The acidity of the watershed was fairly effectively neutralized for some 17 years by the discharges from a limestone quarry operation near the headwaters. Slippery Rock Creek is used for public and private water supplies and the watershed is extensively used for private and public recreation. There are two major State parks in the area.

In December, 1957, the limestone mining company ceased mining and preparation plant operations and discontinued the discharge of alkaline water to the creek. By October, 1958, some three and one-half miles of the creek had become acid impregnated. The intrusion of mine drainage acid had continued unabated, with a serious fish kill occurring in July, 1964 when acid mine drainage, primarily from the watershed's headwaters, was flushed out during a period of heavy rainfall. The Fish Warden estimated that more than two million fish were killed because of the acid drainage.

In 1963, the Pennsylvania Department of Health conducted a. study to determine the effects of mine drainage on the . stream quality in the watershed. Their findings were presented in 1965. Briefly, they reported that the main branch of the creek was polluted from tributaries which comprise less than 25% of the total watershed area and that the bulk of the acid load was from the headwaters (Zone I) as shown on Figure 3. More than 83% of the acid mine water was from abandoned underground workings.

In 1967, The Chester Engineers conducted further investigations .relative to the pollution of Slippery Rock Creek for the Department of Health. That study and report generally confirmed and amplified the findings of the 1965 report and in addition, recommended pollution abatement action programs. Among the recommendations was a plan to construct a mine drainage treatment plant at the headwaters of the North Branch Slippery Rock Creek.

Concurrently, a study was conducted by M.A. Shellgren,
E.D. Reitz, and J.F. McInroy, of Slippery Rock State College, on the biological condition of the watershed. That study made recommendations as to the location of the proposed acid neutralization plants. One of the recommendations was that a neutralization plant be constructed on the North Branch.

The Sanitary Water Board for the Commonwealth of Pennsylvania approved the report and recommendations. The State Department of Mines & Mineral Industries then adopted the construction of the North Branch Treatment Plant to improve the water quality not only in the headwaters of the North Branch of the Slippery Rock Creek but also to minimize the effect of acidity contributed by acid tributaries at some distance downstream. From Figure 4 it can be seen that the abandoned mine drainage sources were all tributary to one reach of the stream. Eventually additional projects might have to be constructed to further improve the water quality throughout the entire watershed.

It had been concluded that a mine drainage treatment plant capable of neutralizing the acid in one reach of the North Branch stream and removing the iron, would return the total stream to a clean water classification and the stream could support aquatic life. The western reaches of the stream were being kept stocked with trout by the Pennsylvania Fish Commission. In addition to returning one stream to public use, the project would also reduce the acid load from Zone I (See Figure 3), which had been estimated to contribute 70 percent of the acidity, by some 20% or 2,000 lb/day. Acidity was determined with reference to pH 8.3, using phenolphtalein indicator, and is expressed in terms of calcium carbonate.

PLANT DESCRIPTION

The plant design was based upon the analytical data gathered during the 1963 and 1967 investigations.

To accomplish the objective of making the North Branch Slippery Rock Creek a clean stream, it was necessary to neutralize all the acid mine drainage and in addition, to remove all the insoluble by-products of that neutralization. The treatment of a major portion of a stream watershed of three square miles and the removal of settleable solids was a significant undertaking and to our knowledge, had not been done before.

The use of average figures in the design have little meaning when flows, acidity, iron and manganese concentrations in the stream may vary considerably with intensity of rainfall. Furthermore, it was not possible or practical to design a plant to handle the total flow which could be expected in the stream, with the peak being on the order of 3450 cfs or 1550 million gallons per day (MGD).

Review of the data and laboratory investigations indicated that the plant objective could be satisfied if some 6,000 lb/day of acidity were neutralized and as much as 50,000 lb/day of solids were removed from the neutralized stream. From this, the peak design flow rate was set at 10 MGD (7,000 gpm). It was expected that the median flow would be 3 MGD (2,100 gpm). Average lime use was expected to be 1900 lb/day, peak 6,300 lb/day, and minimum 190 lb/day. The median flow was the design basis.

A simplified arrangement of the plant is presented on Figure 5 and a simplified flow sheet on Figure 6. The general arrangement and flow sheet are shown in greater detail respectively on Sheets 1 and 7 in the Appendix.

Principal unit processes included the following:

1. Flow diversion - A concrete dam, with acid-proof lining, spillway and diversion structure was constructed to divert the peak design flow to the plant. The dam, spillway and downstream channel were designed to take peak stream flow, i.e., 3450 cfs.

2. Equalization - A 2,000,000 gallon impoundment lagoon with an impermeable membrane and variable head orifice serves to lessen the shock loads to the plant.

3. Neutralization - Stream flows by gravity to a well agitated tank where lime slurry is automatically added under pH control. The pH in the neutralization tank is continuously monitored and, the lime feed rate to the tank is in proportion to the extent of departure of the pH from an adjustable set point (pH - 8.5). A back-up pH and lime feed system is provided at the clarifiers center well for emergency use. The set point is normally maintained at pH 8.5.

Dry hydrated lime delivered in 22-ton quantities in tank trucks is. made into a 30 to 35 percent by weight slurry by pneumatically unloading and mixing it with water in a storage tank provided with a turbine mixer. The specific gravity of the slurry is controlled in a dilution tank and the slurry is fed to the treatment plant by means of proportioning weirs which are pneumatically actuated and continuously adjusted by pH control. The weirs are designed to give a 100 to 1 rangeability; if lime demand is less than the 100 to 1, the flow from the weirs stops for whatever interval is necessary to keep the pH at or slightly below a given set point.

4. Wastewater Pumping - The head loss through the plant made it necessary to lift the stream water. That required special design considerations because of the extremely wide range of flow. Screw pumps which use Archimedes' principle and are extensively used in Europe, were selected. Screw pumps are essentially surge-free; will handle highly variant flow rates; have non-clogging characteristics; have an efficiency of about 85%, which remains relatively constant of variations in volume.

The pumps are located between the flash mix neutralization tank and the clarifier: one to handle flow from 150 to 2000 gpm, the other from 300 to 6000 gpm.

From a process standpoint, it was felt that the pumps would not destroy the floc developed during neutralization and would aerate the waste converting ferrous iron to the ferric form. Relatively low iron concentrations of less than 20 mg/l were expected.

5. Clarification - Laboratory Settling studies had indicated that the settling rates under quiescent conditions at low temperature (47°F) were 0.11 ft/min at high iron concentrations (50 mg/1), and 0.33 ft/min at low iron concentrations (2 mg/1). Low iron concentrations were associated with high flow.

A 75 ft diameter, solids-contact type clarifier was selected to handle the varying loading and settling rates. The clarifier provides one hour nominal detention time at peak flow.

In addition, a 200,000-gallon lagoon was provided for use in an emergency, i.e., the clarifier had to be taken out of service.

6. Solids Handling - Settled solids from the clarifier were expected to be light; therefore, a 30 ft diameter thickener was provided to reduce the water content of the clarifier sludge and to temporarily store the sludge. The thickened sludge is pumped to one of two sludge lagoons, each 150,000 gallons, for further dewatering and storage.

7. Miscellaneous - Also included in the plant are: A polymeric flocculent feeding system; filtration of treatment plant effluent for potable water use, process water system which reuses the plant effluent without further treatment; compressed air system, and a sanitary sewage treatment system.

Detailed drawings of-the structures, equipment, electrical wiring, instrumentation, and the technical specifications on the equipment are shown in the appendix.

The remote location and critical nature of the plant make it necessary to assure that malfunction of the treatment plant does not go unattended.

The alarm signal on the panel board is connected by telephone to the area telephone operator. Telephone numbers of personnel are tape read to the operator in the proper sequence. There is a 15-minute delay between malfunction and telephone message to the operator. The alarm will signal malfunction of the lime feeding and pH control systems, overloading of the rake drives on the clarifier and sludge thickener, and will also signal high levels in a number of locations.

The plant is manned by two operators during the day shift, usually one during the second shift, and is unattended during the night shift, operating, therefore, completely automatically.

Most of the problems that were experienced because of improper installation or equipment or instrumentation have been resolved. Among the most vexing problems was the proper control of the specific gravity in the lime slurry tank. Once the instrumentation: was corrected and means were provided to unplug the air bubblers once a day, that system became operational.

COSTS

The plant was constructed between Summer, 1968 and December, 1969. The total construction cost was $750,000 of which $700,000 was for general and mechanical construction, and $50,000 for electrical construction.

The annual cost of operating the plant is some $51,000 with $5,000 for chemicals, $7,000 for electricity, $34,000 wages and salaries and labor, $1,500 for telephone and alarm services, and the balance for miscellaneous items.

OPERATING RESULTS

Operating results for 1971, based on daily analyses performed by operating personnel are presented in Table 1. As seen from the table, an average of 2520 gpm was treated at the plant, and the plant effluent normally had a pH in the range of 7 to 9, with the pH of the North Branch of Slippery Rock Creek consistently over 6.8. Plant effluent had little or no iron and no acidity.

Physical and chemical analyses of grab samples collected on four occasions in 1970 and 1971 are shown in Tables 2 and 2A. Of note as regards the influent, is the fluctuation in total solids which is probably related to an increase in sulfates and total hardness, and the presence of manganese which is sometimes higher in concentration than iron. This was recognized during the initial investigations, but it was decided that the plant would be operated to remove primarily acidity and iron.

Manganese could be removed by treating at higher pH values
and taking advantage of the sludge re-circulation characteristics of the solids-contact clarifier. The presence of freshly precipitated manganic salt should catalyze the oxidation and removal of the soluble manganous salt. It is noted from the tables that some manganese is removed, particularly at the higher pH values.

Although the clarified effluent appears on occasions to contain more suspended solids than the raw influent, it should be realized that the concentration of suspended solids in the neutralized influent, although not reported in these tables, is greater than that of, the effluent.

Sludge analyses are shown in Table 3. It is noted that the manganese concentration in
the sludge is either equal or

greater than the iron concentration. This would indicate that the concentration of manganese in the influent is normally equal or greater than. that of iron, and that probably a relatively high percentage of manganese is removed by treatment. Of note is the fact that the sludge is thickened considerably upon storage in the sludge lagoon. In fact, samples collected at a latter date (Table 4) exhibited even greater concentration. A bottom sample contained 6.74 percent total solids or a suspended solids (particulate matter) concentration of approximately 6.3 percent by weight.

It is expected that the sludge stored in the lagoon will continue to thicken during storage. To date no sludge has been withdrawn in spite of the fact that the lagoons were full of sludge approximately eight months ago.

It is noted that the concentration of solids in the clarifier and thickener sludge was considerable lower in-Table 4 than in Table 3. This was due to the fact that all of the sludge had been pumped out of the clarifier.

The experience gained by the operators particularly in the last year has contributed to better utilization of the solids-contact clarifier and sludge thickener. One measure of the degree of success of the plant is the fact that trout have now migrated downstream below the plant discharge.

The performance of the treatment facilities has been in accordance with expectations. As much as 50 mg/l of iron can be removed. For the removal of greater concentrations it would probably be necessary to install aeration facilities between the flash mix neutralization tank and the solids-contact clarifier, unless the screw pumps provide greater oxygenation capacities than expected.

Limestone could also be used as a neutralizing agent in place of hydrated lime if modifications are made in the chemical feeding system. It is doubtful, however, that this reagent has an advantage over hydrated lime because of the following facts:

1. The pH value of the influent is in the mildly acidic range which would further slow down the lower reactivity of limestone, compared to that of hydrated lime.

2. A very finely divided limestone would have to be used which should pass through a 200-mesh screen. This would be more costly than coarse limestone, and would reduce the price advantage of limestone over hydrated lime.

3. Even if a larger (10,000 gallon) neutralization tank were used to counteract the lower reactivity of limestone, it

is doubtful that the neutralization reaction would be sufficiently completed. Therefore, a larger tank is not initially recommended, and if any trials were made they should initially be with existing equipment at low flow.

4. The use of a reaction tank involving coarse limestone, tumbled in a rotating drum, would require relatively major changes.

5. The raw waste has a relatively low acidity to phenolphthalein, and the volume of sludge produced is relatively small. Both of these factors militate against the possible, although not proven, benefits of using limestone with wastewater of this quality. The total annual cost of chemical reagents is approximately $5000, comprising $2800 for hydrated lime and $2200 for polymeric flocculents. No matter what savings could be effected with the successful use of limestone, they could not be greater than $1000 per year for an average flow of 3000 gpm on an annual basis, assuming that the acidity of the influent is approximately the same as in 1971.

6. The fact that it is easier to maintain the pH value below the allowable maximum of 9 with limestone than with lime is not of particular importance since little, if any, problems are experienced with maintenance of proper pH with hydrated lime.

Provisions have been made for the additional metering of hydrated lime slurry at the plant outfall to neutralize water flowing over the dam, when the flow exceeds approximately 10 million gallons per day. This practice, although not suitable for the removal of iron, maintains the pH value of water diverted from the plant in the neutral range.

Interest in the treatment facilities has been exhibited not only by local residents but also by others. The visitors
are impressed by the automatic treatment features, the type of equipment required for clarification compared to what is required solely for neutralization, and the pleasing appearance of the building and the other structures.

PROBLEMS & SOLUTIONS

Most of the problems experienced with start-up of the plant were the malfunction of instrumentation and particularly with the lime slurry specific gravity system,. the pH electrode assemblies, the level indicator in the lime make down tank. Usually, malfunction of instrumentation is one of the greatest problems in wastewater treatment plants.

There were also two major mechanical problems: the operation of the screw pumps, the mechanical agitator in the lime make down tank and on the flash mix neutralization tank.

A dual pressure (D/P) cell and expansion chamber were used in place of the mercury manometer control to eliminate malfunction of the specific gravity system.

Tees on air bubbling tubes in the lime slurry dilution tank were extended from the basement to the floor above and provided with plugs and gun cleaning brushes. That made it easier for the operator to reach and unplug the bubbling tubes.

The problem experienced with the pH electrode assembly was with the breakage of the top of the reference electrode. This problem had never been experienced in the past and may have been due to poor manufacture. This problem was eliminated by the use of a plastic electrode which had just been developed on a commercial scale.

The malfunction of the level indicator is due to bridging of the capacitance probe to the tank wall. This could be corrected by either using a diaphragm actuated liquid level column inside a tube, or a sonic or nuclear level indicator.

The malfunction of the screw pumps was due to misalignment and to the fact that the lower bearings were not lubricated. This was corrected by the addition of a manual grease lubrication system using a grease gun.

The problem with the mechanical agitators was due to the fact that the turbine for the flash mix tank was installed as the bottom turbine on the lime slurry make down tank and vice-versa which ruined the bearings on the lime slurry make down mixer.

The decantation of water from the sludge storage lagoon which is presently flowing by gravity to the neutralization tank should be connected to the screw pumps wet well.

One of the questions that has been raised is about the effects that maximum and minimum flow may have on the operation of the plant. The answer is that flow has only a negligible effect, within the design capacity of the plant.

Minimum flow will only have an effect on possible "overshooting" of pH because of the fact that the hydrated lime slurry proportioning weir boxes may feed a trickle of slurry due to leakage even when the pH controller does not call for lime. The leak can be eliminated by simple modifications of the equipment.

Maximum flows greater than the hydraulic capacity of the system will be partially bypassed to the North Branch of Slippery Rock Creek, but may affect the clarification ability of the solids contact clarifier if they cause hydraulic shocks within the unit. Under those circumstances the clarified effluent will contain more suspended matter than expected for good operation. The utilization of the 250,000-gallon bypass lagoon will either eliminate or minimize the problem. If, as expected, because of the presence of the 2.,000,000-gallon impoundment lagoon, the increase in flow is gradual, the effect on the solids-contact clarifier should be negligible.

Maximum flows accompanied by maximum concentrations of acidity should not affect the chemical feeding system if they are within. the design capacity of the feeding system. The proportioning weir boxes will respond instantaneously to any changes and provide the necessary quantity of reagent within that design capacity.

As regards the possibility of operating the plant less than 24 hours per day at low flow, the capacity of the 2,000,000-gallon impounding lagoon provides that capability. This should result in. savings in labor costs, if manpower can be temporarily released and made available when required, and should result in some savings in power costs. During interruption of operations, with the exception of perhaps one screw pump, the majority of the electrical equipment would probably remain in operation for different reasons that are not ennumerated here. Water should be recirculated through the solids-contact clarifier to prevent carryover of floc caused by starting the operation of the solids-contact clarifier from zero to some flow within the design range. This effect may be felt for 1 to 2 hours, depending on the extent of the incremental increase in flow and in the depth of the sludge blanket.

CONCLUSIONS AND RECOMMENDATIONS

The plant is performing satisfactorily. There are, however, a number of improvements that should be investigated, as recommended below:

1. Installation of fuel operated standby power generating station essentially for the lime slurry make down agitator, lime slurry dilution tank agitator, neutralization tank flash mixer, sludge thickener. scraper motor, one lime slurry pump from dilution tank to neutralization tank, and pneumatic control on instrumentation system.

2. Divert acid stream gob pile seepage from downstream to upstream of dam.

3. Although sludge storage lagoons have had greater retention capacity because of the smaller volume of sludge produced, and greater thickening action by gravity settling than initially expected, the lagoons will eventually overflow. Therefore, provisions should be made for the transfer of the sludge to another area.

On the basis of current D.E.R. requirements the storage area should be lined with an impermeable lining. Because of the costs involved in the construction of an acceptable lagoon, consideration should be given to mechanical sludge dewatering.

Consideration should also be given to the possible use of powdered limestone in place of hydrated lime to further reduce the sludge volume. This may require some additional facilities. It should be realized, however, that the plant may not be suitable for the use of powdered limestone because of its slower reaction characteristics which are of greater significance when limestone is used with water of relatively low acidity and high pH, as in this case, than with water having higher acidity and lower pH.

4. Possible recycling of sludge from the thickener to the center well of the solids-contact clarifier to improve flocculation and settling of the suspended particles and to produce a denser sludge.

ACKNOWLEDGEMENT

The assistance of Messrs. A. E. Molinski, J. J. Buscavage, James Forrester, Robert Gibson, Dale Eury, John Eury, all formerly with the Department of Mines and Mineral Industries: Messrs. G. B. Morrill and Paul S. Soltis, with The Chester Engineers, is gratefully acknowledged. The cooperation of these and other persons lessened considerably the difficulties normally experienced with the start-up of a wastewater treatment plant, not to mention improving its operation.

DEPARTMENT OF ENVIRONMENTAL RESOURCES
SLIPPERY ROCK CREEK

MINE DRAINAGE TREATMENT PLANT

HISTORY

The mine water treatment plant is located near the headwaters of the North Branch of Slippery Rock Creek, which is in turn the headwaters for the Slippery Rock Creek drainage area.

Slippery Rock Creek is a tributary of Connoquenessing Creek and encompasses a watershed of some 400 square miles including parts of Beaver, Butler, Lawrence, Mercer and Venango Counties, in Pennsylvania.

The general location of the drainage area is shown on Figure 1. The total creek watershed and the North Branch drainage area are shown on Figure 2.

The geology of the basin includes the Brookville, Clarion and Kittanning coal seams of the Allegheny Series with the coal seams having a general dip of 1% to the south. As in other areas through the bituminous coal fields, deep mines were developed and extensively worked in the early 1900's resulting in the attendant acid discharges to the watershed. A number of mines were sealed under the WPA Programs in an effort to reduce the acid load. By 1945, most of the deep mines were abandoned and there remained only a small number of active mining operations. Strip mining started in 1940.

Recognition is also due to Dr. H. B. Charmbury, formerly Secretary of the Department of Mines and Mineral Industries, who provided encouragement and advice from the inception until the successful completion of this project, and to Dr. D. R. Maneval, formerly Director, Research and Development, for the Department of Mines and Mineral Industries, who made suggestions and took a very active part in the entire project.