ENVIRONMENTAL PROTECTION AGENCY

WATER QUALITY OFFICE

ASSESSMENT OF PROCESS OPERATIONS & WASTE CONTROL
HOMESTAKE GOLD MINE
LEAD - DEADWOOD, SOUTH DAKOTA

PREPARED BY
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FOR

OFFICE OF ENFORCEMENT & STANDARDS COMPLIANCE

DIVISION OF FIELD INVESTIGATIONS - DENVER CENTER

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CLEAN WATER

Assessment of Process Operations and Waste Control

Homestake Gold Mine

Lead-Deadwood, South Dakota

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Division of Field Investigations - Denver Center
Office of Enforcement and Standards Compliance
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INTRODUCTION

The following discussion gives a tentative assessment of conditions believed now existing at the Homestake Mining Company operations at Lead-Deadwood; changes that have probably taken place over the past few months; and suggested alternative measures for waste handling/disposal practices. This assessment is based upon past reports including 1959 river pollution and industrial plant studies made by the U.S. Public Health Service and the South Dakota Department of Health; a reconnaissance and in-plant visit made by Environmental Protection Agency personnel on December 2, 1970; and a literature review of the status of technology in the gold and silver milling industry.

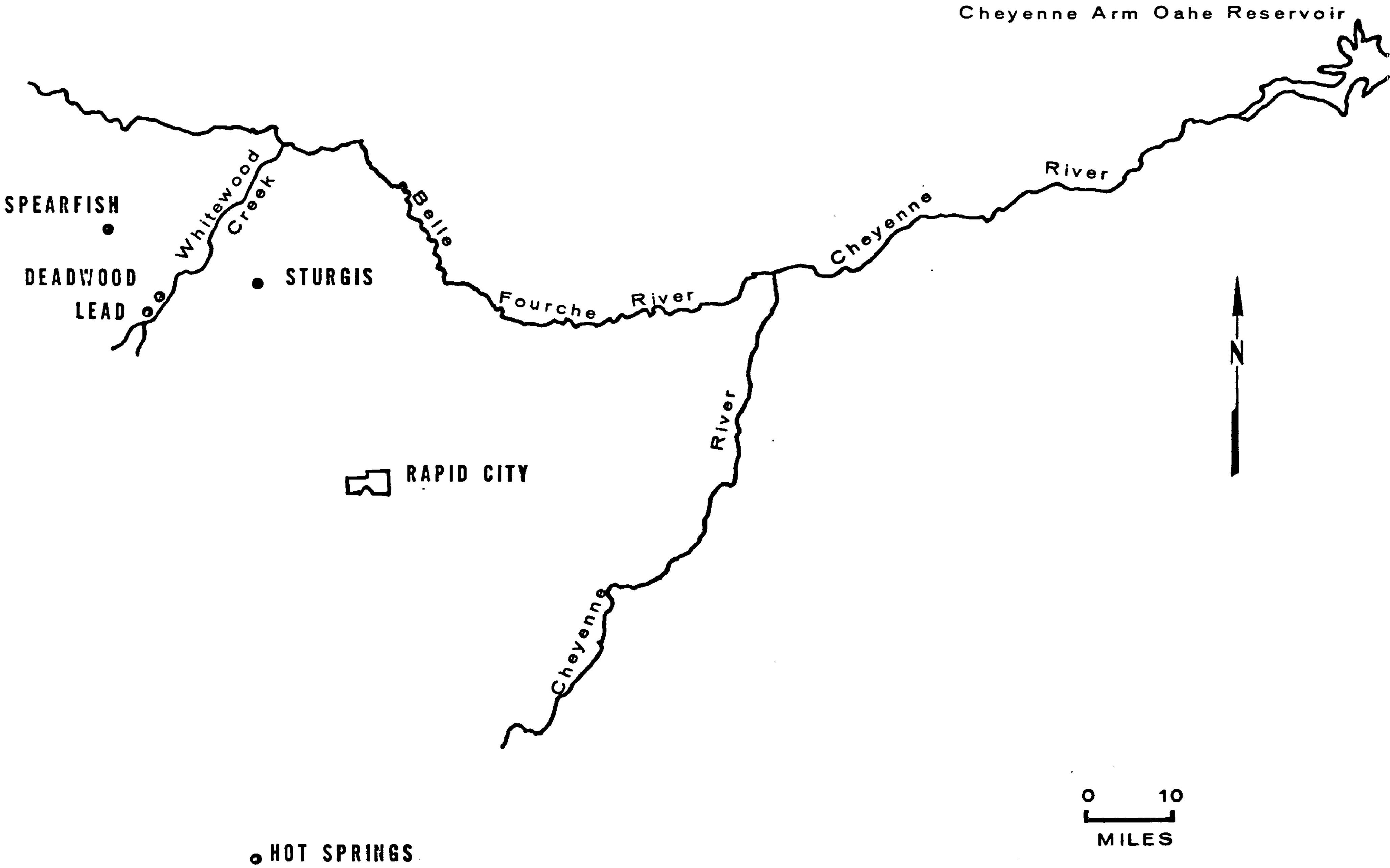

Figure 1. Location Map Deadwood - Lead, South Dakota

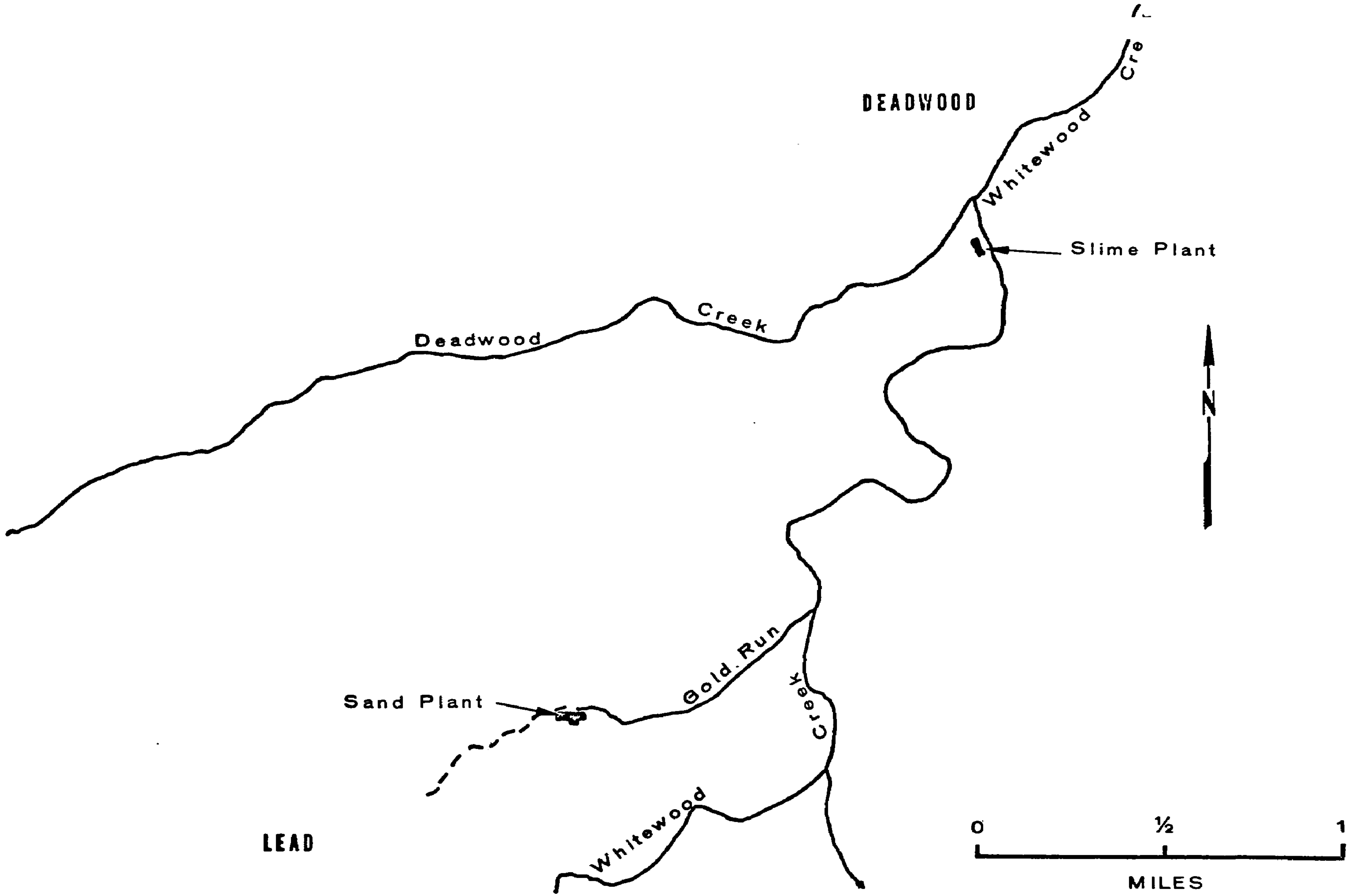

Figure 2. Location of Homestake Mining Co. Facilities at Deadwood - Lead, South Dakota

BACKGROUND

The Homestake mine, near Lead, South Dakota, has operated continuously since about 1887. The first sand leaching plant was started around 1901 at Lead. One of the oldest cyanide mills in the United States was located at Deadwood, designed by the Gold and Silver Extraction Company about 1894. The Homestake Mining Company was founded in the very early 1900's and is currently the largest gold producer in the United States. In 1948, monthly production from the Homestake Mining Company was reported in excess of $7 million in gold bullion. Over the years to the present time, all the milling and sand-leach operations came to be located at the town of Lead, whereas the slimes are gravity-fed to a central plant at Deadwood, several miles below Lead. Gold ores containing as little as 0.2 oz. troy/ton can be mined and Homestake ores contain around 0.4 oz./ton or possibly slightly higher in recent years. Ore production at the Homestake Mining Company has increased steadily over the years from 4,800 tons/day in 1949, to around 5,800 tons/day in 1963, and 5,800-6,000 tons/day at present.

Amalgamation (mercury treatment) of ores has been used in the Lead area since before the turn of the century. Up to three months ago, Homestake had employed amalgamation as a cheap method of gold recovery preceding cyanidation. Figures given for the late 1930's and early 1940's show that 70 to 75 percent of incoming Homestake gold ore was considered "free" gold. The Clark-Todd amalgamators removed 60 percent of this coarse gold, giving 43 percent overall gold recovery.

These early figures show that only 1/8 oz. troy mercury was used per ton of ore crushed (about half of this mercury was consumed). The Clark-Todd amalgamators, until recently, were installed in the closed circuit with the rod and ball mills. In contrast with these figures, the 1959 study by the South Dakota Department of Health showed that 75 percent of total gold recovered was achieved by amalgamation compared to 25 percent by cyanidation. However, in 1959, reported use of mercury was greater than 0.45 oz. mercury/ton ore. These figures indicate the highly important role of amalgamation in the previous Homestake process line. Amalgamation at the Lead plant is reported to have been completly phased out as of January 1971.

From the July 1959 stream studies conducted by the USPHS and South Dakota Department of Health, the data show that total cyanide concentrations in Whitewood Creek ranged from 0.60 - 9.10 mg/l with an average of 2.6 mg/l. In this same study, cyanide levels in Belle Fourche River waters were around 0.50 mg/l. Cyanide levels critical to fishlife are generally considered to be in the range of 0.1 - 0.3 mg/l. We also note the USPHS Drinking Water Standards specify a maximum limit of 0.2 mg/l cyanides, but they strongly advise that 0.01 mg/l not be exceeded. For body contact recreation, fisheries and farmstead supplies, unpublished water quality criteria guidelines have specified an upper limit of 0.02 mg/l cyanides.

Nearly all gold milling operations currently employ the all-sliming process in cyanidation of gold ores. Homestake has retained separate treatment of sand and slimes because of separate recovery and reuse of sands as backfill in the mine; because of amalgamation; and due to the high metallurgical efficiency achieved by this separation on an ore that is somewhat different to treat. The relatively high pyrrhotite (Fe_5S_6 to $Fe_{16}S_{17}$) and ferrous iron content of this ore would normally indicate difficulties in direct cyanide extraction of gold.

During the 1940's, Homestake was recovering silver in addition to gold. At that time, gold bars were produced at about 997 fine, and silver at 980 fine. Current prices for gold and silver are about $35/troy oz. gold and $1.70/troy oz. silver (1 troy oz. = 1.097 avoir. oz.).

PLANT PROCESSES

A. Comminution-Grinding-Concentration

Based upon background information, the ores enter the Lead mill previously crushed to about one-half inch size and then subjected to fine grinding in a rod mill-ball mill-Dorr classifier closed circuit. Water enters the mill with the crushed ores, and wet grinding is employed; no cyanide or barren solutions (cyanide solution from which gold has been precipitated) enter the grinding circuits, although considerable water containing some cyanide is returned from the sand dam site. According to the EPA trip report of December 14, 1970, the South Mill (at Lead) was utilizing four banks of rod and ball mills. Previous to January 1971, the Clark-Todd amalgamators were contained in this circuit at the effluent of the ball mills. The plant flow diagram for 1956 shows three banks of rod and ball mills, with a fourth bank consisting of a rod mill, a screening bank for separating coarse material, and Kreb cyclones for separation of fine particle sizes. Apparently the latter grinding circuit has been replaced by a rod mill-ball mill circuit. The precise status of the amalgamators is not known as of February 1971 but presumably they have been cleaned and remain on standby.

Since amalgamation has been stopped, the Lead mill has likely reverted to grinding its ores to finer particle size so as to enable more intimate contact and greater extraction of gold in the cyanide leaching circuits. To compensate for the removal of amalgamators from the circuit, the plant may also be currently substituting some gravity-concentration unit operations. These could take the form of hydraulic traps, unit cells and hydraulic cones such as the Denver Sub-A flotation cell, jigs (usually mechanically-pulsated), and the possible use of corduroy blankets (alternate to gold tabling). These unit operations are mentioned as alternates rather than probable substitutes since they have in the past been followed by amalgamation. Homestake may now be giving serious consideration to gravity concentration unit operations, but more likely they will attempt to extract the large majority of gold by use of previously existing grinding circuits and cyanide circuits. If a high level of gold extraction cannot be achieved by this means, a change to finer grinding (higher percentage of slimes) and significantly increased cyanide consumption may be made. Whether with these changes the Homestake operations can maintain a 97 percent gold extraction (as cited in the 1960 reports) is not known.

Flotation processes have been employed extensively in milling operations. However, Homestake ore is not amenable to this procedure.

Secondary classification of ground ore at Homestake is achieved by a series of large Dorr bowl classifiers (settlers) which serve to separate the ore into sands and slimes. According to the 1967 size distribution table provided by Homestake Mining, ground particles are roughly separated into sands and slimes, somewhere around the 200-mesh size range. In the metallurgical industry, slimes are generally considered as comprising those particles finer than 50 microns, i.e., passing through 325-mesh screens. Homestake maintains its cyanide circuit feeds somewhat high on the sands side. In 1949, the Homestake operation was separating its ore into 56 percent sands and 44 percent slimes at a mill throughput rate of 4,800 tons per day. In 1967, based upon a milling rate of 5,195 tons ore/day (note yearly average rate), the percentage of sands was increased to 60.1 percent and slimes decreased to 39.9 percent. It appears the Lead mill has more flexibility for increased capacity compared to the Deadwood mill. All slimes are transferred to the Deadwood mill for cyanidation, and all sands are cyanidized at the East and West plants at the Lead mill.

B. Cyanidation of Sands and Slimes

1. Sands Treatment. The sands fraction in the form of a sand-water slurry is diverted to the East Sand Plant and the West Sand Plant at the Lead mill. The sands are loaded into 35 sand vats (23 in the East Sand Plant and 12 in the West Sand Plant), through which cyanide solution is allowed to slowly percolate downward removing the gold values in the sands. Sand leaching at the Homestake mill is entirely a batch-type operation requiring in the order of seven to eight days to complete the sand treatment cycle. The vats are filled with water; charged with sands; and the tank water content is drained. This is followed by first aeration, alkaline wash and first strong cyanide leach solution. The vat is again drained of water; aerated a second time; subjected to a second strong cyanide leach solution; drained and aerated a third time. This is followed by a weak cyanide leach; washing and finally sluicing the sands to the sand dam site. Gold extraction efficiency in 1967 was reported in the order of 84.5 to 87.5 percent.

It is axiomatic that the finer the sand the higher the gold extraction. Previous data from Homestake show that extraction varies from better than 90 percent for the minus 200 mesh particles, to less than 50 percent for particles coarser than 50-mesh. Homestake maintains around 46 percent of its material as somewhat finer than 200-mesh and 54 percent greater than 200-mesh but none coarser than 48-mesh. Phosphorous levels are maintained on the high alkaline side by lime additions and sodium cyanide solution strengths are reported as 0.02 to 0.06 percent. However, repeated mention of Aero-cyanide is made which implies that calcium cyanide is apparently used rather than sodium cyanide. Aero-cyanide (having 50 percent NaCN equivalent) had a reported use of 0.57 lb/ton sand treated in 1967 together with 1.7 lb lime/ton sand. Various cyanide waste flows result from draining alkaline wash, leach discharge and from sluicing the sands to the sand dam. Some slime overflows from the vats enter the Dorr thickeners, also located in the sand plant. Barren solution is reused back in the cyanide circuit. In 1963, it was reported that, of the 3,420 tons/day exhausted sands and 8,945 tons water discharged from the mill to the sand dam, approximately 685 tons/day of sand and 6,730 tons/day of "water" (77 percent of total) was subsequently discharged from the sand dam to Gold Run. Cyanides and cyanide complexes are present in all of these discharges. Two other waste sources previously reported, in the 1959 study, are the overflow from the Dorr thickener and the sand-vat filling-water overflow. Excess from the thickeners not reused in the mill finds its way to the city sanitary sewers and/or the mill pond and Gold Run. The vat overflow was also previously released to the sanitary sewer. Some of the above waste streams may have been eliminated over the past few years.

2. Slimes Treatment. Slimes after concentration and dewatering in the Dorr thickeners (at the Sands Plant) to a relatively high solids content, are conveyed in slurry form to the Deadwood plant and directly into a series of rather large Merrill filter presses. The Merrill press is essentially a plate and frame press and is practically automatic in filling and discharge. Each of the presses has 90 frames; 6 feet x 4 feet x 4 inches, and the press will hold 26 tons or more of slimes. The Deadwood plant, in the 1940's, had 31 Merrill presses. Whereas other mills may use Merrill presses for washing, the Homestake mill is believed to be the only plant utilizing direct cyanide treatment in the Merrill presses.

The complete slime treatment cycle in the Merrill presses requires only about 8 hours, it is a batch-type operation, and 2-3 charges can be made in a single day. Gold extraction efficiency is reported between 88 and 90.5 percent. Slime pulp is loaded into the frames with lime followed by aeration; a strong cyanide solution leach; a second aeration; a second strong cyanide solution leach; a weak leach (using barren solution) washing; and, finally, sluicing of the slimes from the frames. Leach solution concentrations vary from around .015 to .04 percent (as NaCN) and the use of Aero-cyanide and lime respectively appears to be in the order of 0.62 and 2.0 lb/ton slime treated. Pregnant cyanide solution (containing gold) is withdrawn from the first solution leach; the second solution leach, and the first half of the weak leach period. The pregnant liquors are presumably then deaerated in separate facilities followed by immediate addition of zinc, and precipitation of the gold, silver, etc., without exposing the solution to the atmosphere. The rare metals precipitates are likely removed via small filter presses and the barren cyanide solutions returned for reuse in the Merrill presses.

In 1963, it was reported that 2,380 tons/day of slime were entering the Deadwood mill and this solids (slime) material, after extraction, together with 12,520 tons/day water and considerable metals impurities was entirely discharged into Whitewood Creek. Approximately three-quarters of the water needs are represented by that required in sluicing the slimes to the creek. Sluicing water originates as ditch water, part coming from the sand dam, and part as recycle water from inside the slimes plant. In addition to cyanides and cyanide complexes contained in the interstitial water of the exhausted slimes, all of the above sources of sluice water except ditch water contain some cyanides. Under normal operating conditions, the mechanical loss of cyanide discharged with the tailings (both slimes and sands) is a very important factor in cyanide loss in the plant and consequently in the amount of cyanides found in the plant waste effluents. The loss of cyanides would appear higher in the slimes than the sands at Homestake although the latter is also probably high. Another source of cyanide loss at the Deadwood mill is the overflow from the press filling water reclaim tank. Used compressor water also is discharged from the Deadwood mill.

Its cyanide content would seem very minimal, but depending upon plant origin may merit further check. Entrainment of high strength liquids and solids across condensers and boilers may be possible. Some of these waste streams may have been eliminated in recent years.

3. Cyanide Circuits. (a) Homestake has previously used relatively low amounts of cyanide in their leaching circuits owing in large part to previously-employed amalgamation and a careful chemical balance in the circuits. (b) Cyanide consumption in direct sands and slimes leaching will probably now show significant increase which in turn will require: (c) greatly improved waste treatment and abatement measures.

Homestake in 1967 was using approximately 0.57 lb. Aero-cyanide/ton sands treated and 0.62 lb. Aero-cyanide/ton slimes treated. Since Aero brand cyanide contains about 50 percent NaCl and lime, it has an NaCN equivalency of only 0.5. NaCN equivalent use in 1967 was, therefore, about 0.3 lb/ton ore treated which is low in gold milling. In 1959, plant records show augmented consumption of 0.90 lbs. Aero-cyanide/ton ore equals 0.45 lb. NaCN equivalent per ton. Newton (1942) mentions that slimes extraction normally requires 0.1 to 1.0 lb. of cyanide per ton of ores. He also states that sand leaching usually requires 4-6 lb. of cyanide/ton sands. It is noted that cyanidization of sands, although generally consuming higher amounts of cyanide is considered an inexpensive process when fine grinding is not necessary for good extraction and when the chemical composition of the ore permits this process. Homestake not only needs sands for backfill in the mine, but also, the prior use of amalgamation had taken the burden of high extraction from the cyanide circuits. It is believed that small amounts of mercury in the cyanide circuits have served as a catalyst or active agent toward increasing subsequent cyanide extraction efficiency. Dorr and Bosqui (1950) observed that mechanical loss of cyanide will depend upon the type of treatment used, but for gold ores, the total cyanide consumption will average about 1.5 lb. NaCN per ton of ore. Although this cyanide use would appear high, it does illustrate the very large amounts of cyanide that may be necessary in straight alkaline cyanide leaching. From past information, Homestake ores are moderately difficult to treat by straight cyanidization.

Understanding the cyanide circuit is in large part understanding the impurities and cyanicides (CN consumers) present in the cyanide solutions. Impurities are kept below tolerable levels by "bleedout", usually replacing the moisture leaving the plant in the solids residues by freshwater; sometimes by dumping part of unworkable CN solutions; or by regenerating CN solutions. Without doubt, the very large quantities of cyanide-laden waters leaving the Homestake mills with the exhausted sands and slimes serve as a most effective means of bleeding the cyanide circuits of impurities. If these waste streams were contained in the plant, cyanide and alkaline levels would rise substantially, and additionally, other means of relieving the circuits would need to be found. Cyanicides most frequently comprise copper and copper compounds, ferrous hydroxide, antimony arsenic and bismuth materials, pyrrhotite, native iron and metallic iron from grinding, graphite, organic material, zinc, reduced sulfur, etc. Oxygen and lime content are maintained at high levels in the cyanide solutions to minimize reaction with potential cyanicides. Barren solutions will usually contain appreciable amounts of zinc, copper, thiocyonates and ferrocyanides. Many complex forms of cyanide will exist in the circuit, i.e., $Na_2Zn(CN)_4$, $Na_2ZnFe(CN)_6$, $Na_2Zn_3Fe(CN)_{12}$, $KCu(CN)_2$, $Na_4Fe(CN)_6$, to mention only a few. The complex cyanides, once formed, do not appear to harm the circuit but neither do they have any attraction for gold. Their accumulation results in their eventual discharge inplant effluents.

It is commonly thought that the complex cyanides have very low toxicity to aquatic fauna compared to free cyanide. Yet past studies have shown that 15.5 mg/l sodium ferrocyanides, i.e., $Na_4Fe(CN)_6$ yields 3.8 mg/l cyanide in 30 minutes. Likewise 2 mg/l potassium ferrocyanide was found to produce 0.36 - 0.48 mg/l CN which in the particular study cited in the literature, was sufficient to kill all test species of fish within 60-90 minutes.

4. Previous Homestake Cyanidization. Homestake ores appear to have various minerals containing iron in the ferrous state such as pyrrhotite (Fe_5S_6 to $Fe_{16}S_{17}$), chlorite, cummingtonite (iron-magnesium amphibole), etc. Arsenopyrite and pyrite (FeS_2) are also constituents. The sulfides oxidize rather rapidly and steadily through the cyanide circuits, taking up CN and producing thiocyanates. With this material, past experience shows that cyanidization should be started promptly following grinding, and high levels of oxygen are necessary to prevent gold mixtures from settling out in the circuit. Ores containing pyrrhotite have always been difficult to treat properly by cyanide owing to their rapid decomposition in most atmospheres, particularly

in aqueous solutions. Large quantities of ferrous compounds are formed in solution, compared to nonpyrrhotitic ores, and special care must be taken in grinding and in preaerating such pulps before cyanidization.

After amalgamation at Homestake, the sulfide minerals have been found to yield their gold easily, provided careful attention is given to the chemical and mechanical preparation of the pulp for cyanidization. For the above reasons, Homestake crushes its ores in water rather than recycling barren cyanide solutions back to the grinding cycle, as is the practice in many other gold mills. Aeration of the pulp prior to cyanide leaching is carried out in an alkaline solution. The alkalinity is kept as low as possible since excess alkalinity interferes with gold dissolution. Homestake has apparently found that direct cyanidization by grinding in solution is unsatisfactory with poor gold recovery and high cyanide consumption. However, the addition of lead compounds can serve to largely overcome these unsatisfactory results. These lead additions may cause a film to be produced on the pyrrhotitic which acts as an oxidation inhibitor. Past observations, however unverified, suggest that very small amounts of mercury, if present in cyanidization, are of some benefit in dissolving the gold into solution.

Counter-Current Decantation (CCD in a series of 3 to 5 thickeners) has been mentioned as a possibility at Homestake. Besides heavy initial investment, CCD appears useful only for all-sliming cyanidation, which is not the case at Homestake. Although CCD would probably provide a higher degree of reuse of CN solution, this generally implies that partially-dewatered slimes will still be discharged from the last thickener in the series. In essence, this is a form of bleedout from the circuit. It is, however, recognized that CCD could have inherent merits. The higher degree of automatic control in CCD would likely reduce errors of judgment and mishandling associated with batch-type operations. Although one of the main purposes of CCD is to recover dissolved values from the finely ground solids without the need for filtration, a filter can be installed on the effluents from the final thickener; the filtrates are returned to CCD. It is believed that a number of gold mills incorporate filters at the tailend of CCD when the pulp will not settle to at least 50 percent solids, or where a dewatered filter cake is desirable or necessary for tailings disposal.

WASTE SOURCES

The waste effluents from the Lead and Homestake gold milling operations represent very heavy waste loads placed upon Gold Run, Whitewood Creek, the Belle Fourche, and the Cheyenne River. The mill effluents contain very substantial and unacceptable amounts of dissolved, suspended and total solids together with high levels of various metals, many of which are toxic to fish and aquatic life and impair receiving waters for practically all reasonable uses except waste disposal. Tailings solids being discharged to the receiving streams are in excess of 3,000 tons/day. Field surveys during the spring of 1971 by DFI-DC call for heavy metals analyses on cyanide, mercury, zinc, arsenic and copper. Besides unknowns, additional metals that may merit attention include iron, magnesium, sulfur (nonmetal), antimony, tin, chromium, cadmium, selenium and tellurium. An emission spectrophotometer scan of all possible metals is probably indicated.

In discussing various waste sources in this report, smelting operations have not been included since Homestake has not operated a smelter for many years. Residue stock piles from past smelting operations should possibly be checked. The spread of airborne contamination from previous smelting operations over the surrounding countryside is not known. Precipitation and recovery of gold and the fluxing of gold and silver will not cause problems since these solutions will be recycled and strict plant control is undoubtedly provided at this point in the operations to minimize gold loss and theft. However, another check may be in order since plant flow diagrams for these processes are lacking.

Waste sources are summarized as follows:

A) Sand Plant

1. Sand vat filling water overflows (previously routed to Lead sanitary sewers). Cyanide will originate from the water obtained from behind the sand dam.
2. Excess overflows from Dorr thickeners not reused in the mill escape to the mill pond and/or Lead sewers or Gold Run. This amount of water is considerable and contains some slimes, cyanide etc. originating from sand vats.
3. First water drain from sand vats after filling (approximates characteristics of sand vat filling overflows but likely contains additional sulfates and thiosulfates).
4. Effluent from alkaline wash after first drain.
5. First strong solution leach drain. Water is displaced from vat and sand interstices until cyanide and thiocyanates are detected. These wastes are high in alkalinity, iron, sulfates, various minerals, thiocyanates, etc. This effluent shut-off is presumed to be manual, and without close attention, appreciable cyanide could be lost.
6. Second drain (presumably this is the same as 5 above).
7. Sands sluicing to sands dam. This is likely the major source of cyanide, etc. from the sands plant. The very large majority of this water is eventually discharged into Gold Run.
8. Condenser and cooling waters at the Lead Plant.
9. Runoff from residual materials piles at the Lead site.

10. Mill Pond Overflows. This waste source is mentioned in the 1960 report. It is not identified in the 1963 and 1967 flow diagrams and information, possibly this source does not exist today.

11. Spills, operator error, accidents, pump failure, etc.

12. Sanitary wastes.

B) Slimes Plant

1. Press filling reclaim tank water overflows. Part of this water originates from the slime leach circuit containing cyanide, etc. This waste stream is discharged to Whitewood Creek.

2. First drain or displacement water. This waste shows up in the 1960 State report but not in the 1967 plant information on the slime plant treatment cycle. Flow diagram is insufficient and this waste should be checked further.

3. Slimes sluicing direct to Whitewood Creek. This is without doubt the major source of cyanide in wastes leaving the Deadwood plant (likely the major source of solids, cyanide and the various pollutants at Homestake).

4. Condenser and cooling waters at Deadwood plant. Part of this is evidently recycled back into the plant and part wasted. Origin of this water should be verified.

5. Runoff from residual materials piles at plant site.

6. Spills, operator error, accidents, pump failure, etc.

7. Sanitary sewage.

C) Homestake Mine

According to the 1960 State report, some water is returned from the mine which originates mostly from drilling and sand filling operations. Its characteristics and point(s) of discharge should be verified.

WASTE TREATMENT/DISPOSAL

Non-treatment alternatives, i.e., process modifications or additions, have been previously mentioned in this report as possible substitutes for amalgamation, which has now been phased out at Homestake. However, serious consideration should also be given to waste treatment/disposal practices and facilities which are indicated as absolutely necessary for the Lead-Deadwood mills. Some of the possible waste abatement/treatment methods believed to be tentatively feasible are described below.

1. Installation of tailings pond(s) for detention and treatment of waste flows from both plants. As a bare minimum, the slimes and sands sluice waste streams should be directed into tailings ponds. The common tailings pond has been widely used in the metal mining and milling industry for separating water from solids; as a primary settler for gangue; as a storage basin for equalization and chemical precipitation; as a surge basin for controlling waste discharge, and as a water storage area. Too often, however, these tailings ponds have not been properly designed and engineered to give the required degree of treatment. Additionally, a high level of safety and stability must be built into these ponds. Homestake is one of the very few metal milling operations today (if not the only one) that does not employ tailings ponds for waste disposal. Previous data from the 1959 USPHS-State field studies indicated that Whitewood Creek waters when settled for 3 days experienced a decrease in cyanide content from

0.80 to 0.18 mg/l. Although conditions would be vastly different in a tailings pond, we believe that anywhere from 0-3 days' detention of plant flows will not be sufficient to adequately reduce cyanide content. However, regardless of detention time, the tailings pond(s), once constructed, could serve to bring all effluents together into a single waste stream, thereby expediting further treatment of total plant flows.

2. Filtration of spent slimes. From the literature, it appears that filtration of slimes is a process that has been incorporated into a number of gold milling operations throughout the world. Filtration of slimes is indicated as being used prior to discharge to tailings ponds. Filtration of slimes before placement into the ponds would save storage space and provide greatly increased stability of pond embankments. The first drum filters used for dewatering tailings from counter-current decantation of slimes were incorporated into the Hollinger Mill, in Canada, in the 1920's. Slimes from the last thickener will generally contain from 50-75 percent moisture. The cake from a filter, on the other hand, may run from 15-20 percent moisture and may be as low as 7-8 percent. Filtrates are recycled back to the plant. Although filters are relatively slow and expensive compared to thickening, they are highly desirable for waste handling purposes.

3. Chlorination of mill waste flows at pH 8.5 and above. Theoretically, it requires 2.73 parts of chlorine/part of

cyanide and 3.08 parts of caustic/part cyanide to oxidize cyanide to the cyanate (CNO) form. To convert the cyanate to carbon dioxide and nitrogen will theoretically require another 4.09 parts of chlorine/part cyanide and 3.08 parts caustic/part cyanide. Total theoretical requirements will be 6.82 parts of chlorine and 6.16 parts of sodium hydroxide part cyanate although mill wastes will already contain substantial amounts of excess alkalinity. Practical requirements for complete oxidation will probably be in the order of 9 parts chlorine/part cyanide. The first reaction is almost instantaneous whereas the second reaction appears in the order of 30-40 minutes. The amount and type of solids present in the waste streams will undoubtedly affect efficiency of chlorination. Sludges will also be produced, the quantity of which will vary with the particular alkali used.

4. On-line cyanide regeneration. Cyanide regeneration has in the past offered a practical means of overcoming heavy cyanide consumption frequently encountered in treatment of gold and silver ores where cyanicides are present. The common method for regeneration of cyanide in the leach circuits is by acidification of the solutions, although other methods of regeneration such as the carbon-cyanidization, the bromocyanicide, the ammonia-cyanide, and chlorination processes, have been previously used.

In the acidification process, i.e., the Mills-Crowe process, all or part of the cyanogen is converted into hydrogen cyanide gas, which is in turn fixed by an alkali (generally lime) and returned to the cyanide leach circuits. A weak or foul cyanide solution is acidified generally by brining it into contact with sulfur dioxide. The acidified solution is transferred to a closed tank in which air and solution are mixed. The air leaving the tank charged with hydrogen cyanide is then passed to another tank and mixed into an alkaline solution which absorbs the hydrogen cyanide leaving clean air available for more pickup of gas. Large volumes of forced air are necessary in this process, and the higher the velocity of circulated air, the higher the efficiency. On-line cyanide regeneration is believed to be employed in many gold mills in Canada, overseas, and possibly in the United States.

5. <u>In-plant housekeeping</u>. Whereas good housekeeping may afford a sizeable reduction in waste, it probably cannot be substituted (in any large degree) for the significant investment in waste treatment facilities indicated as necessary for the Homestake operations. Errant spills, pump or line failures, carelessness, etc., should, of course, be minimized to the maximum extent possible.

6. <u>Greater recycling of cyanide-laden flows back into the process lines</u>. The 1960 State report indicates that, at that time, only about one-third of total plant(s) water requirement was comprised of recycle water. Many more opportunities exist at the Lead and Deadwood plants for greater reuse of water.

These steps are probably essential for reducing wastewater volumes from the plants in order that the most economical treatment of wastes can be obtained.

7. Creating certain chemical conditions within tailings ponds conducive to maximum precipitation and possible recovery of metals from the waste flows.

8. Separate storage of liquids decanted from tailing(s) ponds. It may be desirable to transfer liquids from tailings piles to individual storage ponds for separate treatment, and/or disposal by evaporation or other means.

9. Segregation of strong from weak wastes for separate handling and/or treatment.

10. Mixing acid wastes (if any) with alkaline wastes to effect neutralization and coagulation.

11. Greater use of condenser and cooling waters in plant processes (if not already practiced).

CITATIONS

1. Environmental Protection Agency, Storm and Combined Sewer Pollution Control Branch, Edison Water Quality Laboratory, "Impact of Highway Salts on the Environment", February 1971. Report awaiting publication.

2. Environmental Protection Agency, Personnel report on trip to Homestake Gold Mill at Lead-Deadwood, South Dakota, December 2, 1970, Files of Division of Field Investigations, Denver Center, 1970.

3. Dobson, J. G., "The Treatment of Cyanide Wastes by Chlorination", Sewage Works Journal, pp. 1007-1020, November 1947.

4. Dorr, J. V. N. and F. L. Bosqui, "Cyanidization and Concentration of Gold and Silver Ores", McGraw-Hill Book Co., Inc., New York, 1950.

5. Gurnham, F. C., "Industrial Waste Water Control", date unknown.

6. Newton, J., "An Introduction to Metallurgy", John Wiley and Sons, Inc., New York and London, February 1949.

7. South Dakota State Department of Health, Division of Sanitary Engineering, "Report on Gold Recovery Wastes, Homestake Mining Co., Lead, South Dakota, 1960".

8. South Dakota State Department of Health, Division of Sanitary Engineering and USPHS, "Report on Water Pollution Studies, Gold Run Creek-Whitewood Creek-Belle Fourche River-Cheyenne River, 1960", Cincinnati, Ohio, 1960.