus, as a flux in the manufacture of steel, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, for water treatment, and for other uses.

Fluorides in sufficient quantity are toxic to humans, with doses of 250 to 450 mg giving severe symptoms or causing death.

There are numerous articles describing the effects of fluoride-bearing waters on dental enamel of children; these studies lead to the generalization that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled enamel in children, and for adults, concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. Abundant literature is also available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay, especially among children.

Chronic fluoride poisoning of livestock has been observed in areas where water contained 10 to 15 mg/l fluoride. Concentrations of 30 - 50 mg/l of fluoride in the total ration of dairy cows is considered the upper safe limit. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree and it is transferred to a very small extent into the milk and to a somewhat greater degree into eggs. Data for fresh water indicate that fluorides are toxic to fish at concentrations higher than 1.5 mg/l.

Samples collected during this study indicate treatment plant effluents routinely contain concentrations of 1 to 2 mg/l of fluorides. Since economic technology does not exist for further removal at these relatively low levels, effluent limitations have not been proposed for flourides.

## Strontium

Strontium is commonly found in drainage from coal mining operations in concentrations slightly above those recommended by existing water quality standards. Little published data is available on toxic effects of strontium and it is not known to interfere with municipal or industrial water treatment processes. In addition, technology has not been developed for economic removal of strontium at relatively low concentrations. In light of its apparently minimal impact on receiving stream quality and the fact that it cannot be removed economically at low concentrations, effluent limitations have not been proposed for this constituent.

## Ammonia

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its un-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate ($NO_3$) by nitrifying bacteria. Nitrite ($NO_2$), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen ($NO_3$-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions ($NH_4^+$) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Effluent limitations have not been proposed for ammonia since the levels observed in coal mine drainage generally do not warrant further concern. However, this parameter should be considered as a routine analysis in future sampling programs because of its sporadic presence in mine drainage. If high concentrations of ammonia are consistently identified in future sampling programs its impact on receiving waters may have to be re-evaluated.

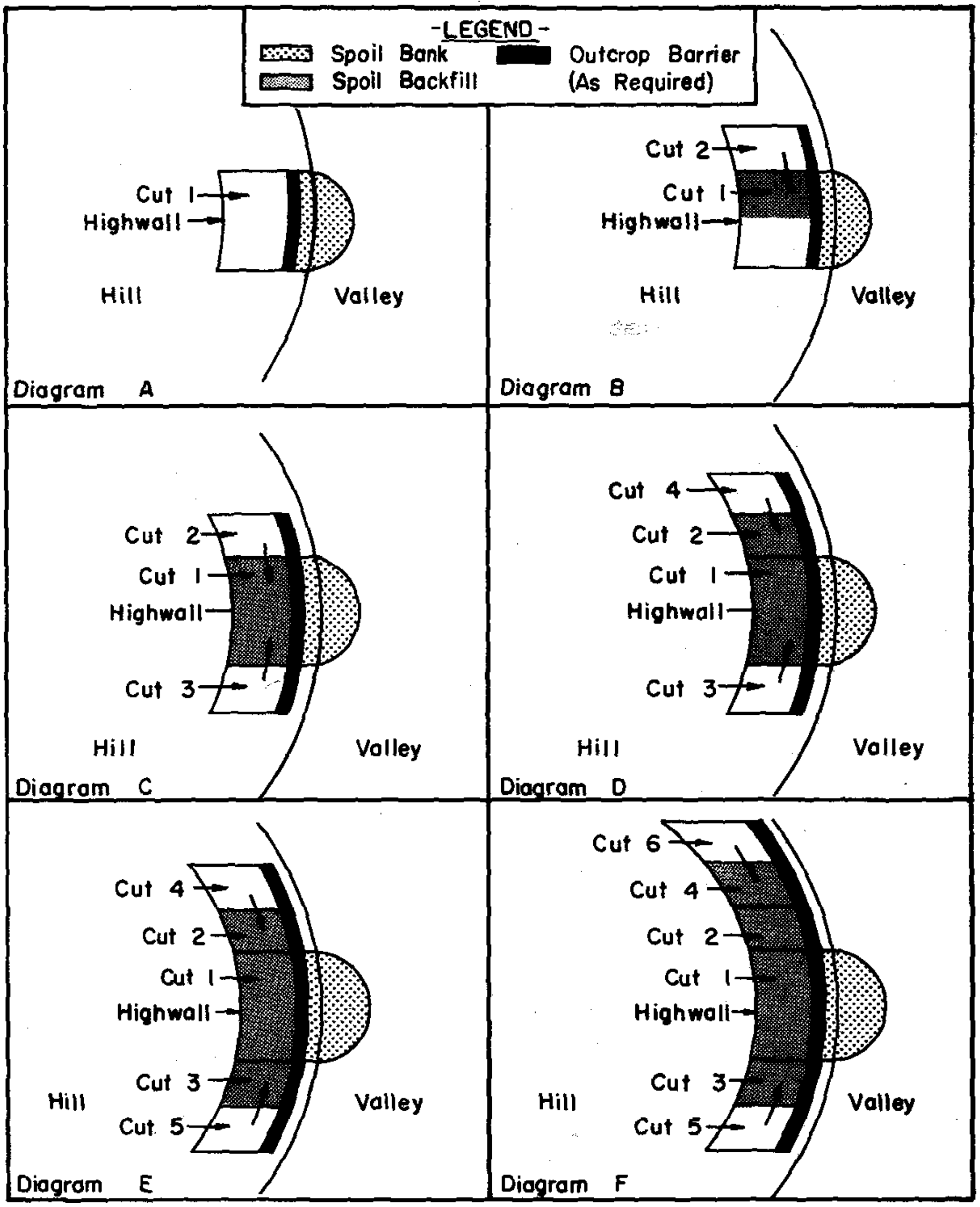
spoil off the bench onto downslope areas. This downslope spoil material can slump or rapidly erode, and must be moved upslope to the mine site if contour regrading is required. The land area affected by contour strip mining is, therefore, substantially larger than the area from which coal is actually extracted. In block cut mining only material from the first cut is deposited in adjacent low areas. Remaining spoil is then placed in mined portions of the bench. As a result, spoil handling is restricted to the actual pit area in all but the first cut, significantly reducing the area disturbed.

An initial cut is made from a crop line into the hillside to the maximum highwall depth desired, and spoil is cast in a suitable low area (see Figure 12). After removal of the coal, spoil material from the succeeding cut is backfilled into the previous cut, proceeding in one or both directions from the initial cut. This simultaneously exposes the coal for recovery and provides the first step in mine reclamation. Provision can be made in this mining technique for burial of toxic materials. On completion of coal loading, most spoil material has already been replaced in the pit, and the entire mine can be regraded with minimal earth handling.

Regrading. Surface mining usually requires removal of large amounts of overburden to expose coal. Regrading involves mass movement of material following coal extraction to achieve a more desirable land configuration. Reasons for regrading strip mined land are:

1) control water pollution
2) return usefulness to land
3) provide a suitable base for revegetation
4) bury pollution-forming materials
5) reduce erosion and subsequent sedimentation
6) eliminate landsliding
7) encourage natural drainage
8) eliminate ponding
9) eliminate hazards such as high cliffs and deep pits
10) aesthetic improvement of land surface

Contour regrading is the current reclamation technique for many of the Nation's active contour and area surface mines. This technique involves regrading a mine to approximate original land contour. It is generally one of the most favored and aesthetically pleasing regrading techniques because the land is returned to approximately its pre-mining



BLOCK CUT

Figure 12

Adapted from drawing in "A New Method of Surface Coal Mining in Steep Terrain"

# SECTION VII

# CONTROL AND TREATMENT TECHNOLOGY

## CONTROL TECHNOLOGY

Control technology, as discussed in this report, includes techniques employed before, during and after the actual coal mining, or coal loading, operation to reduce or eliminate adverse environmental effects resulting from the discharge of mine waste water. Effective pollution control preplanning can reduce pollution formation at active mine sites and minimize post-mining pollution potential.

Control technology, as discussed in this report, has been categorized as to control technology as related to surface mining, underground mining, and coal preparation.

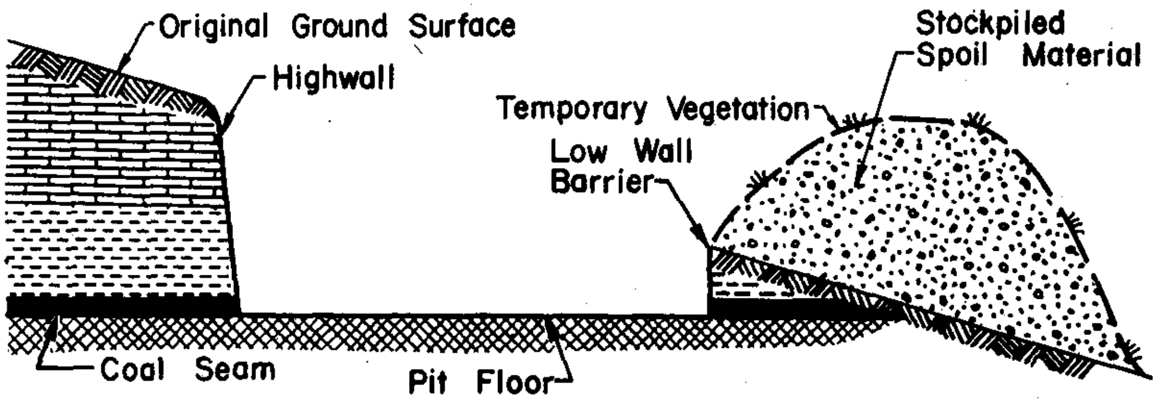
### Surface Mining

Surface mine pollution control technology is divided into two major categories - mining technology (specific mining techniques) and at-source reclamation technology. Surface mining techniques can effectively reduce amounts of pollutants exiting a mine either by containing them within the mine or by reducing their formation. These techniques can be combined with careful reclamation planning and implementation to provide maximum at-source pollution control.

Mining Techniques. Several techniques have been implemented by industry to reduce environmental degradation during actual stripping operations. Utilization of the box-cut technique in moderate and shallow slope contour mining has increased in recent years.

A box-cut is simply a contour strip mine in which a low wall barrier is maintained (see Figure 11). This mining technique significantly reduces the amount of waste water discharged from a pit area, since that waste water can no longer seep from the pit through spoil banks. However, as in any downslope disposal technique, the problem of preventing slide conditions, spoil erosion, and resultant stream sedimentation is still present.

Block cut mining was developed to keep spoil materials off the down slope and to facilitate contour regrading, minimize overburden handling, and contain spoil within mined areas. Contour stripping is typically accomplished by throwing



CROSS SECTION OF BOX CUT

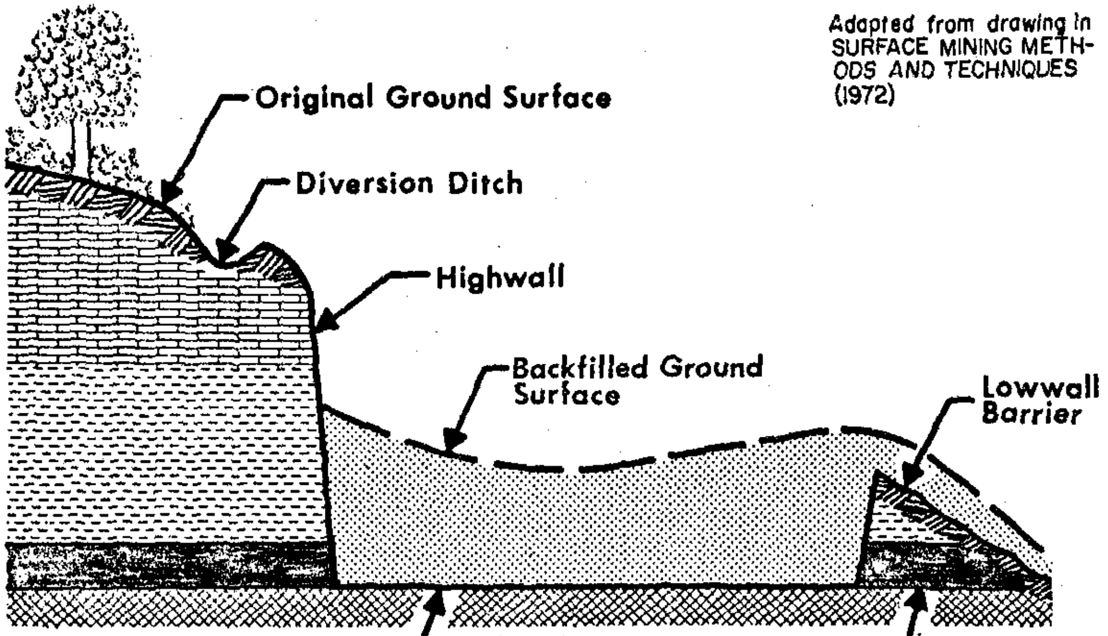
Figure 11

state. This technique is also favored because nearly all spoil is placed back in the pit, eliminating steep downslope spoil banks and reducing the size of erodable reclaimed area. Contour regrading facilitates deep burial of pollution-forming materials and minimizes contact time between regraded spoil and surface runoff, thereby reducing pollution formation. Erosion potential, on the other hand, can be increased by this regrading technique if precautions are not implemented to avoid long, unbroken slopes.

In area and contour stripping there may be other forms of reclamation that provide land configurations and slopes better suited to the intended uses of the land. This can be particularly true with steep-slope contour strips, where large highwalls and steep final spoil slopes limit application of contour regrading. Surface mining can be prohibited in such areas due to difficult reclamation using contour regrading, although there may be regrading techniques that could be effectively utilized. In addition, where extremely thick coal seams are mined beneath shallow overburden, there may not be sufficient spoil material remaining to return the land to original contour.

There are several other reclamation techniques of varying effectiveness which have been utilized in both active and abandoned mines. These techniques include terrace, swale, swallow-tail, and Georgia V-ditch, several of which are quite similar in nature. In employing these techniques, the upper highwall portion is frequently left exposed or backfilled at a steep angle, with the spoil outslope remaining somewhat steeper than original contour (see Figure 13). In all cases, a terrace of some form remains where the originally bench was located, and there are provisions for rapidly channeling runoff from the spoil area. Such terraces may permit more effective utilization of surface mined land in many cases.

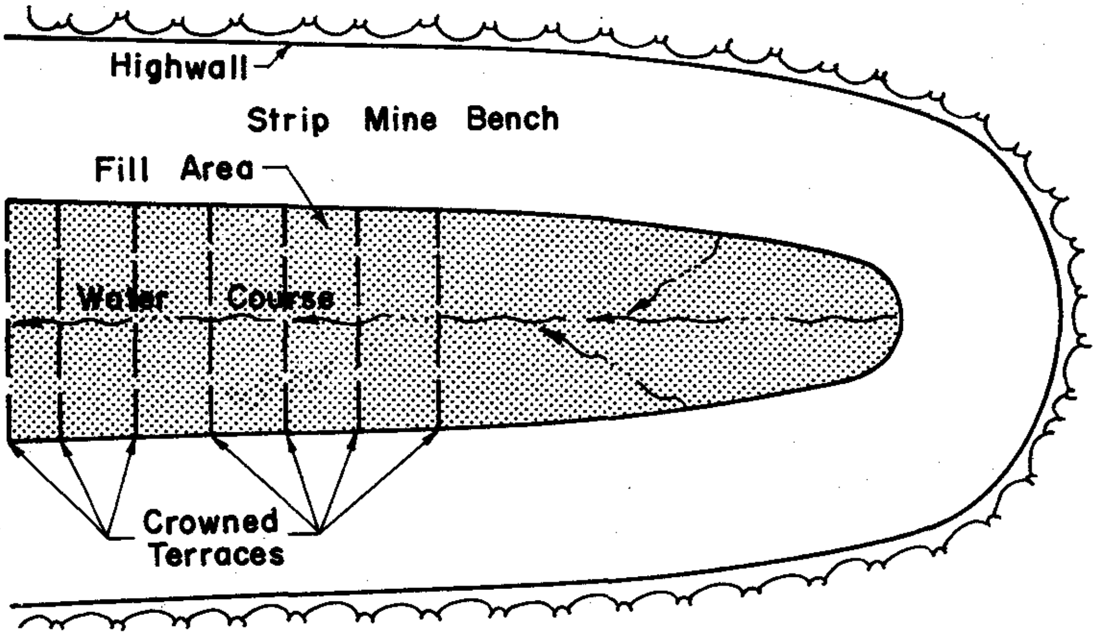
Disposal of excess spoil material is frequently a problem where contour backfilling is not practiced. However, the same problem can also occur, although less commonly, where contour regrading is in use. Some types of overburden rock, particularly tightly packed sandstones, substantially expand in volume when they are blasted and moved. As a result, there may be a large volume of spoil material that cannot be returned to the pit area, even when contour backfilling is employed. To solve this problem, head-of-hollow fill has been used for overburden storage. The extra overburden is placed in narrow, steep-sided hollows in compacted layers 1.2 to 2.4 meters (4 to 8 ft) thick and graded to enable surface drainage (see Figures 14 and 15).



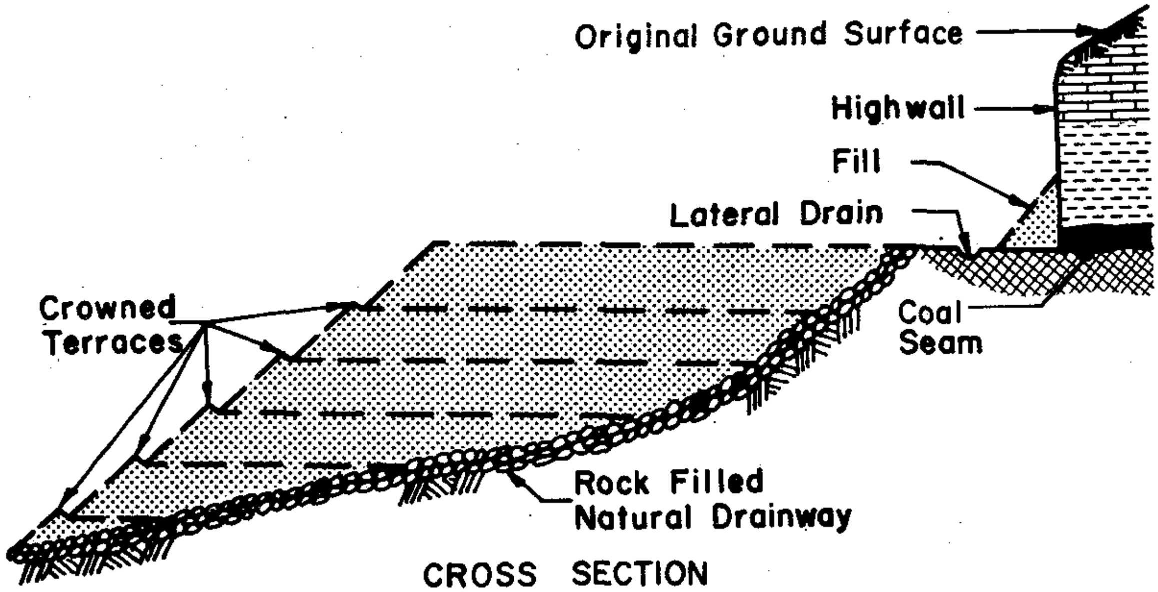
Adapted from drawing in SURFACE MINING METHODS AND TECHNIQUES (1972)

CROSS SECTION OF NON-CONTOUR REGRADING

*Figure 13*



PLAN

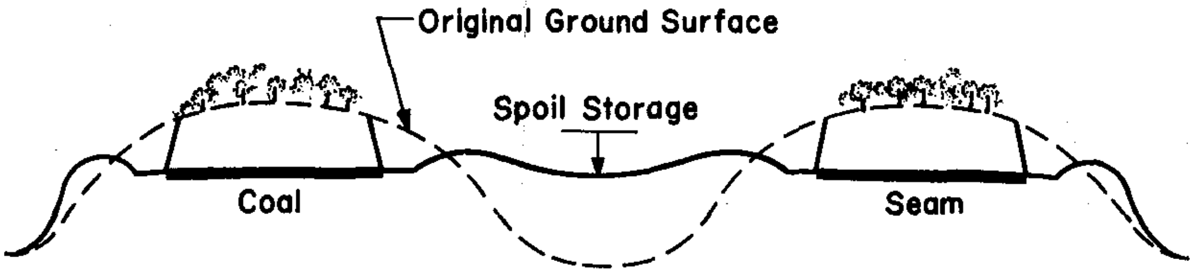


CROSS SECTION

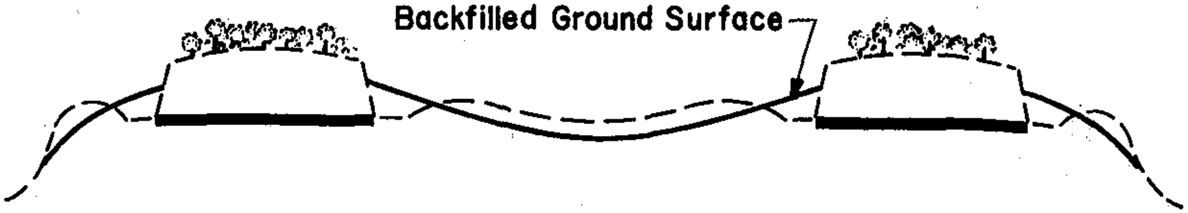
TYPICAL HEAD-OF-HOLLOW FILL

Figure 14

Adapted from drawing in SURFACE MINING METHODS AND TECHNIQUES (1972)



SPOIL STORAGE DURING MINING



REGRADED AREA AFTER MINING

CROSS SECTION
TYPICAL HEAD-OF-HOLLOW FILL
Figure 15

In this regrading and spoil storage technique, natural ground is cleared of woody vegetation and rock drains are constructed where natural drains exist, except in areas where inundation has occurred. This permits ground water and natural percolation to exit fill areas without saturating the fill, thereby reducing potential landslide and erosion problems. Normally the face of the fill is terrace graded to minimize erosion of the steep outslope area.

This technique of fill or spoil material deposition, has been limited to relatively narrow, steep-sided ravines that can be adequately filled and graded. Design considerations include the total number of acres in the watershed above a proposed head-of-hollow fill, as well as the drainage, slope stability, and prospective land use. Revegetation usually proceeds as soon as erosion and siltation protection has been completed. This technique is avoided in areas where under-drainage materials contain high concentrations of pollutants, since resultant drainage would require treatment to meet pollution control requirements.

Erosion Control. Although regrading is an essential part of surface mine reclamation, it cannot be considered a total reclamation technique. There are many other facets of surface mine reclamation that are equally important in achieving successful reclamation. The effectiveness of regrading and other control techniques are interdependent. Failure of any phase could severely reduce the effectiveness of an entire reclamation project.

The most important auxiliary reclamation procedures employed at regraded surface mines or refuse areas are water diversion and erosion and runoff control. Water diversion involves collection of water before it enters a mine area and conveyance of that water around the mine site. Water diversion is usually included in the mining method, or system, to protect the mine and increase the efficiency of mining. This procedure also decreases erosion and pollution formation. Ditches, flumes, pipes, trench drains and dikes are all commonly used for water diversion. Ditches are usually excavated upslope from a mine site to collect and convey water. Flumes and pipes are used to carry water down steep slopes or across regraded areas. Riprap and dumped rock are sometimes used to reduce water velocity in the conveyance system.

Diversion and conveyance systems are designed to accomodate predicted water volumes and velocities. If capacity of a ditch is exceeded, water erodes the sides and renders the ditch ineffective.

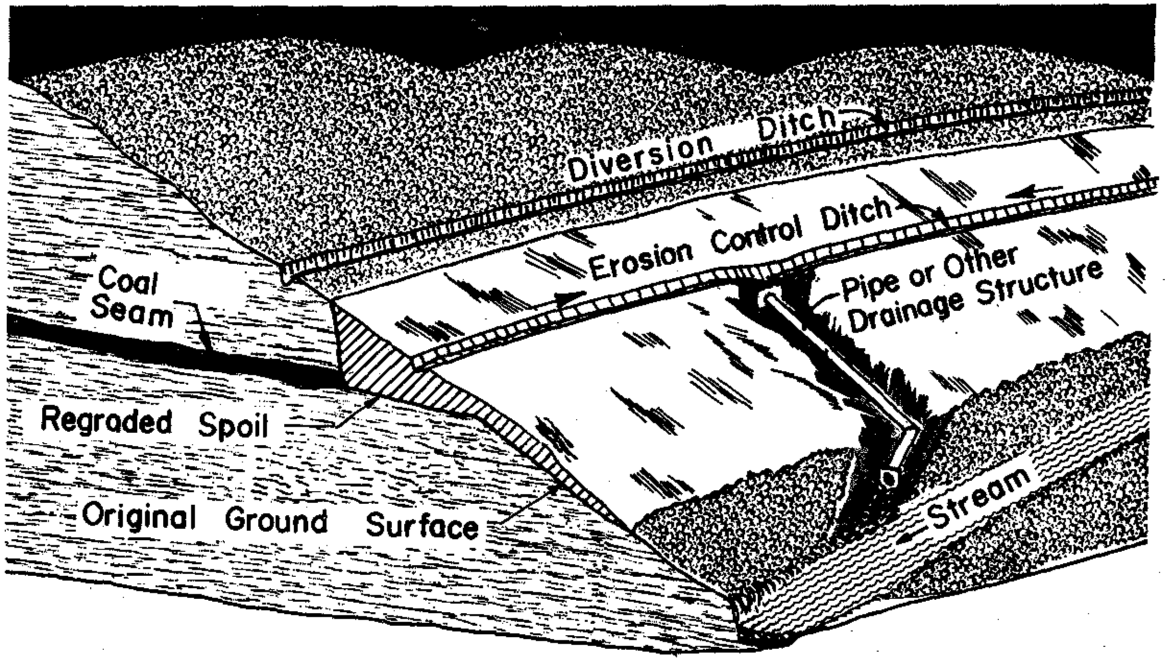
Drainways at the bases of highwalls intercept and divert discharging ground water. In some instances, ground water above the mine site is pumped out before it enters the mine area. Soil erosion is significantly reduced on regraded areas by controlling the course of surface water runoff, using interception channels constructed on the regraded surface (see Figure 16).

Water that reaches a mine site can cause serious erosion, sedimentation and pollution problems. Runoff control techniques are available to effectively deal with this water, but some of these techniques may conflict with pollution control measures. Control of pollutants forming at a mine frequently involves reduction of water infiltration, while runoff controls to prevent erosion can produce increased infiltration, which can subsequently increase pollutant formation.

There are a large number of techniques in use for controlling runoff, with highly variable costs and degrees of effectiveness. Mulching is sometimes used as a temporary runoff and erosion control measure, since it protects the land surface from raindrop impacts and reduces the velocity of surface runoff.

Velocity reduction is a critical facet of runoff control. This is accomplished through slope reduction by either terracing or grading, revegetation or use of flow impediments such as scarification, dikes, contour plowing and dumped rock. Surface stabilizers have been utilized on the surface to temporarily reduce erodability of the material itself, but expense has restricted use of such materials.

Revegetation. Establishment of good vegetative cover on a mine area is probably the most effective method of controlling waste water pollution and erosion. A critical factor in mine revegetation is the quality of the soil or spoil material on the surface of a regraded mine. There are several methods by which the nature of this material has been controlled. Topsoil segregation during stripping is mandatory in many States. This permits topsoil to be replaced on a regraded surface prior to revegetation. However, in many forested, steep-sloped areas there is little or no topsoil on the undisturbed land surface. In such areas, overburden material is segregated in a manner



WATER DIVERSION & EROSION CONTROL
(CONTOUR REGRADING)

Figure 16

Adapted from drawing in
STUDY OF STRIP AND
SURFACE MINING IN
APPALACHIA (1966)

that will allow the most toxic materials to be placed at the base of the regraded mine, and the best spoil material is placed on the regraded mine surface.

Vegetative cover provides effective erosion control, contributes significantly to chemical pollution control, results in aesthetic improvement, and can return land to agricultural, recreational, or silvicultural usefulness. A dense ground cover stabilizes the surface with its root system, reduces velocity of surface runoff, helps build humus on the surface and can virtually eliminate erosion. A soil profile begins to form, followed by a complete soil ecosystem. This soil profile acts as an oxygen barrier, reducing the amount of oxygen reaching underlying pollution forming materials. This in turn reduces oxidation, which is responsible for most pollution formation.

The soil profile also tends to act as a sponge that retains water near the surface, as opposed to the original loose spoil which allowed rapid infiltration. This water evaporates from the mine surface, cooling it and enhancing vegetative growth. Evaporated water also bypasses toxic materials underlying the soil, decreasing pollution production. The vegetation itself also utilizes large quantities of water in its life processes, and transpires it back to the atmosphere, again reducing the amount of water reaching underlying materials.

Establishment of an adequate vegetative cover at a mine site is dependent on a number of related factors. The regraded surface of many spoils cannot support a good vegetative cover without supplemental treatment. The surface texture is often too irregular, and may require raking to remove as much rock as possible, and to decrease the average size of the remaining material. Materials toxic to plant life are usually buried during regrading, and generally do not appear on or near the final graded surface. Dark-colored shaly materials which cause extremely high surface temperatures when left exposed, are often mixed with light materials to enhance vegetative growth. In addition, if the surface is compacted, it is usually scarified by discing, plowing or roto-tilling prior to seeding in order to permit maximum plant growth.

Soil supplements are often required to establish a good vegetative cover on surface-mined lands and refuse piles, which are generally deficient in nutrients. Mine spoils are often acidic, and lime must be added to adjust pH to the tolerance range of species to be planted. It may be necessary to apply additional neutralizers to revegetated minimize erosion and sedimentation. A diverse and permanent vegetative cover must be established and plant succession at least equal in extent of cover to the natural vegetation of the area. To assure compliance with these requirements and permanence of vegetative cover, the operator should be held responsible for successful revegetation and waste water quality for a period of five years after the last year of augmented seeding, fertilization, irrigation, or waste water treatment. In areas of the country where the annual average precipitation is twenty-six inches or less, the operator's assumption of responsibility and liability should extend for a period of ten years after the last year of augmented seeding, fertilization, irrigation or waste water treatment.

## Underground Mining

Pollution control technology in underground mining is largely restricted to at-source methods of reducing water influx into mine workings. Infiltration from strata surrounding the workings is the primary source of water. This water can react with air and pyrite within the mines to form acid mine drainage, or the water may only become polluted with suspended solids. Underground mines are, therefore, faced with problems of waste water handling, and mine drainage treatment.

Infiltration generally results from rainfall recharge of a ground water reservoir. Rock fracture zones and faults have a strong influence on ground water flow patterns, since they can collect and convey large volumes of water. These zones and faults can intersect any portion of an underground mine and permit easy access of ground water. Infiltration also results from seepage from adjacent mines in the same seam. The adjacent mine can be deep or surface and be active or abandoned. This seepage is through barrier pillars left between a flooded mine or flooded portion of a mine and the active deep mine.

In some mines, infiltration can result in huge volumes of waste water that must be handled, and possibly treated, every day. Pumping can be a major part of the mining operation in terms of equipment and expense, particularly in mines which do not discharge by gravity.

Water infiltration control techniques, designed to reduce the amount of water entering the workings, are extremely important in underground mines located in or adjacent to water-bearing strata. These techniques are often employed in such mines to decrease the volume of waste water requiring handling and treatment.

Revegetation of arid and semi-arid areas involves special consideration because of the extreme difficulty to establish vegetation. Lack of rainfall and effects of surface disturbance create hostile growth conditions. Because mining in arid regions has only recently been initiated on a large scale, there is no standard revegetation technology. Experimentation and demonstration projects exploring two general revegetation techniques - moisture retention and irrigation, are currently being conducted to develop this technology.

Moisture retention utilizes entrapment, concentration and preservation of water within a soil structure to support vegetation. This may be obtained utilizing snow fences, mulches, pits, slot chiseling, gouging, offset listering,

Irrigation can be achieved by pumping or gravity feed through either pipes or ditches. This technique can be extremely expensive, and acquisition of water rights may present a major problem. Use of these arid climate revegetation techniques in conjunction with careful overburden segregation and regrading should permit return of arid mined areas to their natural state.

## Mine Closure and Operators Responsibility

Reclamation is recognized as a control technology for surface mining. A surface mine operator can terminate his responsibility for mine waste water by employing complete reclamation.

The desired reclamation goals of regulatory agencies are usually universal: the restoration of affected lands to a condition at least fully capable of supporting the uses which it was capable of supporting prior to any mining, and achievement of a stability which does not pose any threat of water diminution or pollution. The point at which this metamorphosis takes place between unreclaimed and reclaimed surface mined land is difficult to determine, but must be considered in establishing a surface mine operator's term of responsibility for the quality of waste water from the mined area.

In order to accomplish the objectives of the desired reclamation goals, it is mandatory that the surface mine operator regrade and revegetate the disturbed area upon completion of mining. The final regraded surface configuration is dependent upon the ultimate land use of the specific site, and control practices described in this report can be incorporated into the regrading plan to areas for some time to offset continued pollutant generation.

Several potentially effective soil supplements are currently undergoing research and experimentation. Fly ash is a waste product of coal-fired boilers and resembles soil in certain physical and chemical properties. Fly ash disposal has always been a problem, and use of fly ash on regraded surfaces is promising because most fly ash is generated in or near the coal fields. It is often alkaline, contains some plant nutrients, and possesses moisture-retaining and soilconditioning capabilities. Its main function is that of an alkalinity source and a soil conditioner, although it must usually be augmented with lime and fertilizers. However, fly ash can vary drastically in quality, particularly with respect to pH, and may contain leachable materials capable of producing water pollution. Future research, demonstration and monitoring of fly ash supplements will probably develop its potential use.

Limestone screenings are also an effective long term neutralizing agent on acidic spoils. Such spoils generally continue to produce acidity as oxidation continues. Use of lime for direct planting upon these surfaces is effective, but provides only short term alkalinity. The lime is usually consumed after several years, and the spoil may return to its acidic conditions. Limestone screenings are of larger particle size and should continue to produce alkalinity on a decreasing scale for many years, after which a vegetative cover should be well established. Use of large quantities of limestone should also add alkalinity to receiving streams. These screenings are often cheaper than lime, providing larger quantities of alkalinity for the same cost. Such applications of limestone are currently being demonstrated in several areas.

Use of digested sewage sludge as a soil supplement also has good possiblities to replace fertilizer and simultaneously alleviate the problem of sludge disposal. Besides supplying various nutrients, sewage sludge can reduce acidity or alkalinity, and effectively increase soil absorption and moisture retention capabilities. Digested sewage sludge can be applied in liquid or dry form, and must be incorporated into the spoil surface. Liquid sludge applications require large holding ponds or tank trucks from which sludge is pumped and sprayed over the ground, allowed to dry, and disced into the underlying material. Dry sludge application requires dryspreading machinery, and must be followed by discing.

Limestone, digested sewage sludge, and fly ash are all limited by their availability and chemical composition. Unlike commerical fertilizers, the chemical composition of these materials may vary greatly, depending on how and where they are produced. Therefore, a nearby supply of .these supplements may be useless if it does not contain the nutrients or pH adjusters that are deficient in the area of intended application. Fly ash, digested sewage sludge, and limestone screenings are all waste products of other processes, and are therefore usually inexpensive. The major expense related to utilization of any of these wastes is the cost of transporting and applying the material to the mine area. Application may be quite costly, and must be uniform to affect complete and even revegetation.

When such large amounts of certain chemical nutrients are utilized it may also be necessary to institute controls to prevent chemical pollution of adjacent waterways. Nutrient controls may consist of pre-selection of vegetation to absorb certain chemicals, or construction of berms and retention basins where runoff can be collected and sampled, after which it can be discharged or pumped back to the spoil. The specific soil supplements and application rates currently employed are selected to provide the best possible conditions for the vegetative species that are to be planted.

Careful consideration is given to species selection in surface mine reclamation. Species are selected according to some land use plan, based upon the degree of pollution control to be achieved and the site environment. A dense ground cover of grasses and legumes is generally planted, in addition to tree seedlings, to rapidly check erosion and siltation. Trees are frequently planted in areas of poor slope stability to help control landsliding. Intended future use of the land is an important consideration with respect to species selection. Reclaimed surface-mined lands are occasionally returned to high use categories such as agriculture, if the land has potential for growing crops. However, when toxic spoils are encountered, agricultural potential is greatly reduced and only a few species will grow.

Environmental conditions, particularly climate, are important in species selection. Usually, species are planted that are native to an area, and particularly species that have been successfully established on nearby mines with similar climate and spoil conditions.

Decreased waste water volumes, however do not necessarily mean that pollution loads will also decrease. In underground coal mines producing acid mine drainage, oxygen, rather than volume of water flowing through the workings, is the principal controlling factor in pollutant formation. High humidity in a mine atmosphere usually contains sufficient moisture to permit pollutant formation, while water flowing through the mine merely transports pollutants from their formation sites on the mine walls and floor. If the volume of this transporting medium decreases while the volume of pollutants remains unchanged, the resultant smaller discharge will have increased pollutant concentrations and approximately the same pollution load. Formation of pollutants can be significantly reduced in intercepted water, however, by reducing the contact time within the mine.

Reduction in discharge volume can significantly reduce waste water handling costs. Costs for waste water treatment will decline even though concentrations may increase. The same amounts of neutralizing agents will be required since the pollution loads are basically unchanged. However, the volume of waste water to be treated will be reduced significantly, along with the size of the required treatment or settling facilities. This cost reduction, along with cost savings attributable to decreased pumping volumes, makes use of water infiltration control techniques highly desirable.

Most water entering underground mines passes vertically through the mine roof from overlying strata. Horizontal permeability is characteristically much greater than vertical permeability in rock units overlying coal mines. These rock units generally have well developed joint systems, which tend to cause vertical flow. Roof collapse can also cause widespread fracturing in strata adjacent to the roof, and subsequent joint separation far above the roof. These opened joints can tap overlying perched aquifers, or occasionally a flooded mine above the active mine. Roof collapse in shallow mines will often cause surface subsidence, which collects and funnels surface runoff directly to the mine.

Such fracturing of overlying strata is commonly reduced by employing any or all of the following:

1) increasing pillar size
2) support of the roof immediate to the coal
3) limiting mine entry widths, or number of entries
4) backfilling of mine voids

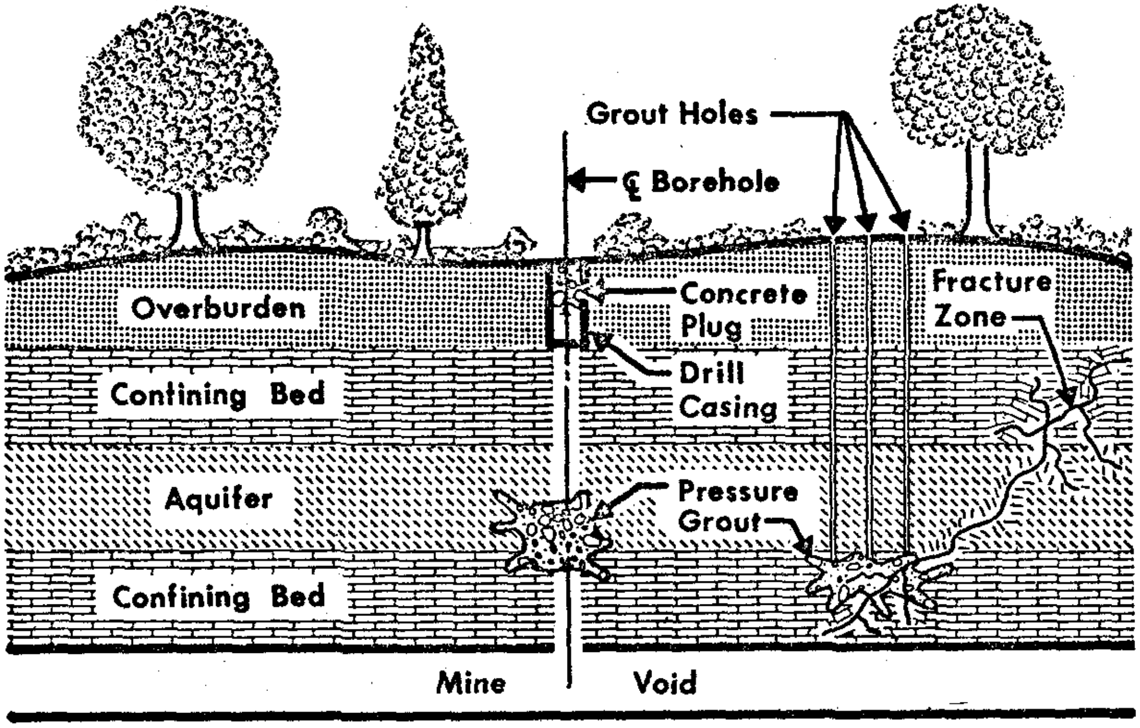
These practices, when utilized to their fullest capability, can assist in controlling mine roof collapse and subsequent fracturing of overlying strata in deep mines with shallow cover.

Boreholes and fracture zones, which act as water conduits to underground mines are also sealed to prevent infiltration. Boreholes remaining from earlier exploration efforts can be present at underground mines. These boreholes are often located from the mine and plugged hydraulically with concrete to prevent passage of water. Difficulties are encountered when sealing must be performed from the surface, since abandoned holes are often difficult to locate on the surface and may be blocked by debris.

Fracture zones, which are usually vertically oriented, planar type features, are often major conduits of water. Their locations can be plotted by experienced personnel using aerial photography. Permeability of these zones is reduced by drilling and grouting. Figure 17 illustrates the sealing of boreholes and fracture zones.

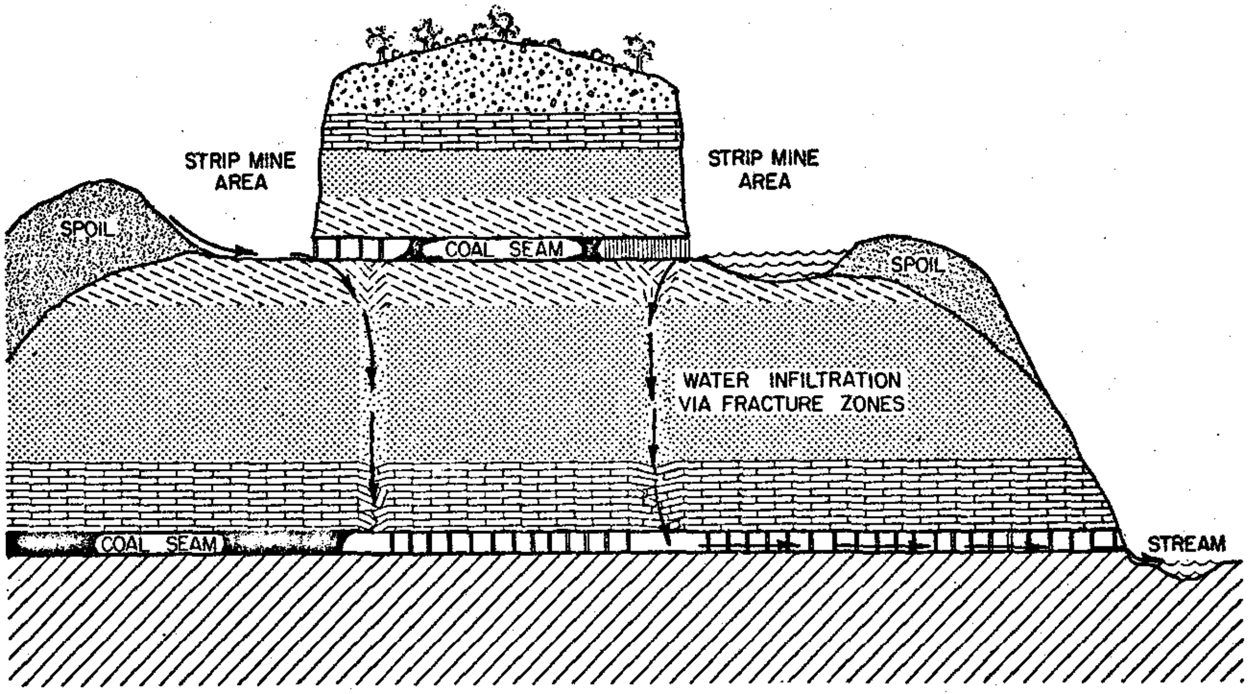
Surface mines can be responsible for collecting and conveying large quantities of surface water to adjacent or underlying underground mines. Ungraded surface mines often collect water in open pits where no surface exit point is available. That water subsequently enters the ground water system, from which it percolates into underground mine workings (see Figure 18). A surface mine does not have to intercept underground mine workings in order to increase infiltration. Surface mines updip from underground mines collect water and allow it to enter permeable coal seams. This water then flows through or near the coal seam into the mine workings. The influx of water to underground mines from either active or abandoned surface mines can be significantly reduced through implementation of a well-designed reclamation plan.

The only actual underground mining technique developed specifically for pollution control is preplanned flooding. The technique is primarily one of mine design, in which a mine is planned from its inception for post-operation flooding or zero discharge. In drift mines and shallow slope or shaft mines this is generally achieved by driving the mine exclusively to the dip and pumping out all water that collects in the workings. Upon completion of mining activities, the workings are allowed to flood naturally, eliminating the acid-producing pyrite-oxygen contact (see Figure 19). This technique should also include the design of the mine's support and barrier pillars. Discharges, if



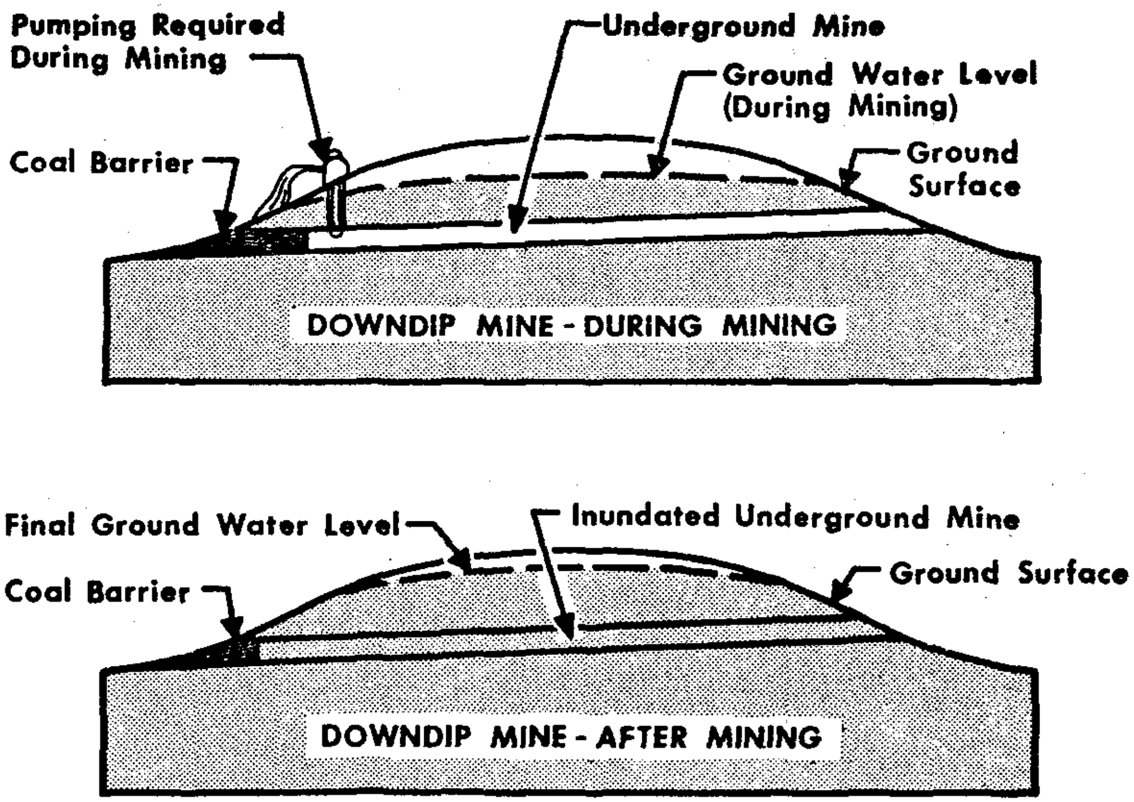
BOREHOLE AND FRACTURE SEALING

Figure 17



WATER INFILTRATION THROUGH UNREGRADED SURFACE MINE

Figure 18



PREPLANNED FLOODING

Figure 19

Adapted from drawing in MINE DRAINAGE POLLUTION PREVENTION AND ABATEMENT USING HYDROGEOLOGICAL AND GEOCHEMICAL SYSTEMS any, from a flooded mine should contain a much lower pollutant concentration.

## MINE CLOSURE AND OPERATORS RESPONSIBILITY

Unless control and treatment technology is implemented, an underground mine can be a permanent source of water pollution after mine closure.

Responsibility for the prevention of any adverse environmental impacts from the temporary or permanent closure of a deep mine should rest solely and permanently with the mine operator. This constitutes a substantial burden, and it therefore behooves the operator to make use of the best technology available for dealing with pollution problems associated with mine closure. The two techniques most frequently utilized in deep mine water pollution abatement are continuing waste water treatment and mine sealing. Waste water treatment technology is well defined and is generally capable of producing acceptable effluent quality. If the mine operator chooses this course, he is faced with the prospect of costly permanent treatment of each mine discharge.

Mine sealing is an attractive alternative to the prospects of perpetual treatment. Mine sealing requires the mine operator to consider barrier and pillar design from the perspective of strength, mine safety, the ability to withstand high water pressure, and in the role of retarding ground water seepage. In the case of new mines these considerations should be included in the mine design to cover the eventual mine closure. In the case of existing mines these considerations should be evaluated for existing mine barriers and pillars, and the future mine plan adjusted to include these considerations if mine sealing is to be employed at mine closure.

Sealing eliminates the mine waste water discharge and inundates the mine workings, thereby reducing or terminating the production of pollutants. However, the possibility of the failure of mine seals or outcrop barriers increases with time as sealed mine workings gradually become inundated by groundwater and the hydraulic head increases. Depending upon the rate of groundwater influx and size of the mined area, complete inundation of a sealed mine may require several decades. Consequently, the maximum anticipated hydraulic head on the mine seals may not be realized for that length of time. In addition, seepage through, or failure of, the coal outcrop barrier or mine seal could occur at any time. Therefore, it seems reasonable to require the mine operator to permanently maintain the seals or provide treatment in the event of significant seepage or failure of the seals or barriers.

## Coal Preparation

Water pollution problems associated with coal cleaning processes are of two general types: (1) process generated waste waters and (2) waste water in the vicinity of plant facilities, coal storage areas, and refuse disposal areas. Coal preparation pollution technology is therefore divided into two major categories - process generated waste water control and treatment and preparation plant ancillary area waste water control and treatment techniques. With proper management and planning, water pollution resulting from the preparation of coal can be minimized. Process generated waste water treatment and control technologies are dependent on the coal preparation process employed.

### Process Waste Water Control and Treatment

Fine coal and mineral particles, such as clays, remain suspended in plant waters resulting in potentially serious pollution from some coal cleaning facilities. Clarification techniques available for removal of these suspended solids include thickeners, flocculation, settling, vacuum filtration and pressure filtration. A typical closed circuit washery could incorporate thickeners or settling ponds with the addition of flocculation reagents to enhance settling of particulate matter. Coal fines separated from plant waters can either be blended with clean coal or transported to a refuse disposal site.

Froth flotation is a unit operation in coal cleaning that provides separation of fine coal from refuse and fine clay. Past industry practices limited froth flotation use to metallurgical grade coals because the additional preparation costs could not be justified with the low selling prices of utility coal. Present market conditions may stimulate more operators to employ froth flotation cells for recovery of a salable product from coal slimes. The refuse and fine clays segregated by flotation are then removed from plant waters via thickeners and filters. This provides an economic method for effecting water clarification.

In addition to removal of suspended solids, washery waters may also require treatment to control chemical parameters, such as pH, iron, sulfates, etc. Such treatment when required, is relatively simple, and is tied to the maintenance of efficient plant operation, acceptable product quality, and minimal pollution - related stress on equipment. Where chemical treatment is required, the most common practice is addition of lime to make-up waters, but treatment can also be performed prior to recycle of waters from settling ponds. As a final resort, process waters may require circulation through neutralization and treatment facilities. This particular water control practice is not common among existing preparation plants, and should only be considered for extremely poor quality process waters.

## Ancillary Area Waste Water Control

Pollution control technology related to preparation plant ancillary areas is generally aimed at prevention of contamination of surface waters (streams, impoundments and surface runoff). Solicitous planning of refuse disposal is a prime control method. Disposal sites are isolated from surface flows and impoundments to minimize pollution potential. In addition the following techniques are practiced to prevent water pollution:

1) Construction of a clay liner beneath the planned refuse disposal area to prevent infiltration of surface waters (precipitation) into the groundwater system.

2) Compaction of refuse to reduce infiltration and help prevent spontaneous combustion.

3) Maintenance of a uniformly sized refuse to insure good compaction (may require additional crushing).

4) Following achievement of the desired refuse depth, construction of a clay liner over the material to minimize infiltration. This is usually succeeded by placement of topsoil and seeding to establish a vegetative cover for erosion protection.

5) Excavation of diversion ditches surrounding the refuse disposal site to exclude surface runoff from the area. Ditches can also be used to collect runoff and seepage from refuse piles with subsequent treatment if necessary.

6) Ponds or ditches to protect against overflow in slurry refuse dams. Slurry refuse disposal requires safety considerations in addition to environmental.

As previously indicated, the immediate area surrounding preparation plant facilities presents another waste water pollution problem requiring careful planning. Haul roads, refuse disposal piles, and outside raw and clean coal storage areas are sources of contamination to near-by surface waters. The elimination of this contamination and the maintenance of environmental quality are responsibilities which must be borne by the coal preparation plant operator. Several current industry practices to control this pollution are:

1) Construction of ditches surrounding preparation facilities to divert surface runoff and collect seepage that does occur.

2) Installation of a hard surface over the entire area with proper slopes to direct drainage to a sump. As is the case in the previous technique, collected waters are pumped into the preparation plant for processing.

3) Storage of coal in bins, silos or hoppers with pavement of haul roads and loading points. Runoff is collected in trenches.

4) Establishment of a good vegetative cover of grasses on the surface surrounding preparation facilities to control erosion and sedimentation and to improve aesthetics.

## Plant Closure and Operators Responsibility

As with coal mines, the waste water pollution from a preparation plant's refuse storage area does not stop upon shutdown of the preparation plant. In that reclamation goals and methods are similar to those for surface coal mines, the operator should be held responsible for successful revegetation and waste water quality for a period of five years after the last year of augmented seeding, fertilization, irrigation, or waste water treatment. In areas of the country where the annual average precipitation is twenty-six inches or less, the operators responsibility and liability should extend for a period of ten years after the last year of augmented seeding, fertilization, irrigation, or waste water treatment.

## TREATMENT TECHNOLOGY

As discussed in Section IV, Industry Categorization, coal mines have been grouped into two separate raw mine drainage categories. The pollutants encountered in these categories were discussed in Waste Characterization - Section V. The current treatment technology and industry practice for acid or ferruginous and alkaline categories is described herein.

### Acid or Ferruginous Mine Drainage

Acid or ferruginous mine drainage is most frequently encountered in the northern Appalachian states. In Pennsylvania, Ohio, Maryland, and northern West Virginia the raw mine drainage usually contains varying degrees of mineral acidity with significant concentrations of iron, aluminum, calcium, manganese, and sulfates, and lesser amounts of magnesium, nickel, zinc, ammonia, fluorides and chlorides. Such drainages may also be found in other localized areas.

Where acid or ferruginous mine drainage is a common problem, there are generally existing state laws requiring that the drainage be treated to remove those pollutants considered harmful to receiving streams. Acid mine drainage treatment facilities were in operation at 62 of the mining operations visited and samples were collected of both the influent to the treatment facility and the effluent from the treatment facility. This includes a sampling program at six selected AMD treatment facilities where influent and effluent samples were collected for 90 days consecutively.

Treated mine drainage has been established as a separate class of coal mine effluent for purposes of establishing limitation guidelines for acid or ferruginous mine drainage.

### Treated Mine Drainage

Treatment facilities are now in operation at an estimated 250 mines that have an acid mine drainage. Most of these are located in the northern Appalachian states. By far, lime is the predominant alkali used by the industry. In addition to the common industry practice of using the conventional lime system, there are several processes in the pilot or demonstration phase for treating acid mine drainage that include: limestone-lime treatment, reverse osmosis and neutrolosis, ion exchange methods, and chemical softening.

### Conventional Neutralization

Acid or ferruginous mine drainage is most often treated by a method that can be called the "conventional lime neutralization system," utilizing hydrated lime or quick lime. Other alkalis available and used at some plants include limestone, soda ash and caustic soda. Treatment plants usually have facilities for 1) flow equalization, 2) acidity neutralization, 3) ferrous iron oxidation, and 4) solids removal. From plant to plant there can be variations to this basic system which may exclude the equalization or oxidation steps, or include methods to enhance solids removal and minimize sludge volume. In addition, where neutralization is not required, excessive concentrations of iron and suspended solids can be reduced by aeration and sedimentation. A description of the facilities employed in the conventional lime neutralization process follows.

1. <u>Flow Equalization</u>. Surface holding ponds or underground sumps are frequently employed to equalize the flow and quality of the acid mine drainage before treatment. These facilities usually have the capacity to provide for one or more day's storage in case of treatment plant shut down. Surface ponds also provide a constant head for gravity flow through the treatment plant.

2. <u>Acidity Neutralization</u>. Mineral acidity in raw mine drainage is neutralized with one of the above mentioned alkalis. In addition to neutralizing acidity, these alkalis also enhance the removal of iron, manganese, and other soluble metals through the formation of their insoluble hydroxides.

3. <u>Iron Oxidation</u>. When iron is present in raw mine drainage in the ferrous form, usual practice is to provide aeration facilities for oxidation to the ferric state. Ferric iron is more insoluble than the ferrous form at lower pH's, thus the reasoning for the oxidation step. Some companies however, remove iron as ferrous hydroxide as the resulting sludge is more dense, producing less volume for disposal.

4. <u>Solids Removal</u>. As a result of the chemical treatment process, suspended solids are formed. Both earthen settling basins and mechanical clarifiers are used for removal of these suspended solids. Earthen impoundments with detentions of from one day to as much as several months are most often used. The detentions provided usually are more dependent on the sludge storage capacity desired than for suspended solids removal.

The manner by which coal operators have approached the design and construction of conventional neutralization treatment facilities varies from somewhat sophisticated plants to simple or rather crude installations. Performance of many of these facilities varied significantly, but this was due to operational problems rather than waste treatment difficulties. Descriptions of several of these treatment plant installations are included here to provide a more complete explanation of the conventional neutralization treatment technology currently in use.

The following mines using conventional neturalization were visited.

## Mine Code A-1

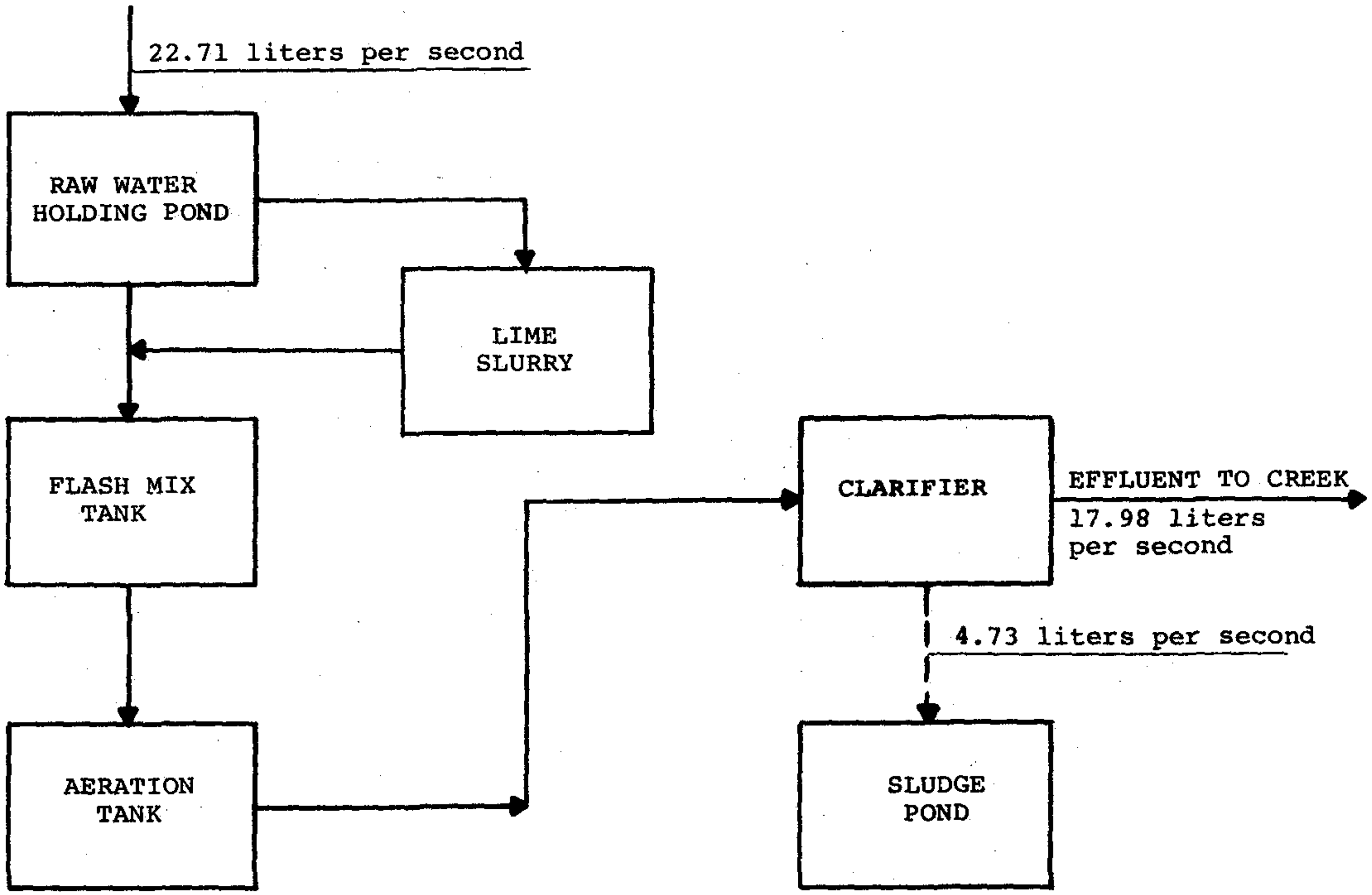
Mine A1 is a deep mine located in southwestern Pennsylvania and operating in the Pittsburgh (bituminous) coal seam. Coal is mined at the rate of 2,963 KKG (3,267 tons) per shift. Based on the 1973 production of 1,846,652 KKG (2,036,000 tons), the estimated life of the present reserves is 42 years.

Treatment is provided for discharge point A1-1 by a conventional lime neutralization plant that was constructed in 1968. Raw water is pumped on demand by a 75.7 liter per second (1,200 gallon per minute) pump to an 11,355 cubic meter (3 million gallon) holding pond. The water is then neutralized at the average rate of 1,586 cubic meters per day (.419 million gallons per day) by mixing with 0.608 KKG per day (0.67 tons per day) of a hydrated lime slurry. The lime neutralization process operates one hour on and one hour off throughout the day. The chemically treated water flows to a 253,595 liter (67,000 gallons) mechanical aeration tank, then to an 18.9 meter (62 ft) diameter thickener before discharging to the adjacent surface stream. The thickener provides a detention of 16 hours at the average flow rate. The sludge resulting from the chemical treatment is removed from the thickener and is pumped to a 30,280 cubic meter (8 million gallon) sludge holding basin.

A schematic diagram of this treatment plant appears in Figure 20. Average raw and effluent analyses of samples collected at this treatment plant are presented in Table 7.

FIGURE 20

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE A-1



## TABLE 7

### Analytical Data - Mine Code A-1

| Constituent | Raw Mine Drainage Point A1-1 Average Quality* | Treated Mine Drainage Point A1-2 Average Quality** |
|---|---|---|
| pH | 2.9 | 7.2 |
| Alkalinity | 0 | 31 |
| Specific Conductance | 5152 | 5993 |
| Solids, total dissolved | 4662 | 4946 |
| Solids, suspended | 133 | 94 |
| Hardness | 1093 | 1710 |
| Iron, total | 212 | 1.44 |
| Iron, dissolved | 185 | 0.28 |
| Manganese, total | 9.17 | 1.09 |
| Aluminum, total | 69.3 | 1.09 |
| Zinc, total | 0.93 | 0.05 |
| Nickel, total | 0.66 | 0.01 |
| Strontium, total | 9.40 | 9.40 |
| Sulfates | 3043 | 2926 |
| Chloride | 73.7 | 124 |
| Fluoride | 2.20 | 2.45 |
| Ammonia | 9.3 | 2.54 |
| Chromium, total | 0.03 | 0.02 |
| Copper, total | 0.18 | 0.01 |

*Based on three consecutive 24 hour composite samples.

**Based on two consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code A-2

Mine A2 is a deep mine located in southwestern Pennsylvania operating in the Pittsburgh (bituminous) coal seam. Coal is mined at the rate of 2,872 KKG (3,167 tons) per shift. Based on the 1973 production of 1,567,300 KKG (1,728,000 tons), the estimated life of the present reserves is eight years. The mine presently has four (4) points of dewatering, all of which are pumped. Two of these discharges require treatment. The analytical quality of treated discharge A-2 is shown in Table 8.

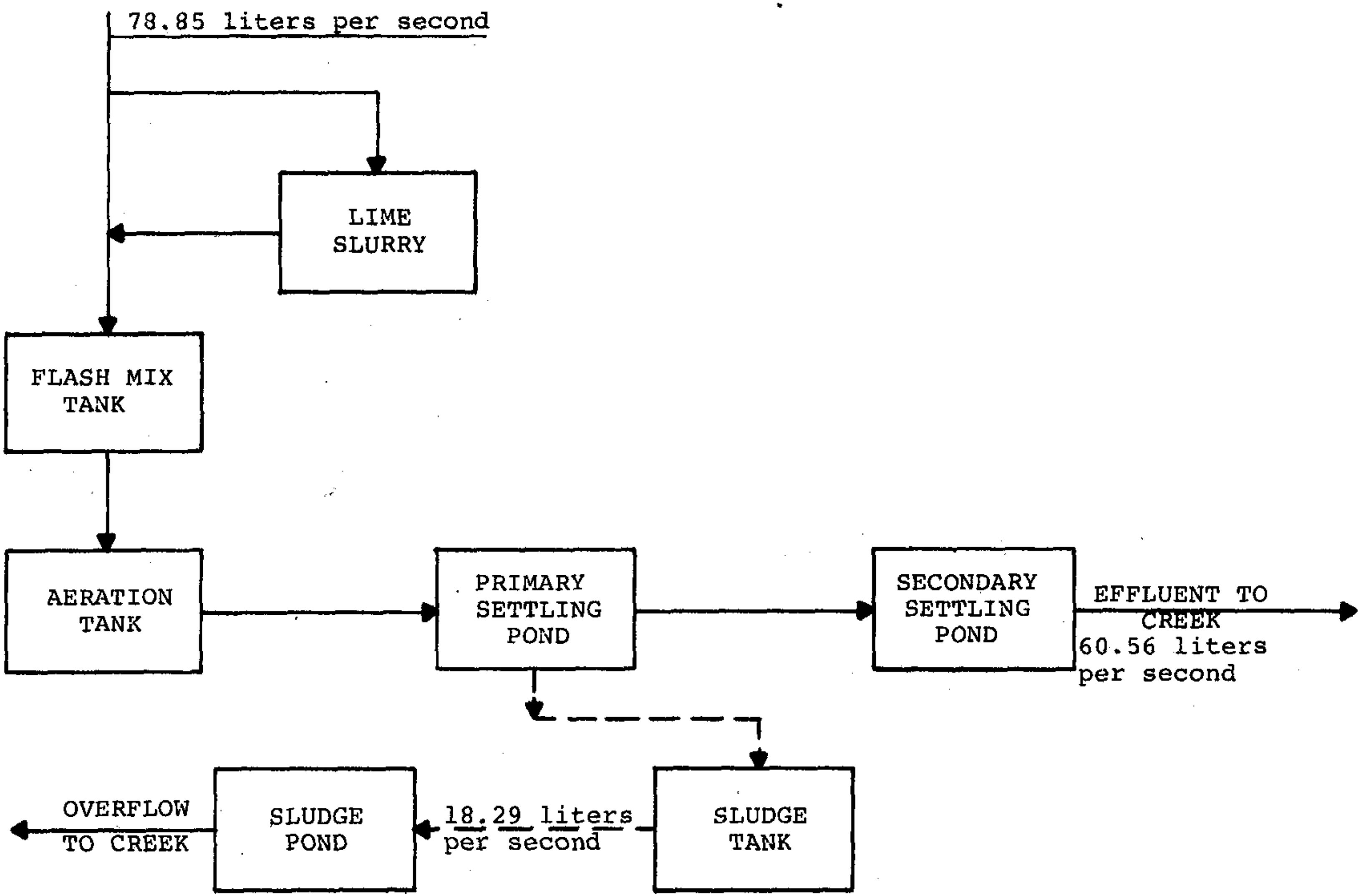
Treatment is provided for discharge point A2-1 by a conventional lime neutralization plant that was constructed in 1968. Raw drainage is pumped through a bore hole by a 78.88 liter per second (1,250 gallon per minute) pump directly to the flash mix tank where it is neutralized by mixing with 6.35 KKG per day (7 tons per day) of hydrated lime as a slurry. The chemically treated water flows to a pre-settling tank and then to a 246,000 liter (65,000 gallon) mechanical aeration tank. The sludge pre-settling tank requires cleaning every 6 months. The aerated water is discharged to a 3,030,000 liter (800,000 gallon) primary settling pond which contains a continuous sludge removal system. The overflow from this pond enters a 4,542 cubic meter (1.2 million gallon) secondary settling pond before discharging to the stream.

The sludge resulting from this treatment system is pumped from the primary settling pond to a 1,022,000 liter (270,000 gallon) holding pond, then pumped directly to a large dewatering basin encompassing approximately 4.05 hectares (10 acres). The overflow from this basin is also discharged to the stream.

A diagram of the treatment sequence is shown in Figure 21. The analytical data for the treatment facility is shown in Table 8.

FIGURE 21

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE A-2



## Table 8

## Analytical Data - Mine Code A-2

| Constituent | Raw Mine Drainage Point A2-1 Average Quality* | Treated Mine Drainage Point A2-2 Average Quality* |
|---|---|---|
| pH | 3.1 | 8.4 |
| Alkalinity | 0 | 52 |
| Specific Conductance | 7103 | 6007 |
| Solids, total dissolved | 6814 | 6053 |
| Solids, suspended | 59 | 115 |
| Hardness | 1627 | 2113 |
| Iron, total | 276 | 1.68 |
| Iron, dissolved | 276 | 0.04 |
| Manganese, total | 11.5 | 0.78 |
| Aluminum, total | 58 | 0.10 |
| Zinc, total | 1.31 | 0.02 |
| Nickel, total | 1.29 | 0.01 |
| Strontium, total | 3.47 | 5.54 |
| Sulfates | 4031 | 3262 |
| Chloride | 168 | 298 |
| Fluoride | 1.19 | 1.62 |
| Ammonia | 41.7 | 4.05 |
| Copper, total | 0.12 | 0.01 |

*Based on three consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

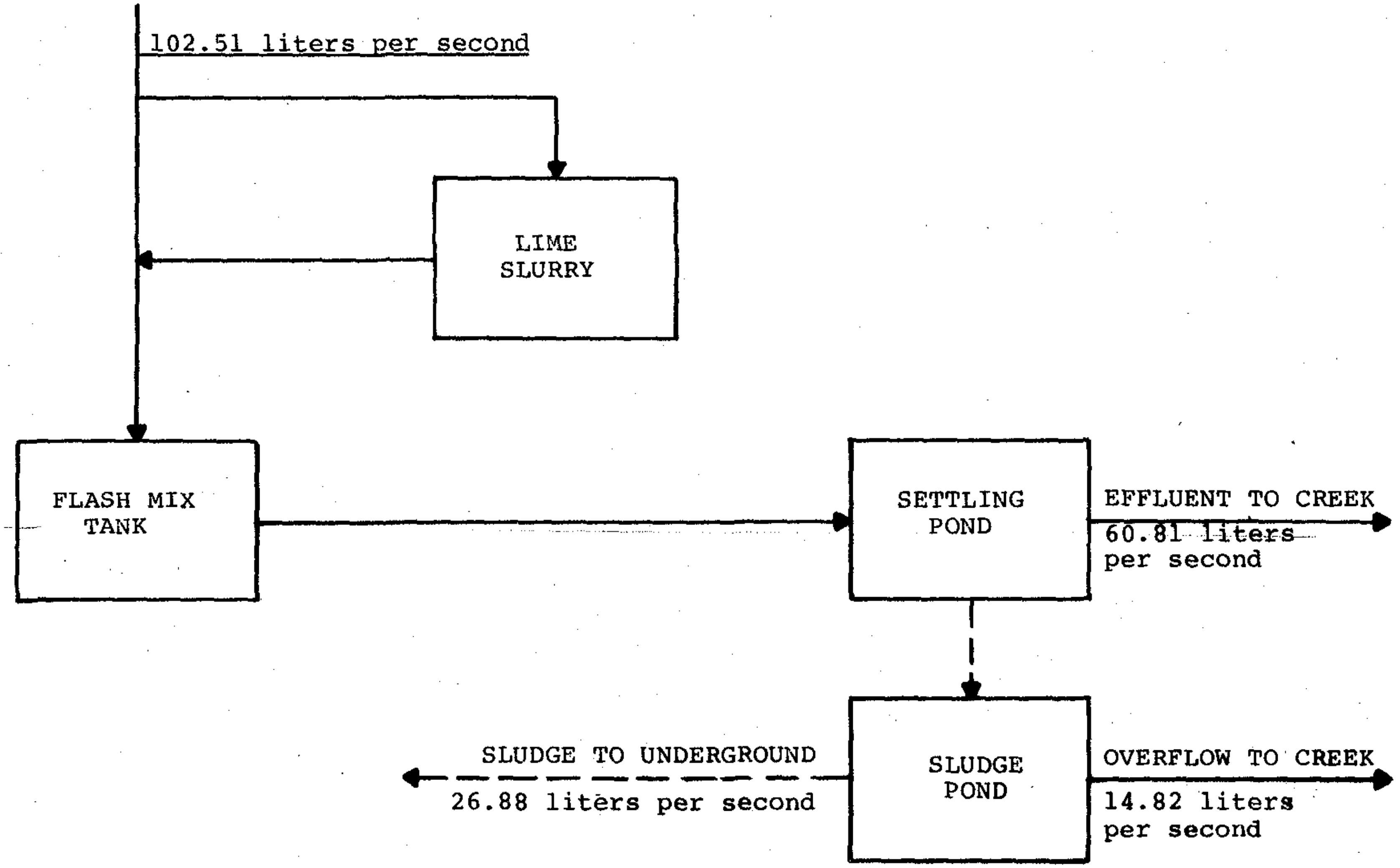
Mine Code A-3

Mine A-3 is the same mine referred to in Mine Code A-2. Discharge A-3 is the second treated discharge from the mine. The analytical data for this treatment plant is shown in Table 9.

The treatment facility for discharge point A3-1 includes lime neutralization followed by a baffled 7,949 cubic meter (2.1 million gallon) settling pond. This plant experienced better settling of the ferrous sludge than the ferric; thus aeration was eliminated. This plant, constructed in 1969, treats 102.5 liters per second (1,625 gallons per minute) of raw water using 5.4 KKG (6 tons) of hydrated lime each day.

Sludge removed daily from the settling pond is pumped to one of two 7,949 cubic meter (2.1 million gallon) ponds. The settled sludge is concentrated with any overflow discharged to the stream. Final disposal of the concentrated sludge is through a bore hole to an abandoned portion of the mine. A diagram of the treatment sequence is shown in Figure 22.

FIGURE 22
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE A-3



## Table 9

## Analytical Data - Mine Code A-3

| Constituent | Raw Mine Drainage Point A3-1 Average Quality* | Treated Mine Drainage Point A3-2 Average Quality** |
|---|---|---|
| pH | 3.0 | 8.9 |
| Alkalinity | 0 | 16 |
| Specific Conductance | 3080 | 2910 |
| Solids, total dissolved | 2650 | 2538 |
| Solids, suspended | 73 | 26 |
| Hardness | 880 | 1120 |
| Iron, total | 164 | 0.35 |
| Iron, dissolved | 139 | 0.01 |
| Manganese, total | 3.83 | 0.07 |
| Aluminum, total | 7.9 | 0.10 |
| Zinc, total | 0.33 | 0.02 |
| Nickel, total | 0.34 | 0.01 |
| Strontium, total | 2.9 | 2.8 |
| Sulfates | 1323 | 1432 |
| Chloride | 52 | 99 |
| Fluoride | 0.87 | 0.76 |
| Ammonia | 5.8 | -- |

*Based on three consecutive 24 hour composite samples.

**Based on one 24 hour composite sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead, and selenium, but these were not detected in significant concentrations.

## Mine Code A-4

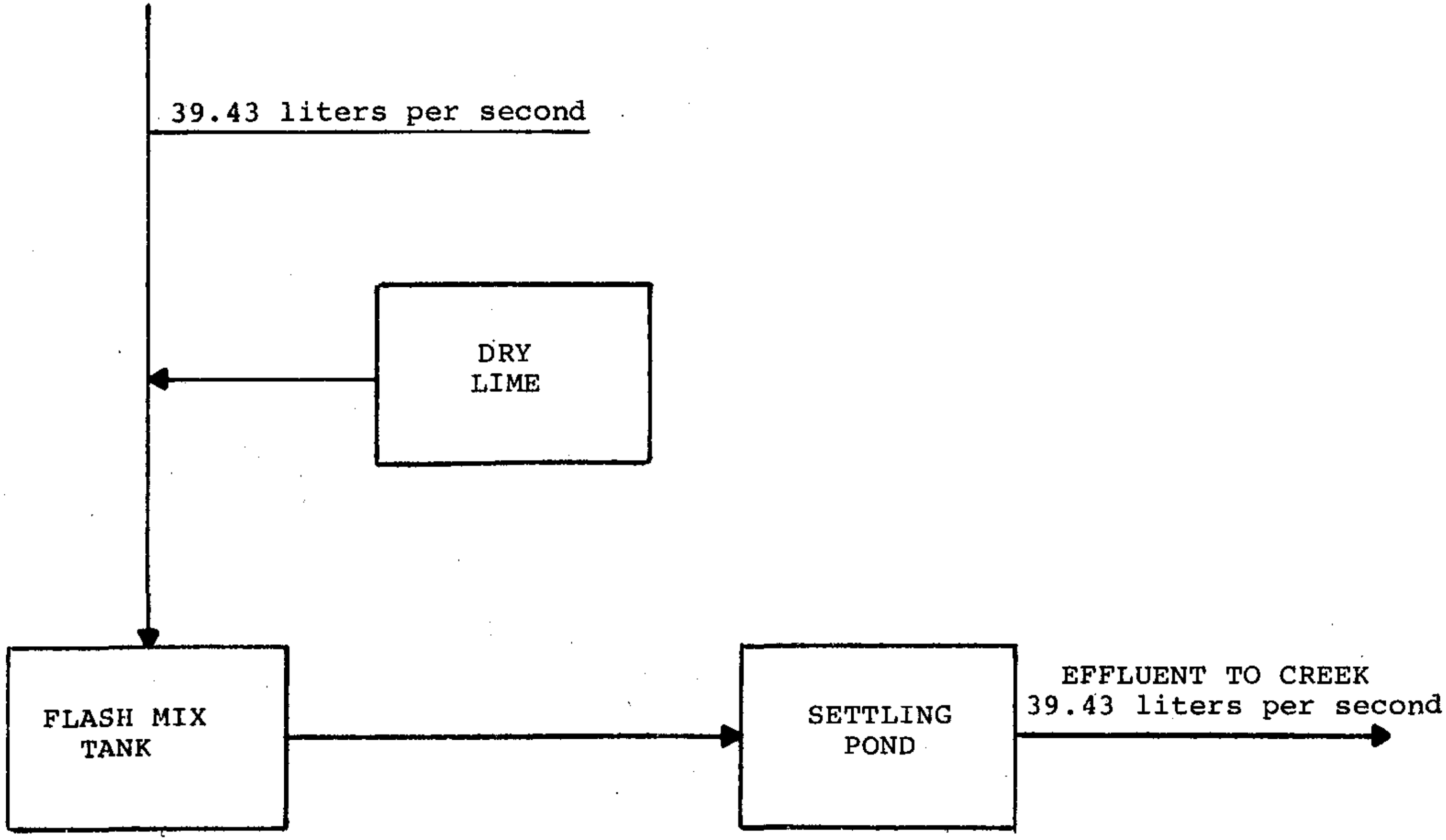
Mine A4 is a deep mine located in southwestern Pennsylvania operating in the Pittsburgh (bituminous) coal seam. The mine encompasses 6885 hectares (17,000 acres), of which 6,075 hectares (15,000 acres) remain. Coal is mined at the rate of 887 KKG (978 tons) per shift with a recovery of about 70 percent. Based on the 1973 production of 638,528 KKG (704,000 tons), the estimated life of the present reserves is 67 years.

The mine presently has four (4) points of dewatering, two of which are pumped to the surface and treated. The analytical quality of the raw and treated discharge of one of these points is shown in Table 10. Treatment consists of a conventional lime neutralization plant that was constructed in 1973. Raw water is pumped out of the mine at a rate of 105.13 liters per second (1,666 gallons per minute) for 15 hours per day. This drainage is neutralized at an average rate of 5,451 cubic meters per day (1.44 mgd) by mixing it with .907 KKG per day (1.0 ton per day) of dry hydrated lime in the flash mix tank. Ferrous iron is oxidized by natural aeration in a long trough as the drainage flows to a large settling basin that has a capacity of 113,550 cubic meters (30 million gallons). It is expected that the settling basin has a sludge capacity for four more years before some other means of disposal will become necessary.

A diagram of the treatment sequence appears in Figure 23.

FIGURE 23

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE A-4



## Table 10

## Analytical Data - Mine Code A-4

| Constituent | Raw Mine Drainage Point A4-1 Average Quality* | Treated Mine Drainage Point A4-2 Average Quality** |
|---|---|---|
| pH | 5.8 | 8.0 |
| Alkalinity | 81 | 291 |
| Specific Conductance | 10,268 | 8098 |
| Solids, total dissolved | 8,774 | 8368 |
| Solids, suspended | 397 | 19 |
| Hardness | 1,487 | 1800 |
| Iron, total | 187 | 0.48 |
| Iron, dissolved | 63.7 | 0.01 |
| Manganese, total | 8.13 | 2.46 |
| Aluminum, total | 36.4 | 0.10 |
| Zinc, total | 0.62 | 0.03 |
| Nickel, total | 0.36 | 0.08 |
| Strontium, total | 3.35 | 4.24 |
| Sulfates | 4,418 | 4001 |
| Chloride | 1,940 | 1737 |
| Fluoride | 0.86 | 1.28 |
| Ammonia | 3.19 | 1.86 |
| Boron, total | 0.30 | 0.30 |
| Copper, total | 0.06 | 0.01 |

*Based on one grab sample and two consecutive 24 hour composite samples.

**Based on three consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, cadmium, chromium, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code B-2

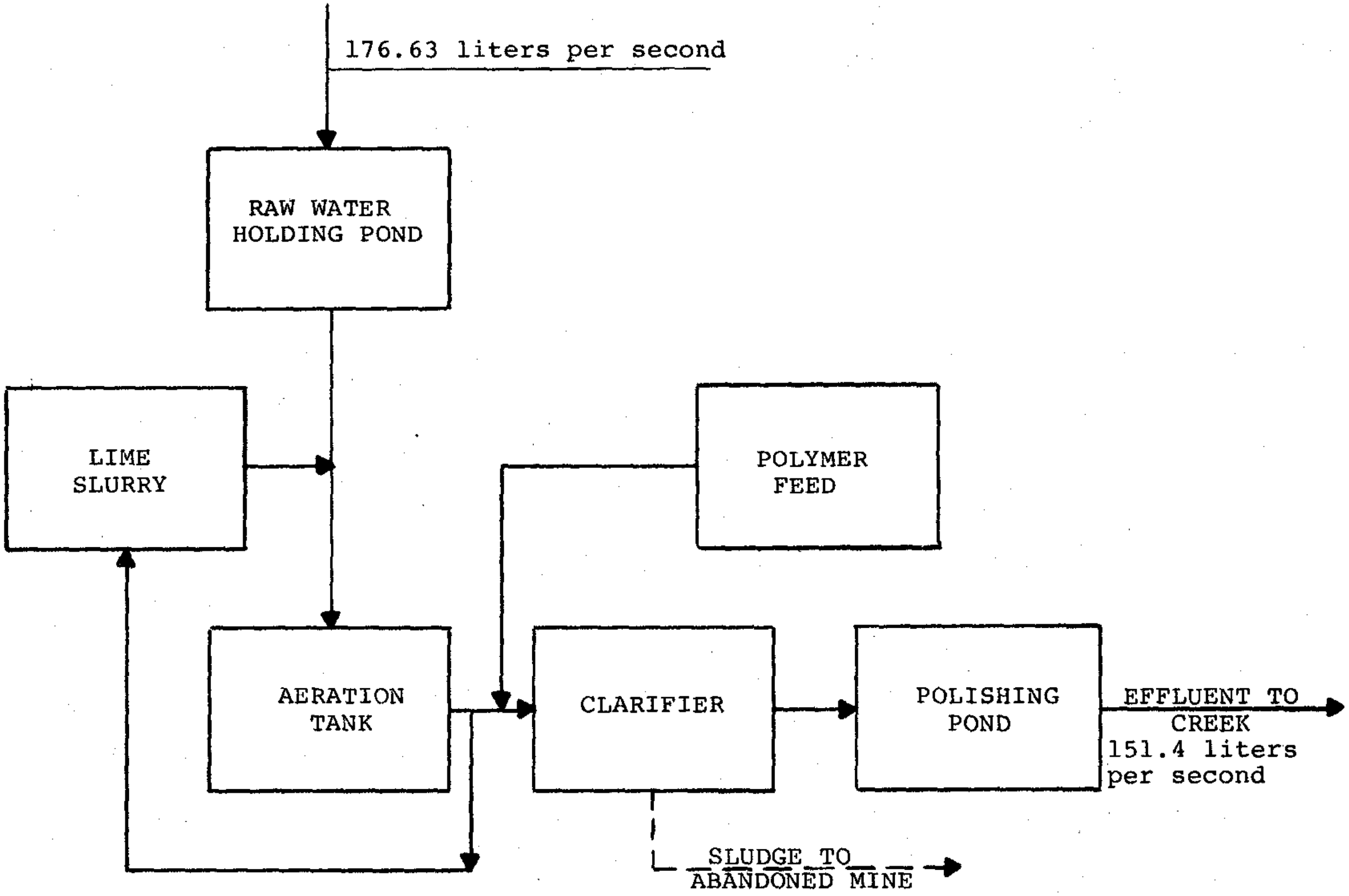
Mine B2 is a large, deep mine located in southwestern Pennsylvania operating in the Pittsburgh coal seam. The mine encompasses an area of 2,633 hectares (6,500 acres) of which 162 hectares (400 acres) remain. The estimated life is about ten years. Coal output is 635 KKG (700 tons) per shift with a recovery of 70 percent. The production rate for 1973 was 498,850 KKG (550,000 tons).

Raw mine drainage is collected at one central point underground and is pumped to the surface at a rate of 176.7 liters per second (2,800 gallons per minute). The analytical quality of the raw and treated mine drainage is shown in Table 11. The treatment provided for discharge point B2-1 includes equalization, lime neutralization, mechanical aeration, primary settling by a mechanical clarifier and effluent polishing in a large 8,176 cubic meters (2.2 million gallon) settling pond. Raw mine drainage is pumped to the equalization pond at 15,261 cu m/day and is neutralized with 19 KKG (21 tons) per day of slaked lime slurry.

A diagram of this treatment sequence appears in Figure 24, and shows capabilities of sludge recirculation; however, the plant's normal operation excludes this as sludge thickening by recirculation was unsuccessful.

FIGURE 24

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE B-2



## Table 11

## Analytical Data - Mine Code B-2

| Constituent | Raw Mine Drainage Point B2-1 Average Quality* | Treated Mine Drainage Point B2-2 Average Quality* |
|---|---|---|
| pH | 2.7 | 6.9 |
| Alkalinity | 0 | 17 |
| Specific Conductance | 5145 | 4080 |
| Solids, total dissolved | 6397 | 4194 |
| Solids, suspended | 183 | 21 |
| Hardness | 1467 | 1920 |
| Iron, total | 412 | 0.15 |
| Iron, dissolved | 95 | 0.06 |
| Manganese, total | 8.8 | 0.47 |
| Aluminum, total | 60 | 0.1 |
| Zinc, total | 1.8 | 0.04 |
| Nickel, total | 0.79 | 0.01 |
| Strontium, total | 1.5 | 3.9 |
| Sulfates | 1453 | 1882 |
| Chloride | 9.2 | 17 |
| Fluoride | 1.05 | 1.41 |
| Ammonia | 35 | 2.9 |
| Chromium, total | 0.09 | 0.01 |
| Copper, total | 0.18 | 0.01 |

*Based on three consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code D-3

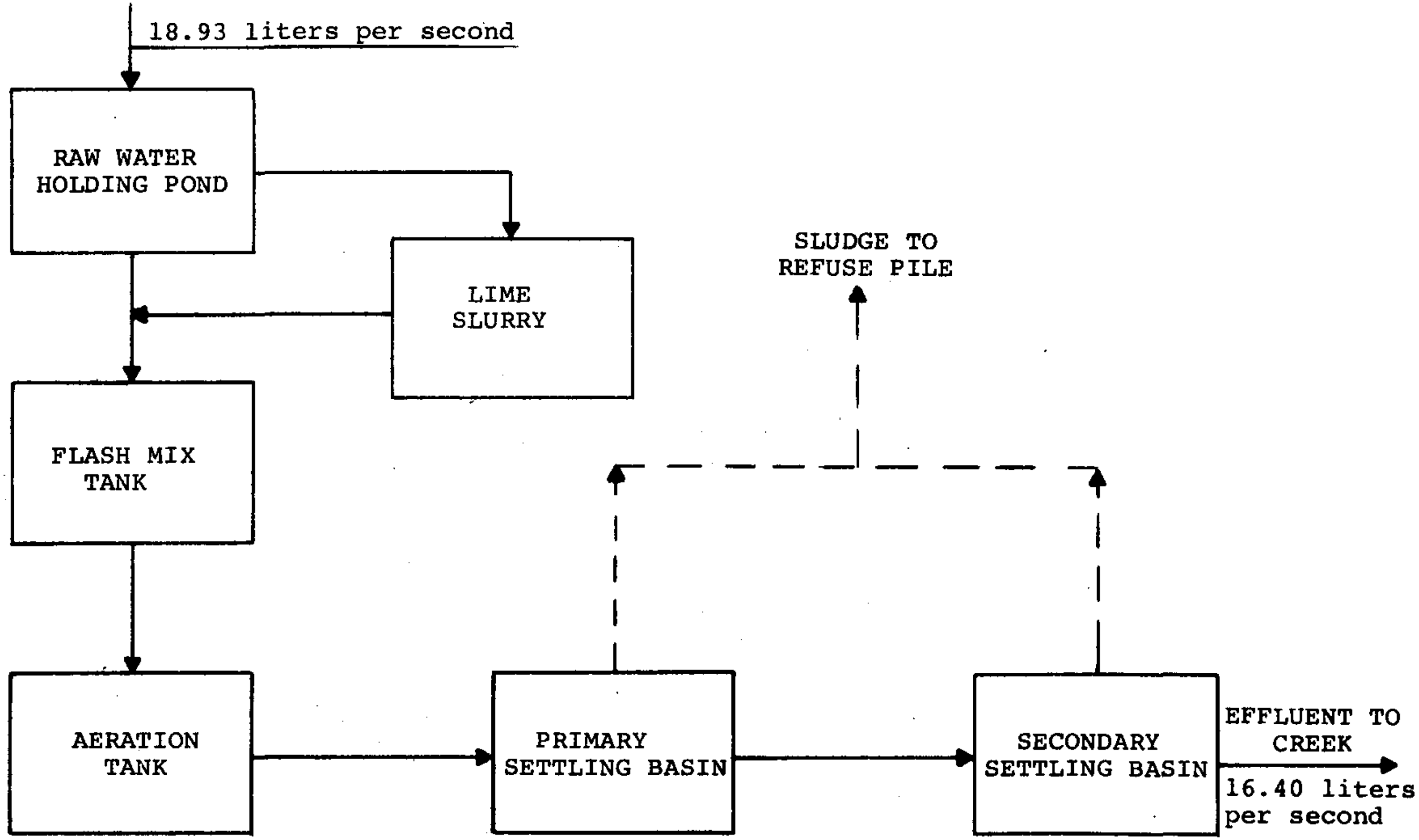
Mine D3 is a deep mine located in northern West Virginia operating in the Pittsburgh (bituminous) coal seam. The mine encompasses 2,680 hectares (6,618 acres), of which 405 hectares (1,000 acres) remain. Coal is mined at the rate of 907 KKG (1,000 tons) per shift with a recovery of about 55 percent. Based on the 1973 production of 671,963 KKG (740,863 tons), the estimated life of the present reserves is 10 years.

The analytical quality of the raw and treated mine drainage is shown in Table 12. Treatment is provided for discharge point D3-1 by a conventional lime neutralization plant that was constructed in 1969. Raw mine drainage is pumped to an 1,893,000 liter (500,000 gallon) holding pond at a rate of 16.4 liters per second (260 gallons per minute), and is then neutralized by mixing with 2.59 KKG per day (2.86 tons per day) of a hydrated lime slurry. The chemically treated water is discharged to a 3,603,320 liter (95,200 gallon) mechanical aeration tank before flowing to two 5,678 cubic meter (1.5 million gallon) settling ponds operated in series.

About once every three months, sludge is pumped from the primary settling basin to the preparation plant refuse impoundment. A diagram of the treatment sequence appears in Figure 25.

FIGURE 25

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE D-3



## Table 12

## Analytical Data - Mine Code D-3

| Constituent | Raw Mine Drainage Point D3-1 Average Quality* | Treated Mine Drainage Point D3-2 Average Quality* |
|---|---|---|
| pH | 5.9 | 7.8 |
| Alkalinity | 22 | 74 |
| Specific Conductance | 2678 | 2855 |
| Solids, total dissolved | 2319 | 2549 |
| Solids, suspended | 287 | 70 |
| Hardness | 890 | 930 |
| Iron, total | 123 | 1.77 |
| Iron, dissolved | 55 | 0.03 |
| Manganese, total | 3.2 | 0.66 |
| Aluminum, total | 15.5 | 0.10 |
| Zinc, total | 0.44 | 0.03 |
| Nickel, total | 0.39 | 0.01 |
| Strontium, total | 2.3 | 2.5 |
| Sulfates | 1394 | 1438 |
| Chloride | 28 | 31.5 |
| Fluoride | 0.54 | 0.83 |
| Ammonia | 3.2 | 1.35 |

*Based on two consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code D-4

Mine D4 is a deep mine located in northern West Virginia operating in the Pittsburgh (bituminous) coal seam. The mine encompasses 7081 hectares (17,485 acres) of which 4,232 hectares (10,450 acres) remain. Coal is mined at a rate of 1,077 KKG (1,187 tons) per shift with a 55 percent recovery. Based on the 1973 production of 742,561 KKG (818,700 tons), the estimated life of the reserves is 100 years.

The treatment provided for discharge point D4-1 is by a conventional lime neutralization plant constructed in 1972. Analytical quality of the raw mine drainage and treated effluent is shown in Table 13. Raw mine drainage is pumped for 18 hours per day at a rate of 15.77 liters per second (250 gallons per minute) directly to a 3,785 liter (1,000 gallon) lime slurry tank. The drainage is neutralized at an average rate of 1,363 cubic meters per day (0.36 MGD) by mixing 1.5 KKG per day (1.66 tons per day) of hydrated lime. Ferrous iron in the drainage is oxidized by a 208,175 cubic meter (55 million gallon) settling basin. This basin has the capacity to provide permanent storage for all sludge for the next ten years of operation. A diagram of this treatment sequence is shown on Figure 26.

FIGURE 26

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE D-4

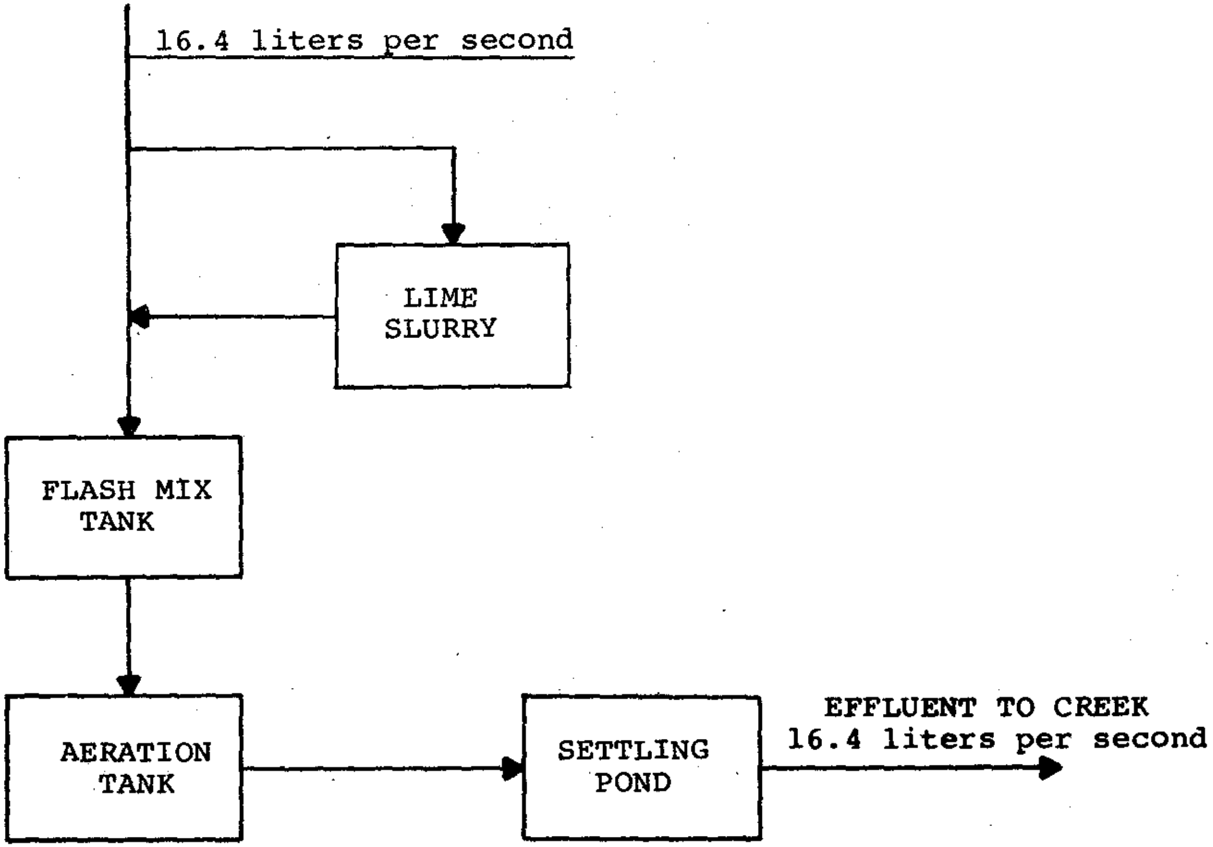


Table 13

Analytical Data - Mine D-4
Acid and Treated Mine Drainage

| Constituent | Acid Mine Drainage Point D4-1 Average Quality* | Treated Mine Drainage Point D4-2 Average Quality* |
|---|---|---|
| pH | 2.6 | 6.8 |
| Alkalinity | 0 | 18 |
| Specific Conductance | 11,780 | 6935 |
| Solids, total dissolved | 15,359 | 6850 |
| Solids, suspended | 621 | 192 |
| Hardness | 1,960 | 1580 |
| Iron, total | 980 | 1.6 |
| Iron, dissolved | 970 | 0.08 |
| Manganese, total | 21 | 0.9 |
| Aluminum, total | 17.4 | 1.1 |
| Zinc, total | 7.2 | 0.06 |
| Nickel, total | 2.6 | 0.01 |
| Strontium, total | 2.6 | 1.9 |
| Sulfates | 7,508 | 3009 |
| Chloride | 115 | -- |
| Fluoride | 0.22 | 1.82 |
| Ammonia | -- | 1.2 |

*Based on three consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code E-6

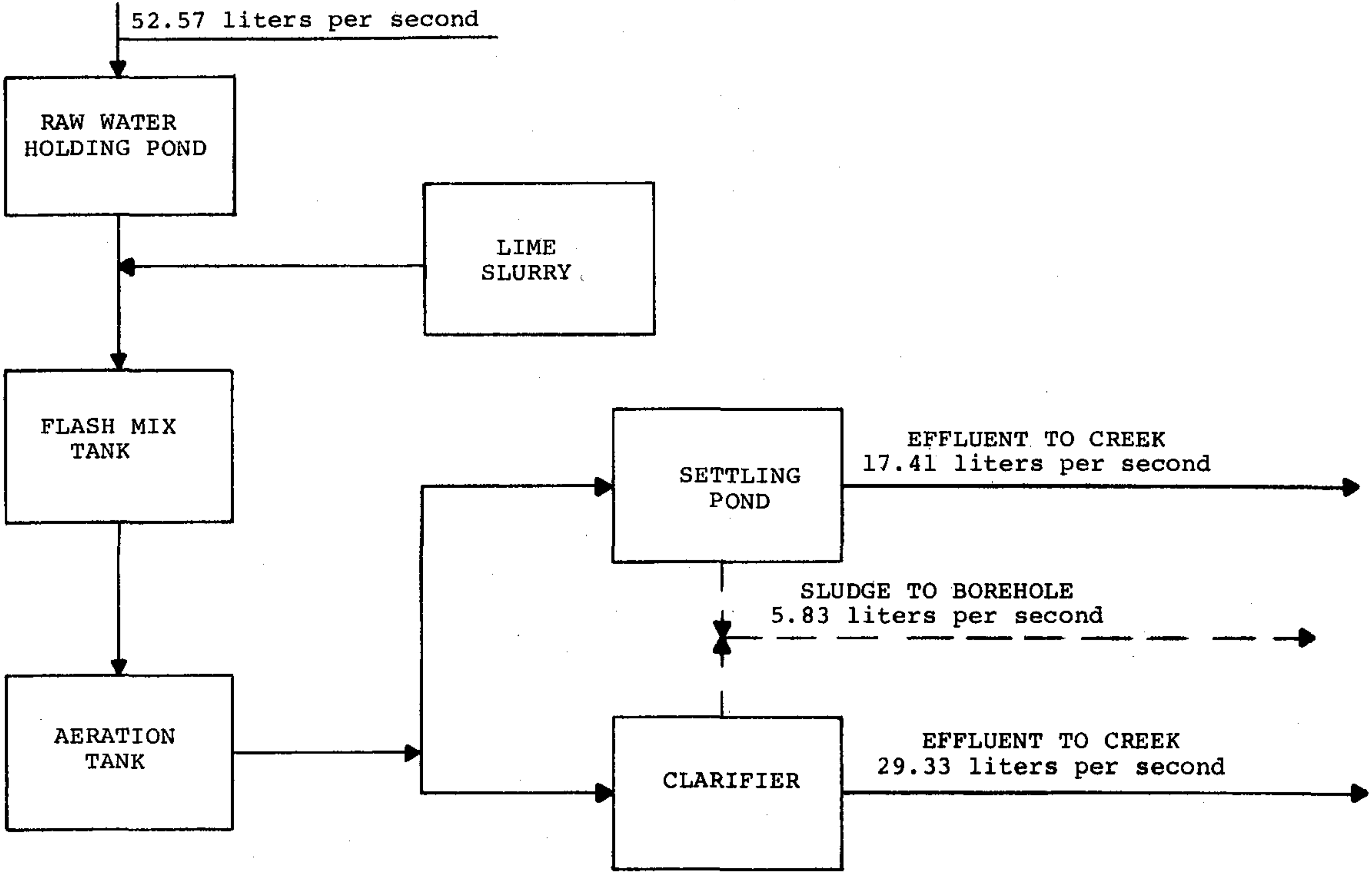
Mine E6 is a deep mine located in central Pennsylvania operating in the Miller "B" or Lower Kittanning (bituminous) coal seam. The mine encompasses 2,273 hectares (5,612 acres), of which 358 hectares (884 acres) remain. Coal is mined at the rate of 735 KKG (810 tons) per shift with a recovery of about 70 percent. Based on the 1973 production of 496,143 KKG (517,045 tons), the estimated life of the present reserve is eight years.

The analytical quality of the two combined and equalized mine discharge points is shown in Table 14. Treatment is provided for these combined discharges by a conventional lime neutralization plant that was constructed in 1969. Acid mine water is pumped on demand from two sections of the mine at a rate of 113.6 liters per second (1,800 gallons per minute) to an 11,355 cubic meter (3 million gallon) holding pond. The drainage is then neutralized at the average rate of 4040 cubic meters per day (1.067 million gallons per day) by mixing with 5.44 KKG per day (6.0 tons per day) of a hydrated lime slurry. The chemically treated mine drainage flow to a 94,625 liter (25,000 gallon) mechanical aeration tank. From here it then splits into two streams; one flows to a 24.4 meter (80 fee diameter clarifier, and the other to a 3786 cubic meter (1 million gallon) pond for settling of the solids. The clarified drainage from both settling facilities is then discharged directly to the nearby surface stream. Sludge removed from the clarifier is pumped into old mine workings through a bore hole. It should be noted that the settling pond effluent quality was below average due to short circuiting caused by sludge accumulation.

A diagram of the treatment sequence appears in Figure 27, while analytical data for this facility is presented in Table 14.

FIGURE 27

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE E-6



## Table 14

## Analytical Data - Mine Code E-6

| Constituent | Raw Mine Drainage Point E6-1 Average Quality* | Treated Mine Drainage Points E6-2, E6-3 Average Quality** | |
|---|---|---|---|
| | | Thickener | Pond |
| pH | 2.7 | 8.2 | 4.0 |
| Alkalinity | 0 | 29 | 5 |
| Specific Conductance | 5105 | 3625 | 3688 |
| Solids, total dissolved | 6337 | 4240 | 4395 |
| Solids, suspended | 357 | 11 | 258 |
| Hardness | 1740 | 2590 | 2520 |
| Iron, total | 760a | 1.34 | 18.4 |
| Iron, dissolved | 760 | 0.26 | 12.9 |
| Manganese, total | 7.0a | 0.55 | 1.7 |
| Aluminum, total | 66.0a | 0.75 | 0.59 |
| Zinc, total | 2.3a | 0.02 | 0.10 |
| Nickel, total | 0.66a | 0.05 | 0.14 |
| Strontium, total | 0.59a | 1.60 | 1.75 |
| Sulfates | 3478 | 2141 | 2168 |
| Chloride | 15 | 13 | 11.5 |
| Fluoride | 1.67 | 0.94 | 0.64 |
| Ammonia | 7.0a | 5.6 | 4.2b |
| Chromium, total | 0.05a | 0.07 | 0.01 |

*Based on two consecutive daily grab samples.

**Based on two consecutive 24-hour composite samples.

a. Based on one grab sample.

b. Based on one 24-hour composite sample. All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

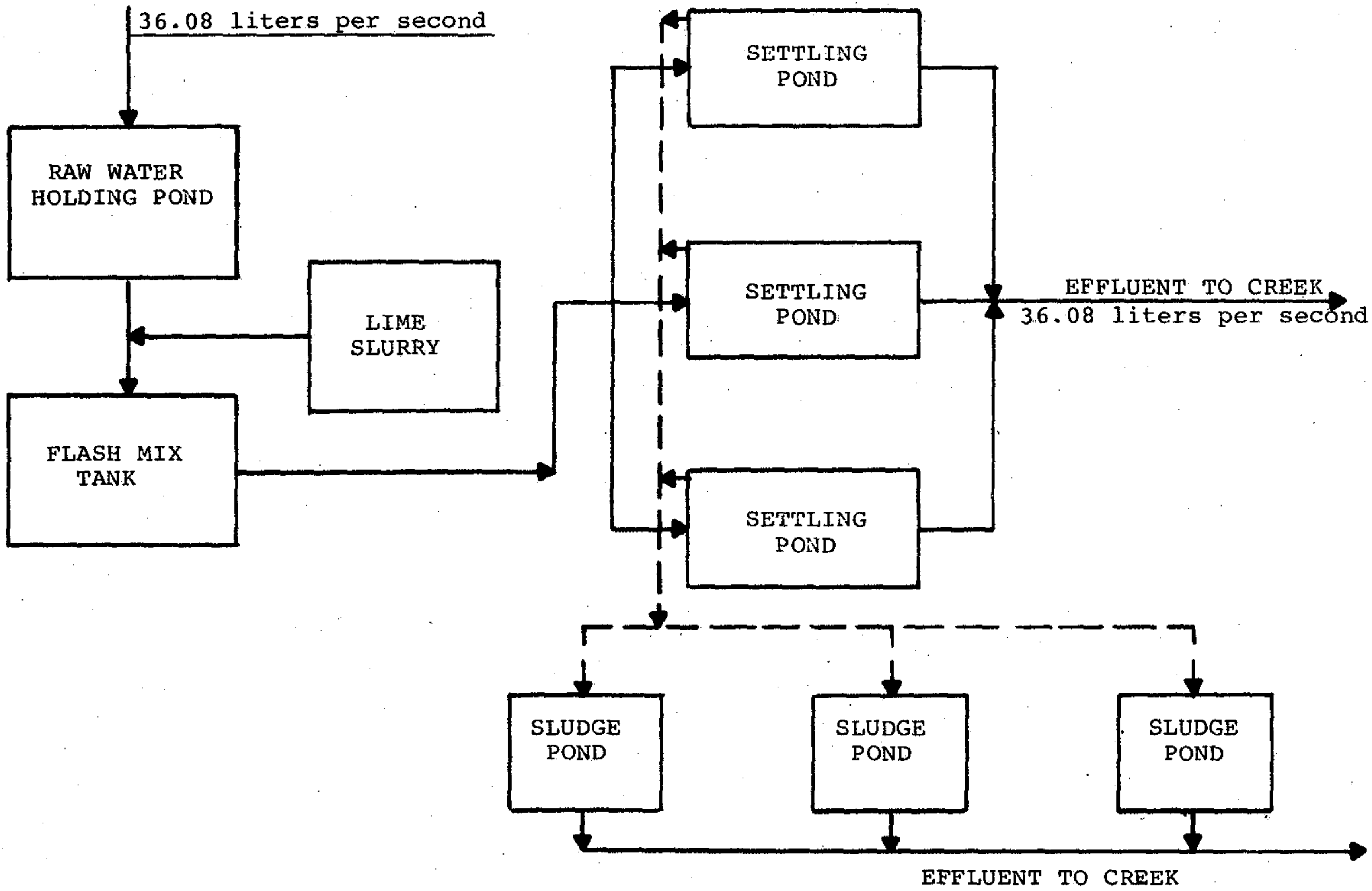
## Mine Code F-2

Mine F2 is a deep mine located in central Pennsylvania operating in the Lower Kittanning (bituminous) coal seam. The mine encompasses 2,289 hectares (5,655 acres), and coal is mined at the rate of 1,133 KKG (1,249 tons) per shift with a recovery of about 70 percent. Based on the 1973 production of 779,280 KKG (859,184 tons), the estimated life of the present reserves is 33 years.

Treatment is provided for this discharge point by a conventional lime neutralization plant that was constructed in 1967. Raw water is pumped on demand to a 2,120,000 liter (560,000 gallon) holding pond. Drainage is then neutralized at the average rate of 3,119 cubic meters per day (.824 million gallons per day) by mixing with 4.44 KKG per day (4.9 tons per day) of a hydrated lime slurry. The chemically treated water is naturally aerated in a short baffled trough then discharged into one of three settling basins, each having capacities of 7,192 cubic meters (1.9 million gallons). Each basin is used until a substantial amount of sludge accumulates, then the flow is directed to one of the others while the sludge is pumped to one of three 1,115 square meter (12,000 square fee sludge drying ponds. Additional sludge ponds are to be constructed as needed. Any overflow from these flows directly to the stream.

A diagram of the treatment sequence appears in Figure 28, and analytical data is presented in Table 15.

FIGURE 28
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE F-2



## Table 15

## Analytical Data - Mine Code F-2

| Constituent | Raw Mine Drainage Point F2-1,3 Average Quality* | Treated Mine Drainage Point F2-4 Average Quality** |
|---|---|---|
| pH | 2.5 | 7.9 |
| Alkalinity | 0 | 30 |
| Specific Conductance | 4465 | 3400 |
| Solids, total dissolved | 5433 | 3638 |
| Solids, suspended | 45 | 8 |
| Hardness | 1320 | 2640 |
| Iron, total | 380 | 1.0 |
| Iron, dissolved | 370 | 0.02 |
| Manganese, total | 4.3 | 0.12 |
| Aluminum, total | 54 | 1.8 |
| Zinc, total | 5.4 | 0.08 |
| Nickel, total | 2.0 | 0.08 |
| Strontium, total | 0.76 | 2.4 |
| Sulfates | 2942 | 2324 |
| Chloride | 17 | 28 |
| Fluoride | 0.54 | 0.58 |
| Ammonia | 14.9 | 6.9 |
| Chromium, total | 0.05 | 0.03 |
| Copper, total | 0.67 | 0.01 |

*Based on two consecutive 24 hour composite samples.

**Based on one 24 hour composite sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, mercury, molybdenum, lead, and selenium, but these were not detected in significant concentrations.

## Mine Code K-6

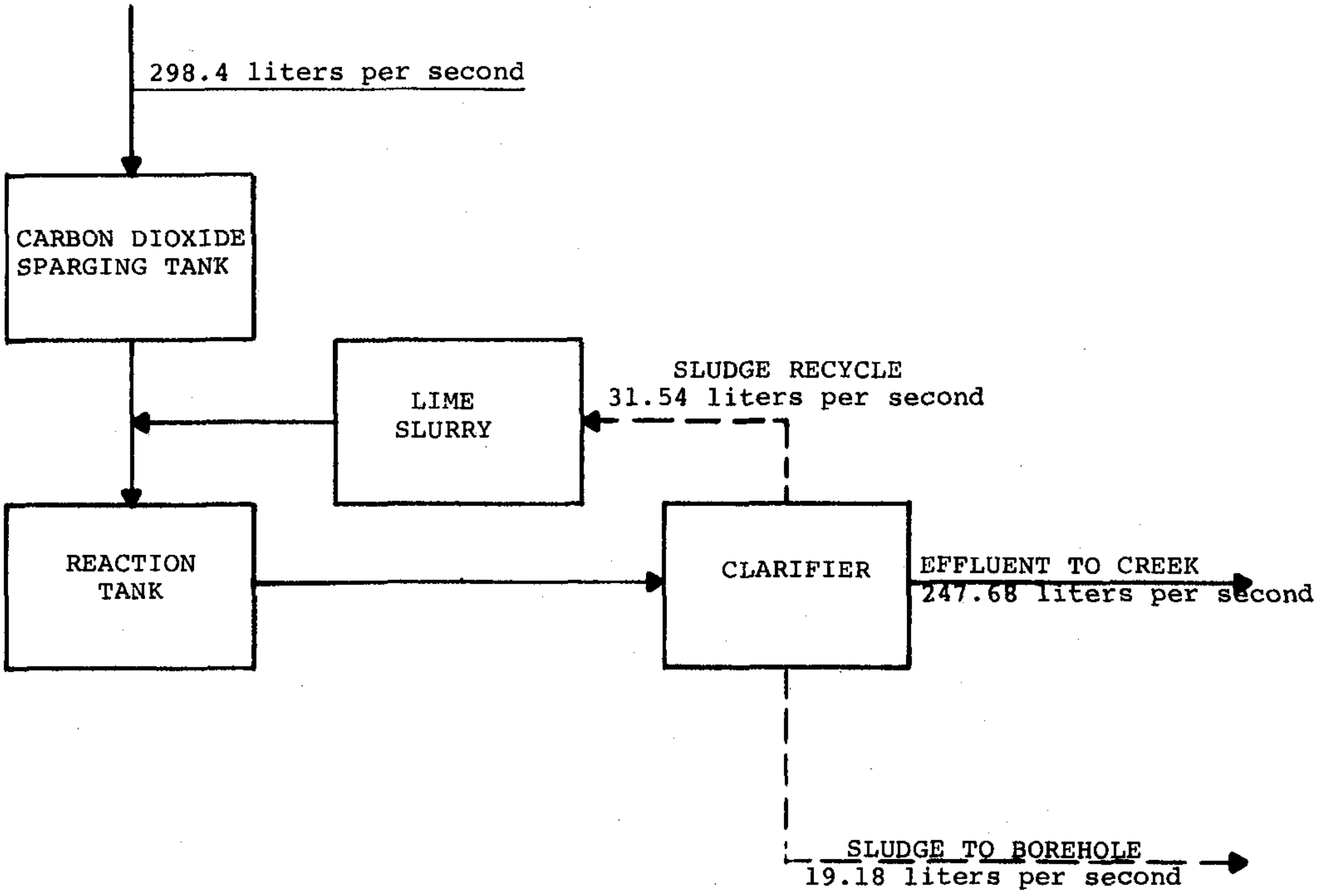
Mine K6 represents a deep mine located in central Pennsylvania operating in the Lower Kittanning (bituminous) coal seam. The mine encompasses 24,098 hectares (59,500 acres), of which 9,477 hectares (23,400 acres) remain. Coal is mined at the rate of 1,938 kkg (2,137 tons) per shift, with a recovery of about 63 percent. Based on the 1973 production of 1,371,967 kkg (1,512,643 tons), the estimated life of the present reserves is 60 years.

Treatment is provided for the raw mine drainage by a lime neutralization plant that was constructed in 1971. Sludge recycle is employed to reduce the final sludge volume requiring disposal.

Raw mine drainage is pumped continuously from an underground sump directly into a carbon dioxide sparging tank at a rate of 233.5 liters per second (3,700 gallons per minute) during the weekdays. Over the weekend the flow rate is increased to 466.9 liters per second (7,400 gallons per minute). The overflow from the sparging tank enters to a 1,021,950 liter (27,000 gallon) aeration tank where it is neutralized with a lime slurry conditioned with recycled sludge. The chemically treated water then overflows to a 54.9 meter (180 fee diameter clarifier. Sludge from the clarifier is recycled back to the lime slurry mix tank at a rate of 31.55 liters per second (500 gallons per minute) while any excess is pumped to an abandoned section of a deep mine.

A diagram of the treatment sequence appears in Figure 29, and analytical data is presented in Table 16.

FIGURE 29
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE K-6



## Table 16

## Analytical Data - Mine Code K-6

| Constituent | Raw Mine Drainage Point K6-1 Average Quality* | Treated Mine Drainage Point K6-2 Average Quality** | |
|---|---|---|---|
| | | WkDay | WkEnd |
| pH | 2.9 | 7.9 | 7.5 |
| Alkalinity | 0 | 51 | 96 |
| Specific Conductance | 2361 | 2193 | 2258 |
| Solids, total dissolved | 2367 | 2292 | 2222 |
| Solids, suspended | 136 | 5 | 17 |
| Hardness | 560 | 910 | 970 |
| Iron, total | 87.8 | 1.7 | 7.4 |
| Iron, dissolved | 82.8 | 0.05 | 0.17 |
| Manganese, total | 3.15 | 0.25 | 3.05 |
| Aluminum, total | 15.3 | 0.70 | 1.0 |
| Zinc, total | 0.62 | 0.02 | 0.55 |
| Nickel, total | 0.46 | 0.02 | 0.15 |
| Strontium, total | 0.26 | 0.67 | 0.70 |
| Sulfates | 1150 | 985 | 1100 |
| Chloride | 12.8 | 18.5 | 16.5 |
| Fluoride | 0.44 | 0.53 | 0.36 |
| Ammonia | 11.6 | 2.15 | 3.0 |
| Selenium, total | 0.04 | 0.08 | 0.06 |

*Based on four consecutive 24 hour composite samples.

**Based on two consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, and lead, but these were not detected in significant concentrations.

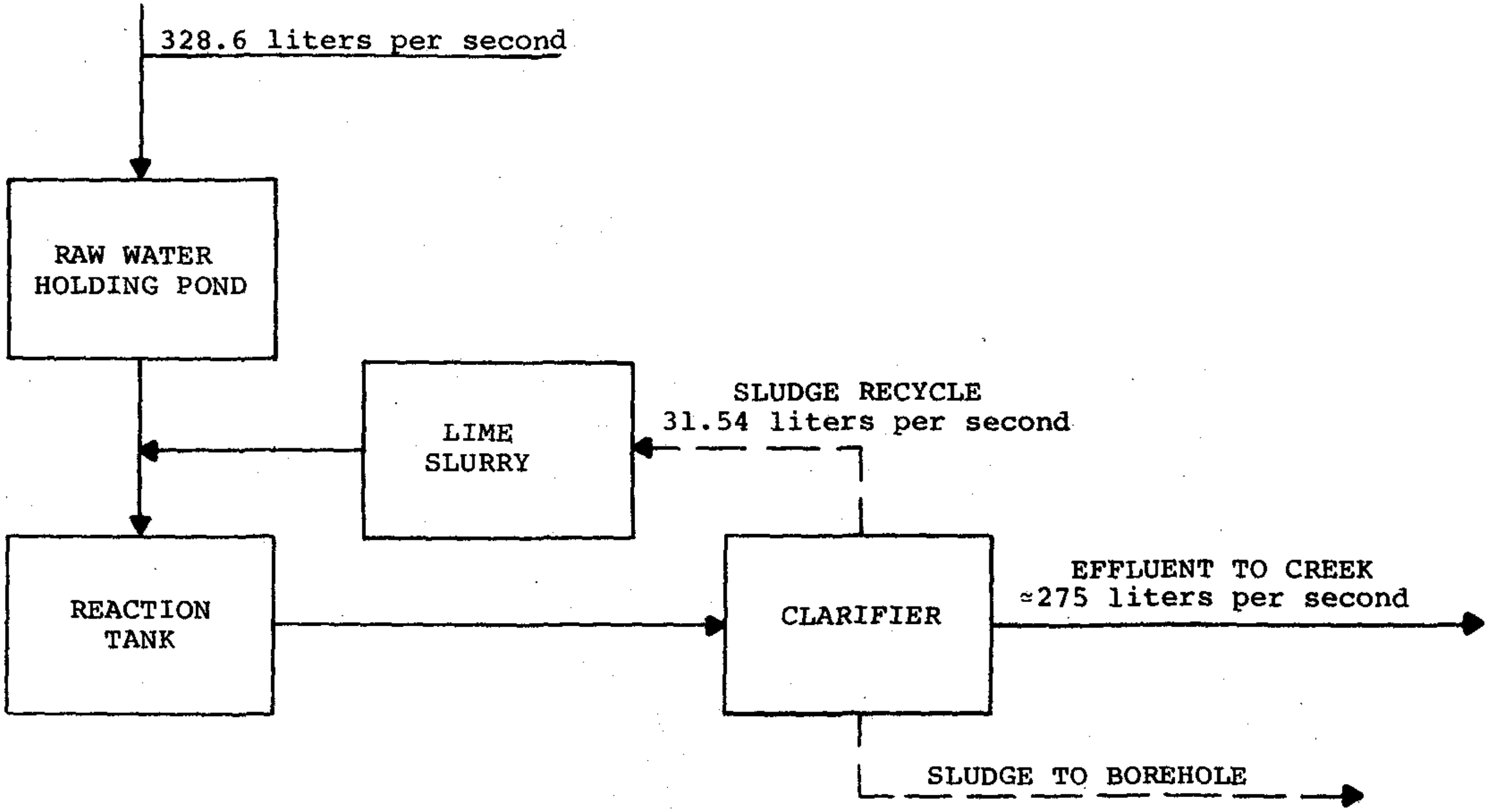
## Mine Code K-7

Mine K7 is a deep mine located in central Pennsylvania operating in the Lower Kittanning coal seam. The mine totals 5,073 hectares (12,527 acres) of which 790 hectares (1,950 acres) remain. Based on the 1973 production of 342,896 kkg (378,000 tons), the mines estimated life expectancy is 32 years.

Raw mine drainage collected underground is pumped through a bore hole to a 3,785 cubic meter (1 million gallon) holding pond. The drainage is treated by lime neutralization at an average flow of 332.4 liters per second (5,268 gallons per minute). Sludge recycle is employed to reduce the final sludge volume requiring disposal. The holding pond overflow proceeds to a 151,400 liter (40,000 gallon) reaction tank where it is neutralized with lime slurry conditioned with recycled sludge. The lime usage is 13.6 kkg (15 tons) per day. The neutralized drainage flows into a 57.9 meter (190 ft) diameter clarifier. Sludge from the clarifier is recycled back to the lime slurry mix tank at a rate of 31.55 liters per second (500 gallons per minute) while any excess is pumped to an abandoned section of deep mine.

A diagram of the treatment facility appears in Figure 30, and analytical data appears in Table 17.

FIGURE 30
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE K-7



## Table 17

## Analytical Data - Mine Code K-7

| Constituent | Raw Mine Drainage Point K7-1 Average Quality* | Treated Mine Drainage Point K7-2 Average Quality* |
|---|---|---|
| pH | 2.5 | 8.8 |
| Alkalinity | 0 | 35 |
| Specific Conductance | 2338 | 2103 |
| Solids, total dissolved | 4115 | 2837 |
| Solids, suspended | 69 | 10 |
| Hardness | 815 | 1600 |
| Iron, total | 802 | 1.8 |
| Iron, dissolved | 32 | 0.03 |
| Manganese, total | 4.25 | 0.03 |
| Aluminum, total | 42 | 1.0 |
| Zinc, total | 2.0 | 0.02 |
| Nickel, total | 1.0 | 0.01 |
| Strontium, total | 0.4 | 1.95 |
| Sulfates | 1550 | 1450 |
| Chloride | 5 | 10 |
| Fluoride | 0.38 | 0.61 |
| Ammonia | 15 | 4.3 |
| Copper, total | 0.2 | 0.01 |

*Based on two consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

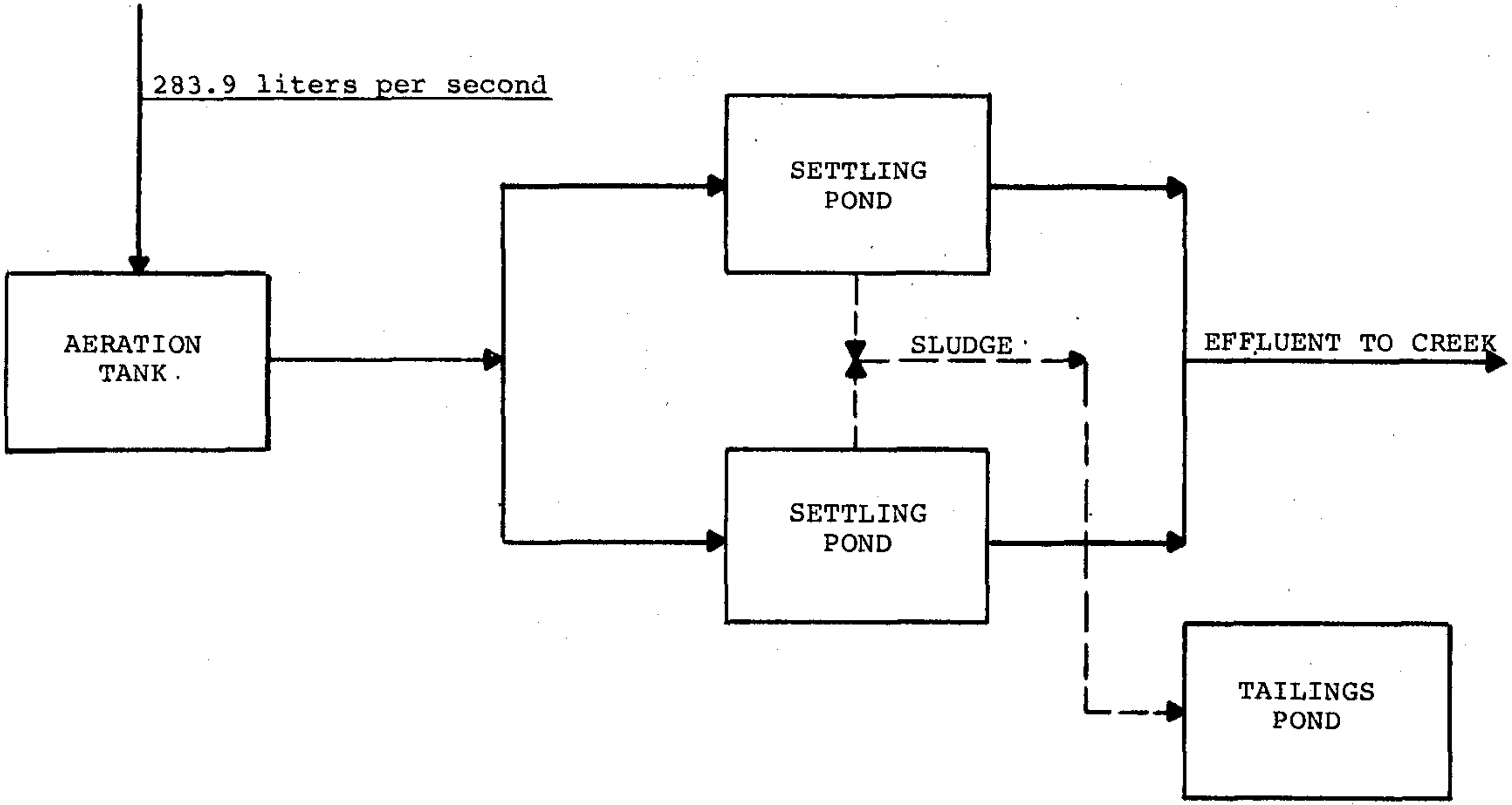
### Mine Code D-1

Mine D1 is a deep mine located in southwestern Pennsylvania operating in the Pittsburgh (bituminous) coal seam. The mine encompasses 4050 hectares (10,000 acres) of which 648 hectares (1,600 acres) remain. Coal is mined at the rate of 907 KKG (1,000 tons) per shift, with a recovery of about 78 percent. Based on the 1973 production of 604,733 KKG (777,740 tons), the estimated life of the present reserves is 15 years.

The drainage from Mine D1 does not require neutralization. Treatment is provided by an aeration/sedimentation process that was constructed in 1968. The average flow of drainage passing through the treatment system is 24,603 cubic meters per day (6.5 million gallons per day). The mine discharge water is pumped directly to a 2,668,000 liter (705,000 gallon) mechanical aeration tank. Following aeration, a coagulant aid is added to promote settling. The overflow from the aeration tank then flows into two 13,250 cubic meter (3.5 million gallon) settling basins operating in parallel, before being discharged. Each basin provides a detention of eight hours at the average flow. Periodically one of the two settling basins is taken out of operation while the sludge is pumped to a nearby tailings pond for final disposal.

A schematic diagram of the treatment plant appears in Figure 31. Average raw and effluent analyses of samples collected at this treatment plant are presented in Table 18.

FIGURE 31
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE D-1



## Table 18

## Analytical Data - Mine Code D-1

| Constituent | Raw Mine Drainage Point D1-1 Average Quality* | Treated Mine Drainage Point D1-4 Average Quality** |
|---|---|---|
| pH | 7.7 | 8.0 |
| Alkalinity | 243 | 607 |
| Specific Conductance | 4210 | 4168 |
| Solids, total dissolved | 3744 | 3134 |
| Solids, suspended | 668 | 164 |
| Hardness | 1133 | 500 |
| Iron, total | 69.3 | 4.37 |
| Iron, dissolved | 67.6 | 0.02 |
| Manganese, total | 4.19 | 1.93 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.04 | 0.04 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 3.07 | 2.36 |
| Sulfates | 1726 | 1322 |
| Chloride | 258 | 340 |
| Fluoride | 0.68 | 0.80 |
| Ammonia | 6.0 | 1.76 |

*Based on three consecutive daily grab samples.

**Based on three consecutive 24-hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

## Mine Code D-5

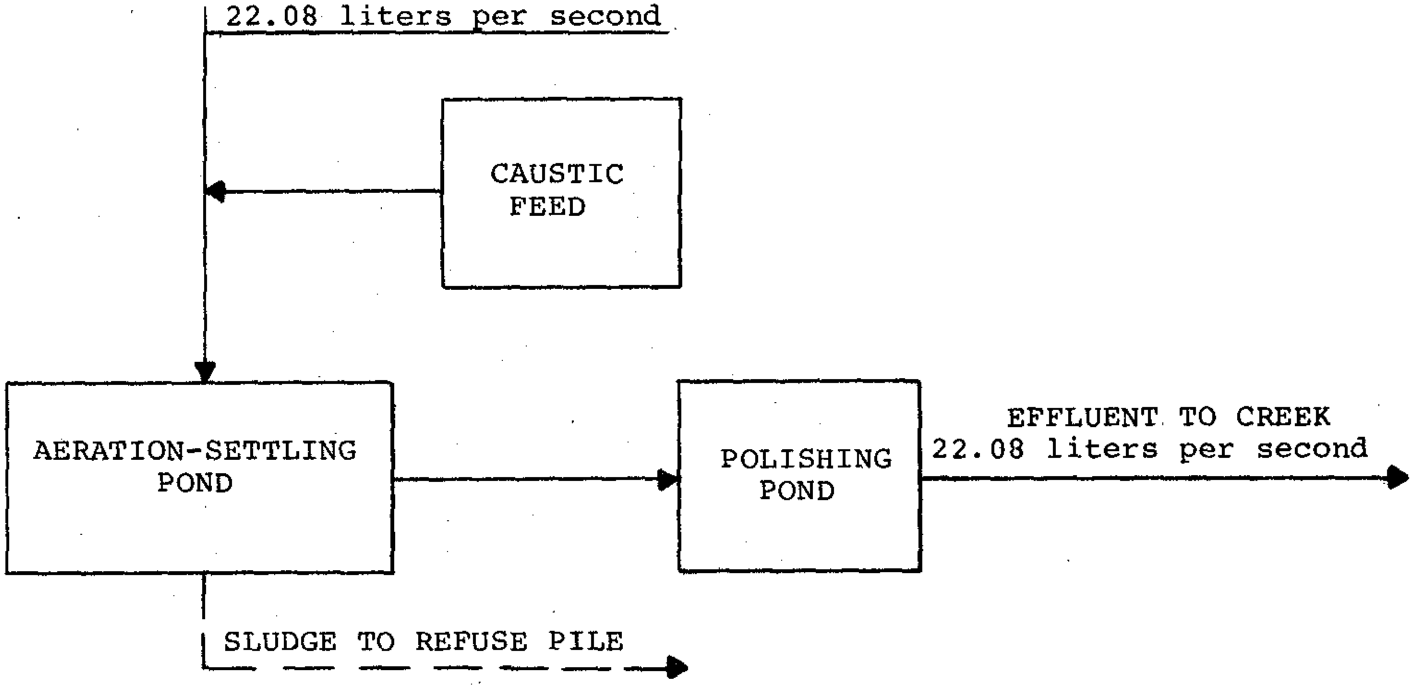
Mine D5 is a deep mine located in northern West Virginia that operates in the Pittsburgh coal seam which is 3.465 meters (88 inches) thick. The exact size of the mine is unknown but it's estimated that the mineable coal will remain for another 20 years' life. The 1973 coal production was 641,342 KKG (707,323 tons) but the mine was severely damaged by a fire in January, 1974 and no coal has been mined since this date. Projected estimated re-opening of the mine is sometime in the first quarter of 1975.

The mine has one major point of dewatering pumped at a rate of 22 liters per second (350 gallons per minute). The analytical quality of the raw and treated mine drainage are presented in Table 19. Treatment of the raw mine drainage consists of sodium hydroxide neutralization, mechanical aeration, and primary and secondary settling. The two settling ponds operating in series have capacities of 15,140 cubic meters (4 million gallons) and 5,677 cubic meters (1.5 million gallons) respectively, which provides for a total theoretical detention of eleven days.

Sludge handling involves cleaning of the primary settling pond approximately once every three years with final disposal atop a refuse pile. The treatment facility is expected to last for the life of the mine. A diagram of this treatment sequence is shown in Figure 32.

FIGURE 32

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE D-5



## Table 19

### Analytical Data - Mine Code D-5
### Raw and Treated Mine Drainage

| Constituent | Raw Mine Drainage Point D5-1 Average Quality* | Treated Mine Drainage Point D5-2 Average Quality* |
|---|---|---|
| pH | 6.35 | 7.7 |
| Alkalinity | 104 | 162 |
| Specific Conductance | 6018 | 6528 |
| Solids, total dissolved | 6348 | 6314 |
| Solids, suspended | 345 | 24 |
| Hardness | 1420 | 1390 |
| Iron, total | 140 | 2.5 |
| Iron, dissolved | 140 | 0.02 |
| Manganese, total | 16 | 2.8 |
| Aluminum, total | 5.5 | 0.1 |
| Zinc, total | 0.24 | 0.05 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 3.7 | 3.95 |
| Sulfates | 3217 | 3414 |
| Chloride | 650 | 625 |
| Fluoride | 1.2 | 1.49 |
| Ammonia | 7.6 | 3.3 |

*Based on three consecutive 24 hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated mine drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

Other treatment processes evaluated for possible inclusion in BPT, BAT, NSPS for acid or ferruginous mine drainage are:

### Limestone-Lime Neutralization

Limestone treatment is claimed to have several advantages over the use of lime; (1) it gives a higher density, lower volume sludge, (2) it is more economical, (3) it is less toxic and therefore easier to handle, and, (4) it eliminates potential pollution by accidental overtreatment. Limestone however, is rarely used because of two main disadvantages; first, it's relatively inefficient rate of reaction results in lime being more economical and reliable. Secondly, limestone is usually unable to produce pH's higher than 7.0 which are necessary for rapid ferrous iron oxidation and precipitation of heavy metals such as aluminum, manganese, zinc, and nickel.

In an effort to combine the advantages of both limestone and lime, a combination neutralization process has been developed to attain a more economical method of acid mine drainage treatment. This process uses the same unit operations as the conventional neutralization process with the exception that the addition of neutralization chemicals occurs in two stages. Since limestone is highly reactive at low pH's, it is added first to the acid mine drainage until a pH of 5.0 to 5.5 is reached. Lime is then used to increase the pH to the level desired. In this process, both limestone and lime are used in their most efficient ranges of reactivity. Utilization of limestone's lower cost results in an overall cost reduction of the combination as compared to either reagent alone. An improvement in sludge characteristics has also been evidenced in this process. The resultant sludge contains 6 to 8 percent solids as compared to 1 to 2 percent solids in lime neutralization sludge. Treated water quality by both the lime and limestone-lime processes is comparable.

It is important to note that the combination treatment is not economically advantageous on all mine waters. A lime to limestone cost ratio of 1.8/1.0 is the break-even point for treating acid mine drainage where an economic advantage would not be achieved by using limestone-lime rather than with lime alone. As this ratio increases, so does the cost advantage of the combination limestone-lime treatment.

### Reverse Osmosis and Neutrolosis Systems

The use of the reverse osmosis systems for the treatment of acid mine drainage has been investigated in studies sponsored by the Environmental Protection Agency. Recoveries of 50 percent to 75 percent of the feed water rate have been obtained with most mine drainages tested. Problems have resulted from membrane module fouling from suspended matter in the feed water, and chemically from the formation of calcium sulfate and iron compounds. Suspended solids can be adequately removed by 20 micron filters; however, chemical fouling problems usually necessitate lower recovery rates with blending of the product and feed waters.

Reverse osmosis is not selective to the removal of specific chemical compounds. The product water will be of low dissolved solids, usually less than 100 mg/l, but it will also have a low pH and may contain iron, manganese, and other parameters in excess of allowable discharge levels. This may necessitate additional product water treatment.

It is also important to consider the means for disposal of the brine from a reverse osmosis system. While the volume may be small, the brine will contain all of the constituents rejected by the membranes at many times their original concentrations in the feed water. The Environmental Protection Agency developed the unique "Neutrolosis Treatment Process" which incorporates a total package concept for using reverse osmosis with proper disposal of the brine and other waste products.

The <u>Neutrolosis</u> Process consists of the basic reverse osmosis system and lime neutralization facilities for chemical treatment of the brine. In this manner, many constitutents such as; iron, manganese, aluminum, and other metals will be almost totally removed by chemical precipitation. Other parameters such as calcium, magnesium, and sulfate will be reduced. The treated water from the neutralization stage of the system is then recycled to the R-O feed water stream. Thus, the total system produces only good quality product water and a sludge.

Costs for treating acid mine drainage by reverse osmosis or neutrolosis are not readily available. Estimated costs therefore have been developed based on the application of reverse osmosis in other fields. Published operating costs of $0.079 to $0.106 per cubic meter ($0.30 to $0.40 per thousand gallons) are common for treating brackish waters at feed recoveries of about 90 percent. These costs are all-inclusive for manpower, chemicals, power, depreciation, etc. Since feed recoveries of 90 percent cannot be expected when treating acid mine drainage additional R-O equipment will be needed to produce the same volume of product water.

Therefore, operating costs have been increased by 100 percent for estimating purposes.

In addition to the cost of operation of a reverse osmosis system is the cost for the neutralization facilities for the brine stream. Operating costs of from $.027 to $.106 per cubic meter ($0.11 to $0.40 per thousand gallons) were obtained for the plants discussed in Section VIII. An operating cost of $.079 per cubic meter ($0.30 per thousand gallons) will be used here for a low volume-high acidity drainage. Based on these estimates, total operating costs of approximately $.27 per cubic meter ($1.10 per thousand gallons) should be considered.

## Lime-Soda Softening

The precipitation method for softening water takes advantage of the low solubilities of calcium and magnesium compounds to remove these hardness causing cations from solution. Calcium is precipitated as calcium carbonate by increasing the carbonate concentration in a water. Similarly, magnesium is precipitated by increasing the hydroxide concentration. While many chemicals can be used to produce the excess carbonate or hydroxide ion concentrations to bring about these precipitations, economics has dictated that the best materials are lime and soda ash.

For applying this treatment to mine drainage or waters affected by mine drainage, the first four unit processes are the same as for conventional lime neutralization; that is , raw drainage equalization, acidity neutralization with lime (to pH 10.8), iron oxidation, and solids removal. The additional unit processes required to complete lime-soda ash softening are described herein. It is important to point out that this treatment process does not greatly change the total dissolved solids of the water; it only replaces the calcium ion with sodium. Other compounds such as sulfate are also unaffected.

Softening. Primary effluent water at pH 10.8 will contain the original non-carbonate calcium hardness, the non-carbonate calcium hardness formed during lime treatment, the calcium hardness due to excess lime addition, and some residual magnesium hardness. Soda ash is then added to remove nearly all of the calcium hardness by precipitation as the insoluble carbonate.

Solids Removal. Following soda ash addition, sedimentation is required to remove the suspended matter formed, which consists mostly of calcium carbonate.

<u>Recarbonation</u>. The softened effluent is usually supersaturated with calcium carbonate and carbon dioxide is added to convert some of the carbonate to bicarbonate. This lowers the carbonate concentration and pH to a level at which no further precipitation of calcium carbonate will occur once the water leaves the plant.

The Pennsylvania Department of Environmental Resources has constructed a water treatment plant near the city of Altoona that employs the Lime-Soda Process to chemically soften a water supply affected by acid mine drainage. The plant only recently was placed in operation and as yet the treated water is not being discharged into the city's water supply.

## <u>Ion Exchange Process</u>

Ion exchange in water treatment is defined as the reversible interchange of ions between a solid medium and the aqueous solution. To be effective, the solid ion exchange medium must contain ions of its own, be insoluble in water, and have a porous structure for the free passage of water molecules. Within the solution and the ion exchange medium, a charge balance or electroneutrality must be maintained; i.e., the number of charges, not the number of ions, must stay constant. Ion exchange materials usually have a preference for multivalent ions; therefore, they tend to exchange their monovalent ions. This reaction can be reversed by increasing the concentration of monovalent ions. Thus, a means exists to regenerate the ion exchange material once its capacity to exchange ions has been depleted.

In the present day technology of ion exchange, the resins available can be classified as strong-acid cation, weak-acid cation, strong-base anion, and weak-base anion types. Combinations of the available resins have been used in systems for treatment of different waters for specific purposes. The applications of these systems to the treatment of mine drainage has been studied mainly to produce potable water where a reduction in the total dissolved solids is required. Processes developed include the Sul-biSul Process and the Modified Desal Process.

<u>Sul-biSul Process</u>. This process employs a two or three bed system. Cations are removed by a strong acid resin in the hydrogen form, or by a combination of weak acid and strong acid resins. Following this, the effluent water is decarbonated to remove carbon dioxide formed in the process. Then a strong-base anion resin operates in the sulfate to bisulfate cycle and removes both sulfate and hydrogen ions during the exchange reaction. The effluent is filtered

according to Public Health Regulations before use as a potable water.

Regeneration of the cation exchange bed is accomplished with either hydrochloric or sulfuric acid. In the regeneration of the anion bed, bisulfate ions are converted back to the sulfate form by the feed water. The addition of lime slurry to the regenerant will speed this part of the process.

The Sul-biSul Process can be used to demineralize brackish water containing predominantly sulfate anions. It can be applied to waters with a dissolved solids content of up to 3,000 mg/l. The raw water should have an alkalinity content of about 10 percent of the total anion content with a sulfate to chloride anion ratio of at least ten to one. This water must be sufficiently alkaline and abundant so that it may be used as a regenerant and then discharged to the stream. If the raw water cannot be used as the anion bed regenerant, other alkalis must be employed. When this is necessary, all tests have indicated that there is a negative net production of water.

A water treatment plant using this process has been constructed at Smith Township, Pennsylvania; however, operational problems with the continuous ion exchange regeneration equipment have prevented its use.

<u>Modified Desal Process</u>. This process uses a weak base anion resin in the bicarbonate form to replace sulfate or other anions, as well as free mineral acidity. The solution of metal bicarbonates is aerated to oxidize ferrous iron to the ferric form and to purge the carbon dioxide gas. The effluent is then treated with lime to precipitate metal hydroxides, settled to remove suspended solids, then filtered if to be used as a potable supply.

Ammonia is used as the alkaline regenerant to displace sulfate from the exhausted resin. Lime is used to precipitate calcium sulfate from the regeneration wastes and to release the ammonia regenerant for reuse. In this way, ammonia is recycled in the process. It is possible to recover the carbon dioxide and lime used in this process by roasting lime sludge wastes in a kiln. In this manner, the principal chemicals used in the process can be recovered to some extent, with only potable water, and an iron hydroxide, calcium sulfate sludge being the resultant products.

The Modified Desal Process is not limited by total dissolved solids or pH levels; however, large quantities of carbon dioxide are required to achieve good resin utilization for high total dissolved solids or alkaline feed waters. The process is limited in application to waters containing less than 2,200 parts per million of sulfate. Another limitation is that mine waters containing iron in the ferric form may cause fouling of the anion bed because of precipitation of ferric hydroxide.

A demonstration plant for treatment of acid mine drainage by the Modified Desal Process has been constructed by the Pennsylvania Department of Environmental Resources at Hawk Run near Philipsburg, Pennsylvania. The purpose of this plant is to provide a drinking water supply. Operating data for this plant is not available.

### Alakline Mine Drainage

Alkaline mine drainage can be encountered in any coal mine region, but is found infrequently in the northern Appalachian states as discussed in "Acid or Ferruginous Mine Drainage."

Treatment of alkaline mine drainage results in one or two classes of effluent: discharge effluent or sediment-bearing effluent.

### Discharge Effluent

Mine drainage falling into this classification is alkaline mine drainage containing low concentrations of metals such as iron, manganese, or aluminum. In most instances, this type of effluent meets the local state requirements for direct discharge without further treatment.

Some states require that discharges in this type flow through a settling basin which is to serve for the removal of any suspended solids and to equalize the flow and quality of the drainage before discharge into the receiving stream. There are no apparent benefits for such settling basins other than to provide for the equalization of effluent quality if such a variation does occur. One disadvantage was noted at Mines J2 and J3 where several basins were observed to have a profound algae growth in the summer months. This apparently contributed to a higher suspended solids' concentration in Mine J-2's effluent than was present in the raw mine drainage.

Although these settling basins did not effect a removal of suspended solids, they did provide sufficient natural aeration to reduce the dissolved iron concentrations, as noted at Mine F8. Case histories for the mine codes referenced in this section follow.

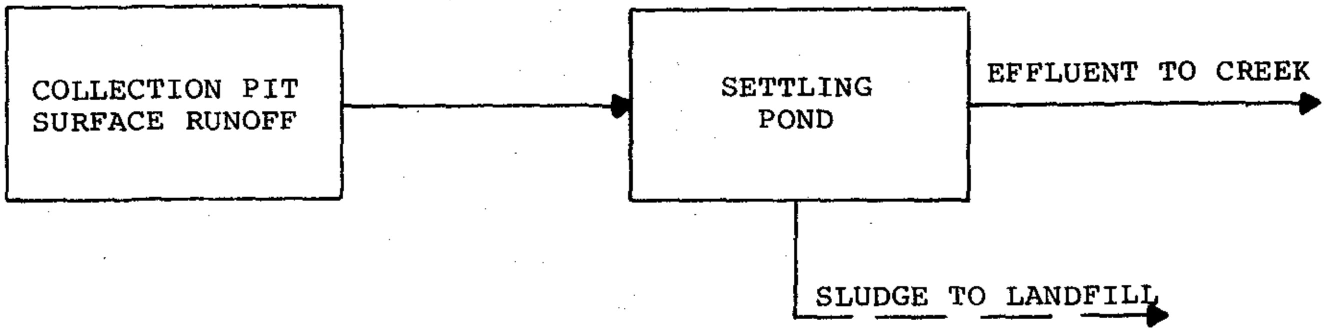
## Mine Code J-2

Mine J2 is a surface mine located in eastern Kentucky operating in the Hance (bituminous) coal seam. The mine encompasses approximately 364.5 hectares (900 acres). Production for 1973 was 1,507,936 KKG (1,662,553 tons).

The analytical quality of the waste water resulting from stripping operations is shown in Table 20. This drainage flows directly to a 26,500 cubic meter (7 million gallon) pond, constructed in 1970, for treatment by sedimentation only. The effluent from this basin then discharges to the nearby surface stream. Every nine months the settling basin is cleaned by dredging the sludge and trucking it to a nearby landfill.

During the sampling period significant algae growth was observed in the pond, probably causing the suspended solids increase evidenced in Table 20. A diagram of the treatment sequence appears in Figure 33.

FIGURE 33
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE J-2



## Table 20

## Analytical Data - Mine Code J-2

| Constituent | Raw Mine Drainage Point J2-1 Average Quality | Discharge Effluent Point J2-2 Average Quality |
|---|---|---|
| pH | 8.2 | 8.2 |
| Alkalinity | 136 | 138 |
| Specific Conductance | 1600 | 1630 |
| Solids, total dissolved | 1558 | 1610 |
| Solids, suspended | 12 | 26 |
| Hardness | 820 | 800 |
| Iron, total | 0.18 | 0.11 |
| Iron, dissolved | 0.18 | 0.01 |
| Manganese, total | 0.19 | 0.19 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.03 | 0.01 |
| Nickel, total | 0.07 | 0.06 |
| Strontium, total | 0.15 | 0.15 |
| Sulfates | 664 | 722 |
| Chloride | 3.7 | 3.6 |
| Fluoride | 0.24 | 0.24 |
| Ammonia | 0.3 | 0.2 |

All average qualities based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and discharge effluent samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

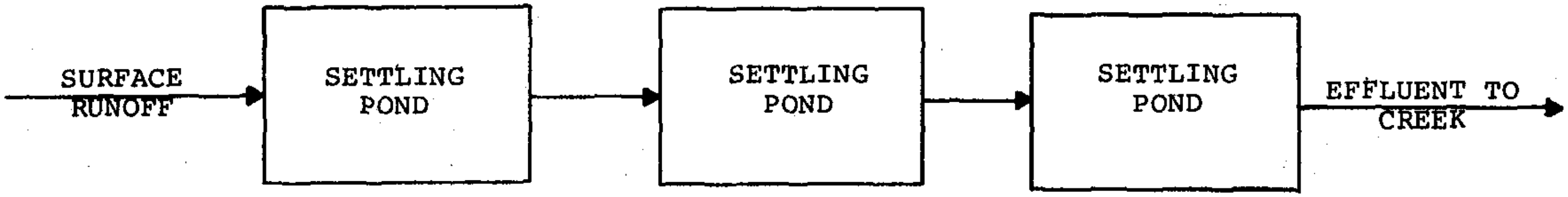
## Mine Code J-3

Mine J3 is a surface mine located in eastern Kentucky operating in the Red Springs (bituminous) coal seam. The mine encompasses approximately 24.3 hectares (60 acres). Production for 1973 was 141,251 KKG (155,734 tons).

The analytical quality of the waste water resulting from stripping operations is shown in Table 21. The majority of this drainage accumulates in an open pit, before flowing to three settling basins operated in series. These basins were constructed in April, 1974 and each has a capacity of 757,000 liters (200,000 gallons). The effluent from the final settling basin discharges to the nearby surface stream. Sludge build-up in these ponds has not yet been a problem.

Significant algae growth in the pond apparently retarded any possible suspended solids reduction as evidenced in Table 21. A schematic diagram of the treatment plant is shown in Figure 34.

FIGURE 34
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE J-3



## Table 21

## Analytical Data - Mine J-3

| Constituent | Raw Mine Drainage Point J3-1 Average Quality | Discharge Effluent Point J3-2 Average Quality |
|---|---|---|
| pH | 8.1 | 7.8 |
| Alkalinity | 66 | 64 |
| Specific Conductance | 360 | 360 |
| Solids, total dissolved | 300 | 298 |
| Solids, suspended | 16 | 16 |
| Hardness | 194 | 186 |
| Iron, total | 0.14 | 0.12 |
| Iron, dissolved | 0.09 | 0.01 |
| Manganese, total | 0.10 | 0.13 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.01 | 0.01 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 0.03 | 0.03 |
| Sulfates | 99 | 93 |
| Chloride | 2.3 | 3.1 |
| Fluoride | 0.26 | 0.15 |
| Ammonia | 0.42 | 0.47 |

All average qualities based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and discharge effluent samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

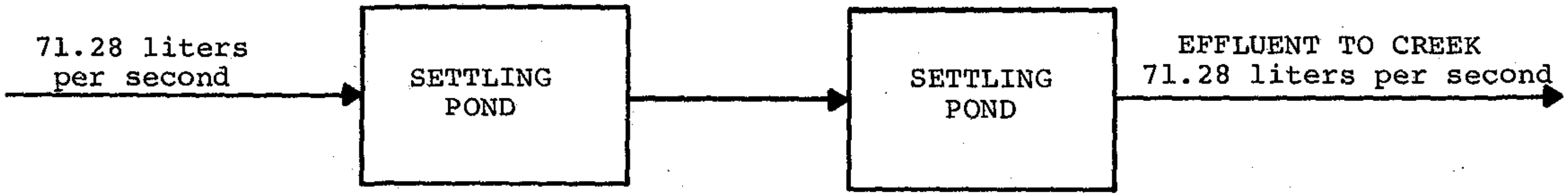
## Mine Code F-8

Mine F8 is a deep mine located in central Pennsylvania operating in both the Lower Freeport and Lower Kittanning coal seams. Coal production for 1973 was 1,011,293 KKG (1,114,987 tons).

Treatment is provided for the mine water by sedimentation through the use of two settling basins operated in series that were constructed in 1970. Each basin has a capacity of 42,468 cubic meters (1.12 million gallons). The average flow through the system is 6,170 cubic meters per day (1.63 million gallons per day) resulting in a total detention of 1.37 days. To date, it has not been necessary to remove sludge from the settling ponds.

It is important to note that although no significant suspended solids reduction occurred, most of the soluble ferrous iron in the water was oxidized and settled as the insoluble ferric form through natural aeration in the settling ponds. This resulted in meeting the State's discharge requirements for dissolved iron (0.5 mg/l) and also lowering the total iron content of the water by precipitation as ferric hydroxide. Analytical data for these settling ponds is presented in Table 22, while a diagram of the treatment sequence is presented in Figure 35.

FIGURE 35
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE F-8



## Table 22

## Analytical Data - Mine F-8

| Constituent | Raw Mine Drainage Point F8-1 Average Quality | Treated Mine Drainage Point F8-3 Average Quality |
|---|---|---|
| pH | 8.1 | 8.2 |
| Alkalinity | 284 | 274 |
| Specific Conductance | 1215 | 1195 |
| Solids, total dissolved | 872 | 858 |
| Solids, suspended | 18 | 14 |
| Hardness | 112 | 116 |
| Iron, total | 5.0 | 2.6 |
| Iron, dissolved | 1.5 | 0.04 |
| Manganese, total | 0.16 | 0.12 |
| Aluminum, total | 0.11 | 0.10 |
| Zinc, total | 0.01 | 0.006 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 0.50 | 0.57 |
| Sulfates | 364 | 298 |
| Chloride | 8.4 | 7.4 |
| Fluoride | 0.50 | 0.48 |
| Ammonia | 1.7 | 2.0 |
| Ferrous Iron | 1.9 | 0.37 |

All average qualities based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and treated drainage samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Sediment-Bearing Effluent

Sediment-bearing effluent results from the treatment of mine drainage of generally acceptable discharge quality except for suspended solids concentrations. Sedimentation ponds have been successfully employed to reduce the suspended to levels of less than 25 mg/l as demonstrated by Mines D6, N6, U5, and W2.

In some instances, the suspended solids may be directly attributed to alumina-type clays. Where this is the case, the solids may be colloidal in nature and very difficult to remove by gravity sedimentation without coagulant aids such as organic polymers. Mines W9 shows such clay problems.

Suspended solids can also be effectively removed by filtration methods, although this method has not been demonstrated by the coal industry as a waste water treatment technique.

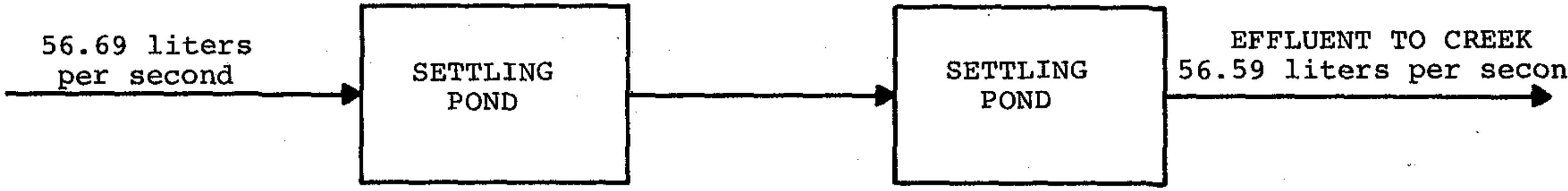
## Mine Code D-6

Mine D6 is a deep mine located in southwestern Pennsylvania operating in the Pittsburgh (bituminous) coal seam. Coal production for 1973 was 1,896,015 KKG (2,090,425 tons).

Mine water is pumped to the surface at an average rate of 4,920.5 cubic meters per day (1.3 million gallons per day) and discharged into two settling basins operating in series. The first basin has a capacity of 11,357 cubic meters (3 million gallons) and the second basin 946,425 cubic meters (250 million gallons). The total detention for the two basins is 195 days. The overflow from the larger basin discharges to the nearby surface stream.

The settling basins appear to provide very good removals of suspended solids. Analytical data for the treatment facility is presented in Table 23, and a diagram of the treatment sequence is shown in Figure 36.

FIGURE 36
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE D-6



## Table 23

## Analytical Data - Mine Code D-6

| | Raw Mine Drainage Point D6-1 | Sediment-Bearing Effluent Point D6-3 |
|---|---|---|
| pH | 8.2 | 8.6 |
| Alkalinity | 705 | 645 |
| Specific Conductance | 3300 | 3160 |
| Solids, total dissolved | 2191 | 2128 |
| Solids, suspended | 244 | 22 |
| Hardness | 146 | 85 |
| Iron, total | 0.28 | 0.16 |
| Iron, dissolved | 0.10 | 0.01 |
| Manganese, total | 0.04 | 0.04 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.03 | 0.03 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 1.35 | 0.87 |
| Sulfates | 635 | 506 |
| Chloride | 480 | 520 |
| Fluoride | 1.54 | 1.41 |
| Ammonia | 0.28 | 0.59 |

*Based on two consecutive daily grab samples.

**Based on two consecutive 24-hour composite samples.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and sediment-bearing samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

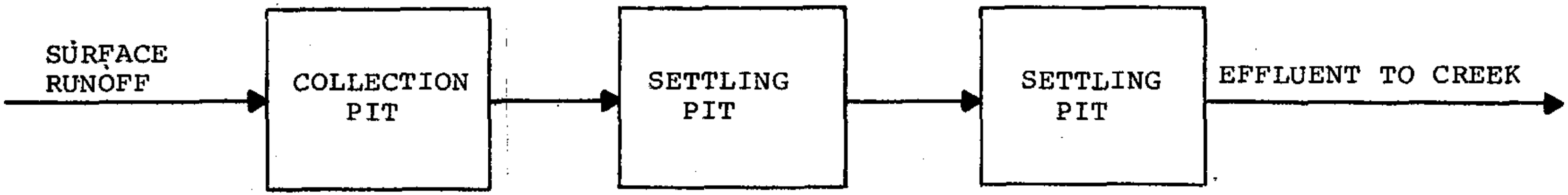
## Mine Code N-6

Mine N6 is a surface mine located in southwestern Pennsylvania operating in the Lower Freeport (bituminous) coal seam. The mine encompasses approximately 20.2 hectares (50 acres) with practically all of the area remaining. No coal was mined in 1973.

The analytical quality of the waste water is shown in Table 24. This water flows into a collection sump and is then pumped into an 852,000 liter (225,000 gallon) settling basin. The overflow from this first pond flows to a second 850 cubic meter pond, then discharges to the nearby surface stream. A schematic diagram of this treatment plant appears in Figure 37.

FIGURE 37

SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE N-6



## Table 24

## Analytical Data - Mine N-6

| Constituent | Raw Mine Drainage Point N6-1 Average Quality | Sediment-Bearing Effluent Point N6-2 Average Quality |
|---|---|---|
| pH | 7.7 | 7.8 |
| Alkalinity | 66 | 78 |
| Specific Conductance | 355 | 725 |
| Solids, total dissolved | 260 | 682 |
| Solids, suspended | 78 | 12 |
| Hardness | 300 | 600 |
| Iron, total | 0.01 | 0.01 |
| Iron, dissolved | 0.01 | 0.01 |
| Manganese, total | 0.91 | 0.11 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.06 | 0.33 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 0.30 | 0.40 |
| Sulfates | 68 | 325 |
| Chloride | 6.0 | 8.7 |
| Fluoride | 0.25 | 0.25 |
| Ammonia | 0.75 | 0.30 |

All average qualities based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

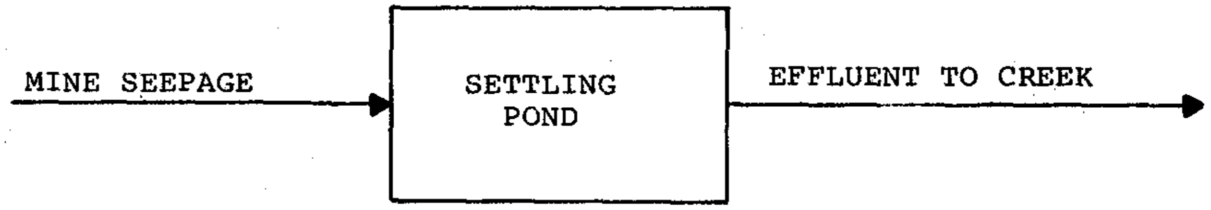
The raw and sediment-bearing samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code U-5

Mine U5 is a surface mine located in northeastern Wyoming operating in the Wyodak (sub-bituminous) coal seam. The total mine encompasses approximately 729 hectares (1,800 acres). Coal is mined at the rate of 2,449 KKG (2,700 tons) per shift. Based on the 1973 production of 658,482 KKG (726,000 tons), the estimated life of the present reserves is 50 years.

The analytical quality of the waste water is shown in Table 25. This water is channeled and pumped where necessary, into a large collection basin where the suspended solids are settled before the mine water is discharged. A diagram of the treatment sequence is shown in Figure 38.

FIGURE 38
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE U-5



## Table 25

## Analytical Data - Mine U-5

| Constituent | Raw Mine Drainage Point U5-1 Average Quality* | Sediment-Bearing Effluent Point U5-2 Average Quality* |
|---|---|---|
| pH | 8.0 | 7.6 |
| Alkalinity | 440 | 414 |
| Specific Conductance | 2470 | 2970 |
| Solids, total dissolved | 2238 | 2742 |
| Solids, suspended | 104 | 18 |
| Hardness | 1140 | 1280 |
| Iron, total | 0.47 | 0.20 |
| Iron, dissolved | 0.03 | 0.01 |
| Manganese, total | 0.10 | 0.15 |
| Aluminum, total | 0.50 | 0.20 |
| Zinc, total | 0.25 | 0.20 |
| Nickel, total | 0.01 | 0.06 |
| Strontium, total | 2.2 | 2.6 |
| Sulfates | 1087 | 992 |
| Chloride | 58 | 138 |
| Fluoride | 0.56 | 0.48 |
| Ammonia | 3.2 | 7.2 |

*Based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

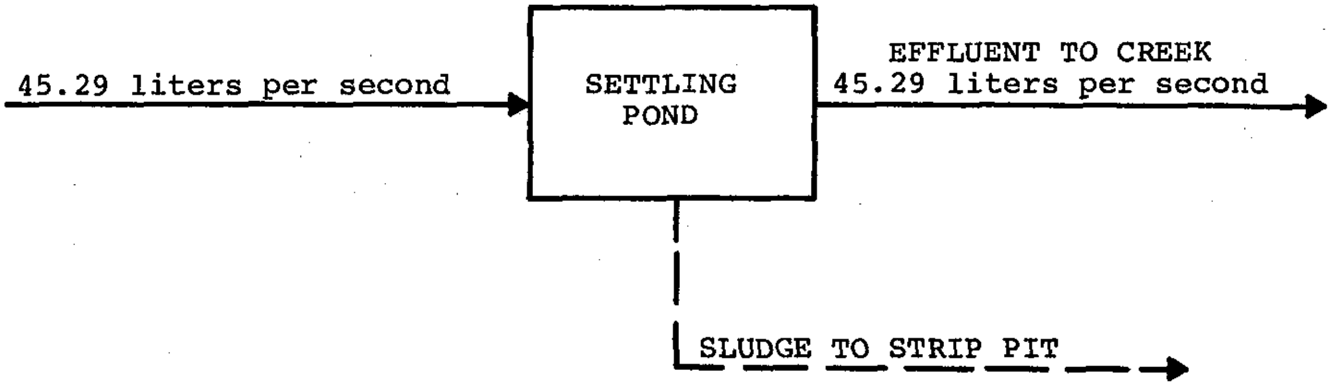
The raw and sediment bearing samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code W-2

Mine W-2 is located in southern West Virginia, and has both surface and deep mining operations in the Powellton (bituminous) coal seam. Both mines together encompass about 3,443 hectares (8,500 acres). Based on the 1973 production of 151,200 KKG (166,700 tons) the estimated life of the present reserves is greater than 300 years.

Mine discharges are pumped into a large 5,980 cubic meter (1.58 million gallon) settling pond for removal of suspended solids before being discharged to the nearby stream. Sludge removal from this basin is accomplished with a drag line with burial of the sediment in a nearby strip pit. Suspended solids are effectively removed from the drainage by this sedimentation pond. Analytical data is presented in Table 26. A diagram of the treatment sequence is shown in Figure 39.

FIGURE 39
SCHEMATIC DIAGRAM FOR TREATMENT FACILITIES AT MINE W-2



## Table 26

## Analytical Data - Mine Code W-2

| Constituent | Raw Mine Drainage Point W2-1 Average Quality* | Sediment-Bearing Effluent Point W2-2 Average Quality* |
|---|---|---|
| pH | 7.7 | 7.7 |
| Alkalinity | 58 | 44 |
| Specific Conductance | 570 | 530 |
| Solids, total dissolved | 566 | 510 |
| Solids, suspended | 60 | 14 |
| Hardness | 284 | 246 |
| Iron, total | 0.24 | 0.06 |
| Iron, dissolved | 0.24 | 0.06 |
| Manganese, total | 0.13 | 0.12 |
| Aluminum, total | 0.10 | 0.10 |
| Zinc, total | 0.13 | 0.16 |
| Nickel, total | 0.01 | 0.01 |
| Strontium, total | 1.04 | 0.93 |
| Sulfates | 223 | 193 |
| Chloride | 3.3 | 3.3 |
| Fluoride | 0.18 | 0.15 |
| Ammonia | 0.09 | 0.06 |

*Based on one grab sample.

All results expressed in mg/l except for pH and specific conductance.

The reported cations listed above were analyzed for both total and dissolved concentrations. Significant differences were not measured except where otherwise reported.

The raw and sediment bearing samples were analyzed for arsenic, barium, boron, cadmium, chromium, copper, mercury, molybdenum, lead and selenium, but these were not detected in significant concentrations.

## Mine Code W-9

Mine W9 represents a surface mine located in southwestern Washington operating in the Smith and Big Dirty (sub-bituminous) coal seams. The total mine encompasses approximately 4,253 hectares (10,500 acres). Based on the 1973 production of 2,928.700 kkg (3,229,000 tons), the estimated life of the present reserves is 35 years.

Waste water from mining operations contains 10,000 - 15,000 mg/l of suspended solids. This water is directed to a primary settling basin where the majority of the suspended matter is removed. The effluent from this basin contains 120 - 130 mg/l suspended solids in the form of colloidal clays which tend to naturally remain in suspension for periods often exceeding one week. This water is treated with a high molecular weight organic anionic polyelectrolyte, used as a primary coagulant, then allowed to settle in a secondary basin. As documented in an article of Mining Congress Journal entitled "Surface Mine Siltation Control," the suspended solids can be reduced to less than 25 mg/l (4 - 15 Jackson Turbidity Units) in this final effluent; however, to achieve this quality of water a rather high dosage (10 mg/l) of polyelectrolyte is required.

Depending upon quantity of rainfall, the two settling basins provide a detention of 8 to 23 hours for flows averaging up to 632 liters per second (10,000 gallons per minute).

## Pollutant Reductions Achieved by Present Treatment Technology

Pollutant removals for each of the classes of mine drainage have been determined by this study. In some instances, known waste treatment technology from other industries has been translated for treatment of certain parameters in mine drainage. A discussion of the removal efficiencies for the various treatment methods follows.

pH, Acidity, and Alkalinity. Acid mine drainage contains mineral acidity in the form of sulfuric acid which occurs by the oxidation of pyritic iron compounds associated with the coal seams. This acidity can be totally neutralized by the addition of an alkali, namely lime, limestone, caustic soda, soda ash, or anhydrous ammonia. In almost all cases, lime in either the hydrated, by-product, or quick lime forms is used by the coal industry for neutralization purposes because of its availability, ease of handling, and reliability of results. For those drainages where acidity is either the main pollutant encountered, or the flow is relatively small, soda ash and caustic soda have both been successfully used, as they are simple to apply and react quickly. Care must be taken not to overfeed these alkalis to the degree that caustic conditions are created in the treated effluent.

A pH determination is a control indicator of the efficiency of the removal of total acidity in acid mine drainage. To be an effective indicator of the total acidity of a discharge effluent from a treatment facility there must be sufficient time allowed for the reaction between the acid mine drainage and the alkali to go to completion and the pH to stabilize. This is particularly true when pH determination is used as an effluent limitation.

Iron. Iron in both the ferrous and ferric forms occurs in acid or ferruginous mine drainage at significant levels. It has been demonstrated that iron can be removed as the insoluble hydroxide by lime neutralization to levels of less than 2.0 mg/l. It was observed that these removals are dependent upon an adequate pH level and require effective sedimentation units. Lime effects better iron removals than the other alkalis and lower iron concentrations were apparent as the pH was increased above 7.0. Temperature may have an effect upon the removal of iron and other metals. Detention periods in settling basins or thickners were not observed to be important as long as the minimum detention was provided. This varies from plant to plant, but at least two hours detention is necessary.

In most plants, ferrous iron is oxidized by aeration once the alkali has been added to raise the pH of the drainage to an alkaline condition. This then changes all of the iron to the ferric form, which can be removed at lower pH's than ferrous iron. Mine A3, however, has found it more advantageous to remove iron as ferrous hydroxide since a more dense sludge is obtained. This usually requires somewhat higher pH in the range of 8.5 to 9.5. Mine A4 has demonstrated that iron oxidation is easy to accomplish and the use of a long, open trough between the lime mix tank and the settling basin has eliminated the need for mechanical aeration equipment.

In a few instances, such as Mine D1, it was found that the mine drainage was alkaline but contained iron at unacceptable levels. It was demonstrated here that aeration and sedimentation with the aid of a coagulant will remove the iron to an acceptable discharge level.

Manganese. Manganese occurs in most acid or ferruginous mine drainages from coal mining operations. This cation can also be removed in the neutralization process as an insoluble hydroxide. The pH required for removal of manganese is somewhat higher than that for ferric iron. It was demonstrated by Mines A2, B2, D3, D4, E6, F2, and K7 that substantial reductions to about 1.0 mg/l can be achieved when the pH is raised to 7.5 or higher. Essentially complete removal cannot be achieved unless the pH is raised to above 9.0 and closer to a pH of 10.0, as shown by Mines A3 and K7. It was also demonstrated by Mine D5 that sodium alkalis do not remove manganese as well as lime.

Aluminum. The occurrence of aluminum in acid or ferruginous mine drainage is more varying than either iron or manganese. In some mines, aluminum concentrations are very high, and in others it is not present at all. Aluminum was shown to be very easy to remove as the insoluble hydroxide. Complete removals were demonstrated at Mines A2, A3, B2, D3, and D5, where the pH in the neutralization process was controlled at levels higher than 7.5. It is important to note that aluminum is an amphoteric metal, which means that it is soluble in both acid and alkaline forms. Theory indicates that aluminum should redissolve if the pH is not controlled to within a close range; however, this effect was not observed in the plants studied.

Sulfates. Sulfates are the basic anion contained in mine drainage. Sulfate concentrations increased in direct proportion to the amount of acidity and iron contained in acid or ferruginous mine drainage. Sulfates are not removed in the neutralization process unless the concentration is greater than the solubility product for gypsum (calcium sulfate) formation. This usually occurs at sulfate concentrations greater than 2,500 mg/l. When sulfates are in excess of this, then removals can be expected. The extent of this will depend upon the amount of calcium ion available for gypsum formation. Since treatment plants are operated for pH control, there is often an inadequate availability of calcium ion from the lime being used for neutralization to achieve maximum sulfate removals.

Gypsum presents problems in the operation of many treatment plants. Gypsum forms a very hard crystalline scale which increases in thickness on anything it contacts. Quite often, tanks, pipes, and mixing equipment can be rendered totally useless because of gypsum formation. In addition, a delayed formation of gypsum crystals in the effluent of the treatment plant can significantly increase the suspended solids analysis for that discharge. This was a noted problem in some samples collected during this project. Where gypsum precipitation is a problem, water samples should be analyzed within one hour to accurately determine suspended solids concentrations.

Suspended Solids. The presence of suspended matter in acid or ferruginous mine drainage is not significantly important since the commonly applied neutralization process involves chemical reactions in which insoluble precipitates are formed. Following this, sedimentation in either earthen basins, large impoundments, or mechanical clarifiers is employed to effect very good removals of high suspended solids as demonstrated by Mines A3, A4, B2, D5, E6, F2, K6, and K7. Suspended solids removals to less than 30 mg/l have been demonstrated. The affect of gypsum formation as disucssed under Sulfates was noticed at Mines A1, A2, and D4.

Suspended solids removals were also observed in settling ponds for alkaline mine drainage such as at Mines D6, N6, and U5.

Pressure or gravity filtration can also be used for the removal of suspended solids. While these units are not being used by the coal industry, the application has been demonstrated elsewhere; namely, iron and steel, metal finishing, and for effluent polishing of biological systems. Considering the volumes encountered, high-rate, mixed-media pressure filters seem most applicable for removing suspended matter from either the effluent of a conventional lime neutralization system after gravity settling, or a sediment-bearing discharge. Removals of 25 to 200 mg/l may be necessary in flows ranging from 15.78 liters per second (250 gallons per minute) to more than 63.1 liters per second (1,000 gallons per minute).

Considering the effluent quality required, and the flows and loadings to be encountered, high rate, mixed-media, pressure filters are the most applicable to this waste water treatment problem. Commonly known as deep bed or in-depth filtration, the process differs from the usual filtration techniques in that solids are removed within the filter media and not on its surface. Higher filtration rates are desirable since the particles are to be forced into the bed. The effluent suspended solids concentration from deep bed filters will be on the order of 10 to 20 mg/l depending upon the filter media size and particle diameter of solids encountered.

<u>Other Parameters</u>. Mine drainage was also observed to contain other parameters in varying concentrations such as zinc, nickel, fluoride, calcium, magnesium, and ammonia. Calcium and magnesium are the metals normally associated with hardness in water and are not presently considered to be pollutants. Zinc and nickel were found to occur up to one or two milligrams per liter. These metals were essentially completely removed in the neutralization process as insoluble hydroxides with proper pH control.

Fluoride was found to be present in mine drainage as a direct affect of coal mining. The concentrations observed were usually slightly in excess of the recommended limits for public drinking water supplies. While fluorides can be removed as insoluble calcium fluoride in a neutralization process, their level of occurrence was usually below the solubility for this compound, and removals were not observed.

Ammonia was also found to be present in acid mine drainage. This compound was usually reduced several milligrams per liter by the neutralization process.

# SECTION VIII

# COST, ENERGY, AND NON-WATER QUALITY ASPECTS

## MINE DRAINAGE TREATMENT

### Costs

Construction costs for plants treating mine drainage were obtained from many of the coal companies interviewed during this study. Most of these treatment facilities were constructed during the last six years. The construction costs obtained are generally low when compared to the costs for similar waste treatment facilities in other industries. These low costs may be reflected in the use of small, rural contracting firms for excavation and construction of the facilities and in the fact that much of the work may have been performed by the coal companies themselves. These costs were difficult to obtain for the most part as they were not maintained as a separate cost account by most of the firms.

Plants for treating acid mine drainage must all provide the same essential equipment including lime storage, feeders, mixers, control facilities, and housing, independent of the flow encountered. The associated facilities such as raw water pumps, holding ponds, aerators, aeration basins and settling ponds or clarifiers may have a cost that varies in proportion to the plant's design flow. For settling ponds treating alkaline mine drainage this is not always true, as the detention provided for sedimentation will vary depending upon the sludge storage capacity provided. Some plants provide settling ponds with detentions of from one to three days while others use large impoundments that provide sludge storage for several years.

### Basis Of Cost Estimates

The more reliable construction costs obtained were adjusted to September, 1974 costs using the Engineering News Record (ENR) Construction Cost Index. For determination of annual capital costs, a straight-line depreciation over fifteen years was used with an 8 percent annual interest rate.

A complete cost breakdown for several AMD plants including adjusted (1974) initial investment, capital depreciation, operating and maintenance, and energy, power and chemicals costs are presented as Water Effluent Treatment Costs, Tables 27, 28 and 29.

Where initial construction costs for plants treating acid mine drainage were incomplete, estimates were used for:

1. Land at $2,469 per hectare ($1,000 per acre).

2. Excavation and pond construction at $0.31 per cubic meter ($1.00 per cubic yard) of total volume.

3. Fencing at $16.40 per lineal meter ($5.00 per lineal foot).

4. Sludge volume at ten percent of plant flow and two percent solids by weight.

   Disposal at $0.026 per thousand liters ($0.10 per thousand gallons), or $4.25 per cubic meter ($3.25 per cubic yard) of sludge dried to sixty percent solids.

5. Power usage at $0.025 per kilowatt hour.

6. Operating manpower at $9.00 per hour which includes overhead and fringes.

The adjusted investment costs were also used in developing Figure 40 where construction cost per unit capacity is plotted against the design capacity. A breakdown of typical construction costs for three AMD plants, two of which were not included in the survey, is presented in Table 30.

Operating costs were also obtained from many of the AMD plants visited. When available, the cost were obtained for chemical usage, electricity, sludge disposal and manpower. These are also presented in Tables 27, 28 and 29.

Alkaline mine drainage frequently use settling basins for suspended solids removal. A review of those basins constructed indicates that there is no correlation between basin capacity and the discharge flow rate; i.e., while a minimum detention is necessary, the actual size of existing basins depends more on the physical characteristics of the area used and the needed volume for sludge storage. As a minimum, at least one day's detention should be provided. Based on this, earthen pond construction can be estimated at $1.05 per cubic meter of capacity ($5.00 per thousand gallons).

The design of a filtration system for either acid mine drainage or alkaline mine drainage will vary depending upon the conditions encountered. A simple system would consist of two settling basins in series preceding the filters. The secondary pond would serve as the source for both filter feed (raw water) and backwash water. Following filter cleaning, the backwash water would be discharged into the primary settling pond. In such a system, the filtration system would consist of feed pumps, filters, backwash pumps, control building and associated piping.

While high-rate filters are very reliable, a minimum of two units must be provided. Some manufacturers claim filtration rates up to 13.58 liters per second per square meter (20 gallons per minute per square foot, the commonly used design rate is 6.79 liters per second per square meter (10 gallons per minute per square foot) and is used here for estimating purposes. As an example, a mine drainage of 63.1 liters per second (1,000 gallons per minute) would require two, 2.44 meter (eight ft) diameter filters. The cost for deep bed filtration systems in these low design flow ranges can be estimated at $6.31 to $7.89 per liter per second ($100 to $125 per gallon per minute) of design capacity. Operating costs for such systems are low and are estimated to be $5.30 per million liters ($20.00 per million gallons) filtered, which includes the cost for power. Labor requirements are minimal with only daily checks of the control system required.

## Energy Requirements

As shown on Tables 27, 28 and 29, energy requirements for the operation of mine drainage treatment facilities can be a siginificant part of the overall operating cost. This is attributed mainly to the cost of operating mine dewatering pumps, which possibly should be considered as a direct mining cost and not as a mine drainage treatment cost. For the most part, these costs constitute more than half of the power demand. Therefore, for future treatment plants to be constructed as a result of this effluent guidelines program, the additional power demand at each mine will be small. Mine dewatering pumps are in operation and additional power requirements will be for several motors in the treatment system.

## Table 27

## WATER EFFLUENT TREATMENT COSTS
## COAL MINING INDUSTRY
## ACID MINE DRAINAGE TREATMENT PLANTS

| Treatment Technology For Levels I, II, and III as Exhibited by Plants Identified | Treatment Plants for Mines | | |
|---|---|---|---|
| | D4 | E6 | F2 |
| Investment (Adjusted For 1974 Dollars) | $172,000 | $453,100 | $340,100 |
| Annual Costs: | | | |
| Capital Costs | 8,627 | 22,729 | 17,060 |
| Depreciation | 11,467 | 30,206 | 22,673 |
| Operating & Maintenance | 6,570 | 26,280 | 9,360 |
| Chemicals | 18,000 | 65,700 | 62,415 |
| Energy and Power | 15,030 | 12,024 | 25,718 |
| Total Annual Cost | $59,694 | $156,939 | $137,226 |

Effluent Quality:

| Effluent Constituents Parameters (Units)* | Resulting Effluent Levels | | |
|---|---|---|---|
| Design flow, cu m/day | 5450 | 4543 | 3271 |
| Iron, total, mg/l | -2.0 | -1.5 | -1.0 |
| pH (all 6-9) | 6.8 | 8.2 | 8.9 |
| Manganese, mg/l | -1.0 | -1.0 | -0.5 |
| Suspended Solids, mg/l | -200 | - 25 | - 25 |

*For raw waste loads, refer to case histories in Section VII.
- Less than

# TABLE 28
# WATER EFFLUENT TREATMENT COSTS
# COAL MINING INDUSTRY
# ACID MINE DRAINAGE TREATMENT PLANTS

| Treatment Technology For Levels I, II, and III as Exhibited by Plants Identified | Treatment Plants for Mines | |
|---|---|---|
| | K6 | K7 |
| Investment (Adjusted For 1974 Dollars) | $477,200 | $540,400 |
| Annual Costs: | | |
| Capital Costs | 23,937 | 27,107 |
| Depreciation | 31,813 | 36,027 |
| Operating & Maintenance | 14,600 | 8,672 |
| Chemicals | 180,200 | 164,250 |
| Energy and Power | 9,352 | 9,143 |
| Total Annual Cost | $259,902 | $245,199 |
| Effluent Quality: | | |
| Effluent Constituents Parameters (Units)* | Resulting Effluent Levels | |
| Flow, cubic meters/day | 25,936 | 28,719 |
| pH (All 6-9) | 8.0 | 8.8 |
| Iron, total, mg/l | -2.0 | -2.0 |
| Manganese, mg/l | -0.5 | -0.5 |
| Suspended Solids, mg/l | - 25 | - 25 |

* For raw waste loads, refer to case histories in Section VII.

\- Less than

Table 29

## TYPICAL CONSTRUCTION COSTS
## ACID MINE DRAINAGE TREATMENT PLANTS

| | Plant | | |
|---|---|---|---|
| | A4 | X | Y |
| FLOW (Cubic Meters Per Day) | 5,450 | 5,450 | 6,540 |
| COSTS | | | |
| Land | 10,000 | 10,000 | 50,000 |
| Holding Basin | -- | -- | 12,500 |
| Control Building | 25,000 | 25,000 | 37,000 |
| Lime Storage | 17,500 | 22,000 | 18,000 |
| Lime Feed and Mixer | 5,000 | 16,000 | 6,500 |
| Aeration Facilities | -- | 20,000 | 23,500 |
| Settling Basins | 85,000 | 55,000 | 26,500 |
| Fencing and Roads | 6,500 | 8,000 | 10,000 |
| Sludge Disposal Equipment | -- | 48,000 | 68,000* |
| Instruments and Electrical | 12,000 | 18,000 | 42,000 |
| Pumps | 35,000 | 35,000 | 33,500 |
| Other | 7,500 | 16,000 | 20,000 |
| Total Construction Cost (1974) | $203,500 | $273,000 | $348,000 |

*Includes $40,000 for a sludge disposal basin with a twenty year life.

## Land Requirements

Since many treatment plants employ earthen settling basins for the treatment of mine drainage, land requirements can become very significant. At some plants, such as Mines A2, A4, D4, and D3, very large settling basins and sludge storage areas were formed by damming entire valleys. In most cases, however, treatment plant facilities are confined to land requirements of less than 10 acres.

Most mine drainage treatment facilities are constructed in rural areas. The cost of land for these facilities should not be a significant aspect of the total cost of the plant. However, several companies reported that they were faced with paying extremely high costs for rural land when the local owners learned of the coal companies needs. This can always be expected in the case of supply and demand.

CONSTRUCTION COST VS. CAPACITY
ACID MINE DRAINAGE TREATMENT PLANTS
(Costs in 1974 Dollars)

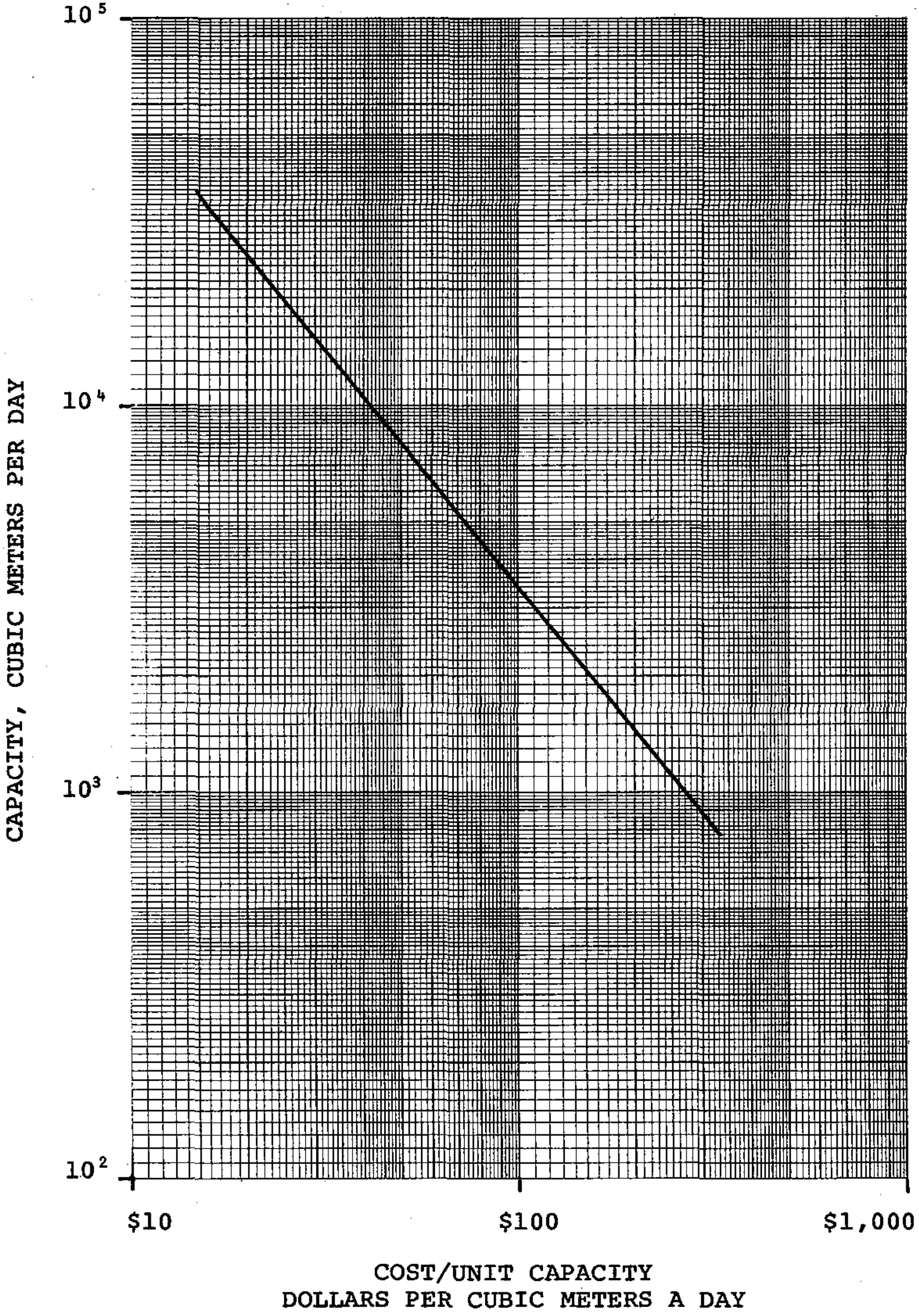


Figure 40

Table 30

## WATER EFFLUENT TREATMENT COSTS
## COAL MINING INDUSTRY
## ACID MINE DRAINAGE TREATMENT PLANTS

| Treatment Technology For Levels I, II, and III as Exhibited by Plants Identified | Treatment Plants for Mines | | |
|---|---|---|---|
| | A1 | A4 | D3 |
| Investment (Adjusted For 1974 Dollars) | $340,800 | $193,500 | $276,000 |
| Annual Costs: | | | |
| Capital Costs | 17,095 | 9,706 | 13,844 |
| Depreciation | 22,720 | 12,900 | 18,400 |
| Operating & Maintenance | 9,855 | 19,710 | 9,855 |
| Chemicals | 7,200 | 10,950 | 31,200 |
| Energy and Power | 24,688 | 8,110 | 18,241 |
| Total Annual Cost | $ 81,558 | $ 61,376 | $ 91,540 |
| Effluent Quality: | | | |
| Effluent Constituents Parameters (Units)* | Resulting Effluent Levels | | |
| Design flow, cu m/day | 3816 | 5420 | 2726 |
| pH (All 6-9) | 7.2 | 8.0 | 7.8 |
| Iron, total, mg/l | -2.0 | -1.0 | -2.0 |
| Manganese, mg/l | 1.1 | -2.5 | -1.0 |
| Suspended Solids, mg/l | -100 | - 25 | - 75 |

* For raw waste loads, refer to case histories in Section VII.

\- Less than

## Sludge Disposal

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located.

The disposal of the sludges produced in the treatment of acid mine drainage is an increasing problem. The earlier constructed plants, those from 1967 through 1970, normally provided facilities which consisted of settling ponds having the capacity for one or two months storage of sludge. The procedure, then, was to take the facility out of operation, and then remove the sludge with front-end loaders. It was found that this was a very messy and difficult operation. The more recently constructed plants now provide settling basins which have capacities of many millions of gallons and can provide for sludge storage for several years. This appears to be a good solution to the sludge disposal problem, providing that suitable land is available for the construction of these large impoundments.

Another method employed for the disposal of sludge produced from treating AMD is to provide for the continuous or intermittent removal from the settling facility for disposal into portions of active mines. This arrangement has also been acceptable when abandoned mines are accessible. Chemically, this should not create a water pollution problem, even if the sludge contacts acid mine drainage, as long as the iron is in the ferric form.

### Availability of Chemicals

As was discussed, neutralization chemicals include lime, limestone, soda ash, and caustic soda. By far, lime is the most commonly used neutralizing agent. Limestone, the raw material is readily available for production of lime; however, there is presently a tight market for the availability of lime due to the closing of several plants for air pollution problems. Soda ash briquettes have also been commonly used by many mines to neutralize intermittent acidic discharges. It has been reported that there is a scarcity of soda ash in this form. If so these mines will have to resort to other alkalis for treatment. On the whole, it does not appear that the availability of alkalis will affect the treatment of mine drainage from active mines.

## PREPARATION PLANT WATER RECIRCULATION

A majority of the coal preparation plants visited in conjunction with development of this document have closed water circuits. These facilities employ thickeners, filters or settling ponds to effect most of the necessary water clarification prior to recirculation. For those existing plants that do not presently have a closed water circuit, recycling water from settling basins in many cases will be the most practical and economic method for conversion to a closed circuit. Exceptions to this assumption would be those plants using thickeners with an open water circuit. These washeries can be converted by adding filters to the system.

The cost of converting to a recycle system is primarily dependent on the purchase and installation cost of the water handling equipment necessary to meet the plants consumption demands. This may vary considerably from one plant to another, depending on the type and size of equipment utilized to process the coal. It would be extremely difficult and inaccurate to project the cost of implementing a recycle system considerate of every contingency. Therefore, Table 31 has been prepared to illustrate the major expenditures required to deliver a variety of flows under different hydraulic head conditions. It is assumed that at least one pond is presently being used in any open circuit system for clarification prior to discharge and that this pond will be utilized as a holding basin for a recycle system. An additional holding pond may be necessary to allow emergency dewatering of the total plant system. The particular capacity required for holding basins is dependent on the total volume of water used by the plant during normal

## TABLE 31

## COAL PREPARATION PLANT WATER CIRCUIT CLOSURE COSTS

| Fluid Delivery Requirements | Head cond. meters & feet | VALVE & PUMP REQUIREMENTS | | | | | | | | | Total Valves Pumps & Install. | PIPING REQUIREMENTS (Based on Average Run of 305 meters or 1000') | | | Energy Cost per 8 hr. shift | Pond Exc. per cu. m. per cu. ft. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PUMPS | | | | VALVES | | | | valve & pump install cost | | | | | | |
| | | H.P. | No. Req. | Unit Cost | Total Cost | Type | No. Req. | Unit Cost | Total Cost | | | Type | Size | Installation per meter, ft. | | |
| 63 liter/sec 1000 GPM | 15m | 25 | 1 | $ 4,300 | $ 4,300 | A | | Gates = $450 Checks= $500 | $ 1,400 | $1,000 | $ 6,700 | Steel Pipe | 20cm 8" | $28.25 per meter $8.61 per foot | $1.50 | $1.30 (cu. meter) $1.00 (cu. yard) |
| | 50' | | 2 | | 8,600 | B | | | 3,250 | | 12,850 | | | | | |
| | 30m | 40 | 1 | 4,600 | 4,600 | A | | | 1,400 | | 7,000 | | | | 3.00 | |
| | 100' | | 2 | | 9,200 | B | | | 3,250 | | 13,450 | | | | | |
| | 76m | 100 | 1 | 7,525 | 7,525 | A | | | 1,400 | | 9,925 | | | | 7.00 | |
| | 250' | | 2 | | 15,050 | B | | | 3,250 | | 19,300 | | | | | |
| 158 liter/sec 2500 GPM | 15m | 50 | 1 | 10,000 | 10,000 | A | * (See Below) | Gates = $900 Checks= $1000 | 2,800 | | 13,800 | | 30 cm 12" | $42.40 per meter $12.93 per foot | 3.50 | |
| | 50' | | 2 | | 20,000 | B | | | 6,500 | | 27,500 | | | | | |
| | 30m | 100 | 1 | 11,700 | 11,700 | A | | | 2,800 | | 15,500 | | | | 7.00 | |
| | 100' | | 2 | | 23,400 | B | | | 6,500 | | 30,900 | | | | | |
| | 76m | 250 | 1 | 20,500 | 20,500 | A | | | 2,800 | | 24,300 | | | | 18.00 | |
| | 250' | | 2 | | 41,000 | B | | | 6,500 | | 48,500 | | | | | |
| 316 liter/sec 5,000 GPM | 15m | 100 | 1 | 12,500 | 12,500 | A | | Gates = $2300 Checks= $2400 | 7,000 | | 20,500 | | 46 cm 18" | $88.56 per meter $27.09 per foot | 7.00 | |
| | 50' | | 2 | | 25,000 | B | | | 16,300 | | 42,300 | | | | | |
| | 30m | 200 | 1 | 23,000 | 23,000 | A | | | 7,000 | | 31,000 | | | | 14.00 | |
| | 100' | | 2 | | 46,000 | B | | | 16,300 | | 63,300 | | | | | |
| | 76m | 450 | 1 | 30,000 | 30,000 | A | | | 7,000 | | 38,000 | | | | 35.00 | |
| | 250' | | 2 | | 60,000 | B | | | 16,300 | | 77,300 | | | | | |
| 631 liter/sec 10,000 GPM | 15m | 150 | 1 | 19,000 | 19,000 | A | | Gates = $3800 Checks= $4000 | 11,600 | $2,000 | 32,600 | | 61 cm 24" | $121.52 per meter $37.05 per foot | 14.00 | |
| | 50' | | 2 | | 38,000 | B | | | 27,000 | | 67,000 | | | | | |
| | 30m | 350 | 1 | 34,000 | 34,000 | A | | | 11,600 | | 47,600 | | | | 28.00 | |
| | 100' | | 2 | | 68,000 | B | | | 27,000 | | 97,000 | | | | | |
| | 76m | 800 | 1 | 57,500 | 57,500 | A | | | 11,600 | | 71,100 | | | | 71.00 | |
| | 250' | | 2 | | 115,000 | B | | | 27,000 | | 144,000 | | | | | |
| 947 liter/sec 15,000 GPM | 15m | 250 | 1 | 28,600 | 28,600 | A | | Gates = $6725 Checks= $7000 | 20,450 | | 51,050 | | 76 cm 30" | $154.16 per meter $47 per foot | 21.00 | |
| | 50' | | 2 | | 57,200 | B | | | 47,625 | | 106,825 | | | | | |
| | 30m | 500 | 1 | 64,500 | 64,500 | A | | | 20,450 | | 86,950 | | | | 42.00 | |
| | 100' | | 2 | | 129,000 | B | | | 47,625 | | 178,625 | | | | | |
| | 76m | 1250 | 1 | 73,000 | 73,000 | A | | | 20,450 | | 95,450 | | | | 106.00 | |
| | 250' | | 2 | | 146,000 | B | | | 47,625 | | 195,625 | | | | | |

*A - 2 Gate Valves & 1 Check Valve
*B - 5 Gate Valves & 2 Check Valves

operation and the precipitation pattern for the geographical area.

To illustrate the costs presented in Table 31 as they apply to a given situation, the following example has been developed.

## EXAMPLE

This example is based on a simple Baum Jig cleaning system, operating three 8 hour shifts each days, 5 day a week. Plant facilities are located 305 meters (1000 ft) away from and 31 meters (100 ft) above a settling pond presently used to retain and treat plant water until it can be discharged. It is anticipated that this pond alone will sufficiently serve a recycle circuit.

A sump already in the plant precludes the necessity of an emergency holding pond system. Presently, the plant is producing 566 kkg (625 tons) of clean coal each hour and utilizing process water at the rate of 158 l/sec (2500 gpm). Assuming the present discharge will be converted to recycle using a back-up pump in addition to the primary pump, the following installation and operating costs can be extracted from Table 31.

### INSTALLATION

| | |
|---|---|
| Two 100 hp. Pumps @ $11,700 each | = $ 23,400 |
| Five Gate Valves @ $900 each | = 4,500 |
| Two Check Valves @ $1000 each | = 2,000 |
| Build Platform & Mount Pumps & Valves in existing Pond | = 1,000 |
| Install 305 meters of 30 cm pipe at $42.40 per meter (1000' of 12" steel pipe @ $12.93 per foot) | 129,300 |
| Total Installation | = $160,200 |

### OPERATION

| | |
|---|---|
| 1 pump cont. operation for 3-8 hr. shifts - 5 days a week @ $7.00 per shift | = $105.00 Mo. |

# SECTION IX

# BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE GUIDELINES AND LIMITATIONS

## INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. This is generally based upon the average of the best existing plants of various sizes, ages, and unit processes within the industrial category and/or sub-category. Consideration must also be given to:

a. the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the processes employed;

d. the engineering aspects of the application of various types of control techniques;

e. process changes;

f. non-water quality environmental impact (including energy requirements)

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process, but includes the control technologies within the process itself, when the latter are considered to be normal practice within an industry.

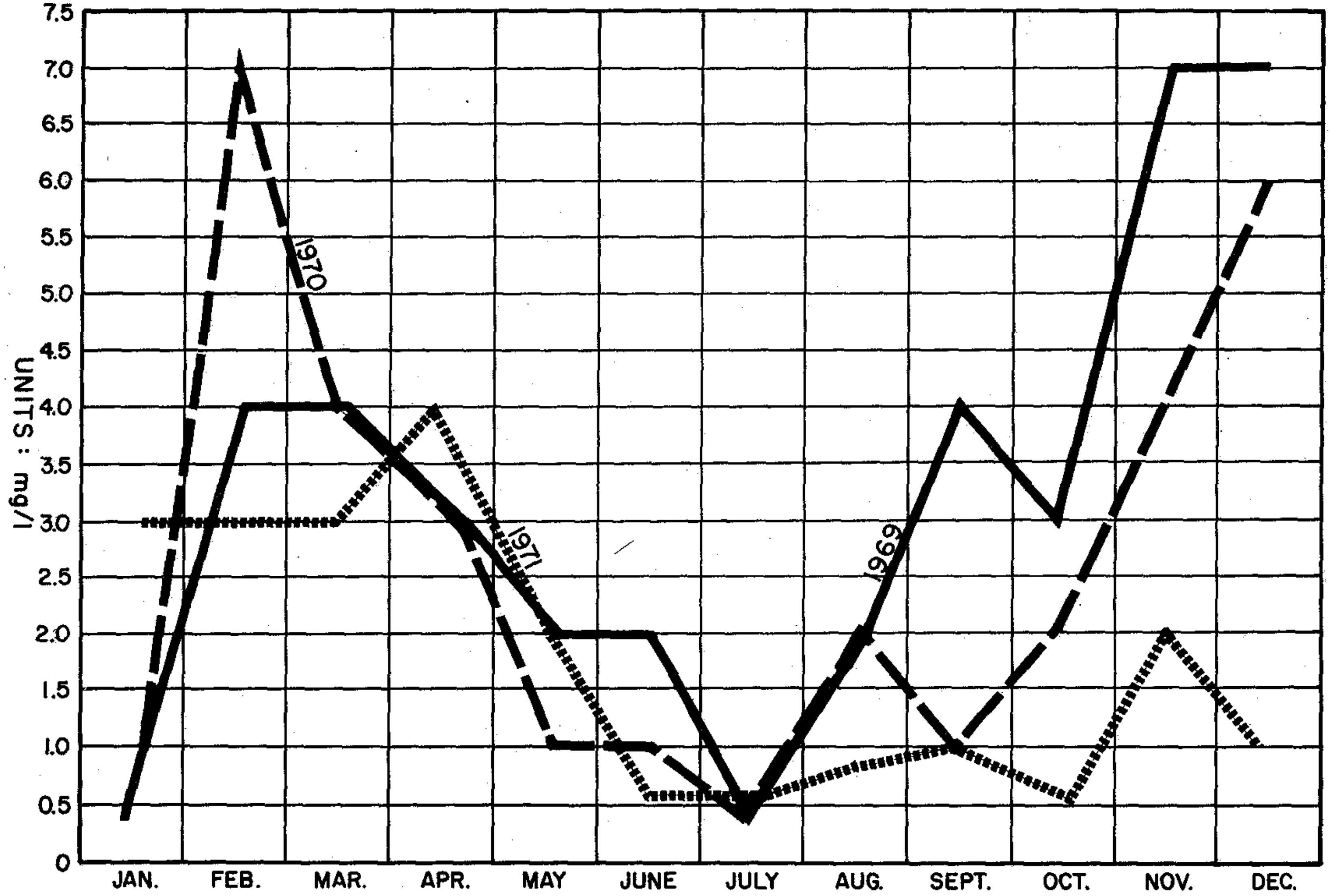
A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

## Acid or Ferruginous Mine Drainage

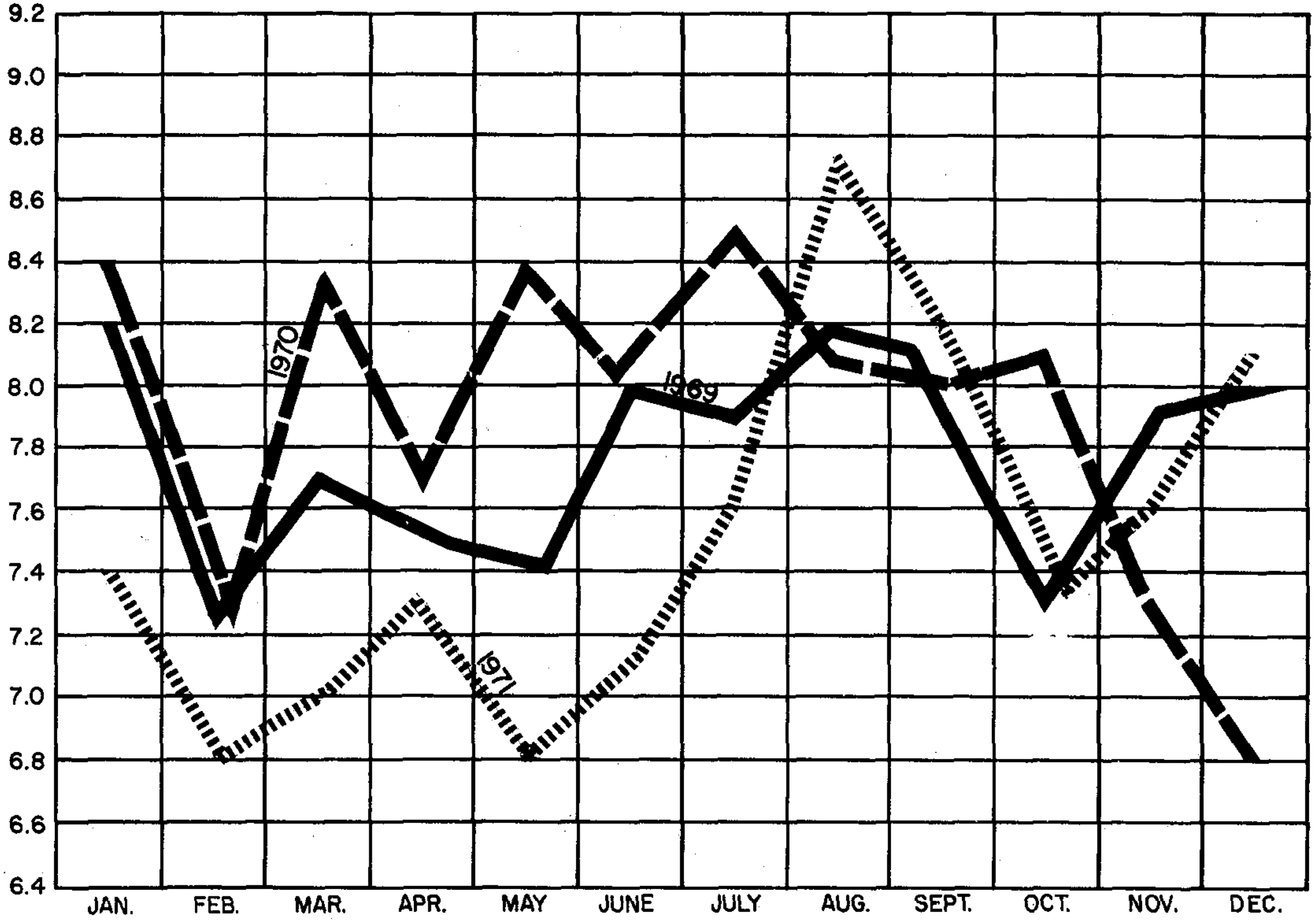
The effluent limitations suggested in the draft report were derived after careful analysis and review of effluent water quality data collected from exemplary plants. This data was substantiated by historical effluent quality information supplied by the coal industry and regulatory agencies. Despite a broad data base in terms of number of facilities visited, major problems were encountered in establishing guidelines based only on the initial samples collected. Due to time restrictions, the initial sampling program was conducted during the summer months. During this period pit pumpage and runoff from surface mines is minimal, and samples of these types of drainage could not always be obtained. In addition, the operation of acid mine drainage treatment facilities was alleged to be much better than during winter and spring. Effluent limitations based solely upon the data obtained during the summer months would have been extremely low and possibly could not be achieved by the exemplary facilities during the winter and spring seasons. To compensate for this shortcoming, the initial analytical data and available historical analyses were compared statistically to develop the suggested effluent limitations.

Historical effluent sample analyses representative of either daily samples or weekly averages of daily samples, were available for 12 of the exemplary treatment plants. This historical data substantiated the information obtained during the initial sampling program, and indicated that the concentrations of pollutants in treated mine drainage varies and was possibly affected by weather conditions. The initial sample data and the historical information also indicated that iron removal was improved by adjusting the pH upward from six. Variations in pH and total iron concentrations are graphically illustrated for three of those facilities in Figures 41 through 49. Total iron was selected for several reasons: 1) iron is one of the most commonly analyzed constitutents of mine drainage, thus data is much more complete for this parameter; 2) iron reduction is generally representative of the overall effectiveness of the neutralization process.

These plots show, as did the initial sampling program, that there are only minimal fluctuations in effluent quality during the summer months. However, daily fluctuations are more sporadic and mean concentrations are greater during fall, winter, and spring months. It should be noted that these fluctuations of pollutant concentrations may not be indicative of effectiveness of the treatment process, but could be reflecting inefficiencies in the operation of



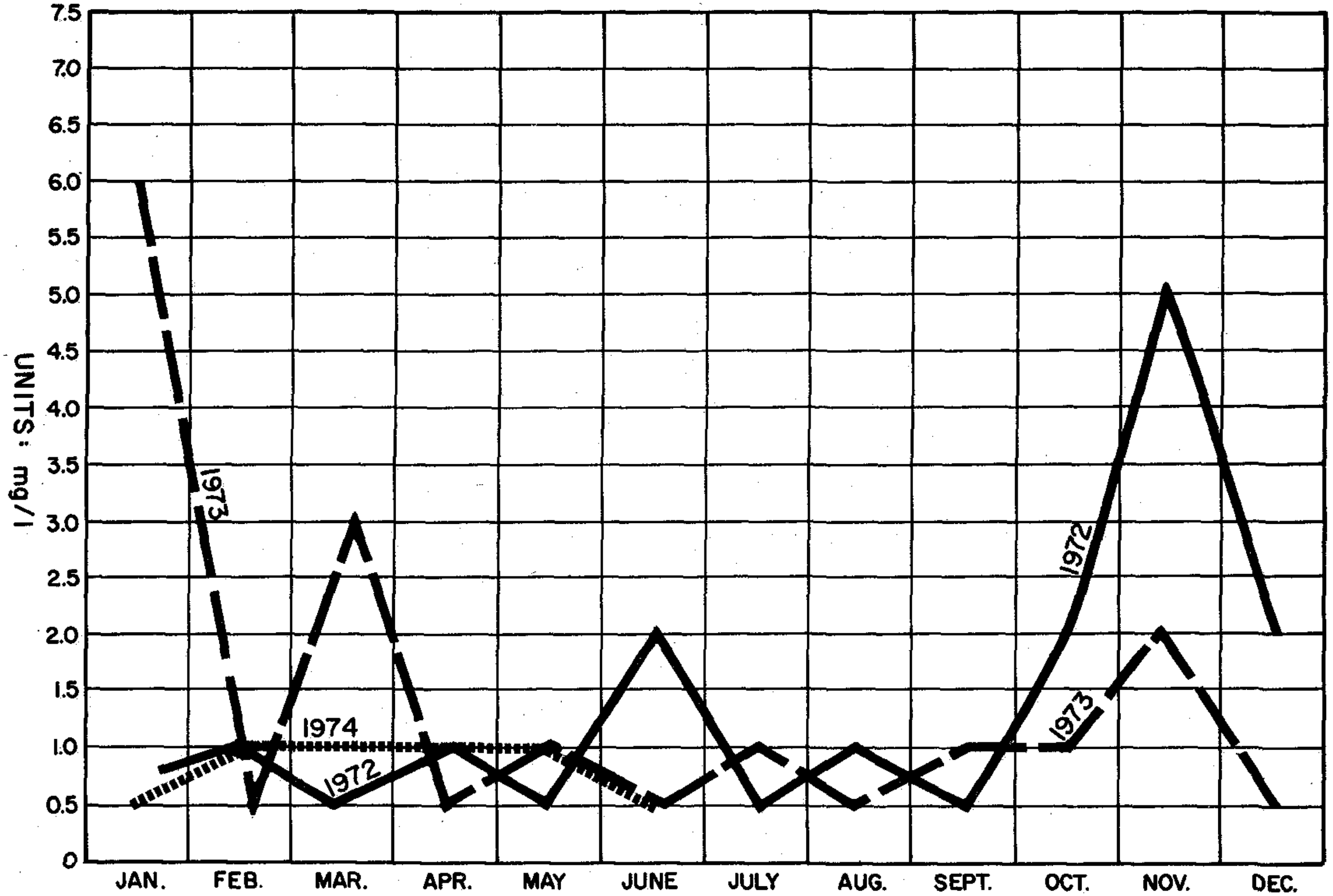
HISTORICAL DATA MONTHLY TOTAL IRON - TREATMENT PLANT A-1
Figure 41



HISTORICAL DATA - MONTHLY pH - TREATMENT PLANT A-1 .

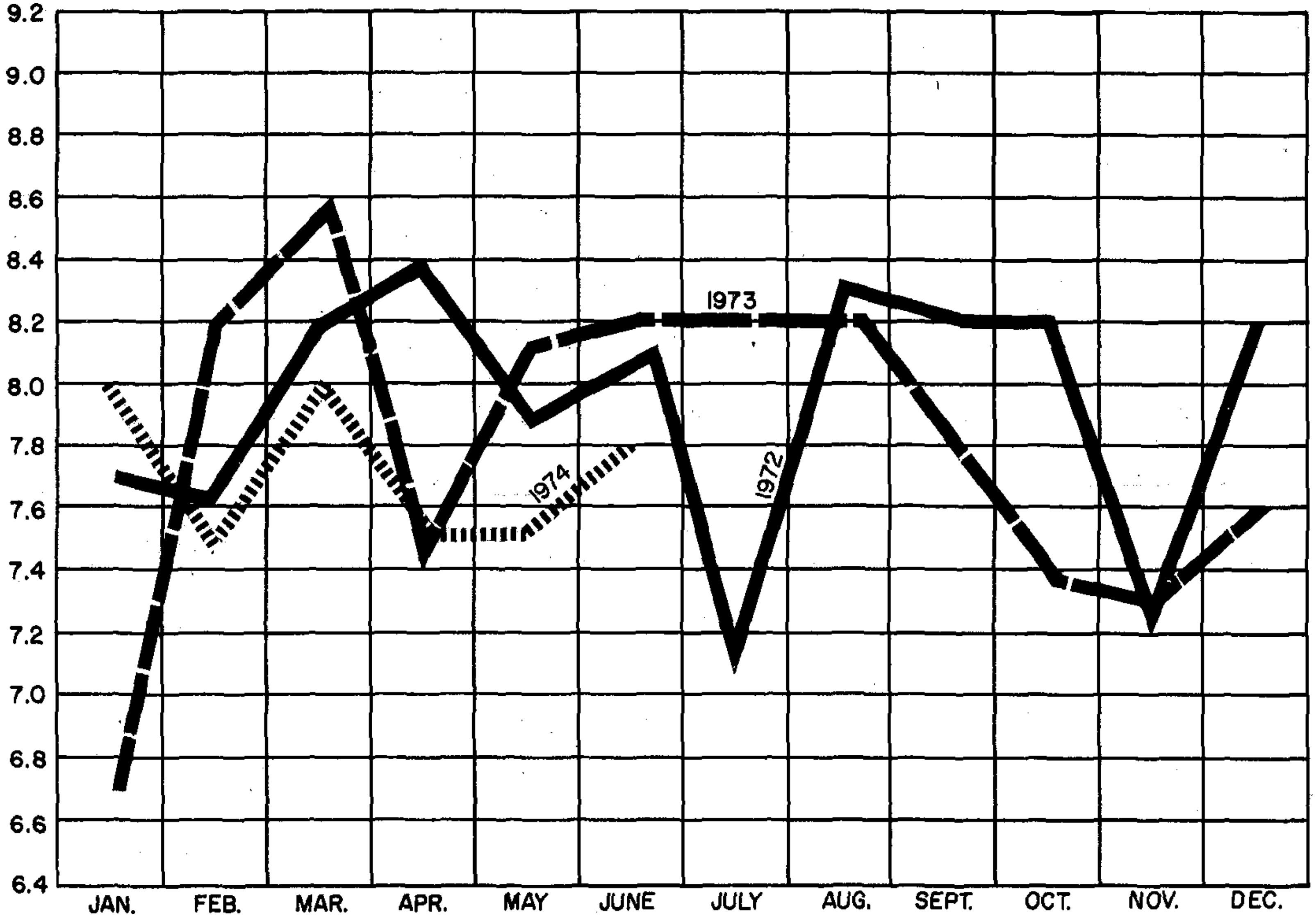
Figure 42

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.



HISTORICAL DATA MONTHLY TOTAL IRON-TREATMENT PLANT A-1
Figure 43

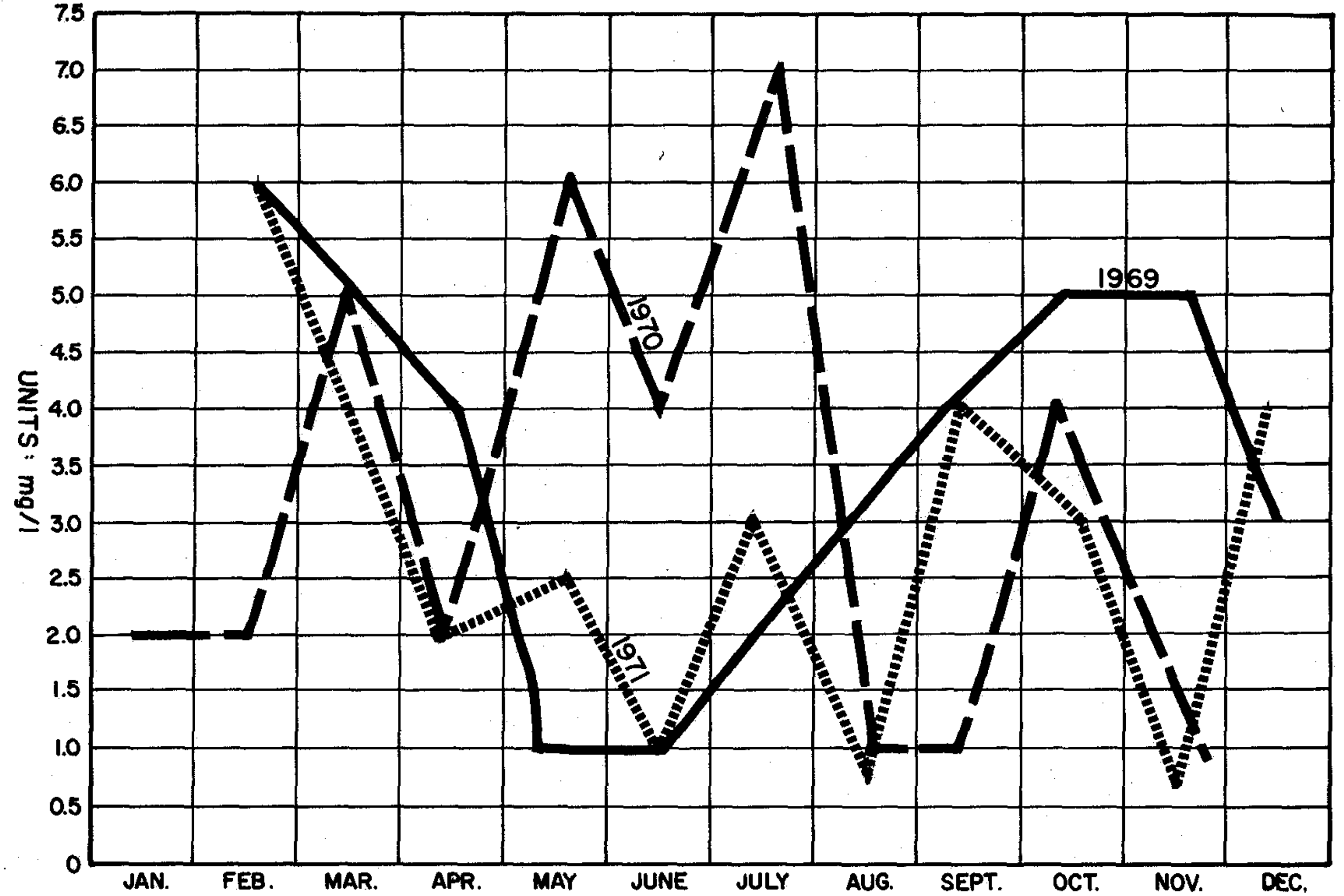
NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further [illegible]



HISTORICAL DATA - MONTHLY pH - TREATMENT PLANT A-I

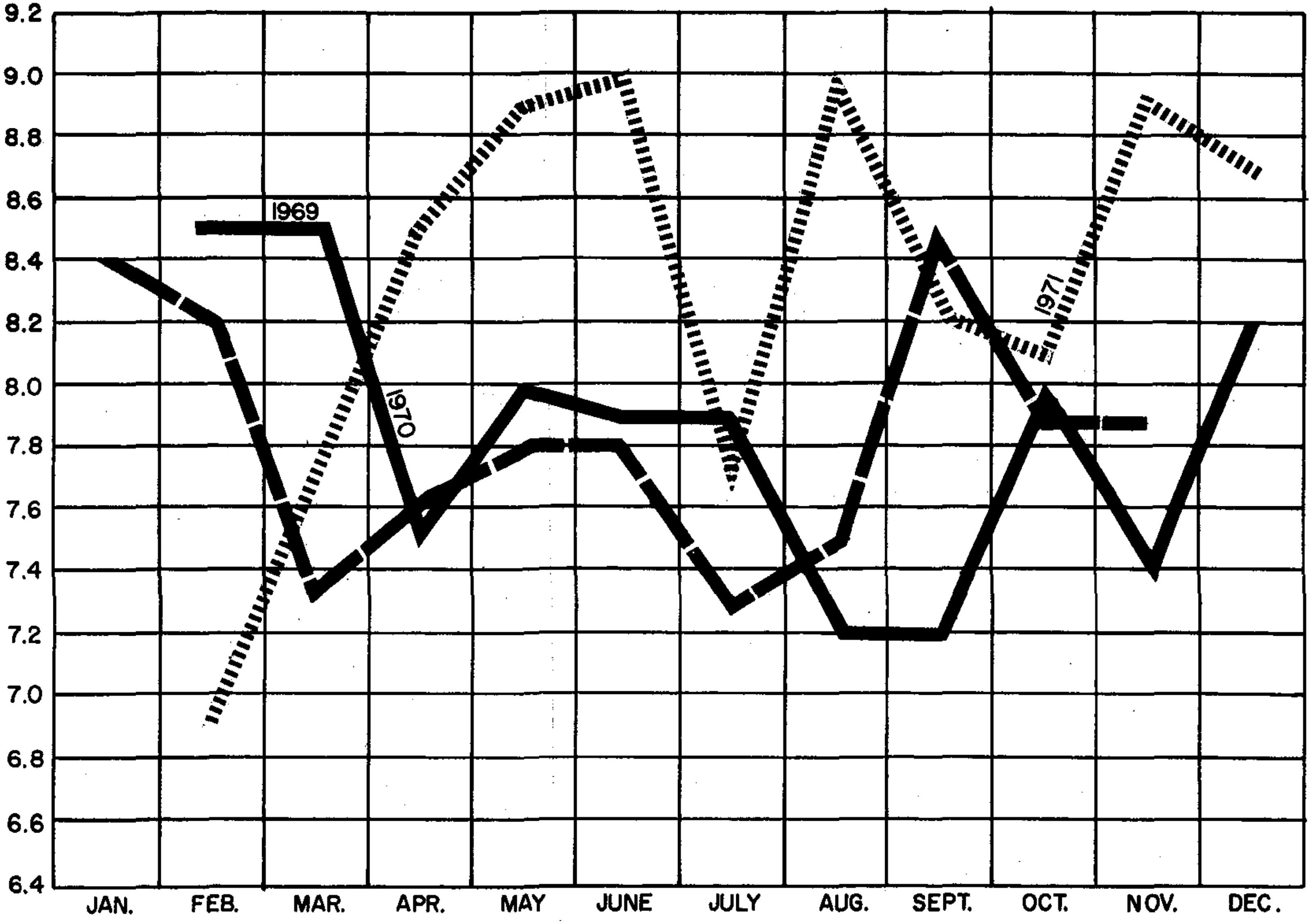
**Figure 44**

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

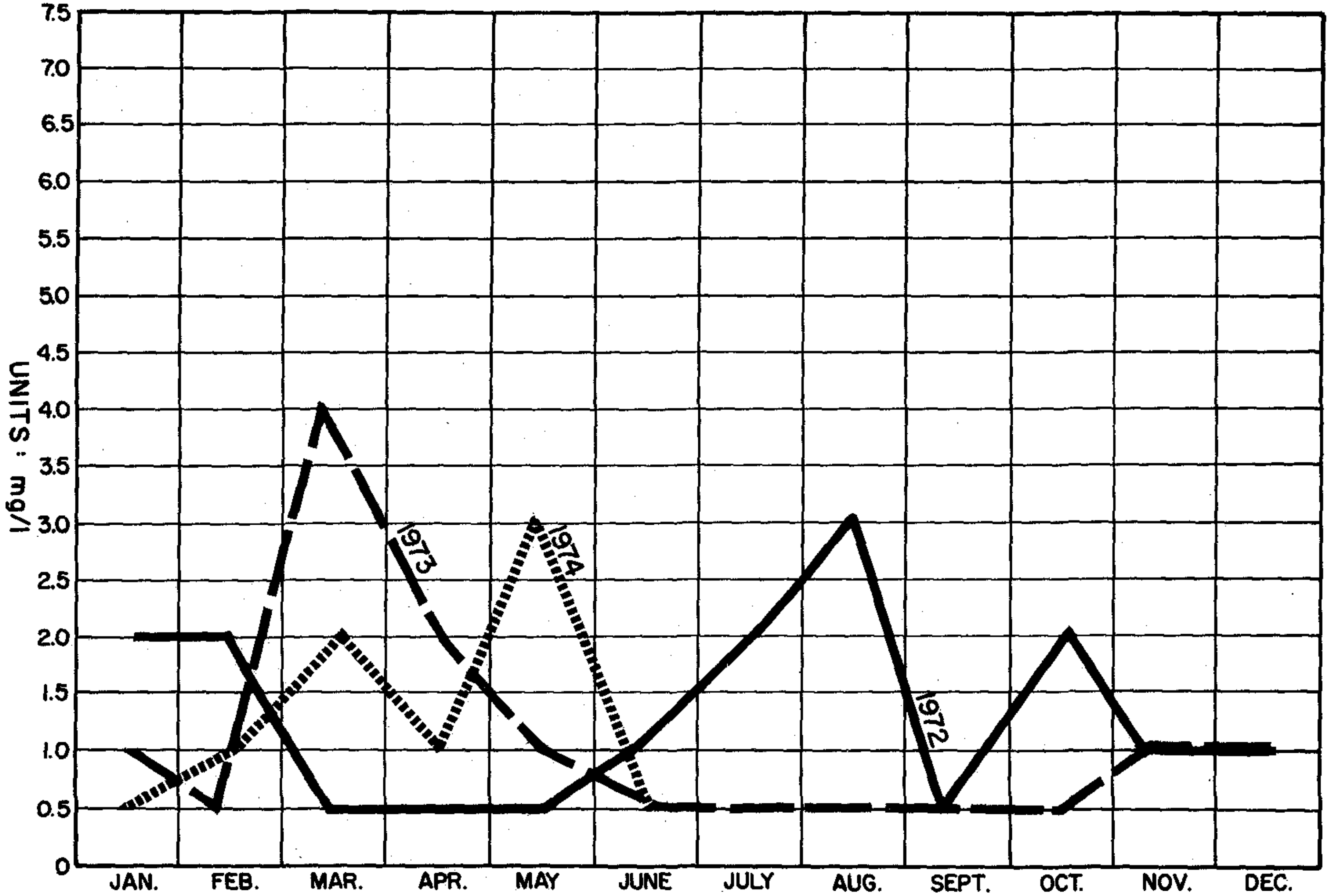


HISTORICAL DATA MONTHLY TOTAL IRON - TREATMENT PLANT A-3
Figure 45

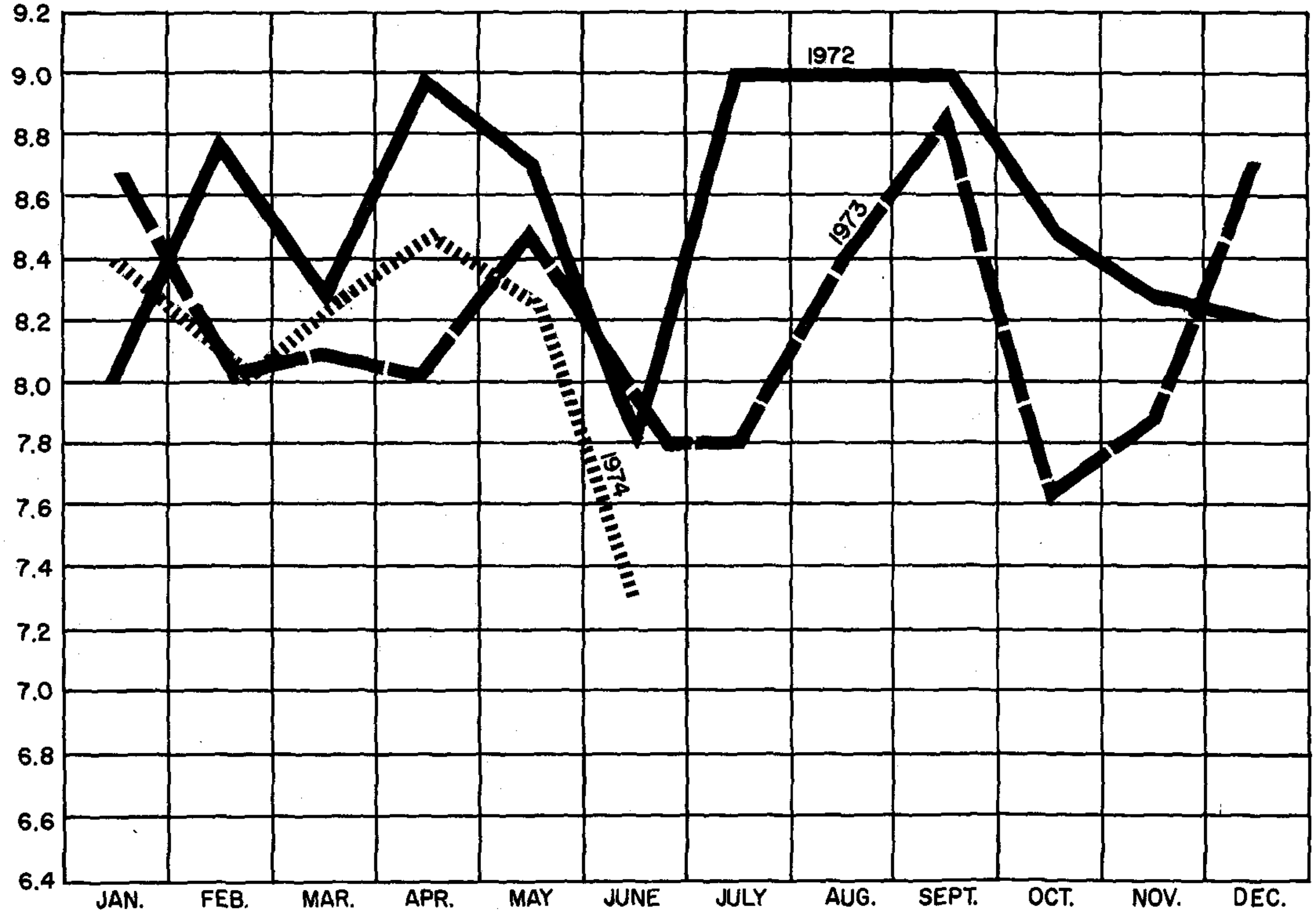
NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.



HISTORICAL DATA - MONTHLY pH TREATMENT PLANT A-3
Figure 46

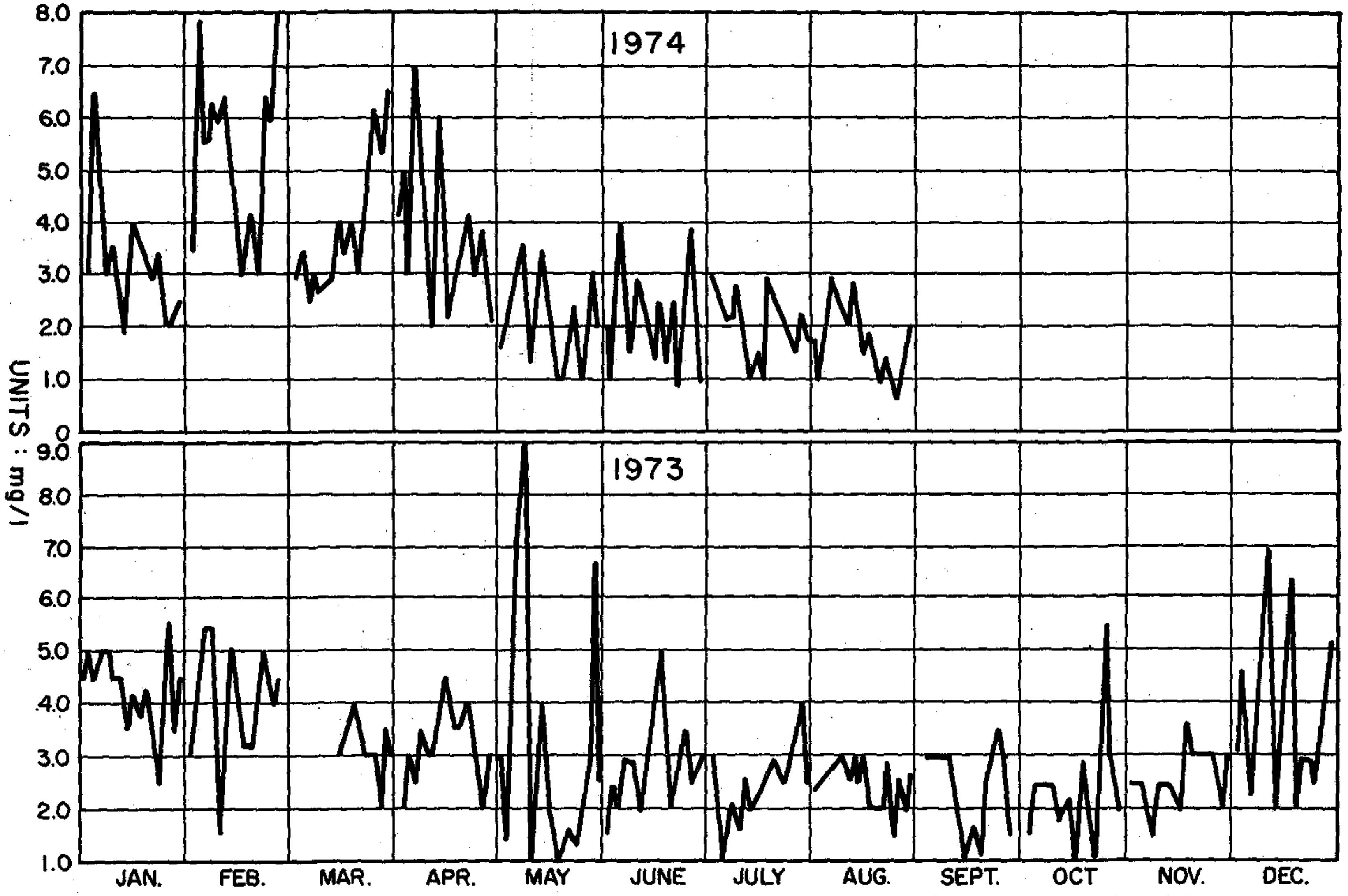


HISTORICAL DATA MONTHLY TOTAL IRON - TREATMENT PLANT A-3
Figure 47



HISTORICAL DATA—MONTHLY pH-TREATMENT PLANT A-3

Figure 48



HISTORICAL DATA DAILY TOTAL IRON - TREATMENT PLANT K-7

Figure 49

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

individual plants, or maintenance problems at individual plants. Treatment plants in the same proximity do not show significant fluctuations during the same time periods.

It was found that mean iron concentrations during these periods of fluctuations at individual treatment plants were slightly less than 3.5 mg/l with maximum concentrations approaching 9.0 mg/l. Statistical evaluation of this historical data and comparison with imitial sample data revealed that the reduction of pollutants during fall, winter and spring was approximately 1.29 standard deviations above that attainable during the summer. On this basis, the suggested 30 day average effluent limitations were computed for each critical parameter by adding 1.29 standard deviations to the mean value computed from the initial sample data. This indicated that 80 percent of the exemplary treatment plants evaluated in the initial study should be able to meet the limitations at all times.

This rationale was not, however, utilized to establish the 30 day average limitation proposed for total suspended solids, because there is a technology available which, when applied in conjunction with normal settling, can achieve the suggested suspended solids concentrations. Coagulants have been successfully and economically utilized to remove fine sediment from mine waste water to consistently achieve suspended solids concentrations observed during the initial sampling.

Examination of historical data also revealed that maximum iron values centered around 7 mg/l, or twice the monthly average value. To maintain uniformity in the establishment of daily maximums, the maximum daily guideline limitations were consistently suggested at twice the thirty-day average values.

To validate and confirm the conclusions and suggested effluent limitations established in part from historical data, a further sampling program was conducted during the winter and spring of 1975.

The suggested guidelines were initially based on careful analysis and review of effluent water quality data collected from exemplary plants. The data was substantiated by historical effluent quality information supplied by the coal industry and regulatory agencies. Selection of minesites for the winter and spring sampling program was made, whereever possible, from those identified as exemplary treatment facilities during the initial study period. Plants were considered on the basis of:

1) Plant design;
2) mode of operation, i.e., manual/automatic, safety features and alarm systems, housekeeping, etc.;
3) stability of plant operation (operational problems)
4) range of operating parameters (pH range, flow rate, settling time);
5) historical data indicating potential problems in meeting the recommended effluent limits.

Based on this analysis, seven plants were selected for further evaluation. These plants adequately represent the complete range of operating parameters and are well designed, maintained, and operated acid mine drainage treatment plants. Of the seven acid mine drainage treatment plants selected for this phase of study, six were included in the orginal list of "best plants;" the remaining plant was included because modifications and design improvements completed after the initial sampling program resulted in improved performance consistent with that of the exemplary plants. All seven plants are located within southwestern Pennsylvania and treat drainage from large underground mines. While this may appear biased toward this specific locale, it must be pointed out that Pennsylvania has long been the leader in acid mine drainage treatment technology and all are in such proximity as to be jointly affected by weather conditions. In addition, the larger mines of southwestern Pennsylvania employ the most sophisticated technology in practice today and are most conscientious in their maintenance and operational programs.

The sampling technique utilized at the acid mine drainage neutralization plants winter-spring sampling program employed automatic samplers to collect composite samples. The composite samplers collected aliquots at 15 minute intervals of the influent and effluent for each treatment plant evaluated during this supplementary study. Once each day composited samples were manually collected, prepared for laboratory analysis (by adding the proper preservatives), and returned to the laboratory. Duplicate samples were collected at each site and submitted to Bituminous Coal Research in Monroeville, Pennsylvania for evaluation and verification of analyses by the National Coal Association. All samples were analyzed for those parameters that were most prevalent in the original study. These parameters are as follows:

pH
Alkalinity
Total Suspended Solids
Iron, Total

Iron, Dissolved
Manganese, Total
Aluminum, Total
Nickel, Total
Zinc, Total
Sulfate, Total

In order to fully assess the treatment plants ability to comply with the effluent limitations for 30 day averages, as well as one day maximums, sampling was conducted at each site for 90 consecutive days. This relatively long duration of sampling enabled an assessment of the influences of temperature and precipitation on treatment plant efficiency during the winter and spring seasons. Sampling was initiated at the seven mine drainage neutralization plants on February 4, 1975 and completed May 5, 1975, a period of 91 days.

All data was correlated to daily U.S. Weather Bureau data and thoroughly reviewed to determine the influence of weather conditions on the operation of the treatment facilities. Unusual variations in effluent quality was also compared to the survey crews' field reports in order that some account could be made for these occurrences due to either maintenance or operational problems. In general, it was not observed that climatological conditions influenced the treatment of acid mine drainage. Most effluent variations observed were directly traced to maintenance or operational problems.

At one plant, however, which utilized a vary large settling basin, definite effluent variations were observed that were influenced by weather and other physical factors. Specifically, suspended solids concentrations in the effluent from this facility varied significantly during periods of ice formation or wind conditions. It is felt that better effluent quality with regard to suspended solids could be obtained by more proper selection of the point of discharge from this settling basin. Variations in the suspended solids concentrations in the discharge from this large basin were also influenced by a naturally occurring phenomenon, in which the pond "turned over" at about the 57th day of sampling. This resulted in a definite color change in the pond as well as a decrease in effluent quality.

Several days after periods of heavy precipitation, it was observed that the volume of drainage treated by plants increased significantly. This also had some affect on deterioration of effluent quality at those facilities which employed clarifiers or settling basins with short detention periods.

In almost all other instances where a significant increase in concentration of a chemical parameter was measured, the cause could be accounted for by some operation or maintenance problem. This included malfunctioning of pH measuring equipment which subsequently influenced lime feeding units, build-up of sludge in the settling basin to the point that there was a carryover in the effluent or malfunction of some other related plant equipment.

All analytical data on effluent quality was evaluated statistically for the seven plants studied during the winter-spring sampling period and the mean and standard deviation values were calculated. This data is presented below, with the values initially obtained on effluent quality during evaluation of the 22 exemplary acid mine drainage treatment plants examined during development of the draft document.

Table 32
Winter-Spring (1975) Analytical Data

| Parameter | Sample Count | Minimum mg/l | Maximum mg/l | Mean mg/l | Standard Deviation |
|---|---|---|---|---|---|
| Total Iron | 567 | 0.03 | 31.0 | 1.51 | 1.81 |
| Dissolved Iron | 517 | 0.01 | 2.1 | 0.08 | 0.18 |
| Manganese | 517 | 0.03 | 6.0 | 0.90 | 1.14 |
| Aluminum | 517 | 0.01 | 4.40 | 0.41 | 0.51 |
| Zinc | 517 | 0 | 0.18 | 0.02 | 0.02 |
| Nickel | 515 | 0.01 | 0.29 | 0.05 | 0.05 |
| Total Suspended Solids | 555 | 1 | 973 | 34 | 70.27 |

## Table 33
## 22 Best Plants (1974) Analytical Data

| Parameter | Mine Count | Minimum mg/l | Maximum mg/l | Mean mg/l | Standard Deviation |
|---|---|---|---|---|---|
| Total Iron | 22 | 0.15 | 7.40 | 1.9 | 1.48 |
| Dissolved Iron | 22 | 0.01 | 0.49 | 0.11 | 0.13 |
| Manganese | 22 | 0.01 | 3.05 | 0.91 | 0.85 |
| Aluminum | 22 | 0.01 | 3.83 | 0.74 | 0.85 |
| Zinc | 22 | 0.01 | 0.59 | 0.09 | 0.16 |
| Nickel | 22 | 0.01 | 0.57 | 0.06 | 0.12 |
| Total Suspended Solids | 22 | 1 | 192 | 34 | 44.92 |

Based upon the close comparison of the mean and standard deviations values for each of the parameters between the twenty-two exemplary plants obtained during the summer and the supplemental sampling survey, the 30 day average and single day maximum values are proposed as initially suggested in the draft development document. Further, the minimum and maximum values for pH are also proposed as previously suggested.

It does appear that any claim that the these effluent limitations cannot be achieved through the winter and spring is not warrented.

In reviewing the data obtained during this supplemental sampling project, further observations were made toward the treatment technology in practice and its efficiency in removing certain pollutants. Specific comments follow:

Acidity, pH - The control of pH in the treatment plant is most important and should be monitored on a continuous basis. It was observed that those plants operating to produce a discharge effluent near the lower pH limit of 6.0 produced effluents of a poorer quality than those that operated at 7.0 and above. A pH determination is a control indicator of the efficiency of the removal of total acidity. To be an effective indicator of the total acidity of a discharge effluent from an acid mine drainage treatment facility time must be allowed for the reaction between the acid mine drainage and the alkali used in treatment, and this reaction must be allowed to go to completion and the pH to stabilize. This is particularly true when pH determination is used as an effluent limitation.

Total Iron - It was demonstrated that total iron can be effectively removed by the treatment technology employed to within the effluent limitations proposed. For the six plants where complete data is available, violations of the recommended daily maximum did not cause the 30 day average values to exceed the proposed limit. Operational or maintenance problems were usually the reason for any total iron values which were in violation of the daily maximum value.

Dissolved Iron - It was observed that there was little problem with these plants in removing dissolved iron. All plants achieved effluent concentrations of dissolved iron consistently within the 30 day average value proposed, although there were some values which exceeded the proposed daily maximum concentration. After careful analysis of the data, it was concluded that any facility exhibiting satisfactory removal of total iron could likewise effect satisfactory removal of dissolved iron.

Manganese - It was generally observed that removals of manganese are affected by the operating pH of the treatment plant. Only one of the plants exhibited difficulty in removing manganese to a level within the recommended 30 day average value. It is theorized that this occurred because the particular plant adds a very small amount of alkali (and alkalinity) to the raw mine drainage, thereby not affecting the manganese at all, or else the long detention period (50 days) permits hydrolysis of precipitated manganese hydroxide. In any event, manganese removals to the proposed levels can be achieved through pH control.

Aluminum, Nickel and Zinc - Effective removals of these metals were observed at all plants. There were no observed values which exceeded the proposed daily maximum concentrations for nickel and zinc at any of the plants, and at only one plant did aluminum values exceed the daily maximum limit. Consequently, it is concluded that well operated treatment plants have very little problem in removal of these parameters.

Suspended Solids - The removal of suspended solids by different methods of gravity sedimentation in these treatment plants produced widely varying results. First, only one plant had suspended solids concentrations which exceeded the recommended daily maximum. This could be attributed to either an insufficient detention period in the settling basin, or to gypsum solids being formed in the sample. In addition, this same plant (A-2) together with plant A-4 exhibited difficulty in complying with the recommended 30 day average concentrations. Problems in plant A-4 can be traced to an observed condition where this very large impoundment "turned over" due to thermal stratification. This caused previously settled solids to raise to the surface and carry-over in the discharge.

Alkaline Mine Drainage

As stated in Waste Characterization (Section V) discharge effluent and sediment-bearing effluent from alkaline mine drainage is commonly superior to the quality of treated mine drainage from the most effluent treatment plants. Alkaline mine drainage is characterized as not requiring treatment or only requiring treatment for suspended solids removal.

While conventional neutralization sucessfully controls most pollutant parameters associated with acid or ferruginous mine drainage, treated mine drainage freqeuntly contains suspended solids in excess of the suspended solids concentration in sediment-bearing effluent from settling facilities used for alkaline mine drainage. Conventional neutralization generally requires the addition of solids as a neutralizing agent which cause an increase in pH of the mine drainage initiating precipitation of previously dissolved constituents. This creates additional solids to be settle out of the waste water.

The primary pollutant in alkaline mine drainage is susended solids. As established in this section, acid or ferruginous mine drainage treatment technology is available which, when applied in conjunction with normal settling, can achieve the suspended solids concentrations suggested in the draft document.

As part of the winter-spring sampling program eight surface mines in selected locations were sampled to verify fluctuations in effluent quality due to winter-spring weather variations.

The rationale for selection of settling basins (alkaline mine drainage) for evaluation differed from that used for selection of acid mine drainage treatment plants for several reasons:

1. Alkaline mine drainage is encountered over an extremely broad geographical area with widely divergent physical and climatological conditions (unlike the relatively isolated acid mine drainage of Northern Appalachia).

2. With the exception of total suspended solids, all parameters are generally within acceptable limits of the proposed guidelines.

Because the areal extent of alkaline mine drainage is so wide, sites were selected in locations which, cumulatively, were considered to be representative of the many variations found throughout the United States. Based on this criteria minesites were selected as follows:

2 Surface Mines in Western Kentucky
2 Surface Mines in Wyoming
2 Surface Mines in West Virginia
2 Surface Mines in Eastern Kentucky

The sampling technique used at the surface minesites employed the use of grab samples. This was necessitated by the unavilability of power sources at the remote locations of the sediment basins serving these minesites. Another factor considered in the decision to utilize grab sampling was the fact that, aside from the influences of storms, alkaline drainage from surface minesites is not as susceptible to plant malfunctions as are neutralization facilities. Based on this decision, samples were collected manually at the discharge from each of the minesites' settling basins. Wherever possible, samples were also collected of the influent to the sediment ponds; in several cases this was not possible because drainage entered the pond from many individual points and a single sample would not accurately represent the overall quality of the raw mine drainage.

In addition to the daily grab samples collected at each of the surface mine sites, weekly composite samples were collected at each sample location. This too, was accomplished manually by taking aliquots at each site over a seven day period throughout the study.

Daily grab samples were analyzed for pH and total suspended solids, while weekly composite samples were analyzed for all parameters defined above in the discussion of neutralization plants included in the winter-spring sampling program. As with the acid mine drainage treatment plants, the duration of sampling was 90 consecutive days. However, due to he divergent locations of the minesites involved, considerable time was required to implement the sampling program; consequently, sampling was not initiated at all sites simultaneously.

Computerization of the supplementary samples from sedimentation ponds where daily samples consisted of only pH and total suspended solids were analyzed using a soft-ware program, whereby the sample statistics were obtained without extensive mine coding.

Sample statistics on these total suspended solids data included:

1. Individual mine
2. Mine type (surface and underground) for alkaline mine drainage
3. All sediment bearing effluent
4. All treated mine drainage

Each analysis included the maximum, minimum, mean and standard deviation for these total suspended solids data.

Based upon the initial sampling program and the winter-spring sampling program the 30 day average and single day maximum values are proposed as suggested in the draft document.

## Coal Preparation Plants and Coal Preparation Plant Ancillary Area

For coal preparation plants, it was demonstrated by a wide segment of the industry that total reuse of process water is feasible. Therefore closed systems, or "zero discharge," has been proposed for BPT. Drainage from a preparation plant's immediate yards, coal storage areas, or refuse disposal areas must comply with the effluent limitations recommended for Bituminous, Lignite, and Anthracite Mining.

The effluent limitation guidelines and standards for "Best Practicable Control Technology Currently Available" are presented in Table 34.

Waste treatment technology for the coal mining industry does not require highly sophisticated methods. Effective removal of pollutants contained in mine waste water has been demonstrated by the industry. For acid or ferruginous mine drainage lime neutralization has been adequately demonstrated as being capable of meeting the effluent limitations requirements for BPT as listed. Effective removal of iron, manganese, aluminum, zinc and nickel can be achieved by maintaining proper pH control. For alkaline mine drainage, sedimentation, or sedimentation with coagulation, will meet the limits recommended. In some few instances it may be desirable to utilize filtration methods

## TABLE 34

## EFFLUENT LEVELS ACHIEVABLE THROUGH APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | No Discharge of Process Water | No Discharge of Process Water | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | | | 3.5 | 7.0 | 3.5 | 7.0 | 3.5 | 7.0 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 35 | 70 | 35 | 70 | 25 | 50 |

*All values except pH in mg/l.

for effective suspended solids removal from mine drainage. It was also demonstrated that those alkaline mine drainages containing dissolved iron can meet recommended limits by natural aeration in holding ponds.

These guidelines do not appear to present any particular problems in implementation. The treatment processes involved are in use by the industry and difficult engineering problems are not usually involved in design or construction. The costs estimated in Section VIII are based primarily on actual plant data, and generally reflect the entire range of flows encountered, as presented in Figure 40. The costs given represent the average situation.

# SECTION X

# BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE, GUIDELINES AND LIMITATIONS

## INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983 are to specify the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable. Best Available Technology Economically Achievable is determined by the very best control and treatment technology employed by a specific point source within the industry category or by technology which is readily transferable from another industrial process.

Consideration must also be given to:

a. the age of the equipment and facilities involved;

b. the process employed;

c. the engineering aspects of the application of various types of control techniques;

d. process changes;

e. cost of achieving the effluent reduction resulting from the application of this level of technology;

f. non-water quality environmental impact (including energy requirements).

Also, Best Available Technology Economically Achievable assesses the availability of in-process controls as well as additional treatment at the end of a production process. In-process control options include water re-use, alternative water uses, water conservation, by-product recovery, good housekeeping, and monitor and alarm systems.

A further consideration is the availability of plant processes and control techniques up to and including "no discharge" of pollutants. Costs for this level of control are to be the top-of-the-line of current technology subject to engineering and economic feasibility. The Best Available Technology Economically Achievable may be characterized by some technical risk with respect to performance and with respect to certainty of costs. The Best Available Technology Economically Achievable may necessitate some industrially sponsored development work prior to its application.

Best Available Technology Economically Achievable is not based upon an average of the best performance within an industrial category, but is to be determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or sub-category, or where it is readily transferable from one industry process to another, such technology may be identified as Best Available Technology Economically Achievable.

Mine Code K-7 was identified in the draft development document as the facility exhibiting the very best overall control and treatment technology for acid or ferruginous mine drainage. After additional analysis, it was determined that other mines (namely, Mine Codes A-1, A-4, and B-2) were comparable to mine K-7 in both sophistication of AMD treatment plant design and efficiency of pollutant reduction.

As has been mentioned in Section IX, the initial sampling program conducted during this study did not accurately represent any possible effects of seasonal variations on mine drainage treatment facilities. The AMD treatment facilities included in the winter and spring sampling study are in the same proximity so as to be equally affected by weather conditions, and include mine code A-1, A-4, and B-2. Mine Code K-7 is not considered to be in the same proximity as the other mines included in the study. For these reasons, mine Code K-7 was not included in the winter-spring sampling program. Mine Codes A-1, A-4, and B-2 are recognized as mines exhibiting the very best overall control and treatment technology.

These mines represent mine drainage treatment facilities using conventional lime neutralization systems. Settling basin, mechanical clarifier, or combination of mechanical clarifier and settling basin are used for suspended solids removal. All three mines are operated primarily to meet the effluent requirements of the State of Pennsylvania.

Statistical evaluations of the data generated at these three mines during the winter and spring sampling program were performed. This included an evaluation to determine the maximum daily concentration of each parameter for each of the three mines; an evaluation to determine the maximum 30-

day average concentration of each parameter for each of the three mines; an evaluation to determine the daily maximum concentration of each parameter at the three mines; and an evaluation to determine the maximum 30-day average concentration of each parameter at the three mines.

Best Available Technology Ecnomically Achievable reflects improved performance at these three mines. The winter-spring sampling program verified that weather conditions do not significantly influence the treatment of mine drainage. Variations in effluent quality were directly attributable to pH control or maintenance problems which are considered to be correctable through improved performance at the individual mine. Those analysis for the days where there were observed correctable operational problems were not included in the statistical evaluations.

The effluent limitation guidelines representing BAT for maximum daily concentrations and 30 day average concentrations of total iron, dissolved iron, total aluminum, total manganese, total nickel, and total zinc are obtainable at any of these three mines 99% of the time with improved performance related to pH control and improved maintenance of the mine drainage treatment plant.

Advanced technology for suspended solids reduction has been demonstrated in the coal industry with flocculant aids and in other industries such as steel and paper using polishing filters. Deep bed or in-depth filtration is capable of achieving effluent suspended solids concentrations on the order of 10 to 20 mg/l, depending upon the filter media size, and particle diameter of the solids encountered. Since this filtration technique has not been demonstrated in coal industry applications, some leeway is allowed in establishing BAT suspended solids effluent limitations. BAT effluent limitation guidelines for suspended solids in the mining segment of the coal industry is established at 20 mg/l as a 30-day average value and 40 mg/l as a daily maximum value.

The limitation guidelines for "Best Available Technology Economically Achievable" are presented in Table 35.

It had been considered that Best Available Technology Economically Achievable could possibly provide for total dissolved solids control. A study of the available processes indicates that Reverse Osmosis is the most applicable. Operating costs for R-O and in particular the "Neutrolosis Process" were discussed in Section VII and were estimated at $0.27 per cubic meter ($1.10 per thousand

# TABLE 35

## EFFLUENT LEVELS ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | | | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | No Discharge of Process Water | No Discharge of Process Water | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 20 | 40 | 20 | 40 | 20 | 40 |

*All values except pH in mg/l.

gallons) of acid mine drainage treated. For those mines that treat acid or ferruginous mine drainage and were presented as case histories in Section VII, the estimated operating cost for a Neutrolis system would range from $0.22 to $9.68 per KKG ($0.20 to $8.78 per ton) of coal mined. The range reflects the age, size and hydrology of the mines. For mines where drainage volumes are small the operating cost of a Neutrolosis Process would be low when compared to the tonnage of coal mined. For those older mines that are affected by large areas, the volume of mine drainage to be treated are significantly greater.

The use of reverse osomsis in the treatment of mine drainage is still in the research stage. While the process shows some promise, its application has not been successfully demonstrated at this time. For both technological and economic reasons, reverse osmosis cannot be recommended as BAT for the removal of dissolved solids.

Significant recycle or zero discharge is not possible to obtain for coal mine drainage.

# SECTION XI

# NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

## INTRODUCTION

The effluent limitations which must be achieved by new sources, i.e., a source, the construction of which is started after proposal of New Source Performance Standards, are to reflect the degree of treatment achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The end result is to identify effluent standards achievable through the use of improved production processes (as well as control technology). A further determination which must be made for New Source Performance Standards is whether a standard permitting no discharge of pollutants is practicable.

Consideration must also be given to:

a. the type of process employed and process changes;

b. operating methods;

c. batch as opposed to continuous operation;

d. use of alternative raw materials and mixes of raw materials;

e. use of dry rather than wet processes;

f. recovery of pollutants as by-products.

In addition to recommending New Source Performance Standards and effluent limitations covering discharges into waterways, constituents of the effluent discharge must be identified which would interfere with, pass through or otherwise be incompatible with a well designed and operated publicly owned treatment plant. A determination must be made as to whether the introduction of such pollutants into the treatment plant should be completely prohibited.

It has been determined that technology does exist for effluent limitations guidelines as proposed for BAT. However, as previously mentioned, the filtration technology upon which a portion of BAT suspended solids limitations are based has not been applied in the coal industry, thus its adaptability, suitability, and economics have not yet been fully determined. In addition, the degree of reliability has not been sufficiently demonstrated to merit inclusion in the consideration of new source performance standards.

The limitation guidelines for "New Source Performance Standards" are presented in Table 36.

## Pretreatment Standards

Wastewaters from the mining industry are not characteristic of those wastes amenable to treatment by biological processes. In addition, these wastes are generally not compatible with sanitary sewage because of their potential acidic nature, metals content, and large volumes. However, there are some metalic salts such as aluminum sulfate and certain ferrous salts which are beneficial to and are used in waste water treatment at publicly owned treatment facilities. These metalic salts are commonly used as coagulants. It has been shown that under controlled conditions municipal waste water and AMD can be treated together in "combined treatment." In certain cases AMD may be an economical source of chemical coagulant, and division of AMD to "combined treatment" would contribute towards the abatement of pollution due to AMD.

It is recognized that portions of the Anthracite mining industry in Pennsylvania have a unique situation in that the State of Pennsylvania has established ten water sheds which are affected by mine drainage, and has established a Pollution Abatement Escrow Fund to build and maintain mine drainage treatment facilities to treat mine drainage from active and abandoned mines. Anthracite mining companies located in these ten water sheds may discharge raw mine drainage and pay the State of Pennsylvania a fee based on the tonnage mined. This fee is intended to offset the operating and maintainence costs of the mine drainage treatment facilities owned by the State. These state owned mine drainage treatment' facilities may be considered publicly owned treatment plants.

## TABLE 36

## NEW SOURCE PERFORMANCE STANDARDS

| Parameter | Bituminous, Lignite, and Anthracite Mining Services | | | | Bituminous, Lignite, and Anthracite Mining | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Preparation Plant | | Coal Storage, Refuse Storage and Coal Preparation Plant Ancillary Area | | Acid or Ferruginous Mine Drainage | | Alkaline Mine Drainage | |
| | 30 Day Average | Daily Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum | 30 Day * Average | Daily * Maximum |
| pH | No Discharge of Process Water | No Discharge of Process Water | 6- | 6-9 | 6-9 | 6-9 | 6-9 | 6-9 |
| IRON, TOTAL | | | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 |
| DISSOLVED IRON | | | 0.30 | 0.60 | 0.30 | 0.60 | 0.30 | 0.60 |
| ALUMINUM, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| MANGANESE, TOTAL | | | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 4.0 |
| NICKEL, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| ZINC, TOTAL | | | 0.20 | 0.40 | 0.20 | 0.40 | 0.20 | 0.40 |
| TOTAL SUSPENDED SOLIDS | | | 35 | 70 | 35 | 70 | 25 | 50 |

*All values except pH in mg/l.

# SECTION XII

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| Kaskan Coal Company | Mr. George Kaskan |
| Kaiser Steel Corporation | Mr. Lynn Huntsman<br>Mr. Edward D. Moore |
| Kemmerer Coal Company | Mr. Louis Engstrom<br>Mr. Michael Zakontnick, Jr. |
| Kemo Mining Company | Mr. Walter Hawkins |
| Kerry Mears Coal Company | Mr. Charles Mears |
| Knife River Coal Mining Company | Mr. Dean Dishon<br>Mr. Frank Eide<br>Mr. Thomas A. Gwynn<br>Mr. A. S. Kane<br>Mr. H. H. Scherbenski |

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| Kocher Coal Company | Mr. Leon Richter |
| Lady Jane Collieries Incorporated | Mr. Paul D. Hineman |
| | Mr. Charles Merritt |
| LaRosa Fuel Company | Mr. James LaRosa |
| Lehigh Valley Anthracite | Mr. Joseph Pagnotti |
| | Mr. Robert Shober |
| | Mr. James Tedesco |
| Lone Star Steel | Mr. J. E. Hurse |
| | Mr. J. Paul Savage |
| Lovilia Coal Company | Mr. Thomas Wignall |
| Mastellar Coal Company | Mr. James Watson |
| Mary Ruth Corporation | Mr. Milford Jenkins |
| Mid-Continent Coal & Coke Company | Mr. J. L. Reeves |
| | Mr. J. H. Turner |
| Miller-McKnight Coal Company | Mr. Gary McKnight |
| Moran Coal Company | Mr. Donald E. Moran |
| Mountain Drive Coal Company | Mr. James Gibbs |
| M & R Coal Company | Mr. Lawrence Scott |
| National Steel Corporation | Mr. William Gadd |
| | Mr. Fred Tucker |
| | Mr. Donald Wills |
| North American Coal Corporation | Mr. Carl Bishop |
| | Mr. C. H. Daub |
| | Mr. Terry Dudley |
| | Mr. Michael Gregory |
| | Mr. Franklin Scott |
| | Mr. Harold Washburn |
| Old Ben Coal Company | Mr. C. E. Bailie |
| | Mr. R. E. Flatt |
| | Mr. Lanny Richter |
| | Mr. Walter Von Demfange |
| P. B. S. Coals, Incorporated | Mr. Albright |
| | Mr. Roger Kalaha |
| | Mr. Shirbine |

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|---|---|
| | Mr. Joseph Whitaker |
| | Mr. Robert Will |
| | Mr. Ziegler |
| Peabody Coal Company | Mr. Ronald Cross |
| | Mr. William Davis |
| | Mr. John Gingrich |
| | Mr. Gene Hendrichs |
| Peabody Coal Company | Mr. Tracy Hendrichs |
| | Mr. James R. Jones |
| | Mr. Thomas Linn |
| | Mr. David G. McDonald |
| | Mr. M. A. McKee |
| | Mr. Ronald Pruett |
| | Mr. Freman Qualls |
| | Mr. Wayne Rosso |
| | Mr. Leonard Sautelle |
| | Mr. Harry Yocum |
| Peter Keiwit Sons' Mining Company | Mr. Frank Kinney |
| | Mr. J. F. Ratchye |
| Pittsburgh & Midway Coal Mining Company | Mr. Charles Atkinson |
| | Mr. J. A. Borders |
| | Mr. Fritz Gottron |
| | Mr. George Hayes |
| | Mr. John C. Willson |
| The Pittston Company | Mr. C. R. Montgomery |
| Premium Coal Company | Mr. Robert Swisher |
| Queen Anne Coal Company | |
| Rock Creek Mining Company | |
| Pyro Coal Company | Mr. George Martin |
| Queen Brothers Coal Company | Mr. Robert Queen |
| Richland Coal Company | Mr. Douglas Blair |
| Rochester & Pittsburgh Coal Co. | Mr. Geroge Kennedy |
| | Mr. J. J. Schaeffer |
| | Mr. Edward Sokal |
| | Mr. Eric Wilson |
| Rockville Mining Company | Mr. Joseph Elliot |
| Russel Shafer Coal Company | Mr. Russel Shafer |

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| Shamrock Coal Company | Mr. Arlo Brown |
| | Mr. Orville Smith |
| South-East Coal Company | Mr. Jack Jenkins |
| Southern Utah Fuel Company | Mr. Martinson |
| Surgener's Coal Sales, Incorp. | Mr. Noah Surgener |
| T. C. H. Coal Company | Mr. George E. Neal |
| U. S. Pipe & Foundry Company | Mr. Lecil Colburn |
| | Mr. C. J. Hager |
| | Mr. Harold Stacey |
| U. S. Steel Corporation | Mr. John C. Anderson |
| | Mr. John W. Boyle |
| | Mr. John E. Caffrey |
| | Mr. Donald K. Cooper |
| | Mr. Herbert Dunsmore |
| | Mr. Gregory Ferderber |
| | Mr. Robert R. Godard |
| | Mr. R. F. Goudge |
| | Mr. Hersch Hayden |
| | Mr. M. A. Holtz |
| | Mr. J. A. Kennison |
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| | Mr. Earl W. Mallick |
| | Mr. A. E. Moran |
| | Mr. Paul Parfitt |
| | Mr. Glen Sides |
| | Mr. E. L. Thomas |
| | Mr. Paul E. Watson |
| | Mr. John E. Young |
| Utah International, Incorporated | Mr. Leo Hendery |
| | Mr. Wayne Sonard |
| Washington Irrigation and Development Company | Mr. Richard McCarthy |
| Western Energy Company | Mr. Michael Grindy |
| | Mr. W. P. Schmechel |
| | Mr. Martin A. White |
| Western Hickory Coal Company | Mr. Harold List |
| West Freedom Mining Corporation | Mr. Russell Haller |
| | Mr. John Smith |

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| Westmoreland Coal Company | Mr. John Gembach<br>Mr. Anthony Nevis |
| Westmoreland Resources Corp. | Mr. Ralph E. Moore<br>Mr. Mathew S. Tudor |
| White Rock Mining Company | Mr. Olaf Shafer |
| Wyodak Resources Development Corporation | Mr. Wilford J. Westre |
| Zeigler Coal Company | Mr. Coy L. South |

## Trade Organizations

| | |
|---|---|
| American Mining Congress | Mr. Richard C. Beerbower<br>Mr. Brice O'Brien<br>Mr. Donald Simpson |
| Bituminous Coal Research | Mr. James F. Boyer, Jr.<br>Mr. Charles T. Ford |
| Independent Miners and Associates | Mr. Clyde Machemar |
| National Coal Association | Mr. Joseph W. Mullan<br>Mr. Robert F. Stauffer |
| National Independent Coal Assoc. | Mr. Louis Hunter |
| Ohio Mining and Reclamation Assoc. | Mr. Neal S. Tostenson |
| Pennsylvania Coal Mining Assoc. | Mr. Franklin H. Mohney |
| Virginia Coal Association | Mr. W. Luke Witt |
| West Virginia Surface Mining and Reclamation Association | Mr. Daniel Gerkin<br>Mr. Ben Lusk |

## Regulatory Agencies

| | |
|---|---|
| Atomic Energy Commission | Dr. Robert L. Spore |
| Illinois - State of Illinois, Energy Office, Assistant | Mr. Don Handy |

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| Energy Coordinator | |
| Indiana - State of Indiana, Director, Water Pollution Control | Mr. Sam Moore |
| Kentucky - Dept. of Natural Resources and Environmental Protection | Mr. Clyde Baldwin |
| | Mr. Kenneth Cobb |
| | Mr. Thomas O. Harris |
| | Mr. William Harris |
| | Mr. William S. Kelly |
| | Mr. Robert Nickel |
| | Mr. Ernest Prewitt |
| | Mr. Kenneth D. Ratliff |
| | Mr. Wensell Sheperd |
| | Mr. Harold Snodgrass |
| | Mr. Robert Warrix |
| | Mr. Nevard Wells |
| MESA (District 7) | Mr. Donald Rheinhardt |
| | Mr. Jerry Spicer |
| Montana - Department of State Lands, Reclamation Division | Mr. C. C. McCall |
| | Mr. Roy Koch |
| North Dakota - North Dakota Dept. of Health (Director of Water Supply) | Mr. Norman Peterson |
| Oklahoma - Oklahoma Water Pollution Control | Mr. Terry Thurman |
| Pennsylvania - Department of Environmental Resources | Dr. John J. Demchalk |
| | Mr. A. E. Friedrich |
| | Mr. Ernest Giovannitti |
| | Mr. Walter Heine |
| | Mr. Howard A. Luley |
| | Mr. A. E. Molinski |
| | Mr. Mark Roller |
| | Mr. Richard Thompson |
| Altonna Water Department | Mr. Dave Barr |
| Tennessee - Division of Surface Mining | Mr. Arthur Hope |
| Tennessee Division of Water Quality | Mr. Collian Goodlet |
| United States Environmental | Mr. Richard Andrews |

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| Protection Agency | Mr. Arthur Chafet |
| | Mr. Elmore Grim |
| | Mr. Gene Harris |
| | Mr. Ronald Hill |
| | Ms. Judith A. Nelson |
| | Mr. John Sceva |
| | Mr. Robert C. Scott |
| | Mr. Robert Scott |
| | Mr. Glenwood D. Sites |
| | Ms. Nancy Speck |
| | Mr. Roger Wilmoth |
| Virginia - Virginia Department of Reclamation | Mr. William Roller |
| Virginia Water Control Board | Mr. Lawrence Owens |
| | Mr. Dallas Sizemore |
| Washington - U. S. Bureau of Mines (Spokane Mining Research Center) | Mr. Thomas Martin |
| West Virginia - West Virginia Department of Natural Resources | Mr. John Ailes |
| | Mr. Donald Bailey |
| | Mr. Joseph Beymer |
| | Mr. Don E. Caldwell |
| | Mr. Owen L. Carney |
| | Mr. James Gillespie |
| | Mr. Benjamin Greene |
| | Mr. Robert McCoy |
| | Mr. Thomas Methaney |
| | Mr. William Raney |
| | Mr. Jerry Starcher |
| | Mr. Basil Sweeney |

## Educational Institutions

| | |
|---|---|
| Colorado State University | Dr. David McWhortor |
| Montana State University | Dr. Richard Hodder |
| Pennsylvania State University | Dr. Harold Lovell |
| University of Tennessee | Dr. Roger A. Minear |
| | Dr. John R. Moore |
| West Virginia University | Dr. G. Lansing Blackshaw |

## SECTION XIII

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# SECTION XIV

## GLOSSARY

AMD - Acid Mine Drainage

Aeration - The act of exposing to the action of air, such as, to mix or charge with air.

Anion - An ion that moves, or that would move, toward an anode. Negative ion.

Anticline - A fold that is convex upward. The younger strata are closest to the axial plane of the fold.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Auger - Any drilling device in which the cuttings are mechanically and continuously removed from the borehole without the use of fluids.

Backfilling - The transfer of previously moved material back into an excavation such as a mine or ditch, or against a constructed object.

Bench - The surface of an excavated area at some point between the material being mined and the original surface of the ground on which equipment can set, move or operate. A working road or base below a highwall as in contour stripping for coal.

Cation - An ion that moves, or that would move, toward a cathode. Positive ion.

Clarifier - A device for removing suspended solids.

Coal Preparation Plant - A facility where coal is crushed, screened, sized, cleaned, dried, or otherwise prepared or loaded prior to the final handling or sizing in transit to or at a consuming facility.

Deep Mine - An underground mine.

Dissolved Solids - The difference between the total and suspended solids in water.

Drift - A deep mine entry driven directly into a horizontal or near horizontal mineral seam or vein when it outcrops or is exposed at the ground surface.

Ecosystem - A total organic community in a defined area or time frame.

Erosion - Processes whereby solids are removed from their original location on the land surface by hydraulic or wind action.

Flume - An open channel or conduit on a prepared grade.

Ground Water Table (or Level) - Upper surface of the underground zone of saturation.

Grout - A fluid mixture of cement, sand (or other additives) and water that can be poured or pumped easily.

Grout Curtain - Subsurface zone of greatly decreased permeability created by pressurized insertion through boreholes of cement or other material into the rock strata.

Highwall - The unexcavated face of exposed overburden and coal in a surface mine or the face or bank on the uphill side of a contour strip mine excavation.

Hydrology - The science that relates to the water systems of the earth.

mg/l - Abbreviation for milligrams per liter which is a weight to volume ration commonly used in water quality analysis. It expresses the weight in milligrams of a substance occurring in one liter of liquid.

Mulching - The addition of materials (usually organic) to the land surface to curtail erosion or retain soil moisture.

Neutralization - The process of adding on acid or alkaline material to waste water to adjust its pH to a neutral position.

Osmosis - The passage of solvent through a membrane from a dilute solution into a more concentrated one, the membrane being permeable to molecules of solvent but not to molecules of solute.

Outcrop - The surface exposure of a rock of mineral unit.

Overburden - Nonsalable material that overlies a mineable mineral.

Oxidation - The removal of electrons from an ion or atom.

Permeability - The measure of the capacity for transmitting a fluid through a substance.

pH - The negative logarithm to the base ten of the hydrogen ion concentration. pH 7 is considered neutral. Above 7 is basic - below 7 is acidic.

Point Source - Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Raw Mine Drainage - Untreated or unprocessed water drained, pumped or syphoned from a mine.

Reclamation - The procedures by which a disturbed area can be reworked to make it productive, useful, or aesthetically pleasing.

Regrading - The movement of earth over a surface or depression to change the shape of the land surface.

Riprap - Rough stone of various sizes placed compactly or irregularly to prevent erosion.

Runoff - That part of precipitation that flows over the land surface from the area upon which it falls.

Scarification - Decreasing the smoothness of the land surface.

Sediment - Solid material settled from suspension in a liquid medium.

Sludge - The precipitant or settled material from a wastewater.

Sludge Density - A measure of solids contained in the sludge in relation to total weight.

Solubility Product - The equilibrium constant for the process of solution of a substance (usually in water). The higher the value, the more soluble the substance.

Spoil Material - The waste material removed from a mine facility that is not considered useful product.

Stratigraphy - The science of formation, composition, sequence and correlation of stratified rocks.

Subsidence - The surface depression created by caving of the roof material in an underground mine.

Suspended Solids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Syncline - A fold that is concave upward. The younger strata are closest to the axial plane of the fold.

Tectonic Activity - Deformation of the earth's crust resulting from vertical and horizontal movement.

Terracing - The act of creating horizontal or near horizontal benches.

Turbidity - Is a measure of the amount of light passing through a volume of water, which is directly related to the suspended solids content.

Table 37

## CONVERSION TABLE

| MULTIPLY (ENGLISH UNITS) | | by | | TO OBTAIN (METRIC UNITS) |
|---|---|---|---|---|
| ENGLISH UNIT | ABBREVIATION | CONVERSION | ABBREVIATION | METRIC UNIT |
| acres | ac | 0.405 | ha | hectares |
| acre - feet | ac ft | 1,233.5 | cu m | cubic meters |
| British Thermal Units | BTU | 0.252 | kg cal | kilogram - calories |
| British Thermal Units/pound | BTU/lb | 0.555 | kg cal/kg | kilogram calories/kilogram |
| cubic feet | cu ft | 0.028 | cu m | cubic meters |
| cubic feet | cu ft | 28.32 | l | liters |
| cubic feet/minute | cfm | 0.028 | cu m/min | cubic meters/minute |
| cubic feet/second | cfs | 1.7 | cu m/min | cubic meters/minute |
| cubic inches | cu in. | 16.39 | cu cm (or cc) | cubic centimeters |
| cubic yards | cu y | 0.76456 | cu m | cubic meters |
| degrees Fahrenheit | $^{o}$F | 0.555 ($^{o}$F-32)[1] | $^{o}$C | degrees Celsius |
| feet | ft | 0.3048 | m | meters |
| flask of mercury | (76.5 lb) | 34.73[1] | kg Hg | kilograms of mercury |
| gallons | gal | 0.003785 | cu m | cubic meters |
| gallons | gal | 3.785 | l | liters |
| gallons/day | gpd | 0.003785 | cu m/day | cubic meters/day |
| gallons/minute | gpm | 0.0631 | l/sec | liters/second |
| horsepower | hp | 0.7457 | kW | kilowatts |
| inches | in. | 2.54 | cm | centimeters |
| inches of mercury | in. Hg | 0.03342 | atm | atmospheres |
| miles (statute) | mi | 1.609 | km | kilometers |
| million gallons/day | mgd | 3,785[1] | cu m/day | cubic meters/day |
| ounces (troy) | troy oz | 31.10348 | g | grams |
| pounds | lb | 0.454 | kg | kilograms |
| pounds/square inch (gauge) | psig | (0.06805 psig +1)[1] | atm | atmospheres (absolute) |
| pounds/square inch (gauge) | psig | 5.1715 | cm Hg | centimeters of mercury |
| square feet | sq ft | 0.0929 | sq m | square meters |
| square inches | sq in. | 6.452 | sq cm | square centimeters |
| tons (short) | t | 0.907 | kkg | metric tons (1000 kilograms) |
| tons (long) | long t | 1.016 | kkg | metric tons (1000 kilograms) |
| yards | y | 0.9144 | m | meters |

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[1] Actual conversion, not a multiplier