IC bureau of mines information circular 8162

WATER REQUIREMENTS AND USES IN ARIZONA MINERAL INDUSTRIES

By M. M. Gilkey and Robert T. Beckman

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
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BUREAU OF MINES
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WATER REQUIREMENTS AND USES IN ARIZONA MINERAL INDUSTRIES

by

M. M. Gilkey[1] and Robert T. Beckman[1]

SUMMARY

This report describes the effects of water shortage on Arizona's mineral industries. The information presented was obtained in interviews with company representatives. Operations covered included all State metal mines using substantial quantities of water and all concentrators and smelters. Also included in the survey were 8 operations in the nonmetallic group; 22 in the plating, metal-fabricating, and metal-forming categories; 1 public-utility power company; and 6 water companies.

The extent of the water shortage in Arizona is reflected in mineral-industry water-use practices, in the high cost and low quality of water used at many operations, and in the stringency of State control of well drilling and pumping. Many mineral-industry operations are among those users most seriously affected by the uneven water supply.

Copper, lead, and zinc operations accounted for most of the mineral production in the State. The copper industry, by far the largest of the three, is the major water user.

New water for the mineral-industry operations was obtained as follows: 87.8 percent was "self-supplied" from ground-water sources, 10.9 percent was "self-supplied" from surface-water sources, and 1.3 percent was purchased. At many operations, inadequacy of the supply necessitated large-scale recirculation.

Forty-five samples of new, recirculated, and discharged water were taken at copper, lead-zinc, and uranium operations. Analyses, shown in the appendix, indicate that new water from 6 of 21 sources sampled is brackish (contains more than 1,000 ppm of dissolved solids). Eight of eleven samples of recirculated water were brackish.

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[1] Mining engineer, Division of Mineral Resources, Bureau of Mines, Denver, Colo.

Work on manuscript completed August 1962.

Cost figures for new water from company-owned wells at 14 operations ranged from 1.0 cent per 1,000 gallons to 57.7 cents per 1,000 gallons, with an average of 12.5 cents per 1,000 gallons, including power, labor, and supplies. Recirculation costs for power, labor, and supplies at three copper operations ranged from 1.0 cent to 1.8 cents per 1,000 gallons.

The mineral-product value of copper, lead, zinc, and byproducts is equivalent to $15.27 for each 1,000 gallons of new water and $26.29 for each 1,000 gallons of consumed water. Thus, a much greater return in product value can be obtained for a thousand gallons of water by using it for mineral production rather than in the production of many other commodities.

Projection of the 1960 water requirements of the copper industry indicates that the gross intake will increase one-half by 1980 and that the demand for new water will increase one-fifth.

INTRODUCTION

Because of the increasing demand by municipalities, agriculture, and industry on Arizona's limited water resources, the quantity or quality of water available to many users is inadequate. This report contains the results of an investigation of the effects of the shortage on the mineral industry, particularly with regard to water-use practices.

The information was gathered mainly by conferring with company officials. Most of the needed data were available, and although some of the water-quantity figures are estimated, general accuracy is considered satisfactory.

Operations supplying data include all metal mines in Arizona using substantial quantities of water and all concentrators and smelters. In the nonmetallic category, eight plants were visited to obtain representative data on the uses of water at cement, mica, lime, and sand-and-gravel plants. Other sources of information include 6 metal-forming plants, 11 plating plants, 5 fabricating plants, and 1 public-utility power company. Six water companies provided data. To prevent disclosure of individual-plant data, the information obtained at several operations is used only in industry or State totals.

In 1960 the value of all mineral production in the State totaled $416 million of which copper accounted for $346 million. Maintaining this large production in water-short Arizona necessitates, at many operations, large-scale reuse of water. Much of the available supply is low in quality. At many operations water is expensive because of high pumping lifts and long pipelines. Some water is purchased, but most is obtained from company-owned or company-controlled sources.

In this report, the uses of water at many of the operations visited are illustrated by schematic waterflow diagrams. On the diagrams new-water intake is balanced by the quantity consumed plus the quantity returned to potential supply. A discussion accompanying each diagram contains additional data pertinent to the water-supply situation at the individual operation.

Forty-five water samples were taken by the Bureau during this investigation. The results of analyses are given in the appendix (Table A-1).

Water for the copper industry is the subject of two recent reports.[2,3] Mussey's report is nationwide in scope; the paper by Michaelson and others is limited to the Western States.

ACKNOWLEDGMENT

The courteous cooperation of the many persons supplying data for this report is gratefully acknowledged.

WATER POTENTIAL

The more densely populated regions in Arizona are in the drier portions of the State. In these dry areas most of the rainfall, which averages less than 15 inches per year, occurs as cloudbursts. Evaporation rates are high, as shown in figure 1.

Ground water constitutes the principal source in the State. Large reserves of ground water are available in most areas, but continued pumping has resulted in serious depletion in some areas. In the lower Santa Cruz Basin and in some areas near Phoenix, the water table has dropped 200 feet in the past 20 years, a depletion necessitating State control of well drilling and of pumping in some areas.

The geography, hydrography, precipitation and evaporation characteristics, and water laws of Arizona are discussed briefly in the following sections.

Geography

Arizona, the sixth largest State in the United States, has an area of 113,909 square miles. Land area is 113,575 square miles; water area is 334 square miles. Population in 1960 was 1,302,161, 73.7 percent more than in 1950. The State has an average of 11.4 persons per square mile. Most of the population is centered in the Phoenix and Tucson areas, which, in 1960, had a combined population of 779,476, or 59.9 percent of the State total.

Although Arizona is usually thought of as a desert State (fig. 2), some plateau and mountainous regions are heavily forested (fig. 3). The highest point in the State is Humphrey's Peak, north of Flagstaff, with an altitude of 12,670 feet; the lowest point, on the Colorado River in the southwestern corner of the State, has an altitude of 100 feet. The average altitude is approximately 4,100 feet.

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[2] Mussey, Orville D. Water Requirements of the Copper Industry. Geological Survey WSP 1330-E, 1961, 219 pp.

[3] Michaelson, S. D., B. H. Ensign, S. J. Hubbard, and A. W. Last. Water, a Raw Material for the Production of Copper. AIME Preprint 60 H 98, 1960, 17 pp.

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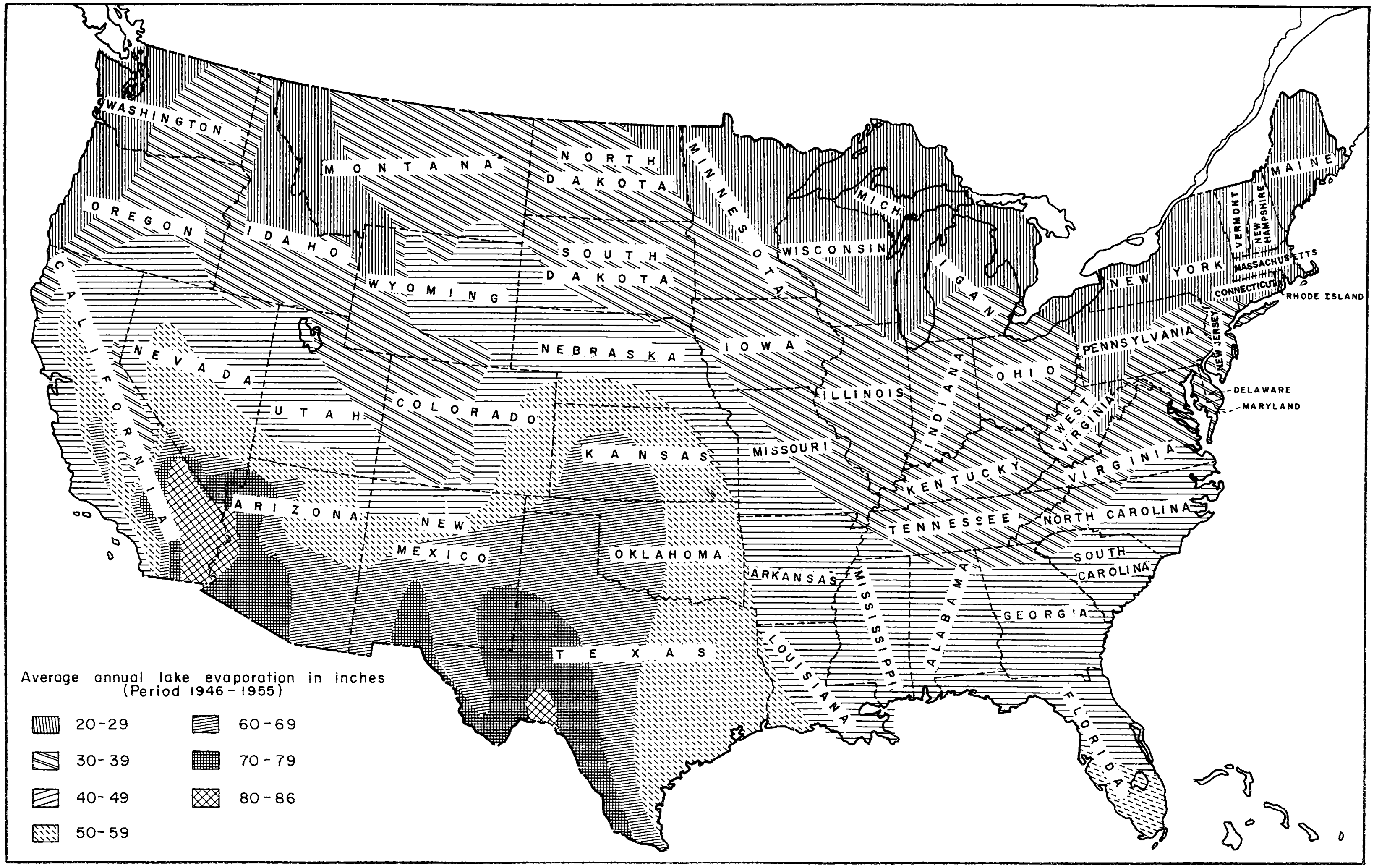

FIGURE 1. - Average Annual Lake Evaporation in the United States, 1946-1955.

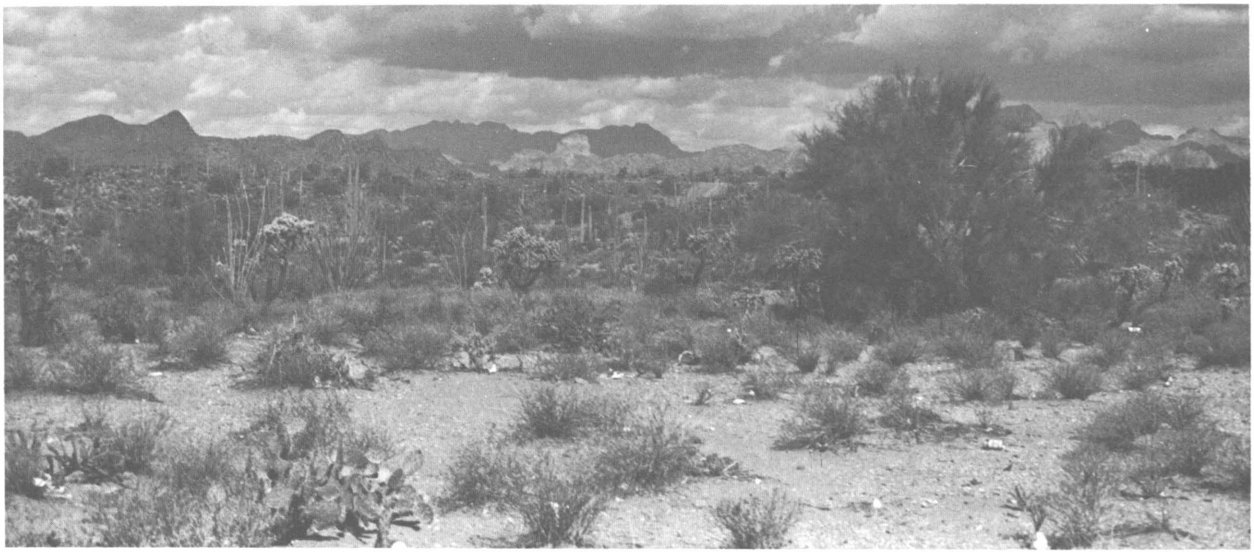

FIGURE 2. - Superstition Wilderness Area, 10 Miles West of Superior, Ariz.

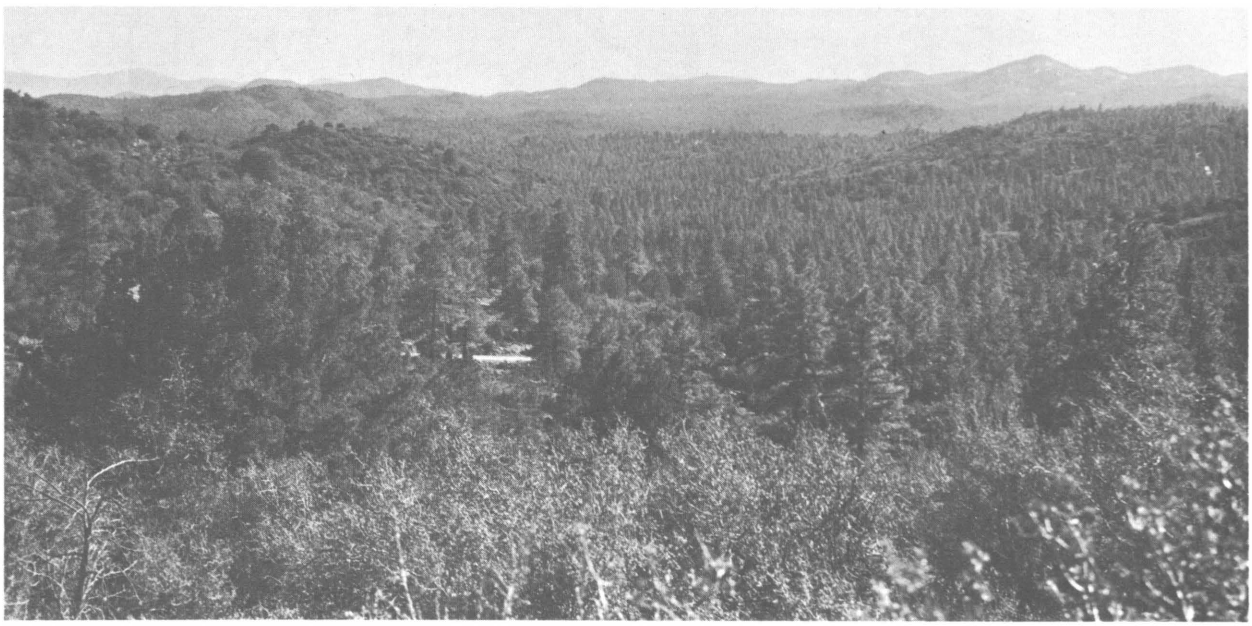

FIGURE 3. - Prescott National Forest, 5 Miles West of Prescott, Ariz.

Hydrography[4]

Figure 4 shows the major streams of Arizona and lists data on streamflow at various points. These data represent the mean discharge for the 1956 water year (October 1, 1955, to September 30, 1956), described as follows in WSP 1443.

[4] Geological Survey. Surface Water Supply of the United States, 1956, pt. 9, Colorado River Basin. WSP 1443, 1958, 466 pp.

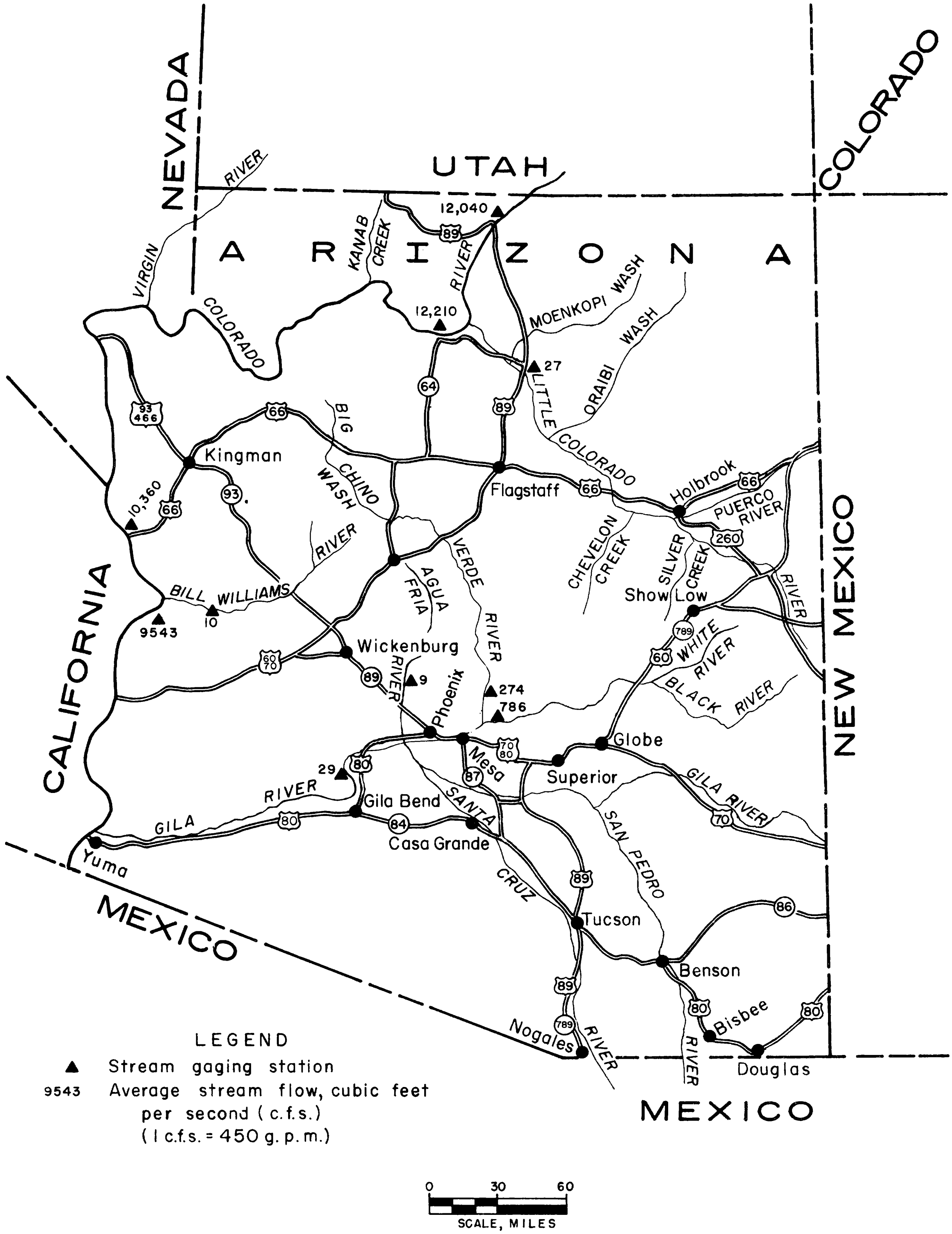

FIGURE 4. - Streams and Streamflow of Arizona, Water Year 1956.

"The water year 1956 was characterized by deficient runoff over most of the area covered by this report....Drought conditions existed in Arizona and southern Utah throughout most of the year and appeared to be much worse at the end of the year than at the beginning. Record low flows for the months of August and September occurred at many gaging station sites in the lower Colorado River basin...."

For information on the quality of surface water in the Colorado River Basin, the reader is referred to WSP 1453.[5]

Precipitation and Evaporation[6]

Precipitation in Arizona ranges from 30 inches annually in some mountainous areas to 4 inches in the desert southwest (fig. 5).

The average number of days on which there is measurable precipitation is 68 at Flagstaff, 49 at Tucson, 36 at Phoenix, and 13 at Yuma. Long periods occur with little or no precipitation. High temperature and low relative humidity account for the high average evaporation rates (fig. 1). Evaporation from exposed water surfaces may amount to as much as 115 inches per year in the Yuma area and 80 inches per year in the Salt River Valley.

Water Laws

Laws pertaining to both surface and ground water are under the jurisdiction of the State Land Commissioner.

In Arizona, as in most Western States, water law is exceedingly complex. General concepts of the Arizona water laws are as follows:

Surface water rights are based on the doctrine of appropriation, under which the first user of any amount of water from a surface source, for a beneficial use, has the right to withdraw the same amount indefinitely. This doctrine is often stated as "The first in time is the first in right".

The Ground Water Act of 1948 prohibits drilling additional irrigation wells in "critical ground-water areas". Drilling wells for domestic, industrial, or transportation (railroad) uses is not necessarily prohibited. However, operating any well having a capacity of more than 100 gallons per minute requires a permit from the State Land Commissioner.

WATER-USE PRACTICES

Large quantities of water are required for mineral production and processing and for fabricating metallic and nonmetallic products. In water-short

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[5] Geological Survey. Quality of Surface Waters of the United States, 1956, pt. 9, Colorado River Basin: WSP 1453, 1960, pp. 22-187.

[6] Jurwitz, L. R., and P. C. Kangieser. Climates of the States (Arizona). U.S. Dept. of Commerce, Weather Bureau Climatography of the United States No. 60-2, 1959, 4 pp.

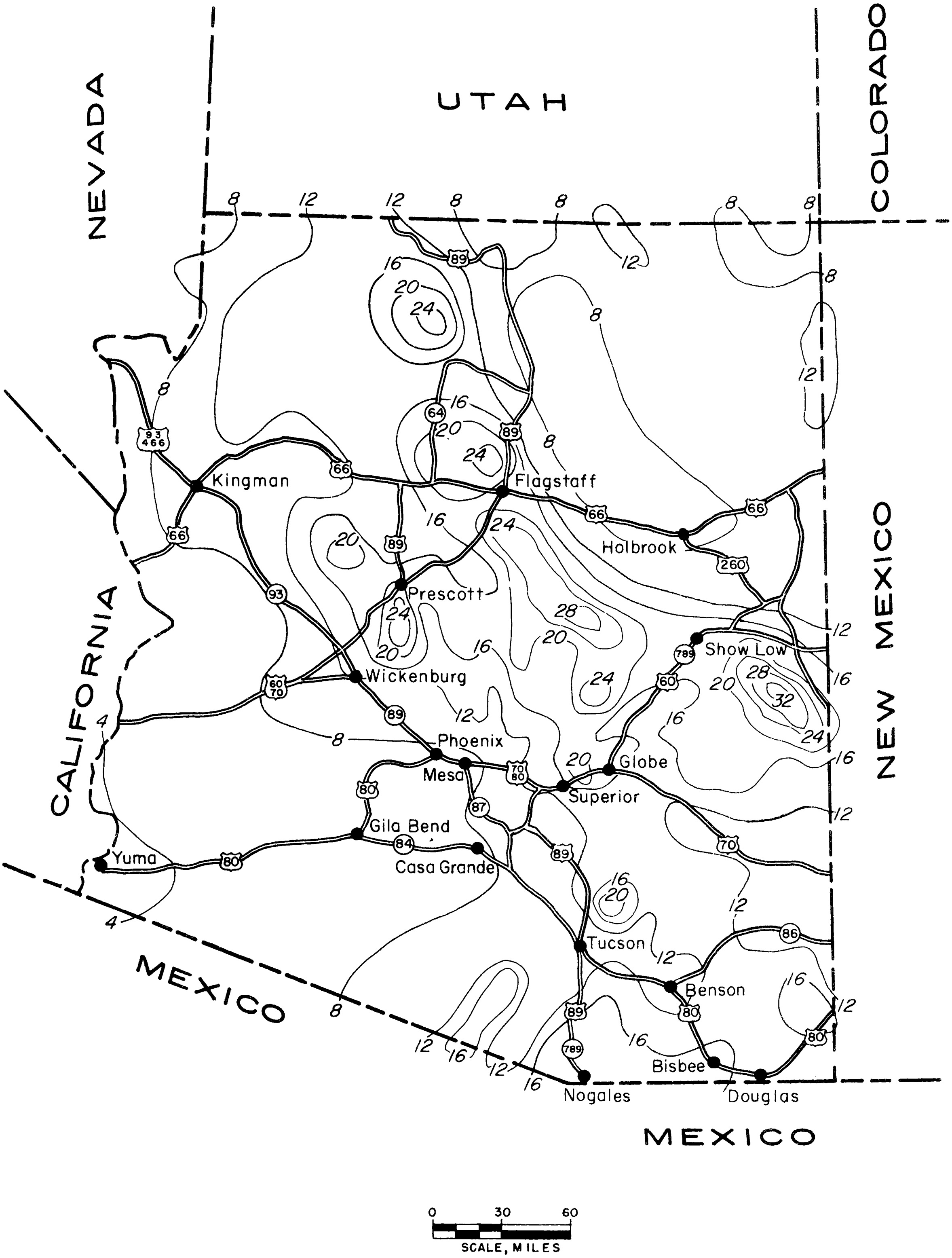


FIGURE 5. - Mean Annual Precipitation, Inches, 1931-1955. (Adapted from Federal Weather Bureau Map).

areas of Arizona, obtaining water for industry often involves competition with agricultural users or with public utilities.

General

Descriptions of individual mineral-industry operations detailed in the following pages were prepared on the basis of discussions with company officials; covered are such items as type of operation, sources of water, quantities of new and recirculated water, evaporation, and seepage.

Most of the descriptions include a waterflow diagram that schematically illustrates movement of water to, within, and from the operation. Many quantity figures shown on the diagrams include, for example, both new and recirculated water. For complex operations, respective approximate amounts of new and recirculated water discussed in the text are computed by the method of proportional distribution.

Evaporation from exposed bodies of water was roughly approximated at 5 gallons per minute per acre, equivalent to about one-fourth inch per day. After evaporation was computed, the amount of seepage (if any) was computed by subtracting. The principle, "water in equals water out," was applied. The evaporation and seepage figures are sufficiently definitive for this report. A more exact determination of evaporation and seepage involving local differences in temperature, humidity, and wind velocity, as well as measurement of evaporation areas was not warranted.

Definitions

Several terms frequently used in the descriptions and diagrams are defined below:

New water - water used for the first time in an operation.

Recirculated water - water returned to its original use, primarily to reduce new-water demand.

Transferred water or solvent - water or solvent sent to another unit in an operation, either to reduce new-water demand, or for metallurgical reasons.

Recycled solvent - leaching solvent reused in a leaching system primarily for metallurgical reasons.

Consumption - loss of water by evaporation or by incorporation in product.

Seepage - water that returns to the subsurface supply. (Theoretically it is available for reuse).

Discharge to stream - any surface flow of water from an operation. (It is available for reuse).

pH - a symbol used to express hydrogen ion concentration. Values from 0 to 14 are measures of relative acidity and alkalinity; 7 is neutral.

The following standard and nonstandard abbreviations are used in this report.

gpm -- gallons per minute
gpd -- gallons per day
gpy -- gallons per year
ppm -- parts per million
tpd -- tons per day
P -- incorporated in product (P is used only in diagrams of certain sand-and-gravel operations)
E -- evaporation (E from concentrators includes moisture in concentrates)
N -- negligible amount
S -- seepage

Evaporation Control

Evaporative losses from exposed bodies of water are reduced by applying hexadecanol or certain other organic chemicals that form a protective film 1 molecule thick on the water surface. Tests by the Bureau of Reclamation and other Government agencies have been made mainly on large reservoirs. The tests indicate that as much as 30- or 40-percent reduction in evaporation is possible under favorable conditions. Effective application of the chemical constitutes a problem. The chemical may be applied as a liquid, flake, or powder, each of which has advantages and disadvantages. Removal of the film by the wind commonly necessitates daily reapplication; therefore, labor is usually the principal cost item. Reportedly, total cost of evaporation control on the large reservoirs ranged from a few cents to 90 cents per 1,000 gallons of water saved.

Evaporation inhibitors have been used experimentally in Arizona on three tailings ponds. The inconclusive results can probably be attributed to improper application of the inhibitor; to removal of the film, either by wind or as a result of withdrawal of water for recirculation, or both; or to destruction of the film by biochemical oxidation.

In its present state of development, this method is probably not feasible for reduction of evaporative losses from the comparatively small tailings ponds and reservoirs at mineral-industry operations.

Mineral Extraction

In 1960 mineral production in Arizona, valued at $416 million, required approximately 28 billion gallons of new water. About 23.5 billion gallons of this amount was used in the metallic-mineral extraction operations shown on figure 6.

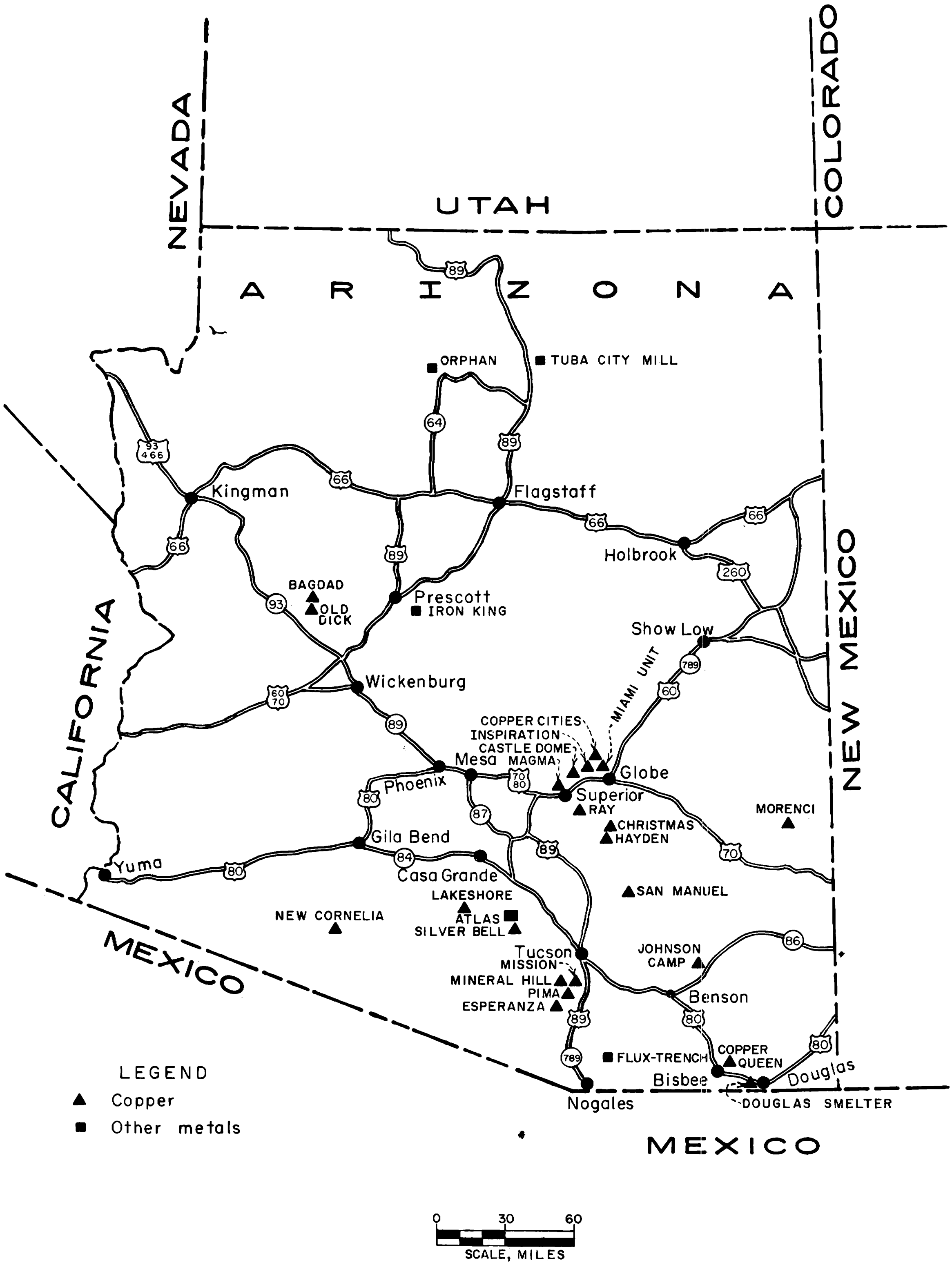


FIGURE 6. - Location Map, Metallic-Mineral-Extraction Operations Included in Arizona Water Study.

Copper

Copper production in Arizona in 1960 amounted to 538,605 tons, about one-half of the Nation's total.[7] This production was worth $345.8 million, or 83 percent of the State's total value of mineral output.

Sulfide-copper ores, with copper content generally ranging from 10 to 100 pounds per ton of ore, are mined by the open-pit or underground method, depending on the type of deposit. Most of the water needed in mining is used for dust control, which, in open pits, includes road sprinkling. A comparatively small amount is used in drilling blastholes.

From the mine, the ore is taken to the crushing plant, where it is reduced to a size suitable for ballmill feed. Water may be used in the crushing plant for dust control, lubricant cooling, and bearing sealing. Water is added to the ballmill-classifier unit in amounts required for grinding the ore to about 48- to 65-mesh. Little water is consumed in this unit.

In flotation, the next major step in beneficiation, sulfide copper is recovered in a froth from a pulp containing suitable reagents and water in proper quantities. Optimum density of the pulp ranges from 15 to 40 weight-percent solids. A 15-percent pulp contains 5.67 tons (1,360 gallons) of water per ton of ore, and a 40-percent pulp, 1.5 tons (360 gallons) of water.

Flotation tailings are commonly discharged to a thickener, where some of the water is recovered. After thickening, the partly dewatered tailings are sent to the tailings pond, where more of the water may be recovered.

The total intake of water per ton of ore for 14 copper concentrating systems is given in figure 7. This bar graph shows the intake of new, recirculated, and transferred water for each ton of ore treated. It also illustrates a breakdown of the new water into consumptive and nonconsumptive uses. The nonconsumptive part is considered returned to potential supply, either by seepage or by surface flow from the operation.

Quantities and proportional amounts of new, recirculated, and transferred water indicated on figure 7 reflect circumstances existing at the individual plants. In general, the extent of reuse of water, by recirculation within a concentrating system or (in an integrated operation) by transfer from another unit, depends not only on adequacy of the supply of new water but also on water-quality requirements and relative costs. (Inspiration and Lakeshore follow nonconventional flotation practices that affect the quantity of water required per ton of ore milled). One of the two weighted averages shown on figure 7 applies to the 14 concentrators, and the other represents all 17 of the copper concentrators in Arizona.

The concentrates, usually containing about 30 percent copper, are smelted in a reverberatory furnace to form copper matte, which is charged into a

[7] Kerns, W. H., F. J. Kelly, and D. H. Mullen. The Mineral Industry of Arizona, 1960. BuMines Area Report III-123, 1961, 10 pp.

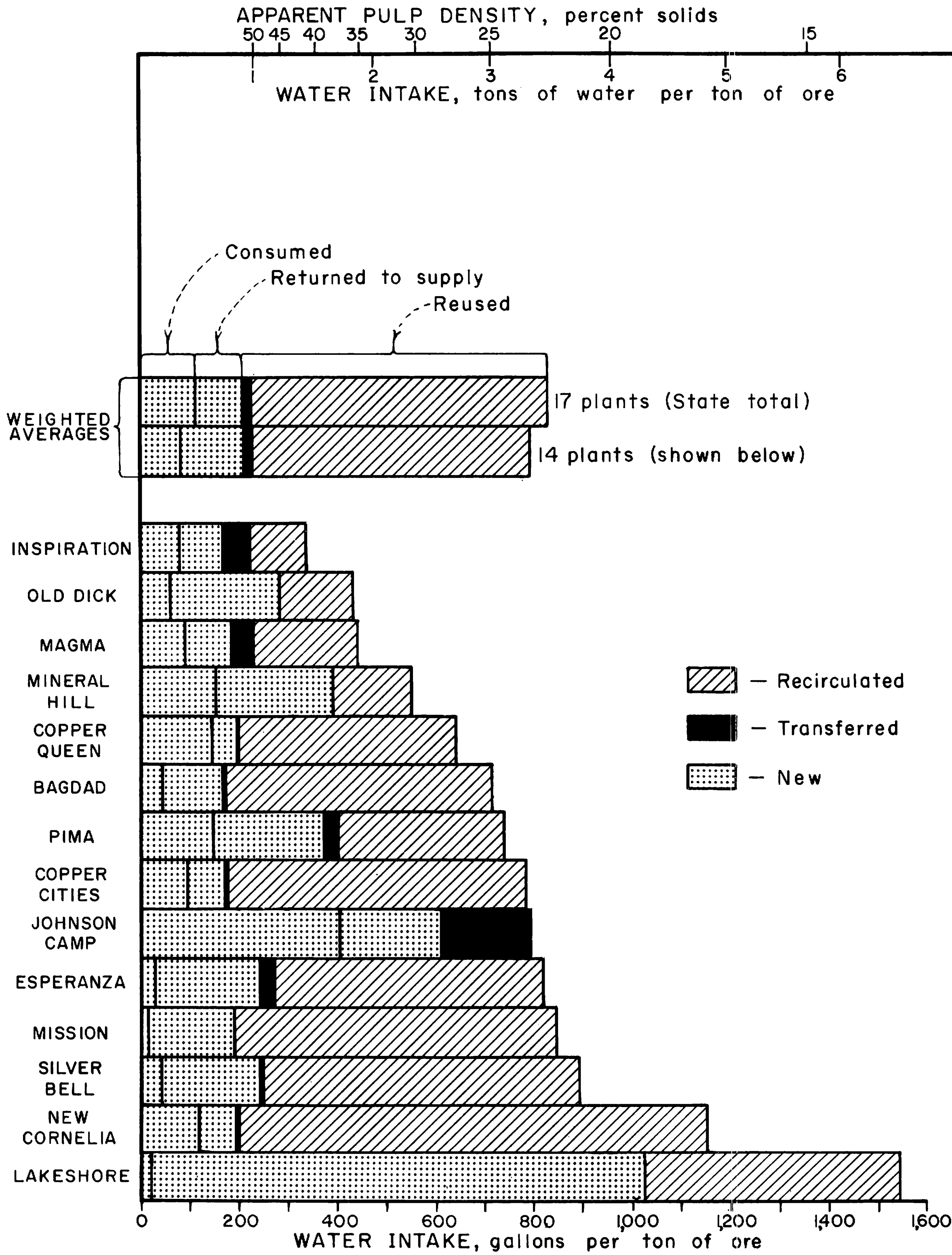


FIGURE 7. - Average Water Intake of Arizona Copper Concentrating Systems; Gallons per Ton of Ore Concentrated.

converter. Blister copper from the converter is cast into anodes, which are shipped to electrolytic refineries outside the State. Water is used in the smelter mainly for cooling the reverberatory furnaces, converters, and copper anodes.

Copper smelters generally utilize "waste heat" to produce electric power. The powerplants require large amounts of water for condensing steam and smaller amounts for boiler feed.

Leaching, another method of recovering copper, is particularly applicable to low-grade oxidized ores. Three types of leaching are in use in the State: Leaching in place, heap (or dump) leaching, and vat leaching. Oxide-copper minerals are dissolved by a dilute solution of sulfuric acid. Some sulfide-copper minerals are soluble in a dilute ferric sulfate solution.

Copper contained in the pregnant solution is precipitated by passing the solution over shredded scrap iron. The recovered cement copper is sent to a smelter. The copper may also be recovered by passing the solution through electrolytic cells, which have insoluble anodes. The product of the latter method is refined copper.

In leaching, evaporative losses and seepage must be replaced by adding new water to the solvent. If ferric sulfate, formed by the action of water on certain sulfides, is present in the solvent, some of the solvent in the system may have to be removed to prevent an undesirable ferric ion "buildup."

Table 1 illustrates the relative water requirements for the mining-flotation-smelting method of recovering copper and for the leaching-smelting method.

TABLE 1. - Average amounts of water required and consumed in producing copper in Arizona, 1960.[1]

	Total intake		Consumption	
	Gallons per pound of copper	Percent	Gallons per pound of copper	Percent
Mining	[2]1.1	1.9	[2]1.0	11.1
Flotation concentrating	[3]56.0	96.2	[3]7.5	83.3
Smelting	[4]1.1	1.9	[4].5	5.6
Total	58.2	100.0	9.0	100.0
Leaching	29.7	96.4	15.1	96.8
Smelting	[4]1.1	3.6	[4].5	3.2
Total	30.8	100.0	15.6	100.0

[1] Excludes water required for powerplants, and for domestic and miscellaneous purposes.
[2] Based on average grade of ore mined.
[3] Based on average grade of feed at concentrators.
[4] Based on smelter output.

Comparison of the figures in table 1 reveals that the mining-flotation-smelting method requires about 89 percent more intake water per pound of copper than does the leaching-smelting method but consumes only 58 percent as much per pound of copper.

Total water figures in gallons per minute and million gallons per year for the Arizona copper industry are listed in table 2.

TABLE 2. - Water balance, copper industry of Arizona, 1960[1]

	Subtotal, gpm[2]	Total, gpm[2]	Million gpy[3]
Total new water in...	-	47,513	23,098
Evaporation..........	29,073	-	13,562
Seepage..............	17,405	-	9,032
Discharge to stream..	1,035	-	.504
Total water out......	-	47,513	23,098
Recirculated.........	325,903	-	[4]158,624
Transferred..........	4,979	-	2,423

[1] Covers all users of appreciable quantities of water and includes all operational and domestic uses.
[2] Operating rates.
[3] Adjusted to number of working days per year at individual operations.
[4] Includes approximately 120 billion gallons of water recirculated at powerplants.

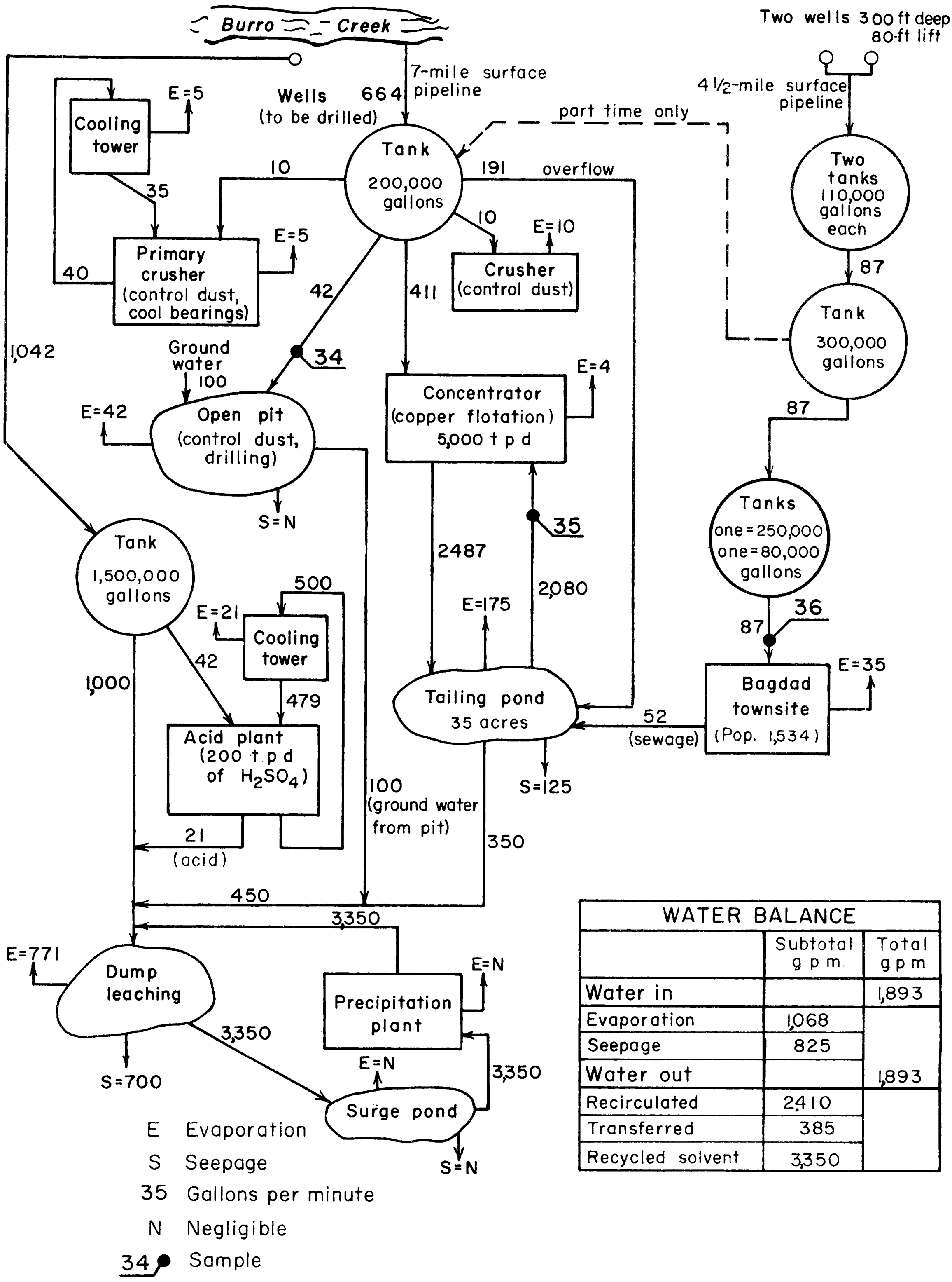
The following descriptions of 17 copper operations illustrate water-use practices followed in the State. Data collected at five other copper operations are included only in State totals.

Bagdad

The Bagdad Copper Corp. operation, just west of the town of Bagdad (fig. 6), includes an open-pit mine, a flotation concentrator, and a dump-leaching unit. (Dump leaching was expected to begin in April 1961). A total of 352 persons is employed. Work schedules are as follows: In the mine, 2 shifts per day, 5 days per week; in the concentrator, 3 shifts per day, 7 days per week; and in the leaching unit, 3 shifts per day, 7 days per week.

New water for the mine and concentrator is pumped from Burro Creek through a 7-mile-long surface pipeline (fig. 8). Water for the town of Bagdad comes from two 300-foot-deep wells; the lift is 80 feet. This water is brought 4-1/2 miles by an 8-inch pipeline. A source of water for the leaching unit is being developed.

The open-pit mine uses 42 gpm for drilling, dust control, and truck washing. All of this amount is evaporated.



WATER BALANCE	Subtotal g p m.	Total g p m
Water in		1,893
Evaporation	1,068	
Seepage	825	
Water out		1,893
Recirculated	2,410	
Transferred	385	
Recycled solvent	3,350	

FIGURE 8. - Schematic Waterflow Diagram, Bagdad Operation, Bagdad Copper Corp., Yavapai County, Ariz.

Total intake for the 5,000-tpd concentrator is 2,491 gpm of new, recirculated, and transferred water. New water totals 556 gpm; 411 gpm of the 556 gpm comes directly from the 200,000-gallon tank, and the additional 145 gpm is computed theoretically by proportional distribution of the 191 gpm of new water entering the concentrating system at the tailing pond. (Water leaving the pond amounts to 175 + 2,080 + 125 + 350 = 2,730 gpm. Therefore, the 2,080 gpm going to the concentrator includes [2,080 ÷ 2,730] x 191 = 145 gpm of the new water overflowing the 200,000-gallon tank.) Similarly computed, recirculated water is 1,896 gpm, and transferred water from the townsite is 39 gpm.

Evaporation from the concentrating system totals 179 gpm. The 4 gpm shown as evaporated in the concentrator includes 2 gpm "incorporated in product" (as moisture in the concentrates). Seepage from the 35-acre tailing pond is 125 gpm.

New water for the dump-leaching unit amounts to 1,167 gpm, which includes a theoretically computed 25 gpm of new water in the 350 gpm from the tailing pond. Intake for the unit also includes 325 gpm of transferred water from the tailing pond. Evaporation from the acid-plant cooling tower and dumps totals 792 gpm. Seepage from the dumps amounts to 700 gpm.

A unique feature of this leaching operation is the large plastic lining in the surge pond.[8]

For domestic uses in Bagdad, the company furnishes 87 gpm. Evaporation from the townsite is 35 gpm. Domestic water requirements in the plant area are negligible.

The limited supply of water necessitates maximum recirculation. Additional sources of water have been developed only with difficulty; as of January 1961, the company had drilled five dry holes in an attempt to develop more water for the leaching system.

Laboratory tests of lignin sulfonate indicated that this dust palliative would depress the copper in the flotation circuits. Therefore, because all roads are in areas draining into the open pit or taining pond, no lignin sulfonate is used to control road dust.

At times, especially during the flood season, the quality of the Burro Creek water is undesirably low, but the lack of an alternate supply necessitates continual use of this source. The well water used for the town is of good quality, except for its high fluoride content. Analyses of sample 34, new water from Burro Creek; sample 35, recirculated water from the tailing pond; and sample 36, new domestic water from the 300-foot-deep wells, are given in the appendix.

All Burro Creek water is treated with a patented compound to prevent scaling, and water for the hospital is softened. Water going to the acid

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[8] Bogert, John R. New Leach Plant Ups Bagdad's Copper Production by 67 Percent. Mining World, v. 23, No. 9, August 1961, pp. 26-28.

plant will probably require treatment, but the type of treatment will not be known until the source is developed.

Castle Dome

The Castle Dome unit of the Miami Copper Co., Div. Tennessee Corp., is about 5 miles west of Miami (fig. 6). Fifteen men are employed in the leaching of waste dumps resulting from former open-pit copper-mining operations (fig. 9). The unit is operated 24 hours per day, 7 days per week. Runoff, collected in two reservoirs, supplies 147 gpm of the process water. An additional 60 gpm from a 150-foot-deep well (fig. 10) is pumped to Castle Dome through a 3-mile-long pipeline. The intake of new water, presently 207 gpm, depends on the amount available: The operation is adjusted to the supply. Most of the new water is evaporated. The quality of the water is satisfactory.

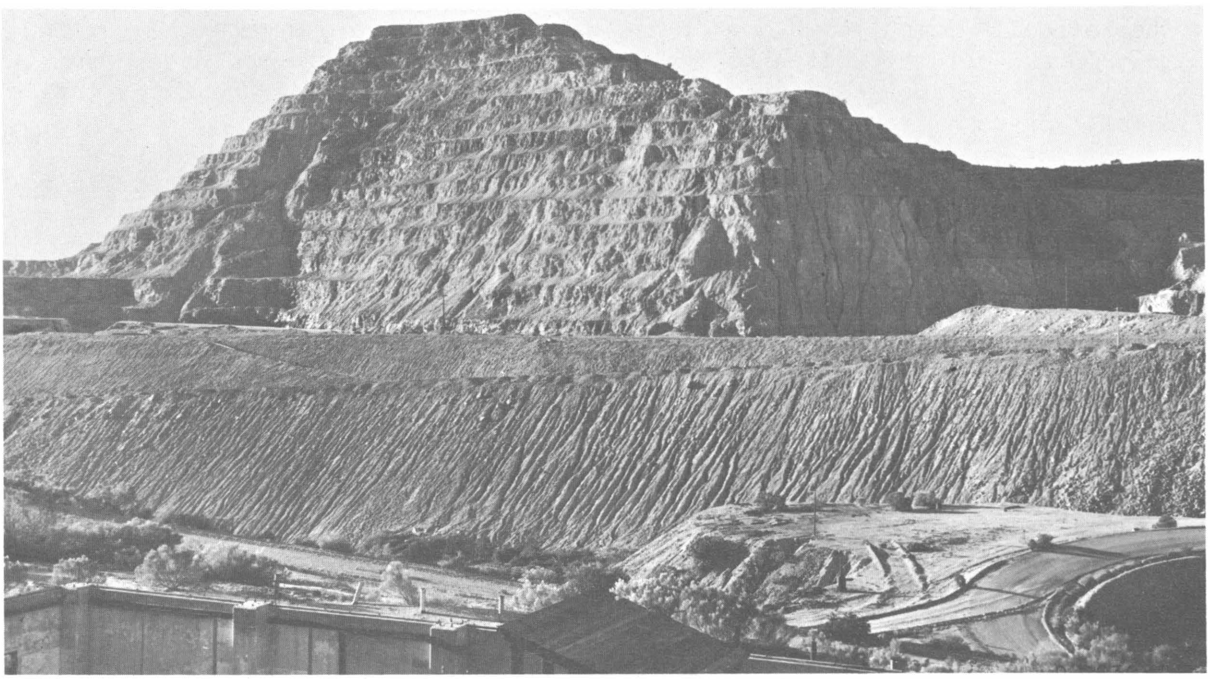
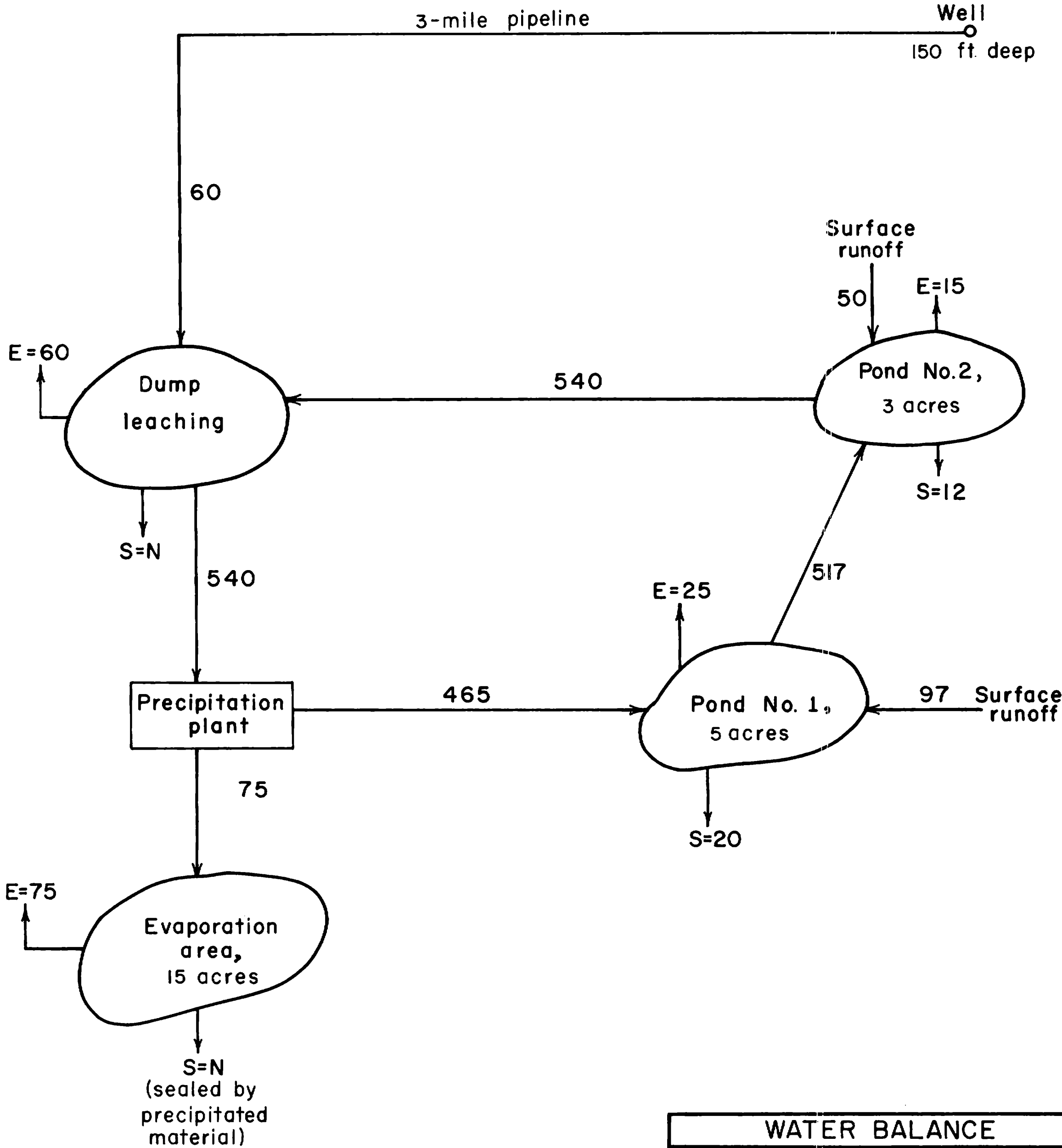


FIGURE 9. - Castle Dome Operation, Site of Dump Leaching by Miami Copper Co., Gila County, Ariz.

Copper Cities

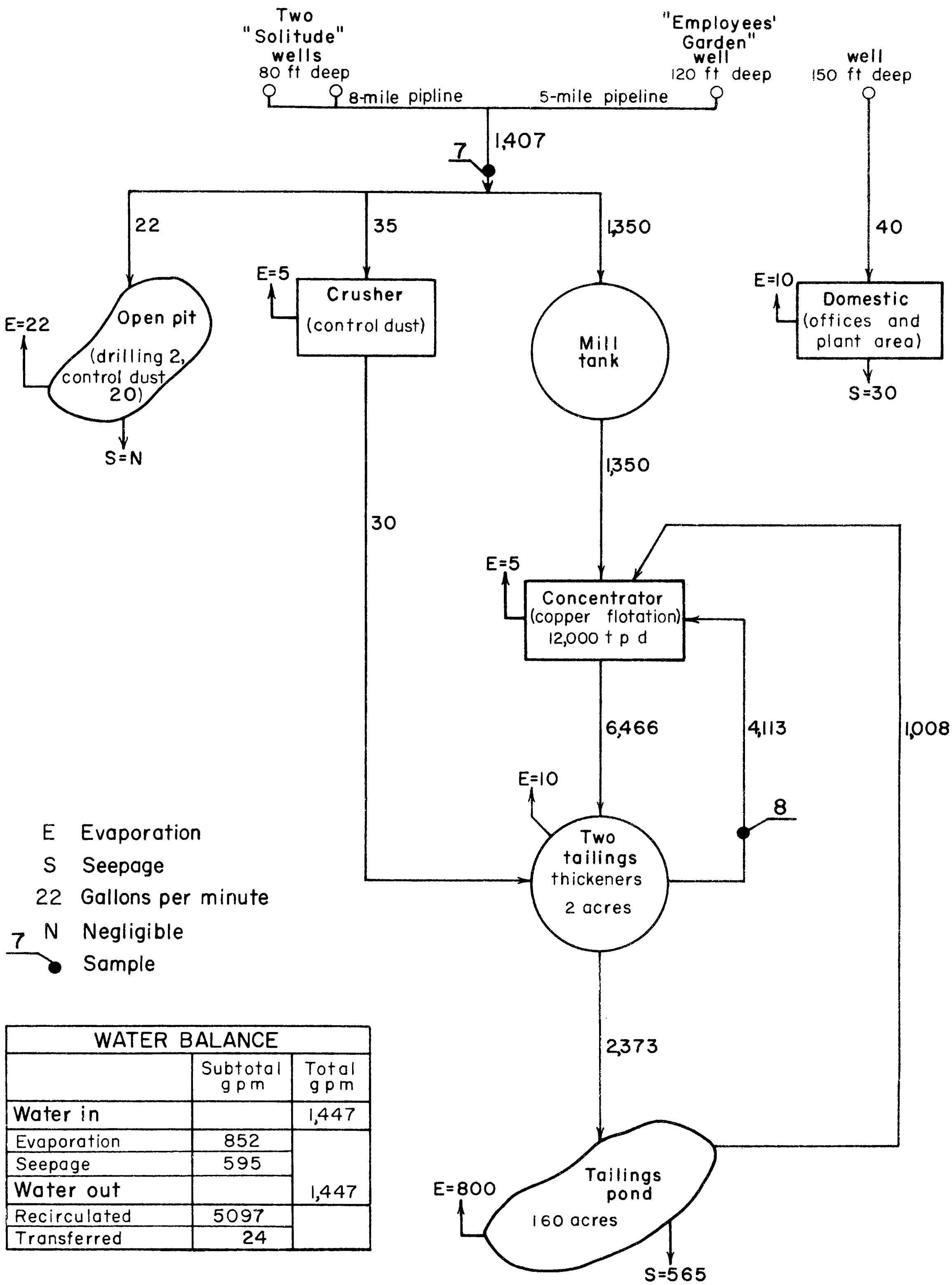
The Copper Cities unit, Miami Copper Co., Div. Tennessee Corp., is 5 miles north of Miami (fig. 6). Employees at the open-pit mine and copper-flotation concentrator total 450. The mine is operated 2 shifts per day and the 12,000-tpd concentrator, 3 shifts per day; both are operated 22 days per month. Industrial water is pumped from three 80- to 120-foot-deep wells (fig. 11), 5 to 8 miles south of Copper Cities. The two Solitude wells are "dug" wells. To collect water, a 125-foot-long drift extends from the bottom of



WATER BALANCE		
	Subtotal g p m	Total g p m
Water in		207
Evaporation	175	
Seepage	32	
Water out		207
Recycled solvent	393	

E Evaporation
S Seepage
60 Gallons per minute
N Negligible

FIGURE 10. - Schematic Waterflow Diagram, Castle Dome Unit, Miami Copper Co., Gila County, Ariz.



WATER BALANCE	Subtotal gpm	Total gpm
Water in		1,447
Evaporation	852	
Seepage	595	
Water out		1,447
Recirculated	5097	
Transferred	24	

FIGURE 11. - Schematic Waterflow Diagram, Copper Cities Unit, Miami Copper Co., Gila County, Ariz.

each "dug" well. A 150-foot-deep drilled well on the property supplies sufficient water for domestic use.

The open-pit mine requires 20 gpm for dust control and 2 gpm for drilling, all of which is evaporated.

The concentrator requires a total intake of 6,471 gpm; 1,350 gpm is new water, 24 gpm is transferred from the crusher, and 5,097 gpm is recirculated. Recirculation not only reduces new-water demand, but also eliminates a waste-disposal problem.

A total of 815 gpm is lost by evaporation from the concentrating system, which consists of the concentrator, tailings thickeners, and tailings pond.

Although the water supply is presently adequate, the water table is dropping at a rate that indicates a shortage within 2 or 3 years.

Sample 7 represents the new industrial water; sample 8 represents the water recirculated from the tailings thickeners (appendix). No sample was taken of the domestic water, reportedly declining in quality.

The cost of new industrial water--including cost of power, labor, and supplies--is 9 cents per 1,000 gallons. This cost is equivalent to 0.6 cent per pound of copper contained in the concentrates.

For the past 1-1/2 years hexadecanol has been applied to the tailings pond to reduce evaporation. The results of this application are inconclusive.

Copper Queen (Bisbee)

Copper Queen Branch, Phelps Dodge Corp., Bisbee, employs 1,684 persons (fig. 6). This branch of the corporation includes the Copper Queen underground mine, the Lavender open-pit mine (fig. 12), a flotation concentrator, a dump-leaching operation, a diesel powerplant, and a turbine powerplant (fig. 13). All major units except the dump-leaching unit are operated three shifts per day, about 5-1/2 days per week; leaching is continual.

Most of the new water is pumped from the underground mine (sample 24 in the appendix). Some high-quality water, from wells near Naco, is bought from a water company. The 316 gpm of water pumped from the underground workings to the leaching area is so highly acidic that stainless steel pumps and Fiberglass pipes are used to minimize maintenance problems.

Dust control and drilling require 244 gpm of water in the open pit and 43 gpm in the underground mine. Evaporation is 243 gpm in the open pit and 5 gpm underground. An estimated 38 gpm seeps back into the ground after it has been used for underground drilling and dust control.

The 20,000-tpd concentrator takes 2,430 gpm mine water, 186 gpm Naco water, and 6,149 gpm recirculated water. Sample 25 (appendix) represents

FIGURE 12. - Lavender Open-Pit Mine, Phelps Dodge Corp., Bisbee, Ariz.

water recirculated from the tailings pond. Evaporation in the concentrator, tailings thickeners, and tailings pond totals 2,022 gpm. Seepage from the 400-acre tailings pond is 594 gpm.

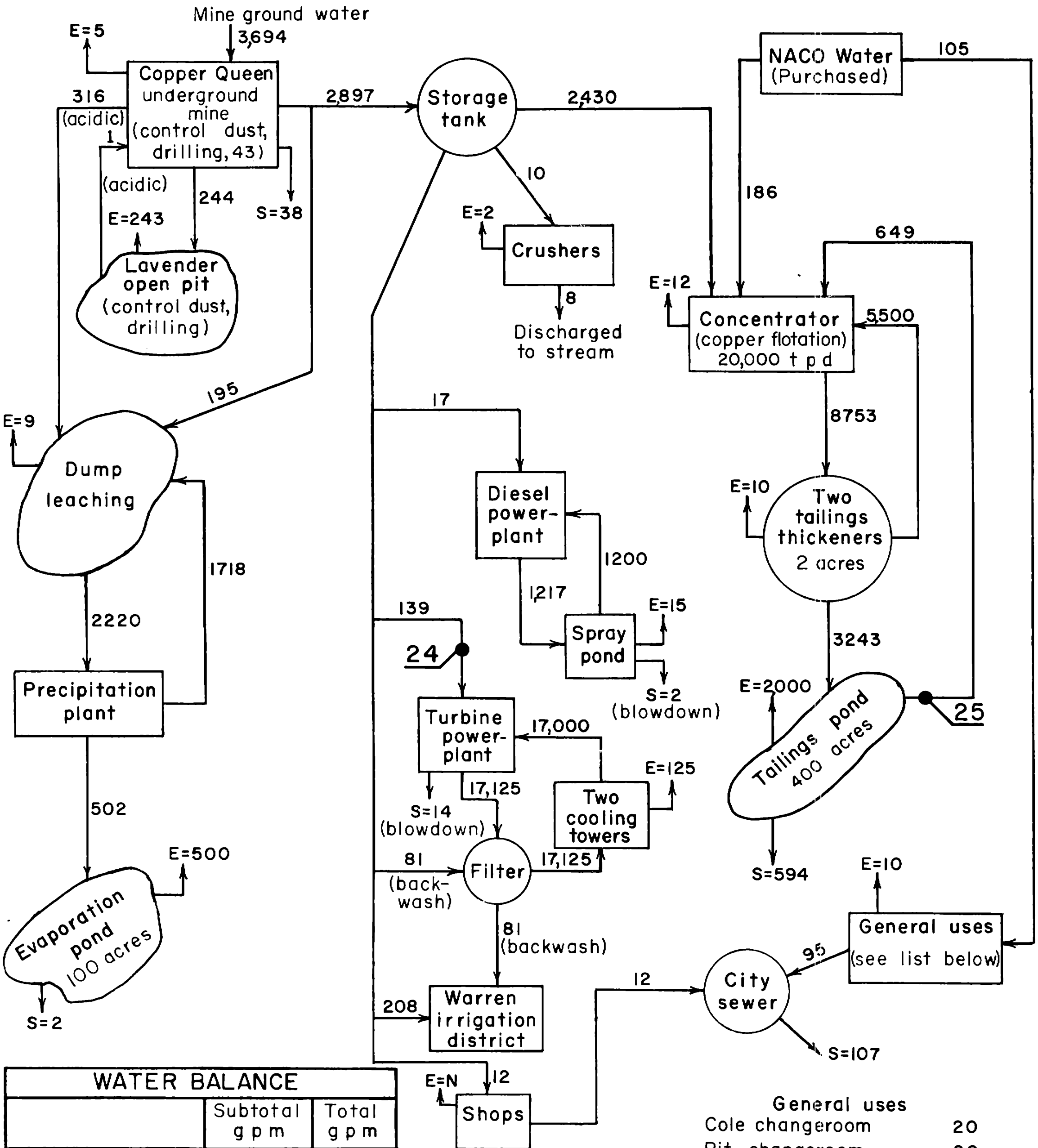
Cooling the diesel powerplant requires 1,217 gpm; 1,200 gpm of this is recirculated, and 17 gpm is new water to replace the evaporative loss and blowdown from the spray pond. The turbine powerplant has a total intake of 17,139 gpm. Recirculation is 17,000 gpm, and new-water intake, compensating for evaporative loss and blowdown, is 139 gpm.

Dump leaching has a new-water intake of 195 gpm of clear mine water and 316 gpm of acidic mine water. A total of 509 gpm is evaporated. Most of the evaporation is from the 502 gpm sent to a 100-acre disposal pond to remove excess iron from the leaching system.

The company has experimentally used hexadecanol and lignin sulfonate, neither of which seemed to save enough water to justify costs.

Cooling water for the turbine powerplant is treated with 14 gpd of concentrated sulfuric acid to lower the pH and with 20 pounds per day of phosphate to prevent scaling. Cooling water for the diesel powerplant is treated with soda ash, a patented algaecide, and a corrosion inhibitor. All quality and treatment problems are handled by a water-consultant firm.

Cost of the Naco water is 57 cents per 1,000 gallons.



WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		3,985
Evaporation	2,931	
Seepage	757	
Discharge to stream	297	
Water out		3,985
Recirculated	24,349	
Transferred	190	
Recycled solvent	1,718	

E Evaporation
S Seepage
316 Gallons per minute
N Negligible
24 Sample

General uses	
Cole changeroom	20
Pit changeroom	20
Standby changeroom	19
Campbell changeroom	17
Dallas changeroom	3
Precipitation plant	6
Hotel	5
Assay laboratory	3
Dispensary	2
Hotel kitchen	1
Offices	8
Hampton pit	1
Total	105

FIGURE 13. - Schematic Waterflow Diagram, Copper Queen Branch, Phelps Dodge Corp., Cochise County, Ariz.

Douglas

The Douglas Reduction Works, Phelps Dodge Corp., is near the town of Douglas (fig. 6) and consists mainly of a smelter and powerplant. Seven hundred employees work three shifts per day and average between 6 and 7 days per week.

All water is pumped from three wells in the plant area (fig. 14). The wells are 400 to 450 feet deep; pumping lifts average 110 feet.

In the smelter 347 gpm of water is required for reverberatory-furnace cooling and then is transferred to anode cooling. From anode cooling, 48 gpm is transferred a second time, for use in molds. All the 48 gpm is evaporated. The remaining 299 gpm used in anode cooling is discharged through a 1-mile-long drain to Whitewater Creek.

Distilled boiler feed for the powerplant amounts to 21 gpm. In the condensing system 396 gpm of new water is required for makeup, and 18,056 gpm is recirculated. From the spray pond 215 gpm is evaporated, and, to maintain quality, 181 gpm is discharged to Whitewater Creek.

Miscellaneous and domestic uses require 316 gpm, of which 157 gpm goes to Whitewater Creek.

In 50 years of operation, the water table has been lowered only 5 feet. The company plans to use all water discharged from the anode section and spray pond in producing a high-iron slag. Sponge iron recovered from the slag is to be used in the Bisbee (Copper Queen Branch) precipitation plant.

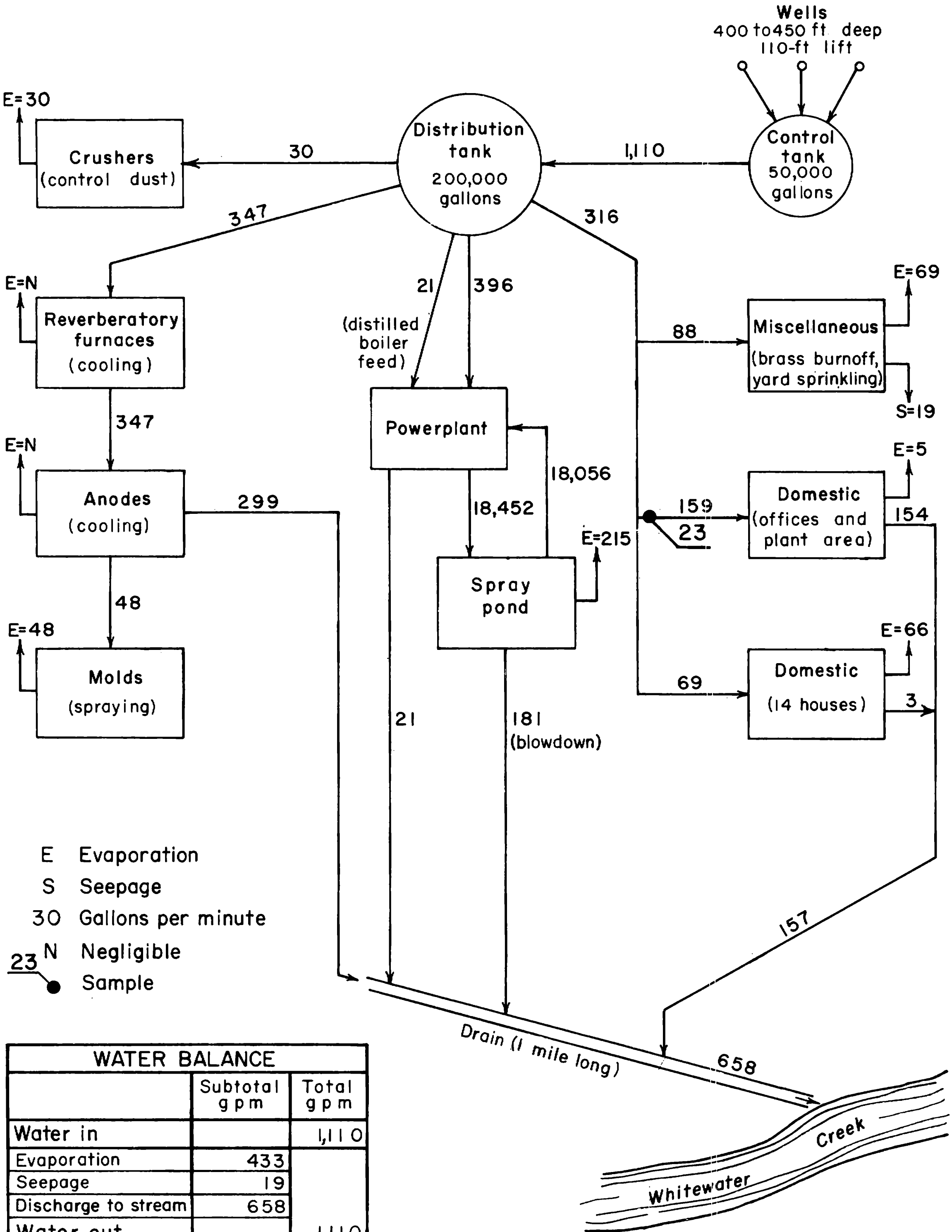
The high-sodium, low calcium-magnesium content of the new well water (sample 23, in the appendix) precludes zeolite softening. New water for boiler feed is evaporated, and the condensate is treated with phosphate to prevent scaling, sodium sulfite to eliminate residual oxygen, soda ash to control pH, and an amine to form a film on the pipes for protection against oxygen and carbon dioxide corrosion. The powerplant cooling water is treated with chlorine to inhibit algae growth and phosphate to prevent scale formation.

Water consultants call at the plant every 3 months, test the water, and recommend specific treatment.

Recirculation costs about 1 cent per 1,000 gallons for power, labor, and supplies.

Esperanza

Duval Sulphur & Potash Co. operates the Esperanza Unit about 25 miles south of Tucson (fig. 6). The unit, employing 350 persons, includes an open-pit copper mine and a 12,000-tpd flotation concentrator. The mine is worked three shifts per day, 5 days per week; and the concentrator is operated three shifts per day, 7 days per week.



WATER BALANCE	Subtotal gpm	Total gpm
Water in		1,110
Evaporation	433	
Seepage	19	
Discharge to stream	658	
Water out		1,110
Recirculated	18,056	
Transferred	395	

FIGURE 14. - Schematic Waterflow Diagram, Douglas Reduction Works, Phelps Dodge Corp., Cochise County, Ariz.

All new water is pumped from three wells on land leased from the State (fig. 15). The wells, 650 to 905 feet deep, have a 350-foot lift. Water is pumped 6 miles to the unit through a 16-inch pipeline, buried 30 inches.

Dust control and drilling in the open pit require 70 gpm, all of which is evaporated.

Dust control in the crushers uses 245 gpm; 8 gpm is evaporated, and 237 gpm is transferred to the concentrator.

Of a 6,776-gpm concentrator intake, 2,029 gpm is new water, 237 gpm is transferred, and 4,510 gpm is recirculated. Water evaporated in the concentrator, tailings thickeners, and tailings pond amounts to 216 gpm. Seepage from the pond is 2,050 gpm.

Domestic use in the plant area takes 30 gpm. Evaporation accounts for 10 gpm and seepage for 20 gpm.

Total new water for the operation, 2,394 gpm, includes 20 gpm required to compensate for a 15-gpm pipeline leak and the 5 gpm evaporated from the 2-million-gallon open reservoir.

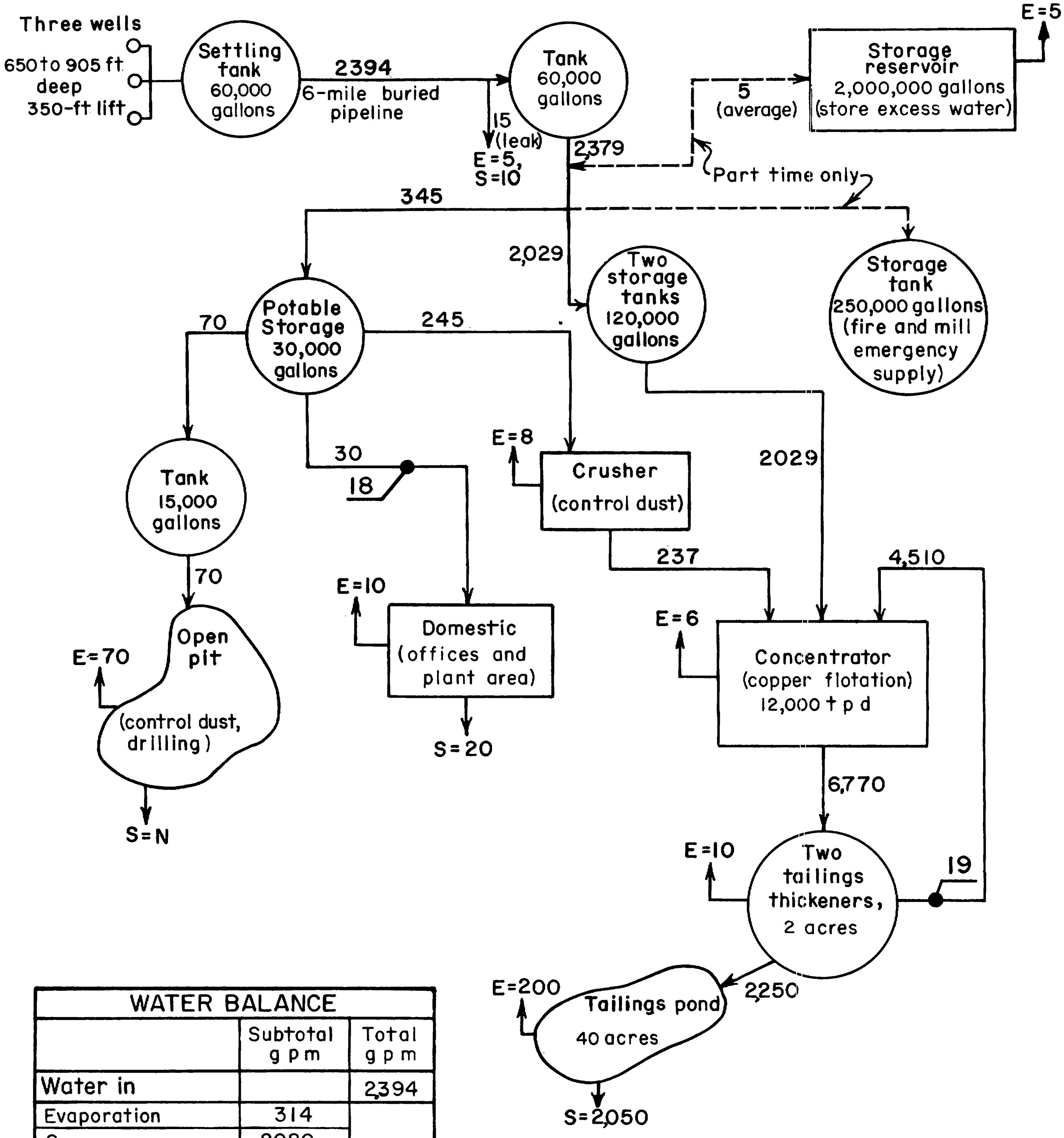
With present recirculation the new-water supply is adequate. The company once used lignin sulfonate as a dust palliative to reduce water requirements. This compound is no longer used because of the frequency of application necessitated by disintegration of the treated road surface following wet weather. Plans are being made for testing hexadecanol as a tailings-pond evaporation inhibitor.

Sample 18 represents new well water, and sample 19 represents recirculated water (appendix). New water is treated with lime and sodium tripolyphosphate; recirculated water also is treated with tripolyphosphate. This treatment is for control of pH and prevention of scaling.

Inspiration

Copper mining and processing operations of The Inspiration Consolidated Copper Co. are in the Globe-Miami mining district. The open pit, the town of Inspiration, and the company's plants and offices are just north of Miami (fig. 6). The principal water-using units--in the open pit, leaching operations, powerplant, concentrator, and smelter--are operated on a 24-hour schedule, 7 days per week. Most of the shops and miscellaneous departments, which use comparatively little water, are operated only on a day shift, 5 days per week. There are about 1,200 employees.

The Inspiration operation is unique in Arizona. The ore is crushed and separated into two fractions, the "slimes" and the "sands." The "sands," after leaching to recover the oxide copper and a portion of the sulfide copper, are sent to the concentrator where the remaining sulfides are separated by flotation. The "slimes" are first sent to the concentrator for



WATER BALANCE	Subtotal g p m	Total g p m
Water in		2,394
Evaporation	314	
Seepage	2,080	
Water out		2,394
Recirculated	4,510	
Transferred	237	

E Evaporation
S Seepage
15 Gallons per minute
N Negligible
18 Sample

FIGURE 15. - Schematic Waterflow Diagram, Esperanza Unit, Duval Sulphur & Potash Co., Pima County, Ariz.

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flotation of the sulfides and then leached to recover the oxide copper. A complete description of the process has been published.[9]

New water for the operation is obtained from 17 company-owned wells, 100 to 150 feet deep, and from surface runoff. Nine wells are in Pringle Basin, about 20 miles north of Inspiration. Other wells are in Kaiser Basin, 1-1/2 miles east of the plant; and in the Fodera, Pinal, and Lower Miami areas, all in the Miami vicinity (fig. 16).

Water used for sprinkling roads in the open pit is taken from Webster Lake, a catch basin for surface runoff and discarded water. The entire 120 gpm going to the pit is evaporated.

A total of 3,292 gpm goes to the concentrator for flotation; about two-thirds of this amount is transferred from other units or recirculated. In the concentrating system, excluding leaching, 778 gpm is evaporated or incorporated as moisture in the concentrates. From the tailings ponds 435 gpm seeps into ground water.

Little of the total intake for leaching operations is new water. More than 500 gpm is evaporated as a result of the leaching operations, and about 300 gpm returns to ground water by seepage. Evaporative loss in the sulfuric acid cooling tower amounts to 50 gpm.

The powerplant develops 4,000 to 8,000 kw. Of the required 200 gpm of new-water intake, 50 gpm of the best quality available is used for boiler feed, and 150 gpm for makeup in the condensing system. Cooled condensing water is recirculated at 30,000 gpm. A total of 60 gpm is removed as blowdown to maintain high quality.

Most of the smelter intake, 130 gpm of new water, is used for anode cooling.

With maximum recirculation, the quantity of water available to the operations is sufficient; however, some of the water must be piped about 20 miles. During the summer the required pumping time is increased because of greater drawdown.

Water available in the vicinity of the plant is generally of poor quality, having a pH as low as 3.5. Sample 3 represents new water from Pringle Basin, and sample 4 represents new water from the Miami area (appendix). The quality of the Pringle Basin water is steadily deteriorating. When pumping began in 1942, the Pringle water contained only 800 ppm dissolved solids. The dissolved-solids content of the Pringle water is now 1,800 ppm.

The water from Pringle Basin is treated at the source with 200 to 300 pounds of lime daily to raise the pH to 8.1 for protecting the 20-mile-long pipeline. Sixty pounds per day of polyphosphate also is added at the source to control corrosion. Water for the powerplant is treated with lime.

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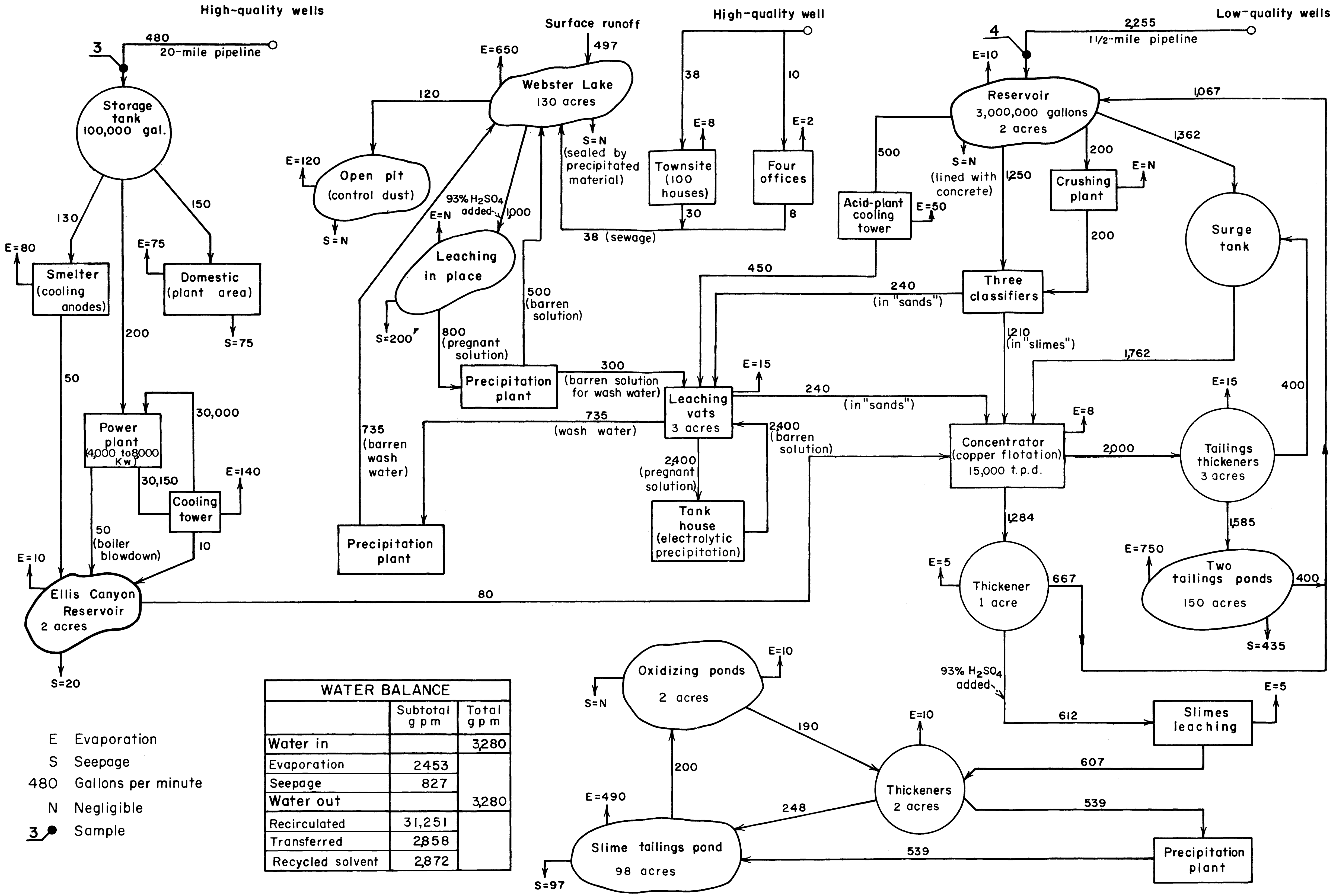
[9] Dayton, Stanley. Dual Process Metallurgy Stretches Inspiration Ore Reserves. Mining World, v. 19, No. 10, September 1957, pp. 50-59.



WATER BALANCE

	Subtotal gpm	Total gpm
Water in		3,280
Evaporation	2453	
Seepage	827	
Water out		3,280
Recirculated	31,251	
Transferred	2,858	
Recycled solvent	2,872	

FIGURE 16. - Schematic Waterflow Diagram, Inspiration Operation, Inspiration Consolidated Copper Co., Gila County, Ariz.

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The estimated average cost of all water--including cost of power, labor, supplies, and treatment--is 20 cents per 1,000 gallons.

Figure 17 is a photograph of the leaching plant and mine area.

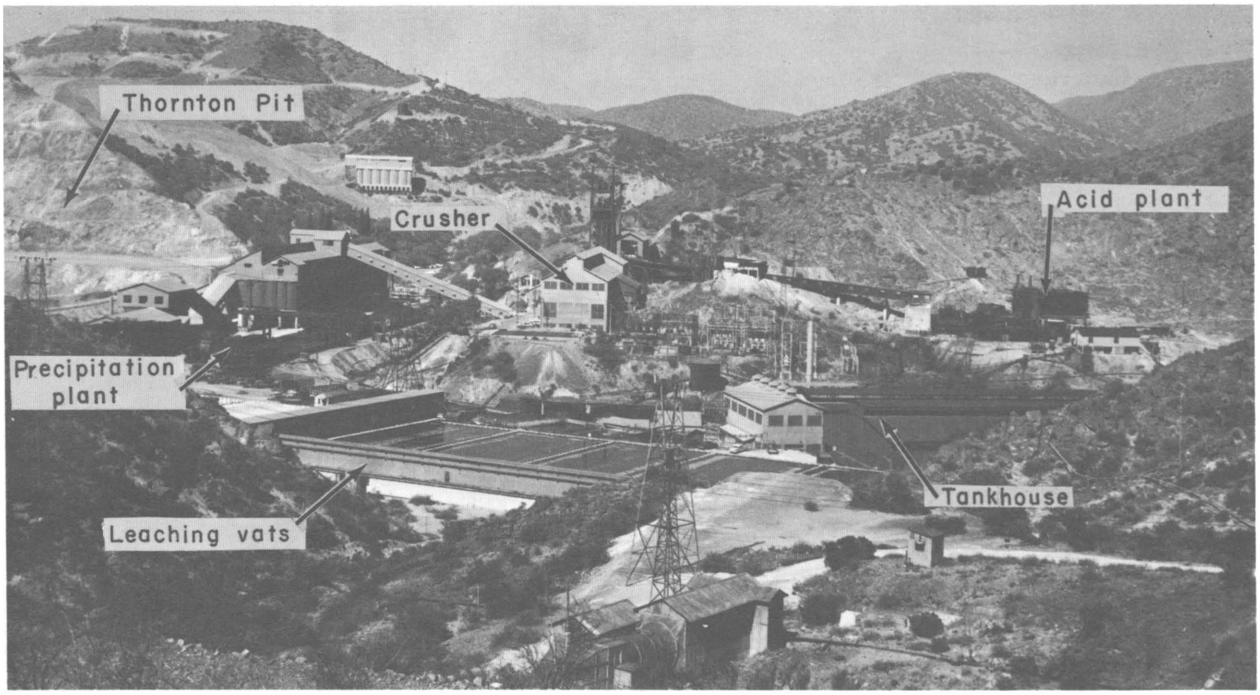


FIGURE 17. - Leaching Plant and Mine Area, Inspiration Consolidated Copper Co., Inspiration, Ariz.

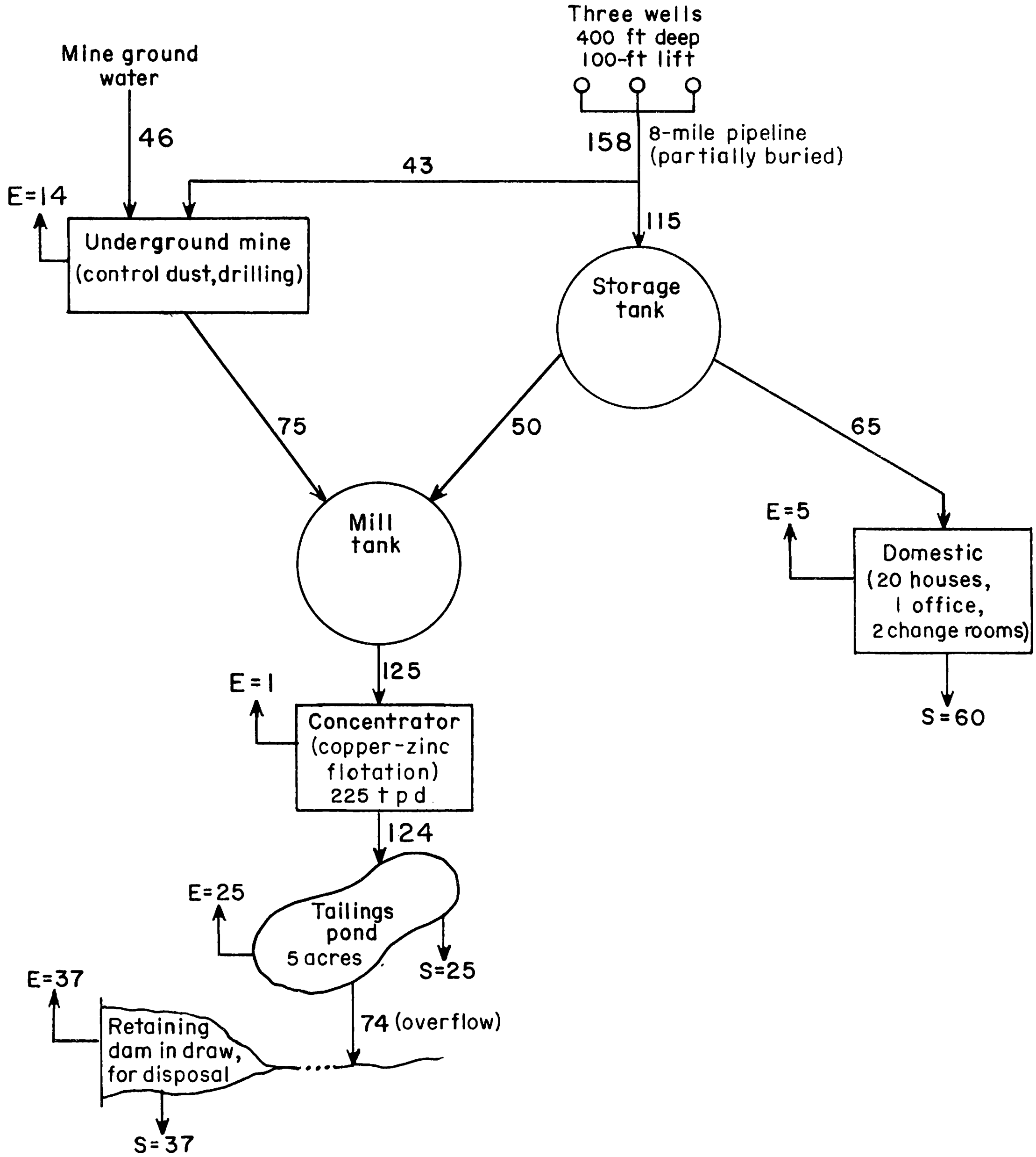
This company also operates a pilot mill on copper ores at Christmas (fig. 6). Water for the pilot mill, pumped from the underground mine, is of good quality. The concentrator to be constructed for the full-scale operation is to recirculate water.

Johnson Camp

The Johnson Camp copper-zinc mine and 225-tpd flotation concentrator, 13 miles northeast of Benson (fig. 6), are operated by McFarland & Hullinger. Employees total 56. The work schedule is one shift per day, 6 days per week in the mine, and three shifts per day, 6 days per week in the concentrator.

New water, from three 400-foot-deep wells, is pumped 8 miles to the concentrator (figs. 18, 19). Part of the 8-mile pipeline is buried. Mine drainage provides additional new water.

Dust control and drilling in the underground mine require 43 gpm; 14 gpm is evaporated, and the remaining 29 gpm is transferred to the concentrator.



WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		204
Evaporation	82	
Seepage	122	
Water out		204
Transferred	29	

E Evaporation

S Seepage

46 Gallons per minute

N Negligible

FIGURE 18. - Schematic Waterflow Diagram, Johnson Camp, McFarland & Hullinger, Cochise County, Ariz.

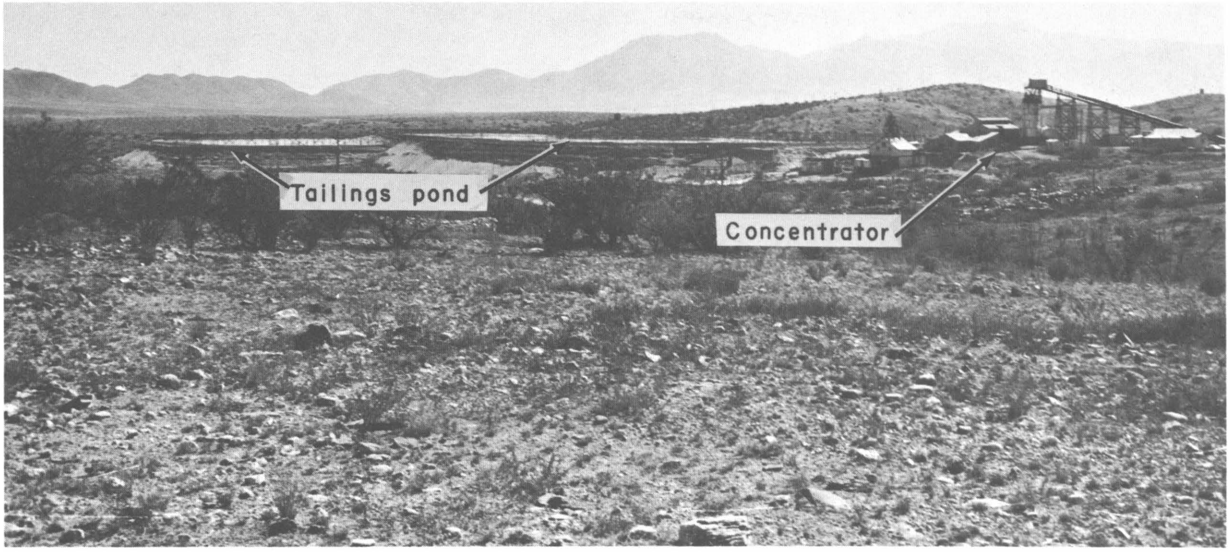


FIGURE 19. - Johnson Camp Concentrator and Tailings Pond, McFarland & Hullinger, Cochise County, Ariz.

The concentrator intake is 46 gpm of new mine water, 50 gpm of new well water, and 29 gpm of water transferred from the mine.

Moisture incorporated in the product and evaporation in the concentrator and tailings pond total 26 gpm.

Domestic water at this operation includes water used in about 20 homes, 2 changerooms, and an office. About 5 gpm is evaporated.

The water supply is presently adequate with no recirculation.

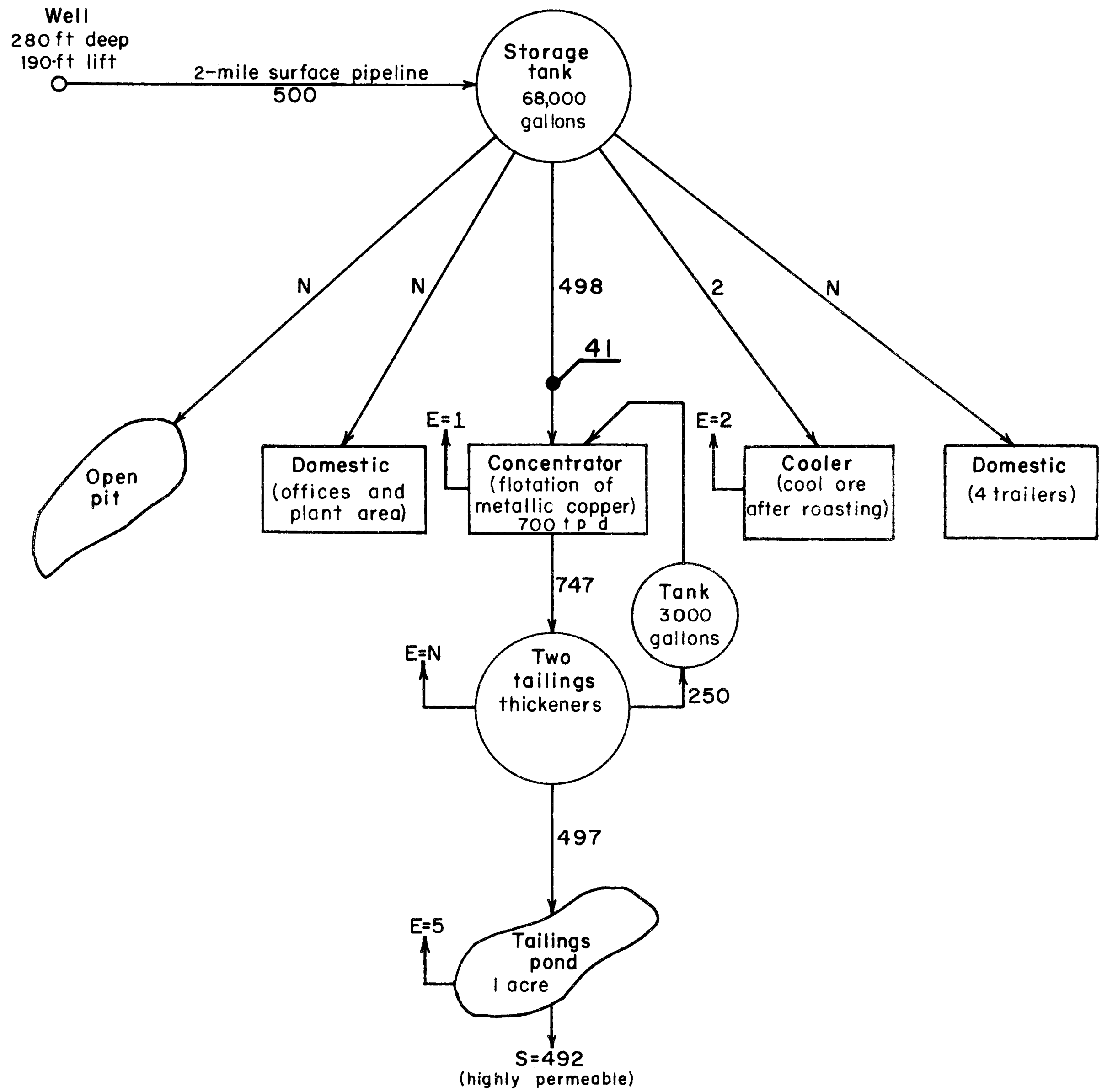
The well water is very soft but has a high fluoride content. The appendix lists the results of analyses made on new well water (sample 26), new and transferred mine water (sample 27), and waste discharged (sample 28).

Lakeshore

The 700-tpd Lakeshore operation, Trans-Arizona Resources, Inc., is 30 miles south of Casa Grande (fig. 6). At this operation, temporarily suspended when visited, 50 persons were to be employed.

Copper is recovered by the segregation process. The dry, crushed copper-silicate ore from the nearby open-pit mine is mixed with sodium chloride and coke, and then roasted in stainless steel furnaces to liberate metallic copper. After cooling, the ore is ground in a ballmill, and the metallic copper is recovered by flotation.

All new water is pumped from a well 280 feet deep and 12 inches in diameter (fig. 20). The pumping lift is 190 feet. The water is delivered to the plant storage tank through a 2-mile-long surface pipeline (fig. 21).



WATER BALANCE	Subtotal gpm	Total gpm
Water in		500
Evaporation	8	
Seepage	492	
Water out		500
Recirculated	250	

E Evaporation
S Seepage
500 Gallons per minute
N Negligible
41 Sample

FIGURE 20. - Schematic Waterflow Diagram, Lakeshore Operation, Trans-Arizona Resources, Inc., Pinal County, Ariz.

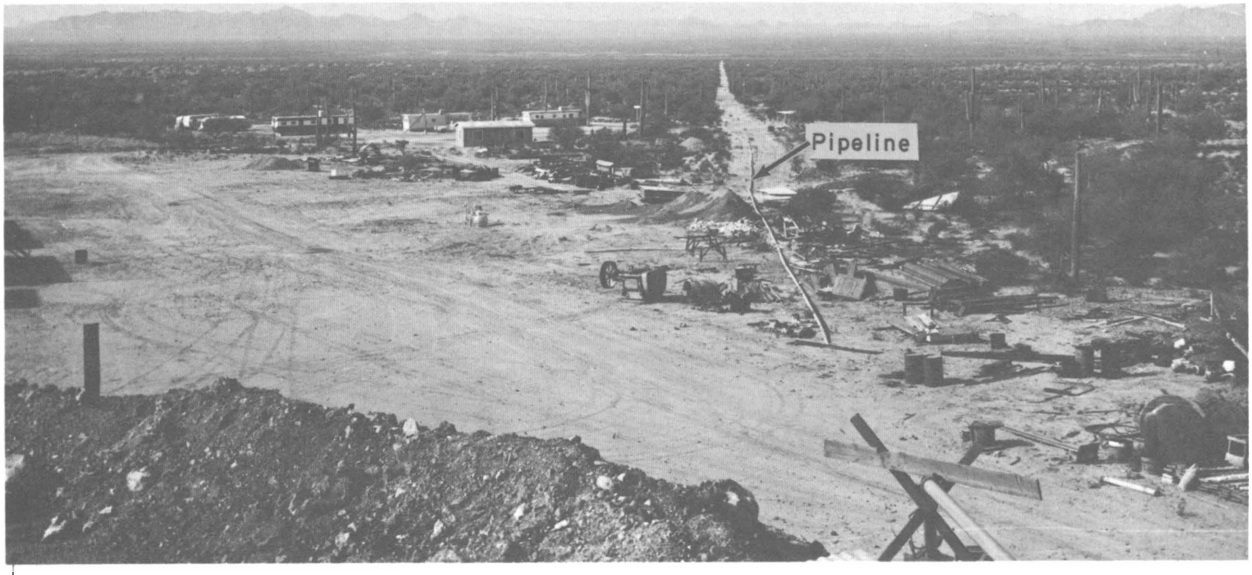


FIGURE 21. - Surface Pipeline and Trailer Camp, Lakeshore, Trans-Arizona Resources, Inc., Pinal County, Ariz.

Flotation in the concentrator, the major water-using unit, will require 498 gpm of new water and 250 gpm of recirculated water from the tailings thickeners. Only 6 gpm will be evaporated in the concentrator and tailings pond. Nearly all of the 497 gpm entering the pond will seep into the very permeable underlying formation.

For the ore cooler, 2 gpm will be required to compensate for evaporation.

The open pit, changeroom, office, and trailer camp will use little water.

With 250 gpm of recirculation, the present supply is expected to be adequate.

Although the new water is of generally good quality (sample 41 in the appendix), pilot tests indicate that softening the cooling water will be necessary to prevent scaling on the cooler.

Cost of the new water - for power, labor, and supplies - is expected to be about 3 cents per 1,000 gallons.

Figure 22 is a photo of the plant.

<u>Magma</u>

The Magma operation, employing about 1,000 persons, at Superior (fig. 6), includes an underground mine, a flotation concentrator, a powerplant, and a smelter as the major units.

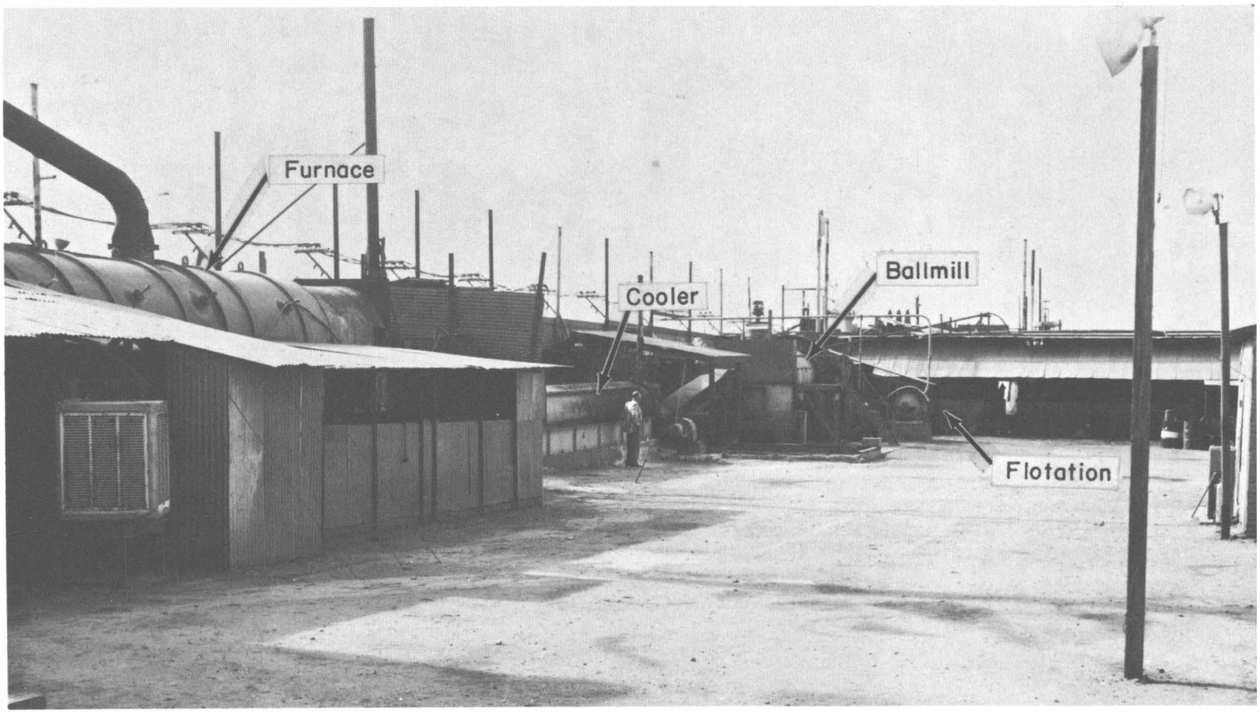


FIGURE 22. - Lakeshore Concentrator, Trans-Arizona Resources, Inc., Pinal County, Ariz.

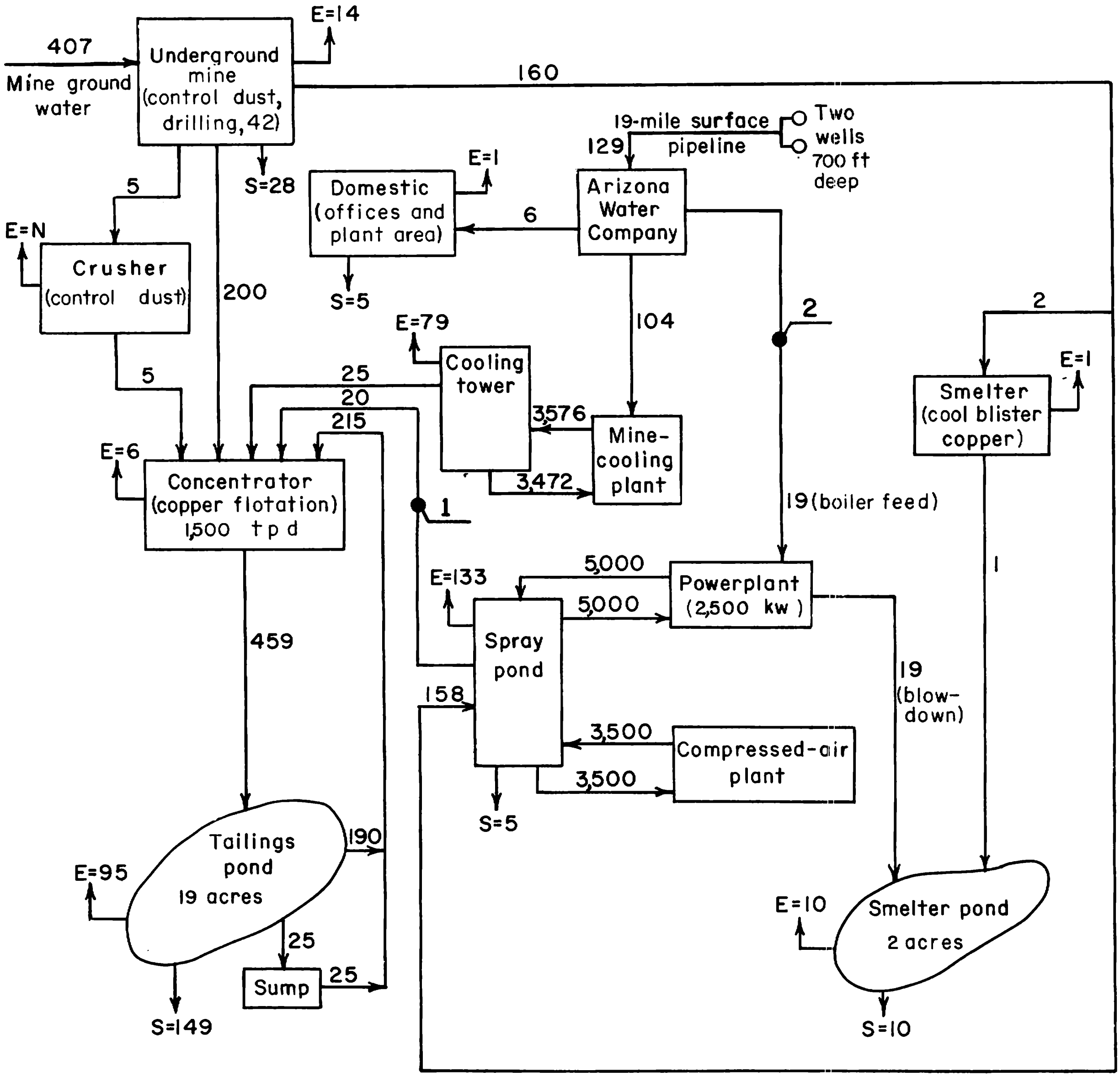
The work schedule is 6 days per week and, except in the mine, 24 hours per day. The mine is operated two shifts per day.

Mine drainage provides about 75 percent of the new water (fig. 23) used in the mine, crusher, concentrator, powerplant, and compressed-air plant. The remaining 25 percent is purchased from the Arizona Water Company for high-quality uses in the powerplant and mine-cooling plant, and for domestic uses. The purchased water, which comes from two 700-foot-deep wells about 19 miles west of Superior, is delivered to the town and company through a surface pipeline.

Approximately 42 gpm is used in the mine for drilling and dust control; an estimated 14 gpm of this amount is evaporated.

The total intake for flotation in the concentrator is 465 gpm: 200 gpm is new mine water, and the remainder is transferred or recirculated. A total of 101 gpm is evaporated in the concentrating system, principally in the tailings pond, or lost as moisture in the concentrates.

The powerplant uses 19 gpm of purchased water as boiler feed. The condensing water from the powerplant and the compressor-cooling water from the compressed-air plant are cooled in a spray pond. The evaporation from the spray pond is 133 gpm, and 20 gpm is transferred to the concentrator.



E Evaporation
S Seepage
5 Gallons per minute
N Negligible
2 Sample

WATER BALANCE		
	Subtotal g p m	Total g p m
Water in		536
Evaporation	339	
Seepage	197	
Water out		536
Recirculated	12,187	
Transferred	50	

FIGURE 23. - Schematic Water Diagram, Magma Operation, Magma Copper Co., Pinal County, Ariz.

The mine-cooling plant requires 104 gpm of purchased water. The cooling water is circulated through a cooling tower where evaporation is 79 gpm; 25 gpm is transferred to the concentrator.

With recirculation of 12,187 gpm and transfer of 50 gpm, the overall supply of water is barely adequate. Apparently little more good-quality water can be developed in the desert 19 miles west of Superior. The company limits the quantity used from this source to avoid a shortage in the town of Superior. Results of an effort to reduce evaporation from the smelter pond, an occasional source of water, by applying hexadecanol, were inconclusive. The amount recirculated will increase with the operation of two recently constructed settling ponds.

Two samples were taken at the Magma operation; sample 1 represents water transferred from the spray pond to the concentrator, and sample 2 represents water bought from the Arizona Water Company. The results of analyses are listed in the appendix. Water pumped from the mine has a pH of 5.0 to 5.2 and, before settling, a total-solids content of about 6,000 ppm.

Purchased water used in the mine-cooling plant is treated daily with 2 pounds of sulfuric acid and 10 pounds of a patented additive (containing orthophosphoric acid) to control scaling. Boiler feed (purchased water) is softened by the zeolite method. All mine-drainage water is treated with hydrated lime to precipitate solids and to raise the pH to about 7.

Mine-drainage water is pumped and treated at $1.16 per 1,000 gallons. The water purchased from the Arizona Water Company costs $1 per 1,000 gallons.

Miami

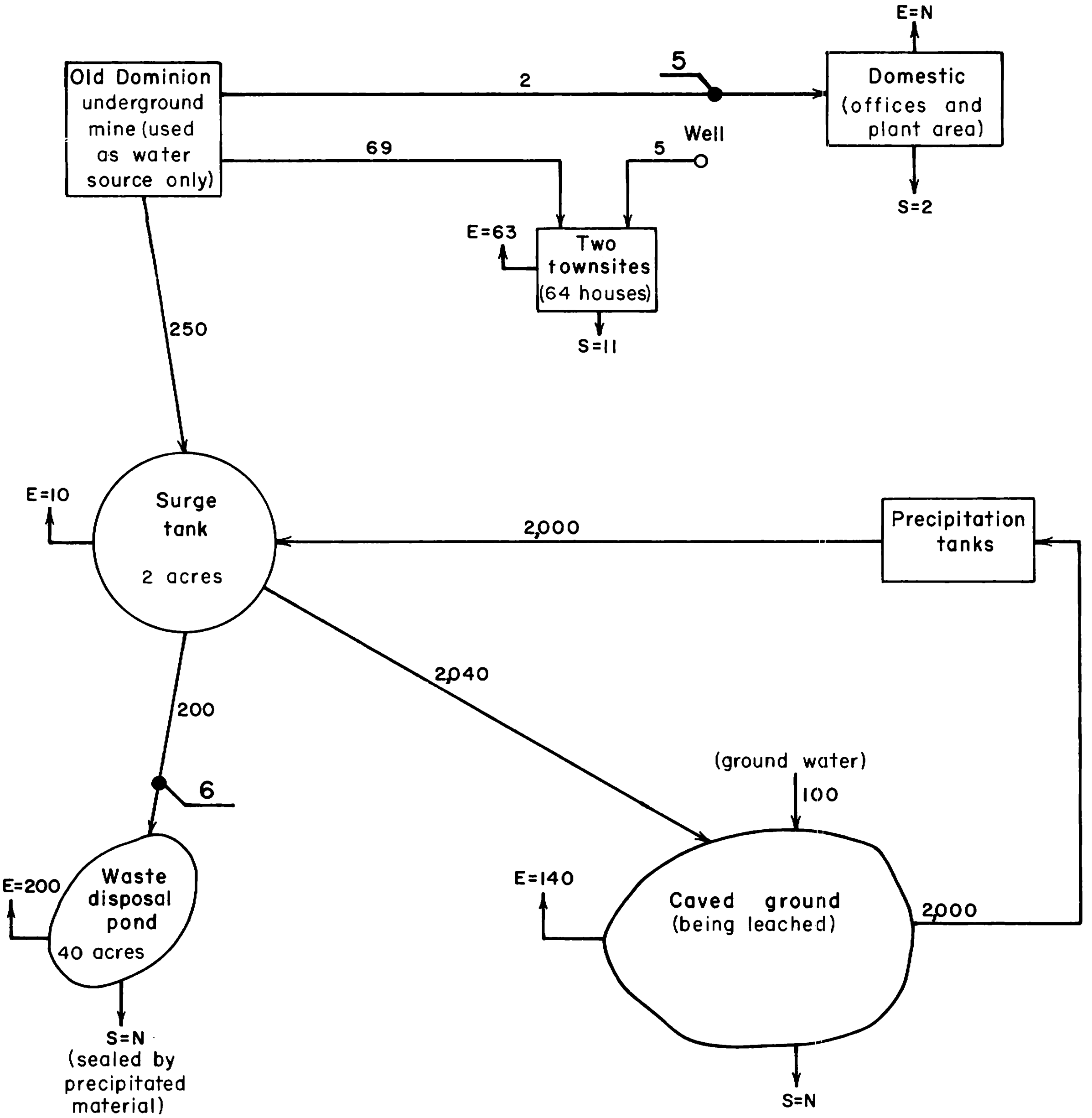
The Miami Unit of the Miami Copper Co., Div. Tennessee Corp., is just north of the town of Miami (fig. 6). This unit, formerly a large block-caving mine, is now a leaching-in-place operation. It employs about 50 persons, 3 shifts per day, 7 days per week.

Leaching solution under pressure is transported in 10- to 12-inch asbestos-cement pipe. Three-inch plastic pipe is used where low pressure is involved. Solution is distributed through 1/2-inch plastic pipe to holes drilled in the leaching area.

New-water intake for leaching totals 350 gpm: 250 gpm is from the inactive Old Dominion mine (fig. 24), and 100 gpm is from ground water in the leaching area. This new water replaces the 350 gpm evaporated.

The offices require 2 gpm from the Old Dominion; the two company townsites take 69 gpm from the Old Dominion and 5 gpm from a nearby well.

Solvent is recycled at 1,900 gpm, that is, 2,000 gpm minus 100 gpm ground water. Even if a large supply of low-cost, good-quality water were available, most of the 1,900 gpm would be recycled for metallurgical reasons.



E Evaporation

S Seepage

69 Gallons per minute

N Negligible

5 Sample

WATER BALANCE	Subtotal gpm	Total gpm
Water in		426
Evaporation	413	
Seepage	13	
Water out		426
Recycled solvent	1,900	

FIGURE 24. - Schematic Waterflow Diagram, Miami Unit, Miami Copper Co., Gila County, Ariz.

The recycled solvent contains some ferric sulfate, necessary for dissolution of the sulfide fraction of the copper in the ore; sulfuric acid, which dissolves oxide-copper minerals; and a small amount of copper. To eliminate excess iron salts from the leaching system, 200 gpm is discharged as waste to the disposal pond.

Water from the Old Dominion is of good quality. Sample 5 represents the new water from the Old Dominion, and sample 6 represents the waste water from the leaching operation (appendix).

Domestic water is chlorinated.

New water from the Old Dominion costs 19 cents per 1,000 gallons, including power, labor, and supplies.

Figure 25 depicts the operation, and figure 26 shows the Old Dominion, near the north outskirts of Globe.

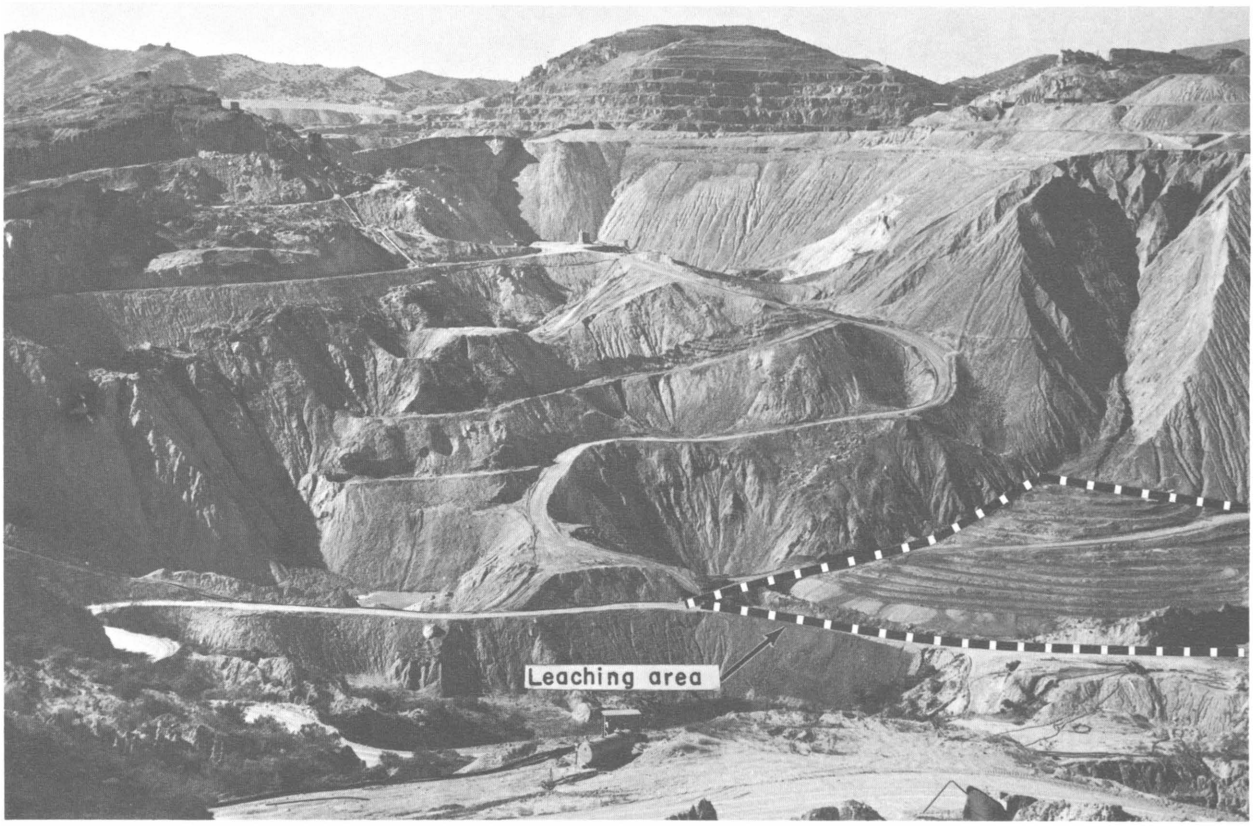


FIGURE 25. - Miami Unit Caved Area, Presently Being Leached by Miami Copper Co., Miami, Ariz.

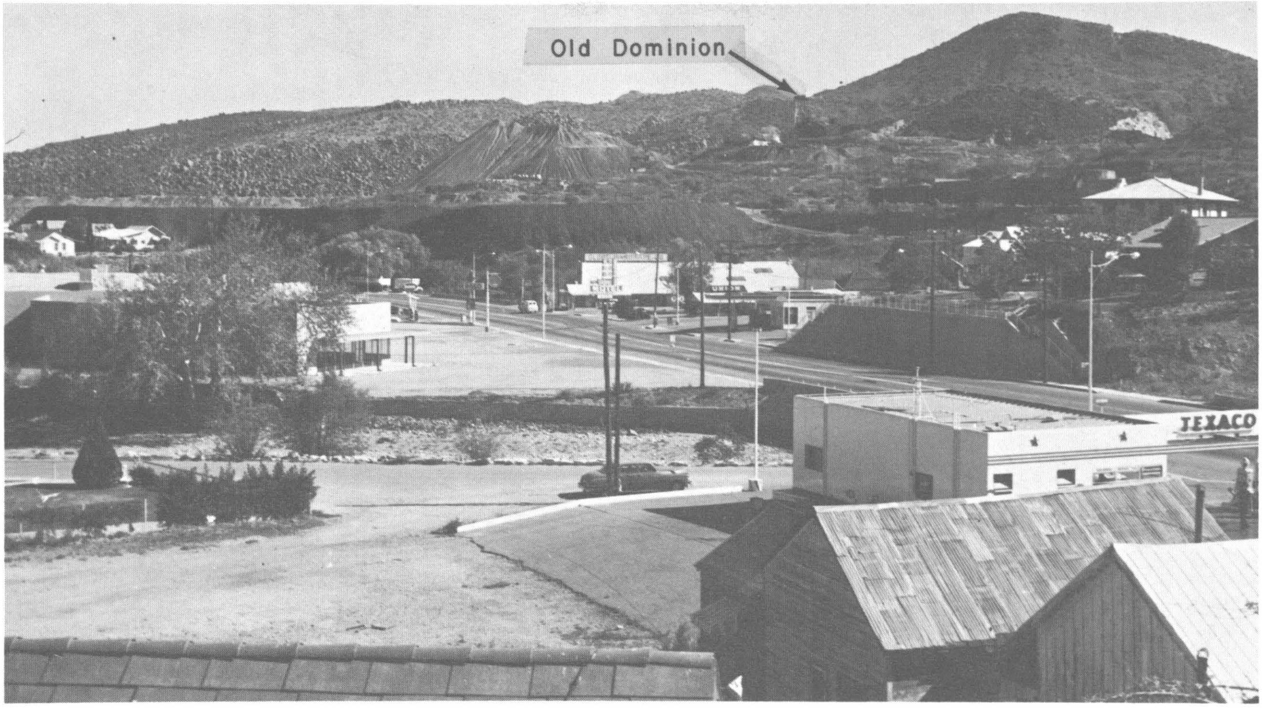


FIGURE 26. - Old Dominion Mine, Northern Outskirts of Globe, Ariz.

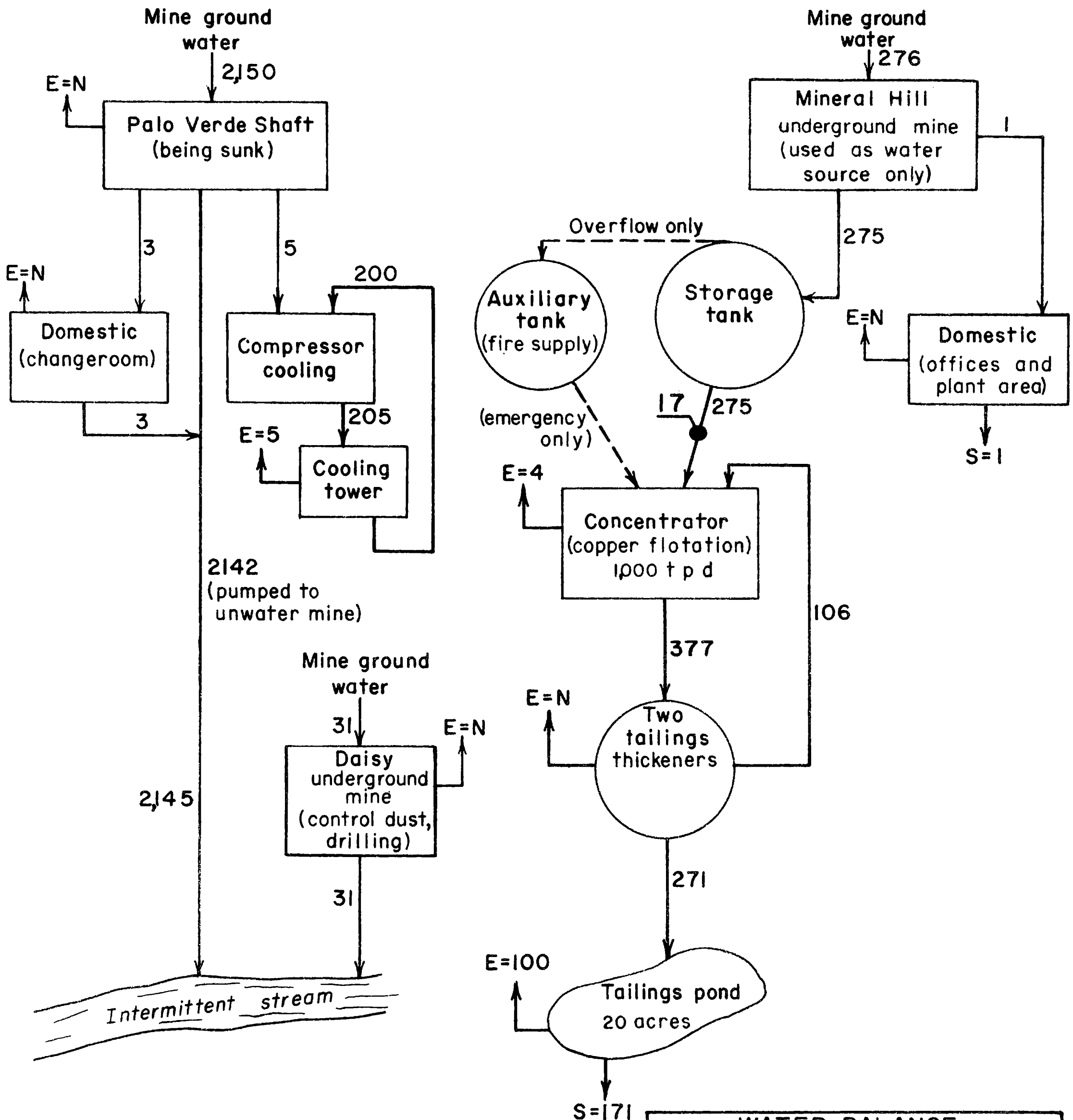
Mineral Hill

The Daisy and Mineral Hill underground mines, the Mineral Hill 1,000-tpd concentrator, and the Palo Verde shaft are about 15 miles south of Tucson (fig. 6). The Daisy mine is worked two shifts per day, 6 days per week; the concentrator and the Palo Verde shaft are operated three shifts per day, 7 days per week. The Mineral Hill mine is inactive. The Banner Mining Co. employs about 200 persons in the entire operation.

A small part of the water collected in the Palo Verde shaft is used in sinking operations: 3 gpm is pumped to the Palo Verde changeroom, and 5 gpm goes to the compressor to make up losses in the compressor-cooling system (fig. 27). Most of the 2,150 gpm pumped from the shaft is discharged directly to an intermittent stream; this water is not utilized in this operation. The 31 gpm pumped from the Daisy mine, part of which has been used for drilling and dust control, is discharged to the stream that receives the shaft water.

New water for the concentrator comes from the Mineral Hill mine. A total of 381 gpm is required for the concentrator: 275 gpm is new water, and 106 gpm is recirculated from the two small tailings thickeners. A total of 104 gpm is evaporated in the concentrating system.

Industrial water supply for these operations is entirely adequate, and would be adequate even with no recirculation. Potable water is hauled in.



E Evaporation

S Seepage

3 Gallons per minute

N Negligible

17● Sample

WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		315
Evaporation	109	
Seepage	172	
Discharge to stream	34	
Water out		315
Recirculated	306	
Pumped, but not used (by this company)		2,142

FIGURE 27. - Schematic Waterflow Diagram, Mineral Hill Operation, Banner Mining Co., Pima County, Ariz.

Results of analysis of the new water for the concentrator are given in the appendix (sample 17). This water is treated with a patented compound to prevent scaling. Water for compressor cooling at the Palo Verde shaft is softened.

Figure 28 shows the concentrator area.

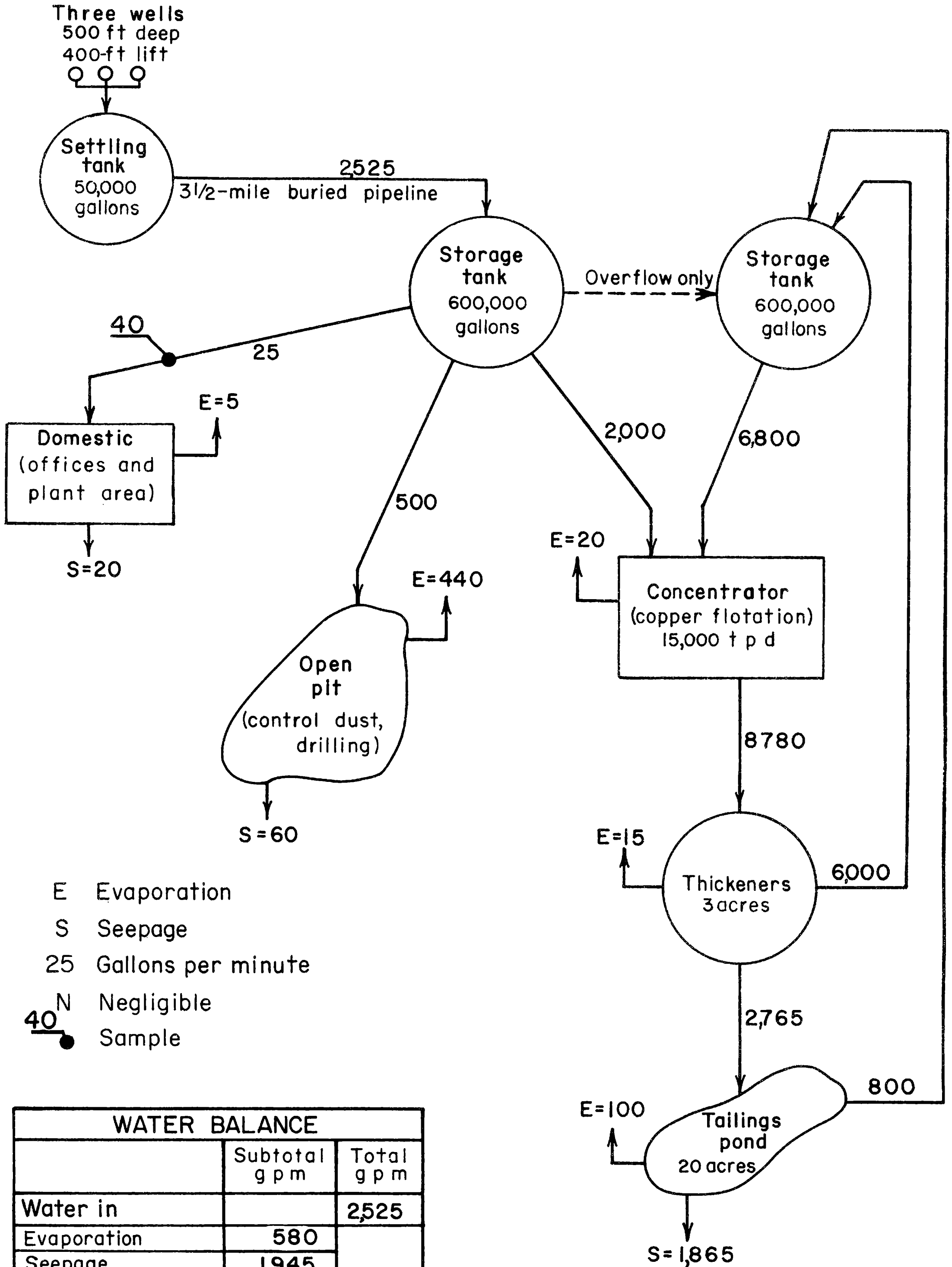
FIGURE 28. - Mineral Hill Mine and Concentrator, Banner Mining Co., Pima County, Ariz.

Mission

American Smelting and Refining Co. was expected to have its Mission Unit in operation late in 1961. The unit, about 15 miles south of Tucson (fig. 6), includes an open-pit copper mine and flotation concentrator. It was visited in October 1960 when waste stripping and plant construction were in progress. The following data and the schematic waterflow diagram (fig. 29) apply to the planned full-scale operation.

At the mine three shifts per day will work 6 days per week; the 15,000-tpd mill will be operated three shifts per day, 7 days per week. A total of 400 employees will be needed.

Water for the operation will be pumped from three 500-foot-deep wells on company property. The wells, 1,200 feet apart, have a 400-foot lift. A booster pump will deliver the water to a storage tank through a 3-1/2-mile-long pipeline. The 18-inch-diameter pipeline is buried 3 to 4 feet.



WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		2,525
Evaporation	580	
Seepage	1,945	
Water out		2,525
Recirculated	6,800	

FIGURE 29. - Schematic Waterflow Diagram, Mission Unit, American Smelting and Refining Co., Pima County, Ariz.

Most of the 500 gpm going to the mine will be used for dust control. Road sprinkling will take about 300 gpm, and spraying banks in front of the shovels will require about 200 gpm. Each drill will require only 1,000 gpd. An estimated 440 gpm will be evaporated in the mine, and the remaining 60 gpm will be returned to ground water by seepage.

Approximately one-fourth of the total concentrator intake will be new water, and three-fourth will be recirculated from the tailings pond and tailings thickeners.

With maximum recirculation in the concentrating system, the amount of water available from the wells should be sufficient. An attempt was made, by putting lignin sulfonate on the main haulage roads, to reduce the amount of water necessary for road sprinkling. The use of this material has been discontinued because of the short duration of its dust-controlling effect.

Quality of the water will be satisfactory for all purposes. Sample 40 (appendix) represents the new water.

Some phosphate may be added to the new water to lessen scaling in pipes. The drinking water will be chlorinated.

Cost of new water is expected to be approximately 5 cents per 1,000 gallons, including cost of power, labor, and supplies.

New Cornelia (Ajo)

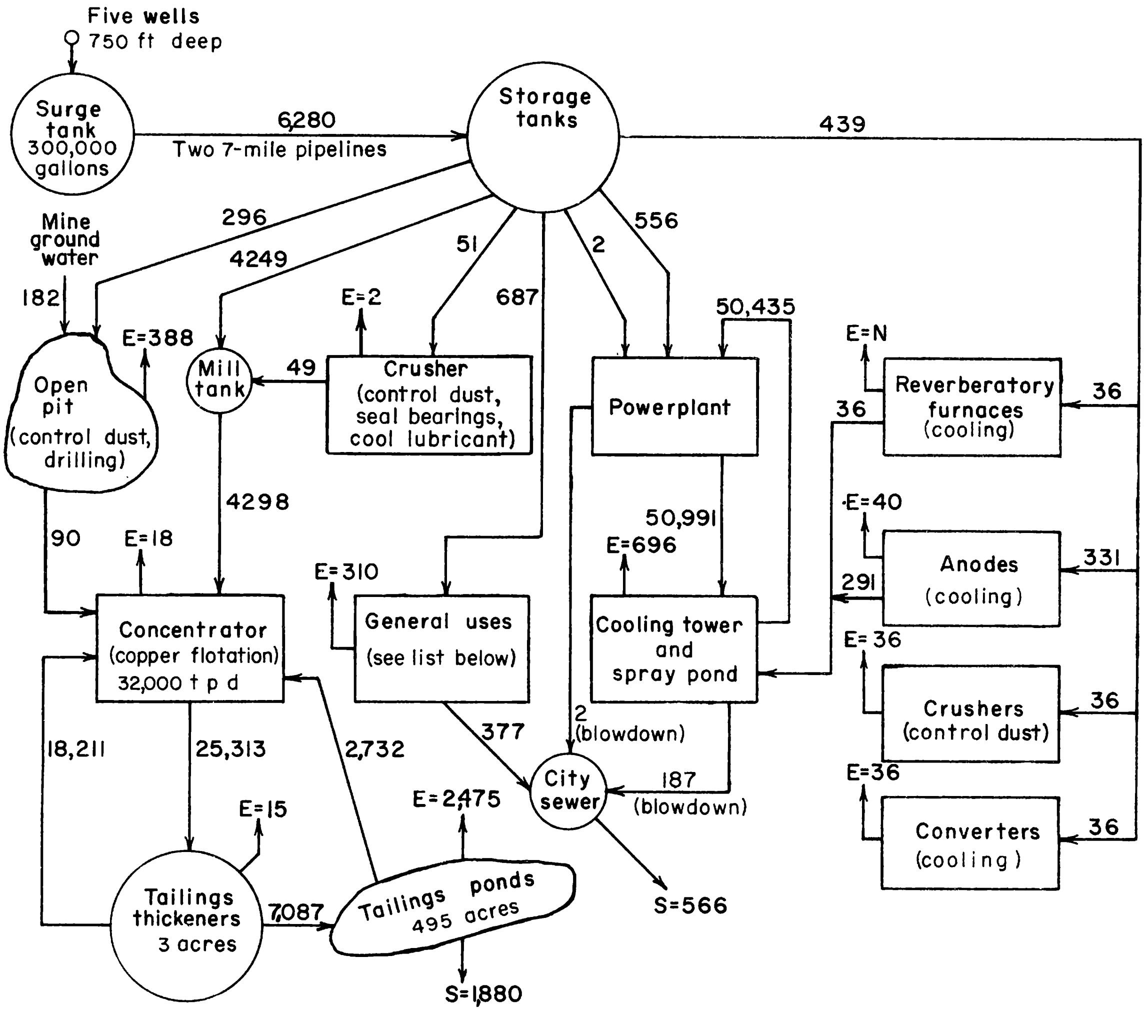
New Cornelia Branch, Phelps Dodge Corp., is at Ajo (fig. 6). Major units of the operation are a large open-pit mine, a 32,000-tpd flotation concentrator, a smelter, and a powerplant. The work schedule is three shifts per day and averages about 5-1/2 days per week. A total of 1,424 employees is required.

Five submersible pumps in five 18-inch wells about 7 miles north of the plant area supply all new water except that picked up in the open pit (fig. 30). The water is pumped to storage tanks through two surface pipelines protected from corrosion by concrete lining and tar coating.

The open-pit mine requires, for dust control and drilling, 388 gpm, all of which is evaporated. Most of this is well water; 92 gpm is ground water collected in the pit. Ninety gallons per minute, of the total of 182 gpm of mine ground water collected, is sent to the mill as new water for the concentrator.

In the crushing plant, intake water for controlling dust, sealing bearings, and cooling lubricant totals 51 gpm; 2 gpm is evaporated, and 49 gpm is transferred to the mill tank.

The concentrator has an intake of 4,339 gpm of new water, 49 gpm of transferred water, and 20,943 gpm of recirculated water--a total intake of 25,331 gpm. A total of 2,508 gpm is lost. Some of this is lost by evaporation



E Evaporation

S Seepage

182 Gallons per minute

N Negligible

WATER BALANCE	Subtotal gpm	Total gpm
Water in		6,462
Evaporation	4,016	
Seepage	2,446	
Water out		6,462
Recirculated	71,056	
Transferred	461	

General uses

Townsite	425
Surface use	73
Grounds and parks	75
Mechanical department	41
Laboratory	36
Domestic (at wells)	19
Iceplant	12
Supply department	3
Offices	3
Total	687

FIGURE 30. - Schematic Waterflow Diagram, New Cornelia Branch, Phelps Dodge Corp., Pima County, Ariz.

from the tailings ponds and thickeners, and some is lost in the concentrator as a result of direct evaporation and incorporation of moisture in the concentrates. Seepage from the 495 acres of tailings ponds is 1,880 gpm.

In the powerplant 2 gpm of new water replaces boiler blowdown, and 556 gpm is new water to replace evaporative losses and blowdown in the condensing system. Noteworthy is the large amount of water, 50,435 gpm, flowing from the cooling tower and spray pond to the powerplant. This flow includes 50,113 gpm of recirculated water and 322 gpm of transferred water from the smelter. The last two figures were computed by proration.

The smelter uses a total of 439 gpm for cooling reverberatory furnaces, anodes, and converters, and for dust control and cleanup. About 112 gpm is evaporated.

For general uses, mostly domestic, new-water needs are 687 gpm; 310 gpm of this amount is evaporated.

The present water supply is sufficient as a result of the large-scale recirculation.

Because of its high silica content, the water requires extensive treatment to make it suitable for use as boiler feed; otherwise it is of good quality. The water comes from the well at 100° F. The high temperature necessitates cooling the domestic and cooling water before use, but in the concentrator, the high temperature is advantageous in that it promotes the action of reagents.

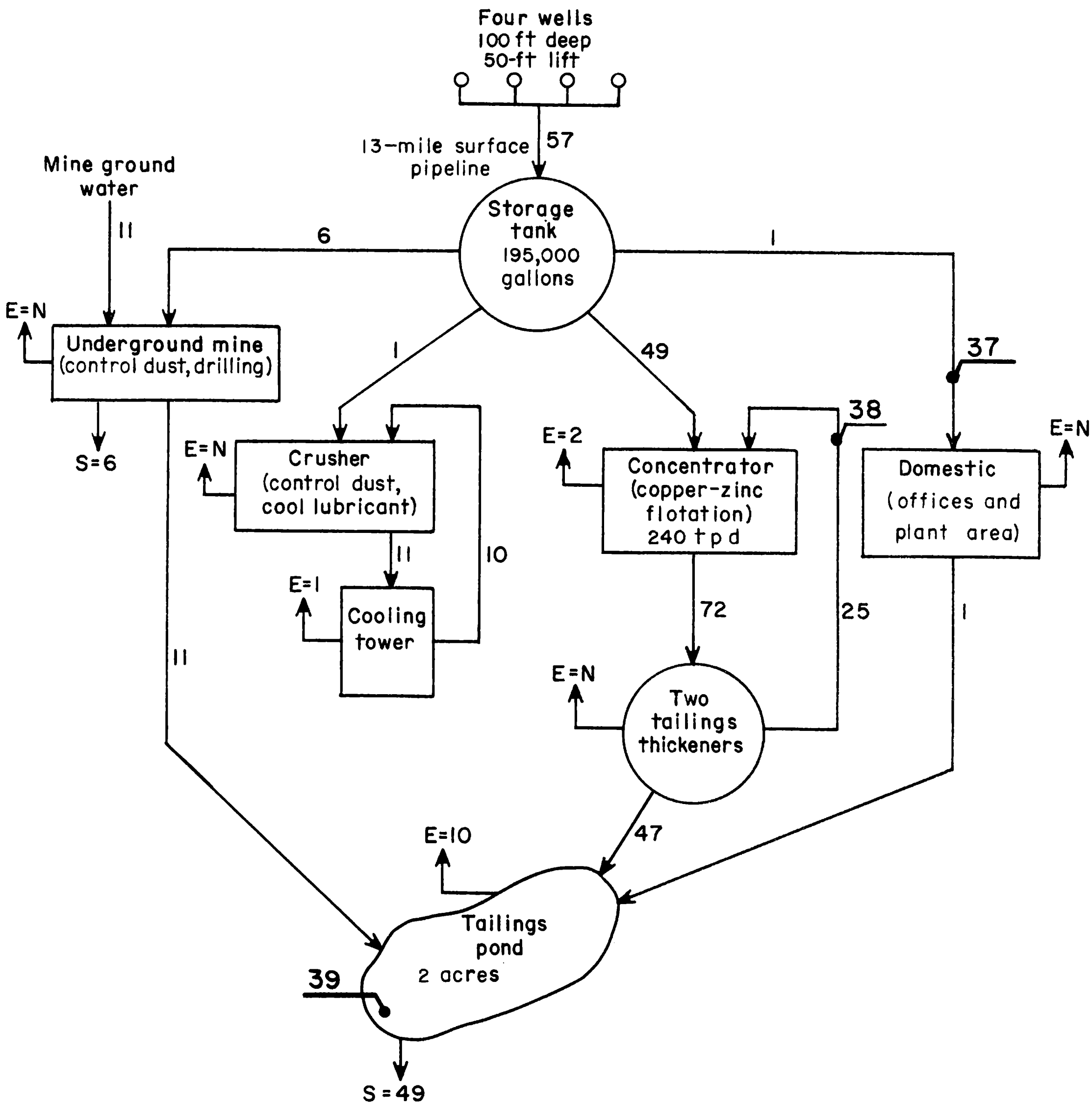
The boiler water is softened with zeolite. Sodium sulfite is added to eliminate residual oxygen, and soda ash is used to control pH. An amine is added to form a film that protects pipelines from corrosion by the action of oxygen and carbon dioxide. Cooling water for the powerplant is treated with zeolite, chlorine, and phosphate, which soften the water, control algae, and keep lime in suspension, respectively. Domestic water is softened with zeolite and treated with chlorine.

Pumping recirculated water costs 1 cent per 1,000 gallons.

Old Dick

The Old Dick Division, Cyprus Mines Corp., about 5 miles southwest of Bagdad (fig. 6), employs 80 persons. In the underground copper-zinc mine the work schedule is two shifts per day, 6 days per week, and in the flotation concentrator three shifts per day, 7 days per week.

New water for the operation is lifted 50 feet from four 100-foot-deep wells near Burro Creek (fig. 31). A 13-mile-long surface pipeline delivers the water to a 195,000-gallon storage tank. Part of the pipeline is owned by Bagdad Copper Corp. and is used by both operations. (This mixing of waters sometimes results in lowering the quality of the Old Dick water).



E Evaporation
S Seepage
11 Gallons per minute
N Negligible
37 Sample

WATER BALANCE	Subtotal gpm	Total gpm
Water in		68
Evaporation	13	
Seepage	55	
Water out		68
Recirculated	35	

FIGURE 31. - Schematic Waterflow Diagram, Old Dick Division, Cyprus Mines Corp., Yavapai County, Ariz.

Six gpm of new water, used in the mine for drilling and dust control, returns to ground water by seepage. About 11 gpm of mine-drainage water is pumped to the surface and discharged to the tailings pond.

Intake for the 240-tpd concentrator includes 49 gpm of new water and 25 gpm of recirculated water.

An estimated 1 gpm of new water is needed in the offices, changeroom, and assay laboratory.

Although the water from the tailings thickeners is of poor quality, the recirculation of 25 gpm is necessary to overcome the shortage of new water.

The quality of the new water for the Old Dick operation is usually good unless lowered by mixing with Bagdad water. Sample 37 (appendix) represents new well water, sample 38 recirculated water, and sample 39 discharged water in the tailings pond.

Water recirculated in the crusher is treated to prevent scale formation and algae growth.

Cost of power and pipeline maintenance for the new well water is 56.7 cents per 1,000 gallons.

Figure 32 is a photo of the operation.

Pima

The open-pit copper mine and 3,500-tpd flotation concentrator of the Pima Mining Co. are about 15 miles south of Tucson (fig. 6). The mine is operated three shifts per day, 6 days per week, and the concentrator, three shifts per day, 7 days per week. Employees total 310.

All new water is obtained from three wells on company-owned land. The water, lifted an average of 250 feet to the surface, is delivered to the mine and concentrator by a 7-mile-long, 16-inch-diameter surface pipeline (fig. 33).

Of 1,200 gpm of total new water required for the entire operation, only 140 gpm goes to the mine. Most of the water used in the mine is evaporated in controlling dust on haulage roads and on the banks in front of the shovels.

New water going to the crushers and concentrator amounts to 1,000 gpm. The demand for new water for the concentrator is reduced by recirculating 800 gpm from the tailings pond. Evaporation from the tailings pond, 350 gpm, accounts for most of the consumption in this part of the operation. Nearly two-thirds of the 1,000 gpm of new water leaves the system by seepage.

Even with recirculation of 800 gpm from the tailings pond, the water supply is barely adequate. Lignin sulfonate is applied to the main haulage roads to lessen water consumption.

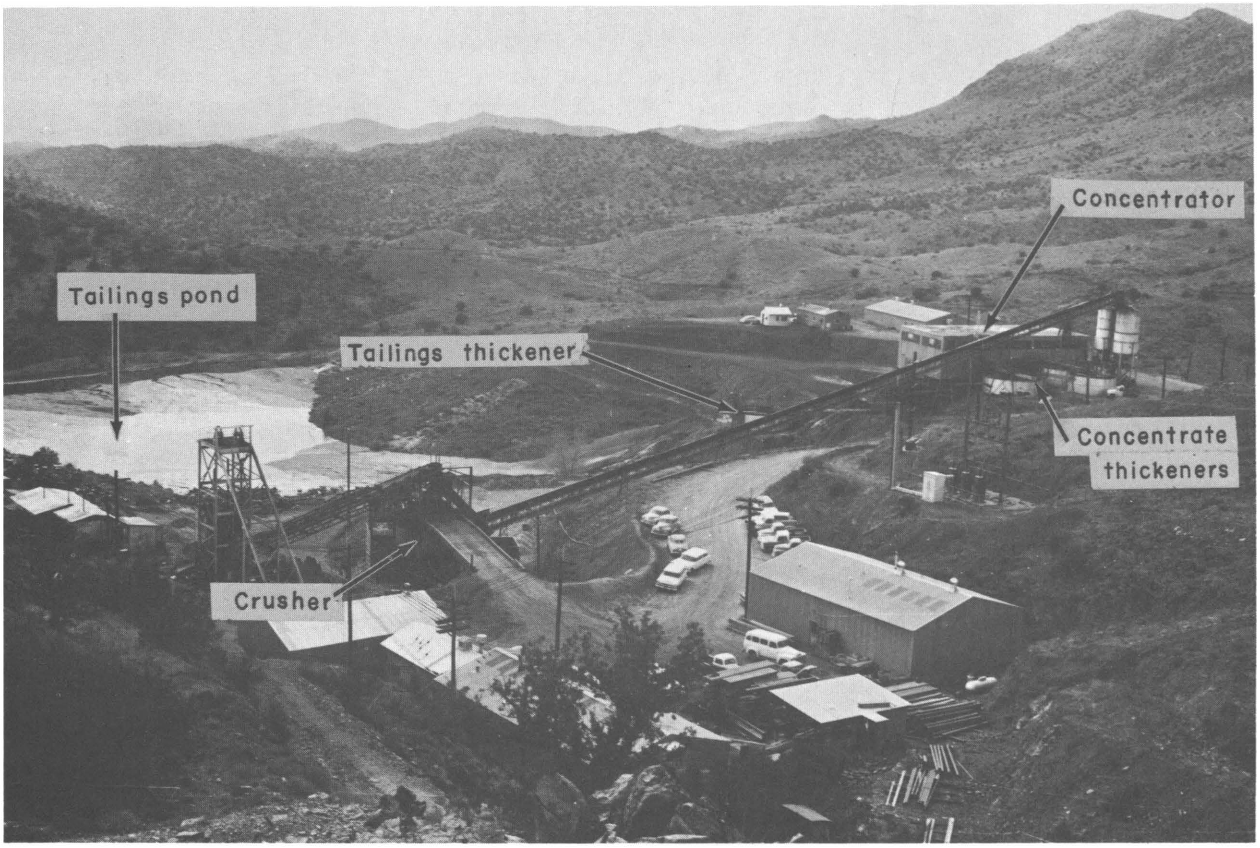


FIGURE 32. - Old Dick Operation, Cyprus Mines Corp., Yavapai County, Ariz.

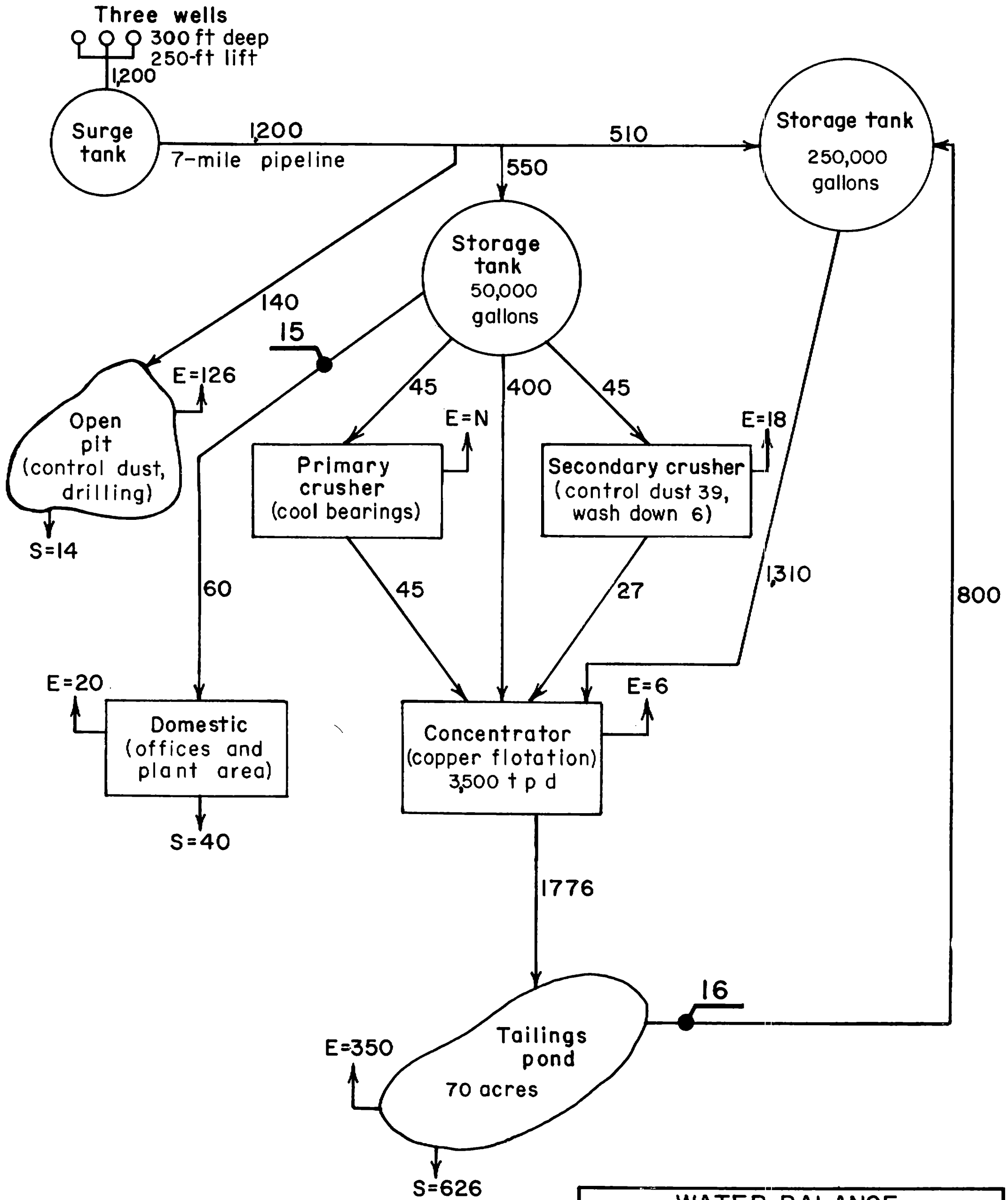
A sample of the new water (sample 15) and one of the water recirculated from the tailings pond (sample 16) were analyzed; the results are given in the appendix.

Treatment is limited to adding 8 ppm of caustic soda to the new water, at 0.4 cent per 1,000 gallons treated. The caustic soda removes most of the 5 ppm of dissolved oxygen, which causes corrosion of metal surfaces.

Cost of power for pumping the new water is 7.2 cents per 1,000 gallons. For recirculation from the tailings pond, power cost is about 4 cents per 1,000 gallons.

Silver Bell

American Smelting and Refining Co. operates the Silver Bell Unit at the town of Silver Bell, about 40 miles northwest of Tucson (fig. 6). This copper operation, employing 225 persons, includes two open pits, a 7,500-tpd flotation concentrator, and a dump-leaching plant. The mines are worked two shifts per day, 6 days per week; the crusher is operated two shifts per day, 7 days per week; and the concentrator and leaching plant are operated three shifts per day, 7 days per week.



E Evaporation
S Seepage
140 Gallons per minute
N Negligible
15 ● Sample

WATER BALANCE	Subtotal gpm	Total gpm
Water in		1,200
Evaporation	520	
Seepage	680	
Water out		1,200
Recirculated	800	
Transferred	72	

FIGURE 33. - Schematic Waterflow Diagram, Pima Operation, Pima Mining Co., Pima County, Ariz.

Water is pumped from six 700-foot-deep wells about 8 miles east of the plant (fig. 34). The automatically controlled pumps operate against a lift of 450 feet. Improper bedding of the vinyl-covered pipeline that delivers water to the operation has caused maintenance problems.

Dust control in the two open pits requires 25 gpm for sprinkling roads and spraying faces. The entire 25 gpm is evaporated. No water is used in rotary drilling of blastholes.

Water is used in the crushing plant for lubricant cooling and in a wet-cyclone-type dust collector. Of the 20 gpm intake, only 2 gpm is evaporated, and 18 gpm is transferred to lower the new-water intake of the concentrator and to recover copper contained in the slurry discharged from the dust collector.

The concentrator intake includes 1,205 gpm of new water, 18 gpm of transferred water, and 3,345 gpm of recirculated water. Total evaporation in the concentrator, tailings thickeners, and tailings pond is 146 gpm.

The dump-leaching system requires 185 gpm of new water to replace 34 gpm of evaporative loss and 151 gpm of seepage.

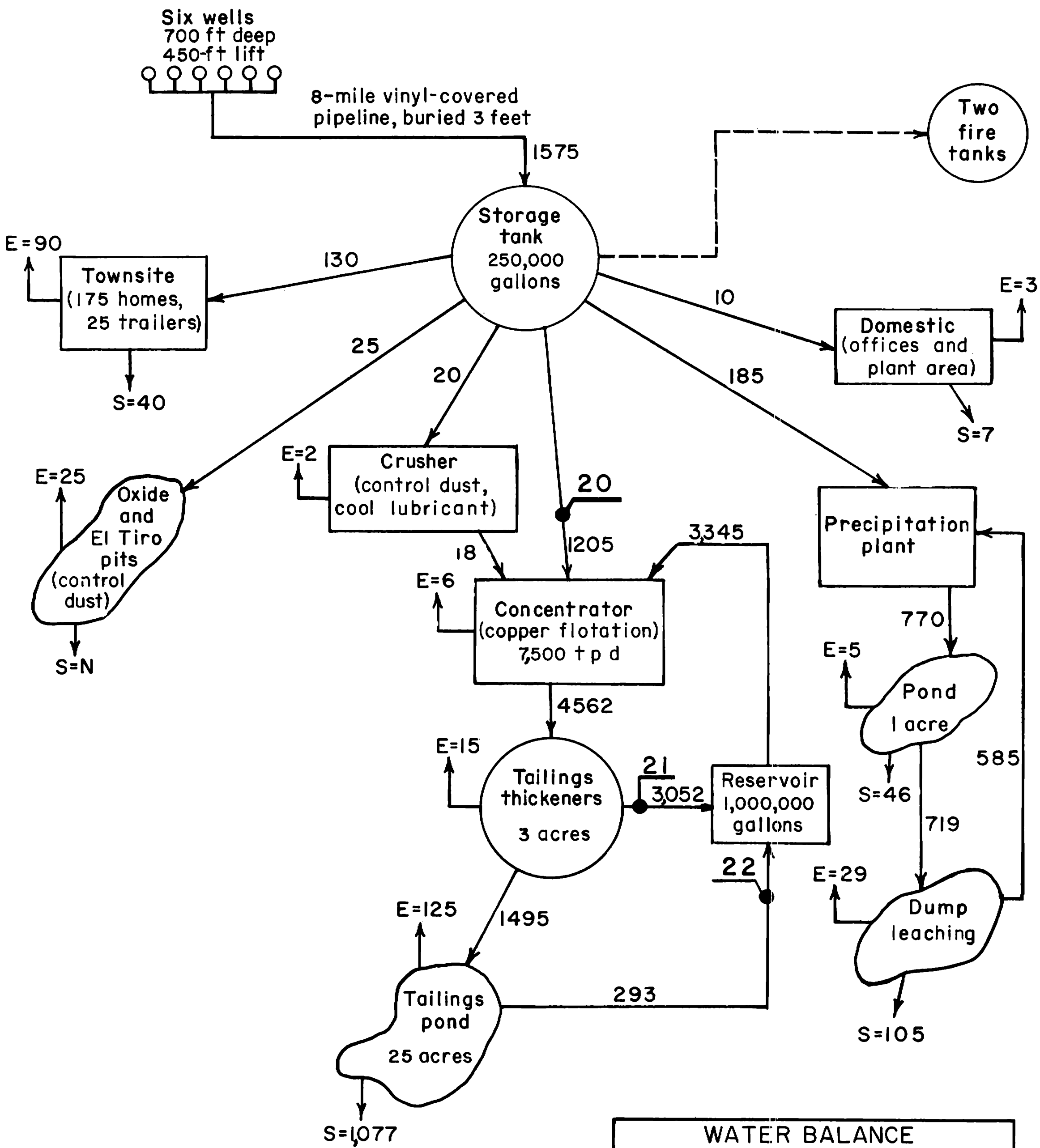
New-water demand at Silver Bell is lessened, not only by recirculation and transfer of water, but also by the use of lignin sulfonate or asphalt on main haulage roads.

After softening, the new water is of satisfactory quality. All new water going to the concentrator is treated with 2 ppm of polyphosphate to prevent scaling, and domestic water is chlorinated for bacteria control. Samples 20, 21, and 22 (appendix) represent new water, tailings-thickener overflow, and tailings-pond overflow, respectively. Current direct cost of new water for power, labor, and supplies is 7 cents per 1,000 gallons.

Other Metals

Two lead-zinc operations, one zinc-copper operation, one uranium mine, and one uranium concentrator account for most of the State's metallic-mineral output not derived from copper ores.

Mined by underground methods, the lead-zinc ore is crushed and ground, and the valuable minerals, generally galena and sphalerite, are recovered by flotation. Lead-zinc flotation usually involves two steps. First, the lead minerals are recovered in the lead circuit, the zinc minerals being depressed by suitable reagents. Second, the zinc minerals are activated and then recovered by flotation in the zinc circuit. (Zinc-copper ores are treated similarly, with a copper circuit instead of the lead circuit.) These processes preclude recirculation as practiced in copper concentrators--the water that could be recovered from the tailings pond cannot be added to the new ore coming into the concentrator as the tailings water from the zinc circuit would activate the zinc, thereby making it necessary to add an excessive amount of depressant to keep the zinc out of the lead concentrate. The recirculations



E Evaporation
S Seepage
25 Gallons per minute
N Negligible
20● Sample

WATER BALANCE	Subtotal gpm	Total gpm
Water in		1575
Evaporation	300	
Seepage	1275	
Water out		1575
Recirculated	3345	
Transferred	18	
Recycled solvent	719	

FIGURE 34. - Schematic Waterflow Diagram, Silver Bell Unit, American Smelting and Refining Co., Pima County, Ariz.

shown on the Atlas, Flux-Trench, and Iron King diagrams are actually recirculated within individual circuits: Water removed from the tailings of the first circuit is added to the new ore, and water removed from the final tailings is added to feed for the second circuit. For simplicity, these two amounts of recirculated water have been combined on these diagrams and in the respective descriptions.

The Orphan mine, one of the largest uranium mines in Arizona, supplies the bulk of the uranium ore processed at the Tuba City mill, which is the only uranium concentrator in the State. Uranium ore is treated at the Tuba City mill by an acid-leaching process that yields a uranium oxide concentrate, popularly called yellow cake.

The following descriptions illustrate present water-use practices at these operations.

Atlas

The Atlas underground mine and 90-tpd zinc-copper flotation concentrator, B. S. & K. Mining Co., are about 6 miles northwest of Silver Bell (fig. 6). Twenty-five persons are employed. The concentrator is operated three shifts per day, 200 days per year.

All new water is pumped from a 318-foot-deep well near the plant area and townsite; the pumping lift is 200 feet (fig. 35).

Water for the concentrator consists of 57 gpm of new water, 4 gpm transferred from the crusher, and 19 gpm recirculated from the thickeners, all computed by prorating flows shown on the diagram. Evaporative loss in the concentrator, including moisture in the concentrates, amounts to only 1 gpm.

Domestic uses in the townsite require 20 gpm; 4 gpm is evaporated, and 16 gpm returns to ground water.

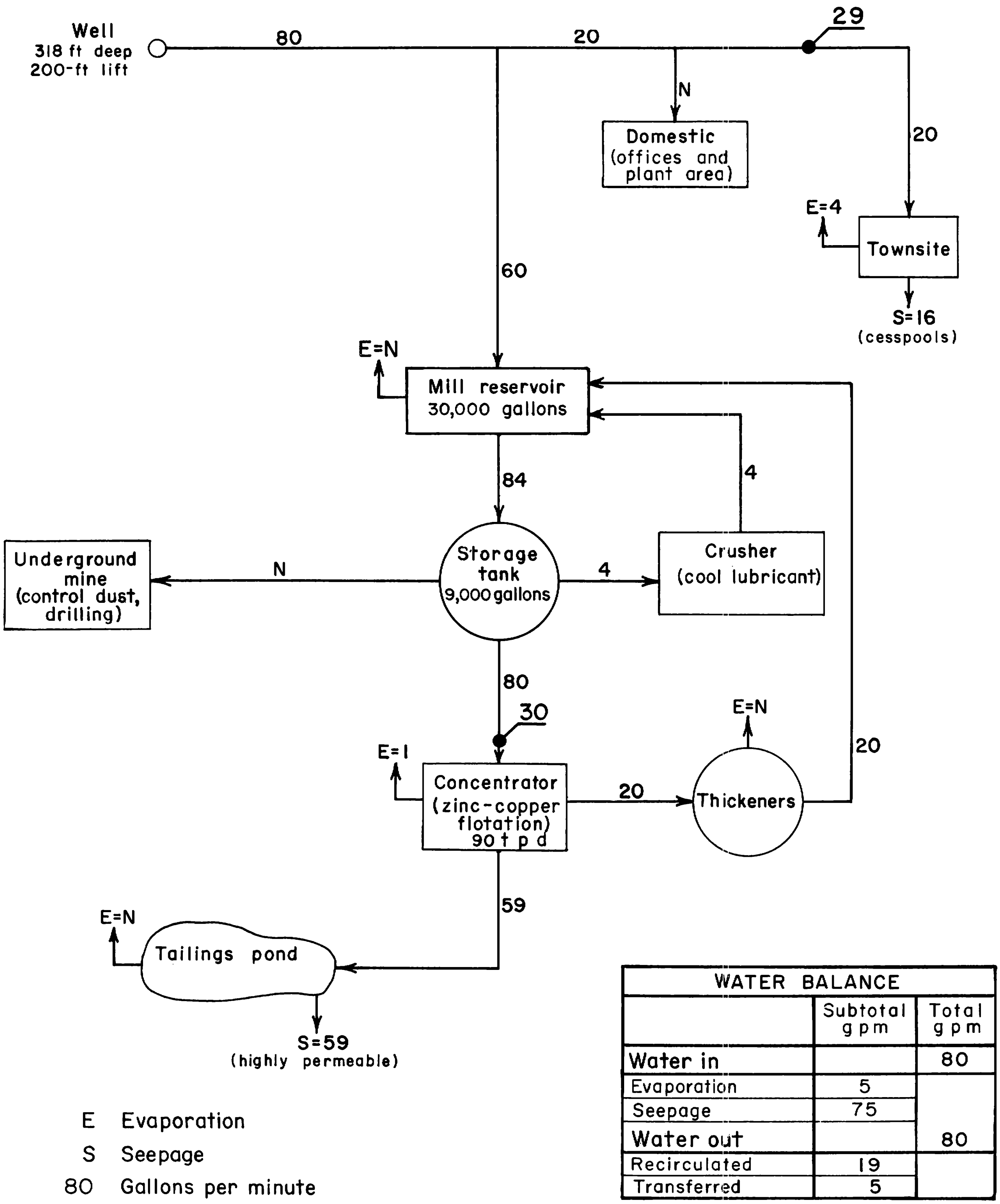
The well supplies a sufficient amount of water for the entire operation, including most domestic uses. However, the excessive dissolved-solids content of the well water makes it unfit for drinking; potable water is trucked in. Samples 29 and 30 (appendix) represent the new water and the mill intake, respectively.

The cost of power for pumping the new water is 9.4 cents per 1,000 gallons.

Figure 36, a picture taken from the townsite, shows the crusher, concentrator, and tailings pond.

Flux

The Flux lead-zinc mine and Trench flotation concentrator, owned and operated by McFarland and Nash, are 55 miles southeast of Tucson (fig. 6). The operation employs about 40 persons, 5 days per week.



WATER BALANCE	Subtotal gpm	Total gpm
Water in		80
Evaporation	5	
Seepage	75	
Water out		80
Recirculated	19	
Transferred	5	

E Evaporation
S Seepage
80 Gallons per minute
N Negligible
30● Sample

FIGURE 35. - Schematic Waterflow Diagram, Atlas Operation, B.S. & K. Mining Co., Pima County, Ariz.

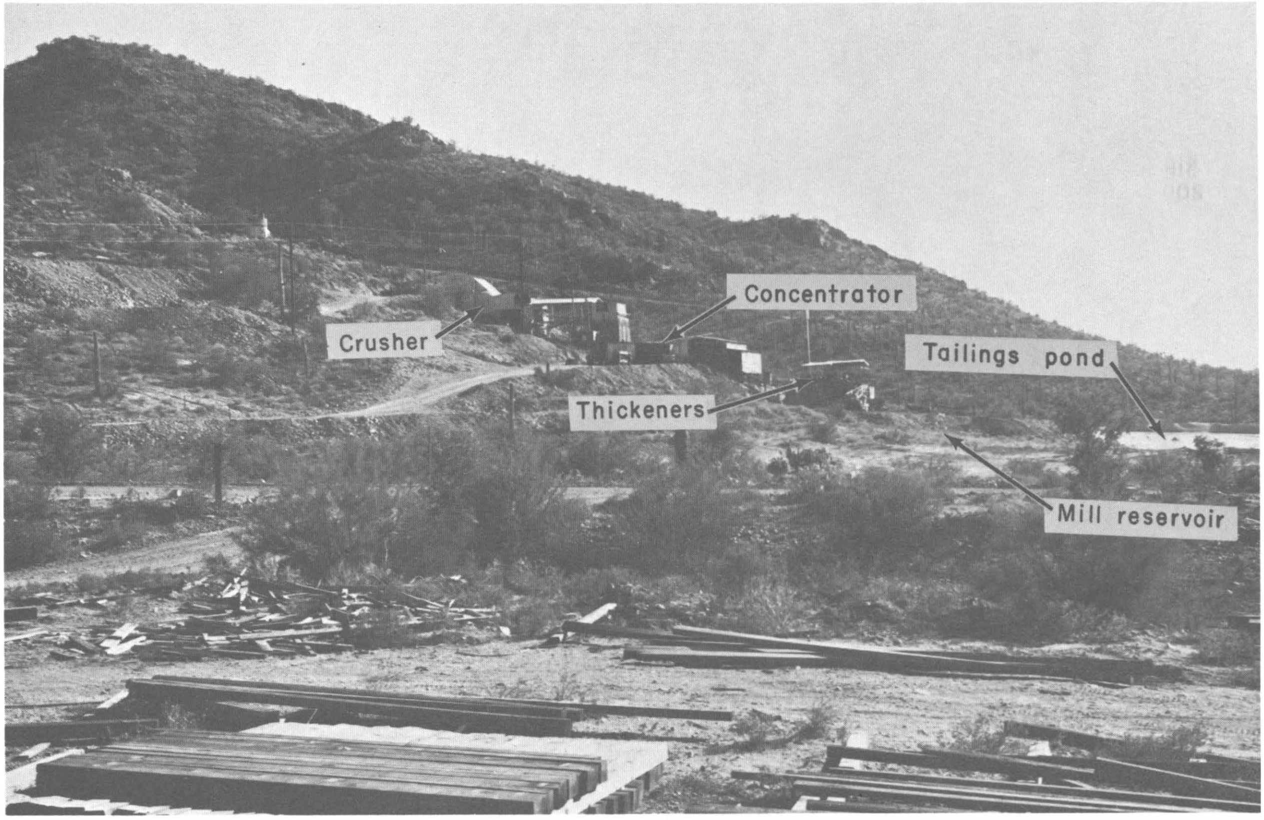


FIGURE 36. - Atlas Operation, B.S. & K. Mining Co., Pima County, Ariz.

Water for drilling and dust control in the mine is pumped from the mine sump (fig. 37). The 2 gpm used for these purposes is evaporated. An additional 8 gpm, pumped to dewater the mine, is discharged to a stream.

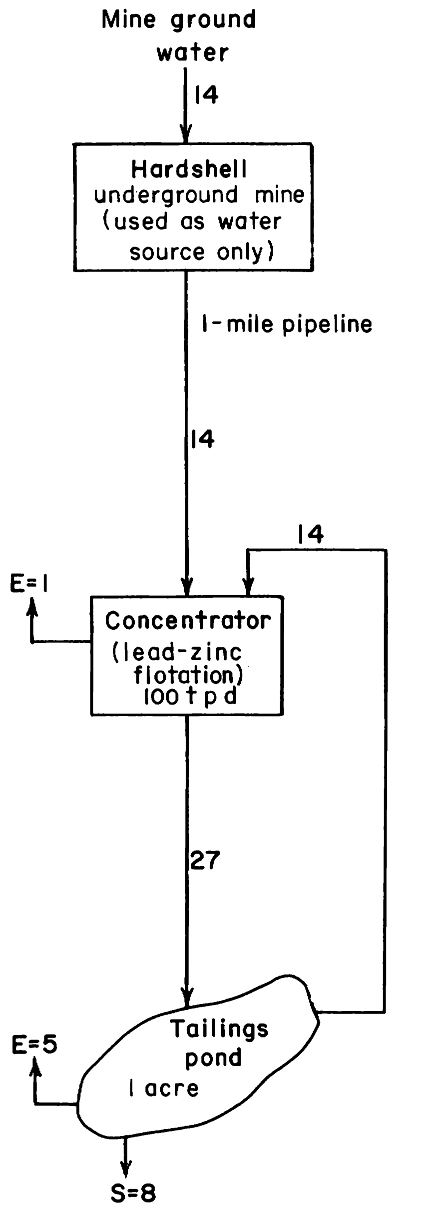
New water for the 100-tpd concentrator is obtained from the inactive Hardshell mine, approximately 1 mile west of the millsite. About 14 gpm of new water and 14 gpm of recirculated water are required for the concentrator. A total of 6 gpm is evaporated in the concentrator and tailings pond, and 8 gpm returns to ground water as seepage from the tailings pond.

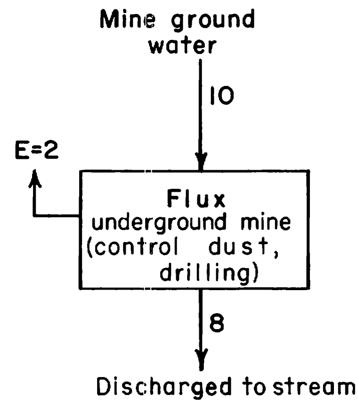
Domestic use in five company-owned houses and a changeroom is only 400 gpd.

This operation has no serious water problems; the quantity and quality of the available water meet requirements for the operation.

Iron King

The Iron King operation of the Shattuck Denn Mining Corp., about 15 miles east of Prescott (fig. 6), consists of a lead-zinc mine and a 1,050-tpd concentrator. The mine is worked two shifts per day, 6 days per week. The concentrator is operated three shifts per day, 6 days per week. Employees total 250.





E Evaporation
S Seepage
14 Gallons per minute
N Negligible

NOTE: Domestic use is about 400 gallons per day.

WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		24
Evaporation	8	
Seepage	8	
Discharge to stream	8	
Water out		24
Recirculated	14	

FIGURE 37. - Schematic Waterflow Diagram, Flux-Trench Operation, Nash-McFarland, Santa Cruz County, Ariz.

New water is pumped from five wells (fig. 38). Water for the nearby town of Humboldt is obtained from three wells 100 to 120 feet deep. A fourth well, 1,395 feet deep, with a lift of 420 feet, and a fifth, 780 feet deep, supply the operation. The company plans to obtain additional water from a sixth well, 850 feet deep, with a lift of 139 feet. All water for the operation is pumped to a gathering tank, from which it is pumped to a 250,000-gallon covered reservoir near the concentrator.

The 18 gpm going to the mine is used for drilling and dust control. An estimated 2 gpm is evaporated in the mine.

A total intake of 1,105 gpm is required for the concentrator; 537 gpm is new water, 4 gpm is transferred from the crusher, and 564 gpm is recirculated from the tailings thickener. Evaporative losses in the concentrator and from the tailings pond, plus moisture in the concentrates, total 45 gpm; 496 gpm returns to supply as seepage and discharge to an intermittent stream.

The compressor plant requires 2 gpm to replace the water evaporated in the spray pond.

Ten gpm goes to the changerooms and offices. The town of Humboldt takes 15 gpm.

The water table in the well area is gradually dropping. In summer, pumping for irrigation on nearby farms causes a temporary drop.

Three samples were taken. Sample 33 was taken at the gathering tank, sample 31 at the tailings-thickener overflow, and sample 32 at the tailings-pond discharge (appendix).

The cost of new water for power, labor, and supplies is 13.9 cents per 1,000 gallons.

Figure 39 is a photo of the operation.

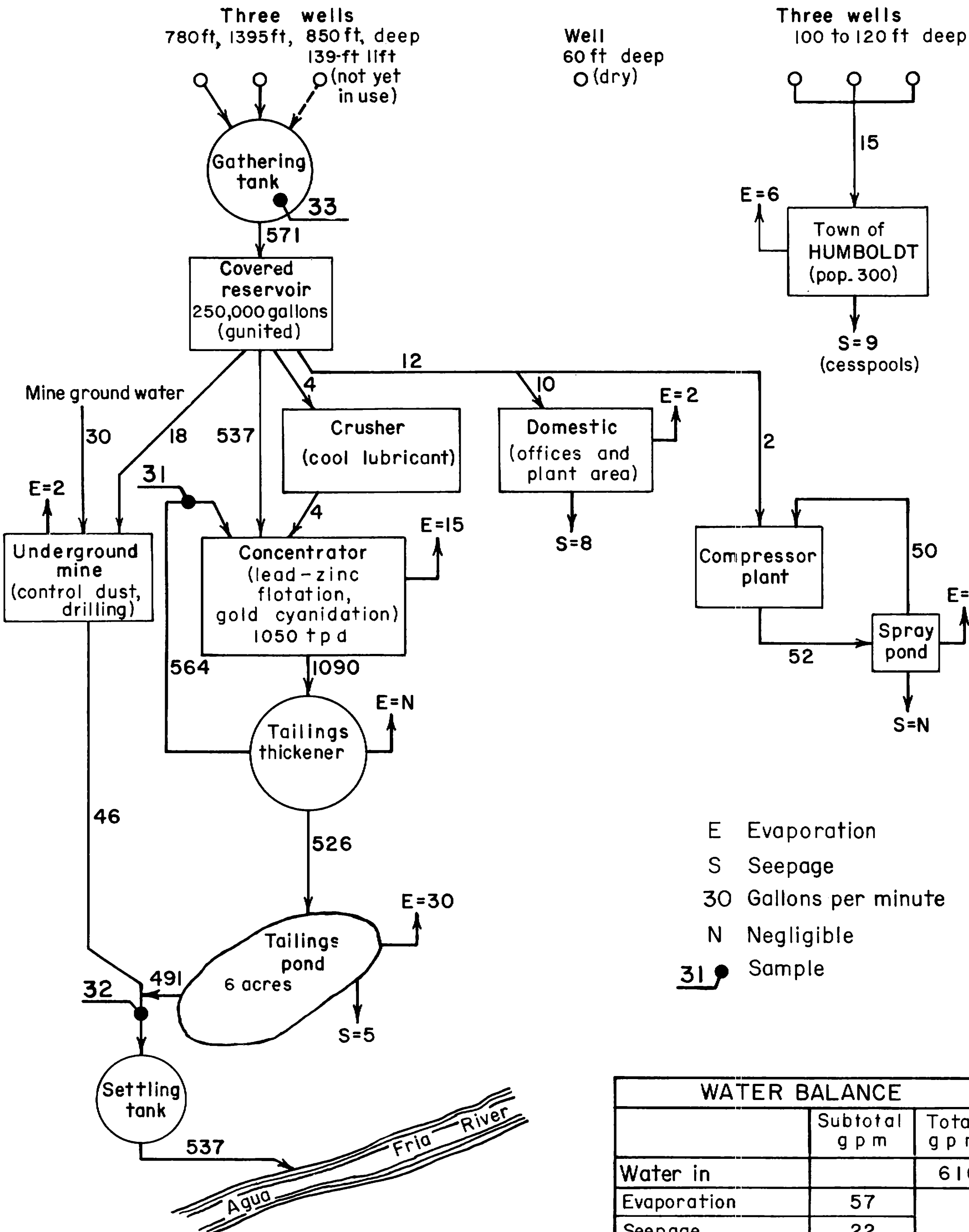
Orphan

Western Gold & Uranium, Inc. employs 125 persons at its Orphan mine in Grand Canyon National Park (fig. 6). The work schedule is two shifts per day, 6 days per week; daily production is 260 tons of uranium ore. This mine, like the other uranium mines in the State, uses relatively small amounts of water.

All water is hauled from Williams, a town 60 miles south of the mine (fig. 40).

The underground mine requires 4 gpm of new water. Intermittent recirculation of drilling water averages about 1 gpm. Three gpm is evaporated.

Company housing takes an average of 7 gpm; 3 gpm is evaporated from septic tanks, and 4 gpm seeps into the ground.



WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		616
Evaporation	57	
Seepage	22	
Discharge to stream	537	
Water out		616
Recirculated	614	
Transferred	4	

FIGURE 38. - Schematic Waterflow Diagram, Iron King Operation, Shattuck Denn Mining Corp., Yavapai County, Ariz.

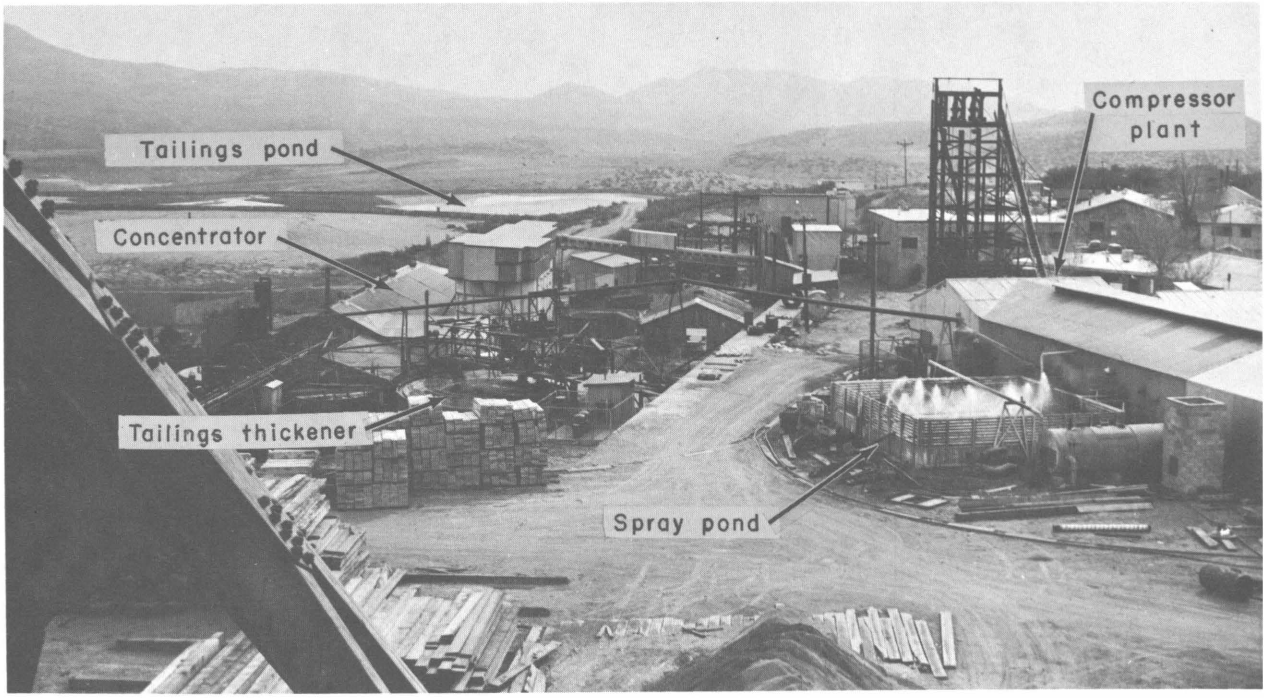


FIGURE 39. - Iron King Operation, Shattuck Denn Mining Corp., Yavapai County, Ariz.

All new water is chlorinated by the addition of a chlorine bleaching fluid. The principal water problem is the high cost, $10.00 per 1,000 gallons delivered.

Tuba City Mill

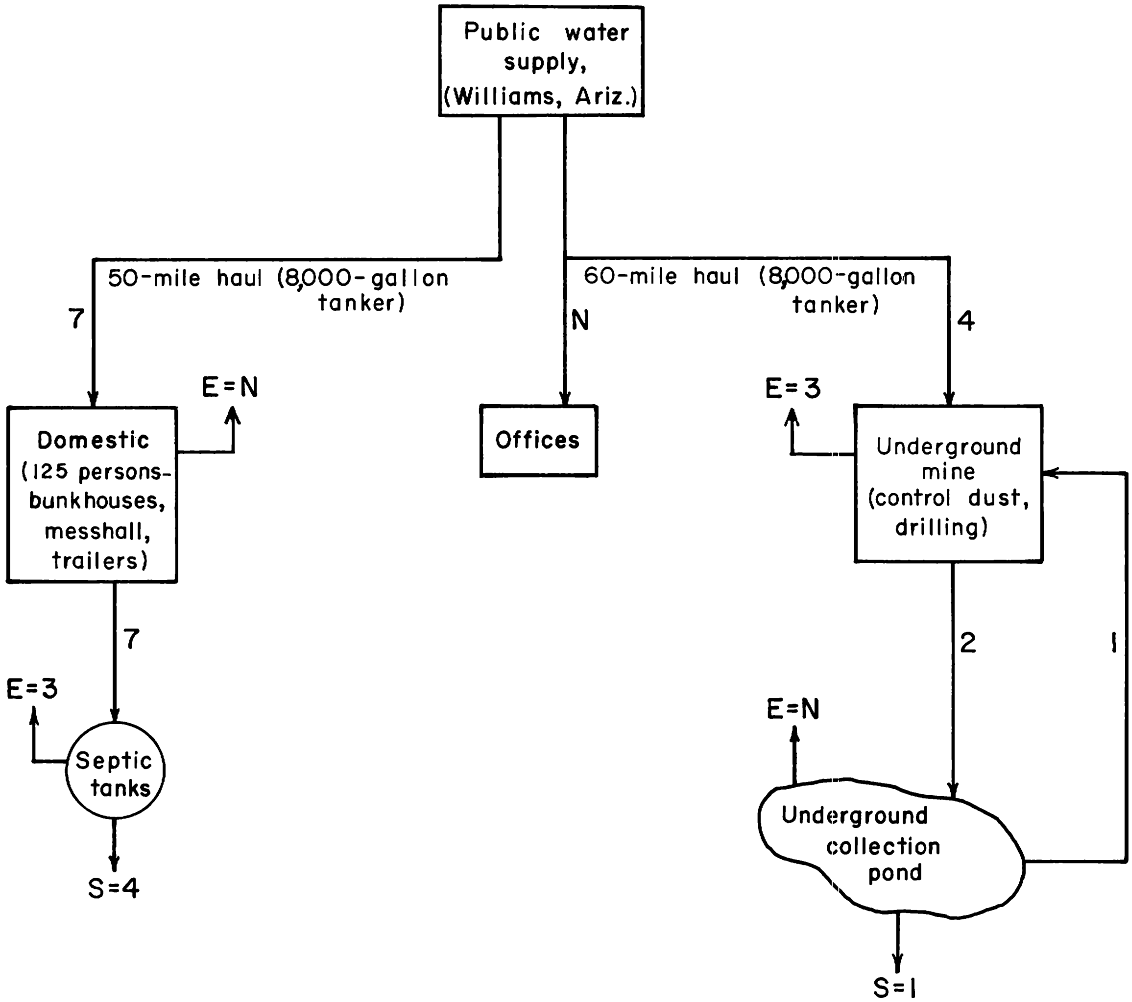
Tuba City Mill, Rare Metals Corporation of America, about 7 miles east of the town of Tuba City (fig. 6), is operated three shifts per day, 365 days per year; employees total 85. The resin-in-pulp method of acid extraction is used in processing 300 tons of uranium ore per day.

All new water is pumped from four company-owned wells about one-quarter mile north of the mill (fig. 41). From the wells, which are 600 feet deep and have a 200-foot lift, the water is pumped to the mill through a buried pipeline. The new water, of very good quality, costs one-half cent per 1,000 gallons, excluding the cost of power.

New-water intake at the concentrator is 99 gpm; 5 gpm is evaporated, and 94 gpm is sent to the tailings pond, where an additional 85 gpm is evaporated.

Other evaporative losses in the plant include 1 gpm used for dust control in the crushers and 1 gpm for boiler feed.

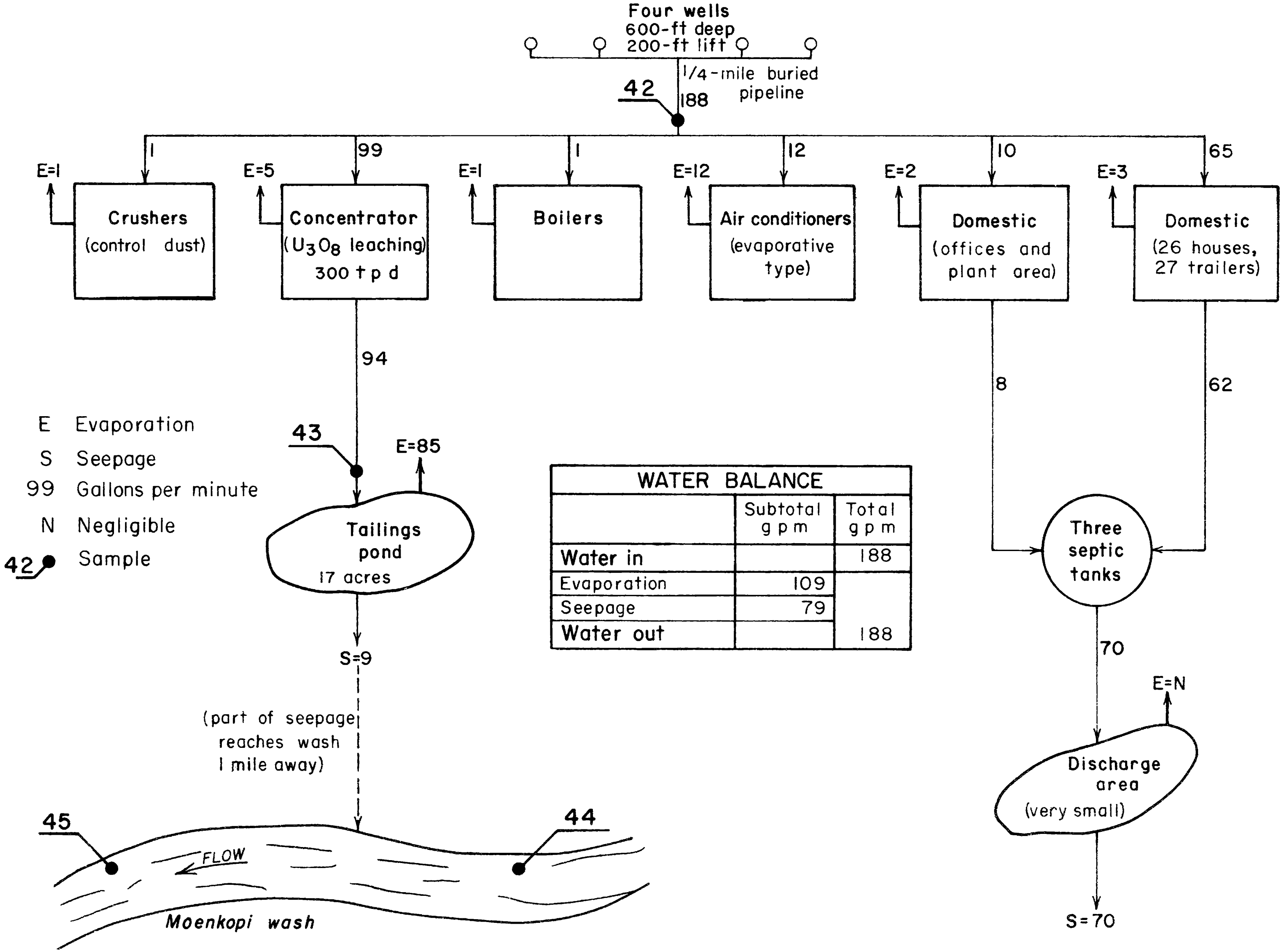
Changerooms and offices require 10 gpm, evaporative-type air conditioners 12 gpm, and company housing 65 gpm. Evaporation from these three units is



E Evaporation
S Seepage
7 Gallons per minute
N Negligible

WATER BALANCE		
	Subtotal gpm	Total gpm
Water in		11
Evaporation	6	
Seepage	5	
Water out		11
Recirculated	1	

FIGURE 40. - Schematic Waterflow Diagram, Orphan Mine, Western Gold & Uranium, Inc., Yavapai County, Ariz.



WATER BALANCE	Subtotal g p m	Total g p m
Water in		188
Evaporation	109	
Seepage	79	
Water out		188

FIGURE 41. - Schematic Water Diagram, Tuba City Mill, Rare Metals Corp. of America, Coconino County, Ariz.

17 gpm. The 70 gpm discharged from changerooms, offices, and housing goes first to septic tanks and then to a small pond from which it seeps into ground water.

The present water supply is adequate; however, the company expects to convert to an alkaline-leach process permitting recirculation, which is not feasible with acid leaching. This change is expected to lower new-water requirements at least one-third.

The major quality problems are encountered in disposal of waste, some of which seeps into Moenkopi Wash. Four water samples (samples 42-45 in the appendix) were taken by a Bureau of Mines engineer; in addition to the 16 regular determinations, total-alpha and Ra^{226} counts were made. Results of the radioactivity analyses are shown in table 3.

TABLE 3. - Radioactivity analyses, samples 42-45, Tuba City Mill

Sample No.	Description	Total disintegrations per minute per liter	
		Ra^{226}	Total alpha
42.........	New well water................	0	0
43.........	Discharge to tailings pond....	1,523	7,487
44.........	Moenkopi Wash, 3 miles upstream from mill............	0	0
45.........	Moenkopi Wash, 7 miles downstream from mill............	[1]21	59

[1] Considered potable by present AEC standards.

Nonmetals

Substantial amounts of water are used at sand-and-gravel operations, cement plants, and lime plants.

Sand-and-gravel operations require water for washing sand and gravel, for mixing concrete, and for domestic uses. Most of this water is pumped from wells in the plant areas, but some is obtained from municipal supplies. Consumption is low; generally about 90 percent is returned to ground water. Few sand-and-gravel plants recirculate water. Table 4 gives water figures for 10 plants of 4 major sand-and-gravel companies in the Phoenix and Tucson areas. In general, plant operation is limited to one shift per day.

Washing operations at the 10 plants represented in table 4 require 4,367,000 gpd of new and recirculated water. This quantity of water is used on 12,475 tpd of sand and gravel; the average is 350 gallons per ton washed. In 1960, commercial and noncommercial sand and gravel washed in Arizona totaled 12,668,600 tons. If it is assumed that the average of 350 gallons per ton washed applied to all other sand-and-gravel-washing operations in the State, the total water required for this purpose in 1960 amounted to 4.44 billion gallons.

TABLE 4. - Water balance, 10 Arizona sand-and-gravel plants, 1960

	Gallons per day	Gallons per day
Total new water	-	3,887,160
Consumed by evaporation and incorporated in product	464,320	-
Returned to ground water by seepage	3,422,840	-
Total water out	-	3,887,160
Recirculated	538,000	-

Cement manufacturing requires water for cooling kilns and lubricants, and for domestic uses.

The following descriptions illustrate present practices in water use at the 2 cement plants, a mica-processing operation, the several lime plants, and 10 sand-and-gravel operations in the State.

American Cement Corp.

A cement-manufacturing plant at Clarkdale is operated by Phoenix Cement Co., Division of American Cement Corp. This plant, with 150 employees, has an annual capacity of 2.6 million barrels of cement.

Two wells about one-eighth mile from the plant alternately supply the required new water. The pumping lift is 500 feet.

Cooling of lubricating oil requires 200 gpm; 40 gpm is recirculated, and 160 gpm is new water. Dust control uses 40 gpm of water transferred from the lubricant-cooling system and 20 gpm of new water. All dust-control water is evaporated.

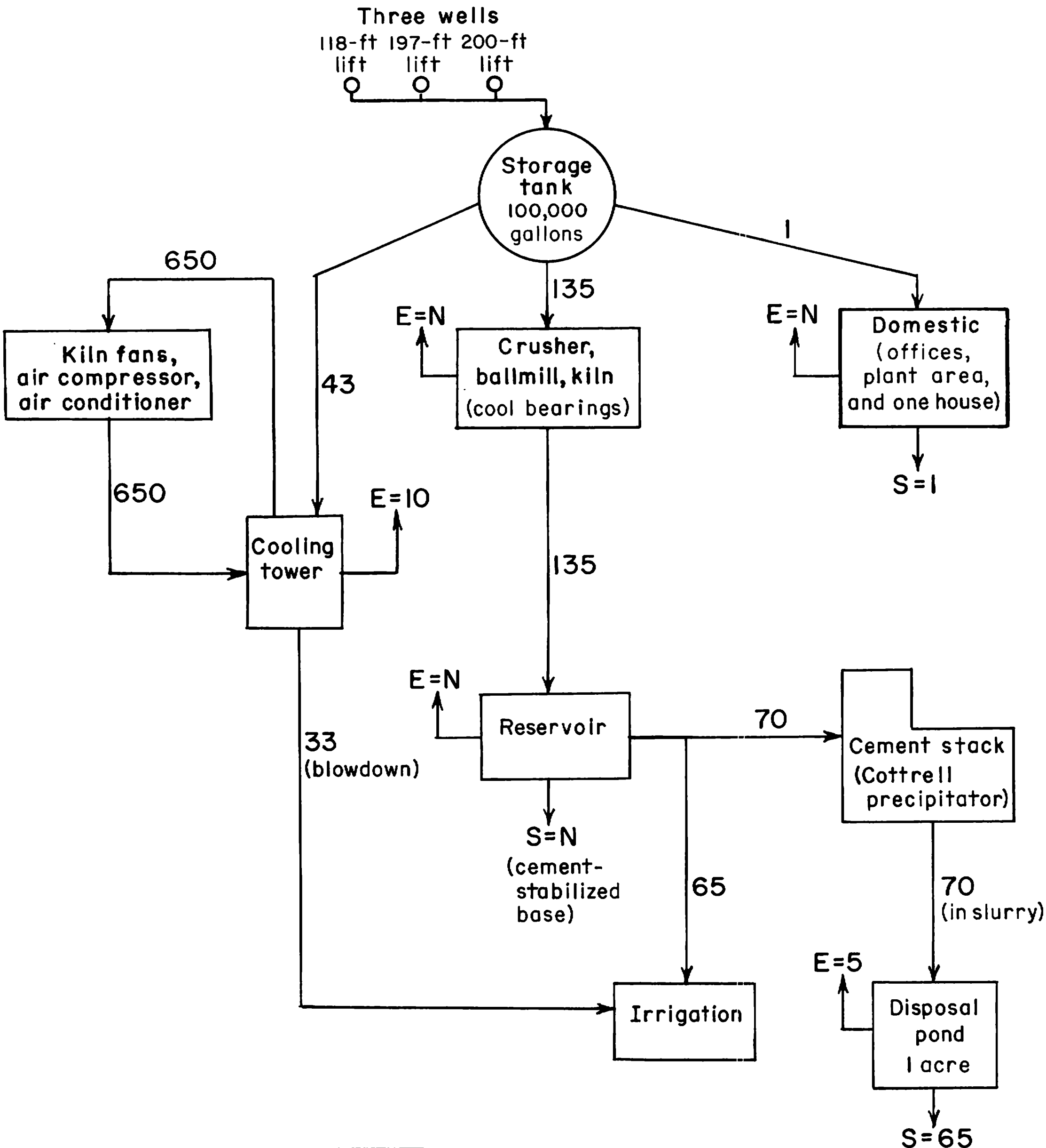
Domestic uses in the plant area require 20 gpm; all of this amount is discharged to cesspools and returned to ground water as seepage.

The quality of the new water is good, although the water used in showers has to be lime softened. Cost of pumping the new water is about 4 cents per 1,000 gallons.

Arizona Portland Cement Co.

A cement-manufacturing plant near Rillito is operated by Arizona Portland Cement Co. This plant, with a capacity of 2.7 million barrels of cement per year, operating three shifts per day, 7 days per week, employs 200 persons.

All new water for the plant is pumped from three nearby wells (fig. 42). Pumping lifts for these wells are 118, 197, and 200 feet, respectively.



WATER BALANCE	Subtotal gpm	Total gpm
Water in		179
Evaporation	15	
Seepage	66	
Discharge to stream	98	
Water out		179
Recirculated	650	
Transferred	70	

E Evaporation
S Seepage
43 Gallons per minute
N Negligible

FIGURE 42. - Schematic Waterflow Diagram, Rillito Cement Plant, Arizona Portland Cement Co., Pima County, Ariz.

A 10-gpm evaporative loss and a 33-gpm blowdown is compensated for by adding 43 gpm at the cooling tower, which cools the 650 gpm circulating through the kiln fans, air compressor, and air conditioner. Blowdown is used for irrigation.

Water for cooling bearings in the crusher, ballmill, and kiln amounts to 135 gpm, all of which is discharged to a small reservoir with a cement-stabilized base. From the reservoir 65 gpm is used for irrigation, and 70 gpm is transferred to make a slurry of the dust caught by the Cottrell precipitator in the cement stack. The slurry is sent to a 1-acre disposal pond where 5 gpm of the contained water is evaporated, and 65 gpm is returned to ground water by seepage.

Only 1 gpm is required for domestic use in the plant area and in the one company-owned house.

The company is making a study to determine the economic feasibility of recirculating water from the reservoir to the crusher, ballmill, and kiln. If the results are practical, new-water requirements will be substantially lowered.

Water for cooling the kiln-fan bearings is treated with a patented compound to prevent scale formation by material precipitated as a result of high temperature.

The cost of new water, for power, labor, and supplies, is 8 cents per 1,000 gallons.

Buckeye Mica Co.

This company, at Buckeye, operates the only mica-processing plant in the State. The small amount of water required, obtained from the municipal supply, is used only for domestic purposes; none is used in the mica-processing operation.

Mica flotation, the process used prior to 1956, was discontinued because of the cost of drying the product and the very careful temperature control necessary to prevent discoloring the product.

Lime Plants

Incomplete data indicate that the half-dozen lime plants in Arizona, employing some 150 persons, use comparatively little water. The following figures are estimations of average daily water requirements and disposal in 1960 when lime production in Arizona amounted to 150,000 tons.

	gpd
New water	125,000
Consumed (evaporated and incorporated in product)	75,000
Returned to supply (by seepage and discharge to stream)	50,000

Most of the new water is obtained from company-owned wells. About 200 gallons of new water is needed per ton of product. Water uses include dust control in quarrying and crushing operations, crusher-bearing cooling, incorporation in product, and domestic uses. Most of the nonconsumptive water returns to supply by seepage.

Tucson Rock & Sand Co.

Two sand-and-gravel-washing and ready-mixed-concrete plants, and two gravel pits are operated in the Tucson area by Tucson Rock & Sand Co. The work schedule for the 55 employees is one shift per day, 240 days per year.

Industrial water is pumped from company-owned wells in the plant areas (fig. 43). Average pumping lift is 150 feet. A small amount of additional water, for the offices, is purchased from the Tucson Water Utility.

The two plants use 125,000 gpd of new water and 154,000 gpd of recirculated water to wash 875 tpd of sand and gravel. New water is required to replace the 31,000 gpd evaporated and the 94,000 gpd returned to ground water by seepage. Ready-mixed concrete requires 13,000 gpd for incorporation in the product.

Water quality is satisfactory; no treatment is necessary.

Undisclosed Company

Two Arizona sand-and-gravel plants, employing 30 persons, are operated one shift per day, 250 days per year.

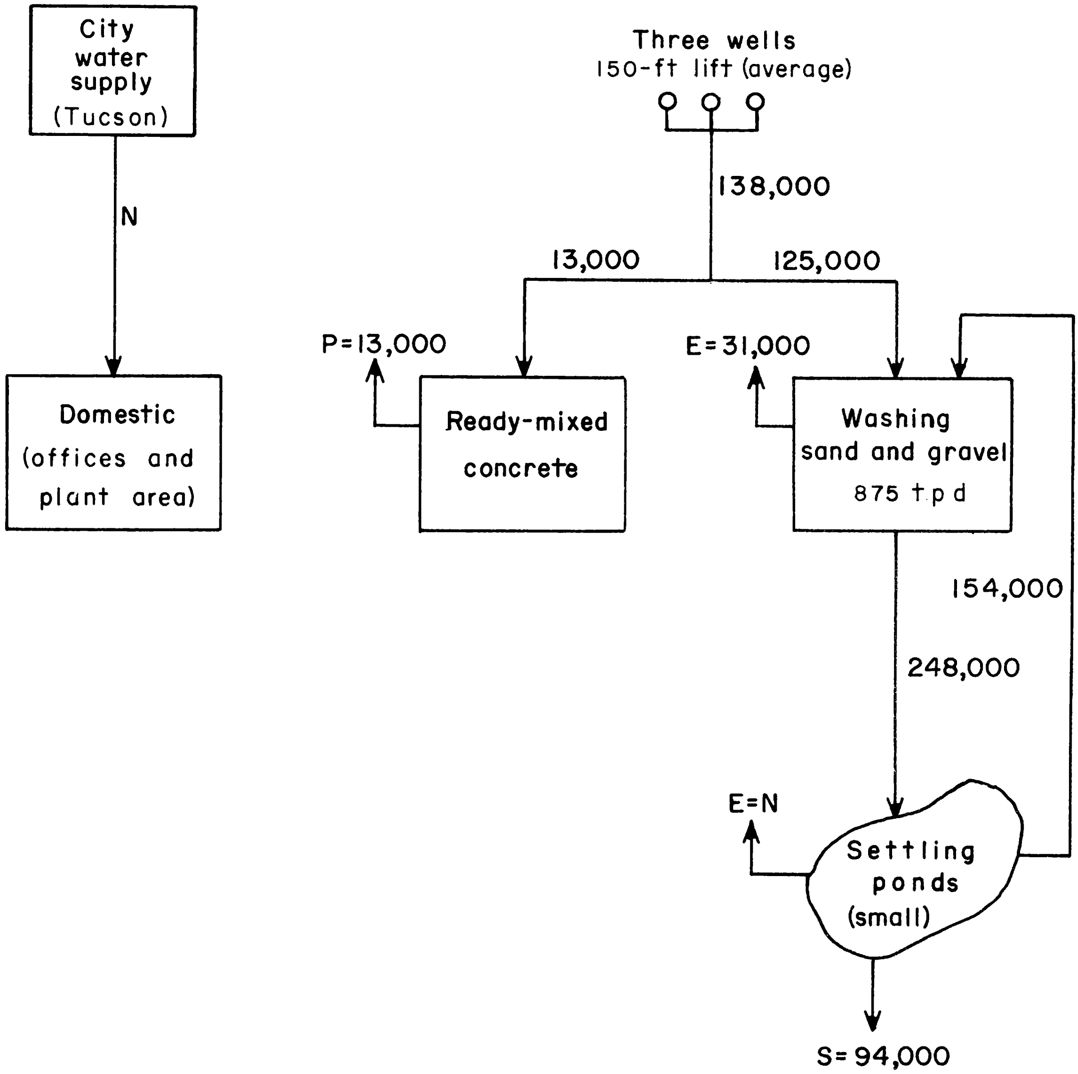
Three wells in the two plant areas furnish the 552,000 gallons of new water needed daily for washing 1,400 tons of sand and gravel (fig. 44). An additional 384,000 gpd is recirculated. Evaporation totals 31,200 gpd, and seepage from the 5 acres of settling ponds is 520,800 gpd. A negligible quantity used in the office is obtained from a municipal supply.

Union Rock & Materials Co.

Union Rock & Materials Co. operates three sand-and-gravel washing plants (fig. 45) and four ready-mixed-concrete plants in the Salt River Valley. Employees, totaling 280, work 8 hours per day, 5 days per week.

Figure 46, showing water uses and disposal in gallons per day, represents the three operations. Most of the water is obtained from company-owned wells. The pumping lift ranges from 180 to 240 feet. At one plant additional water is bought from the Glendale Water Department.

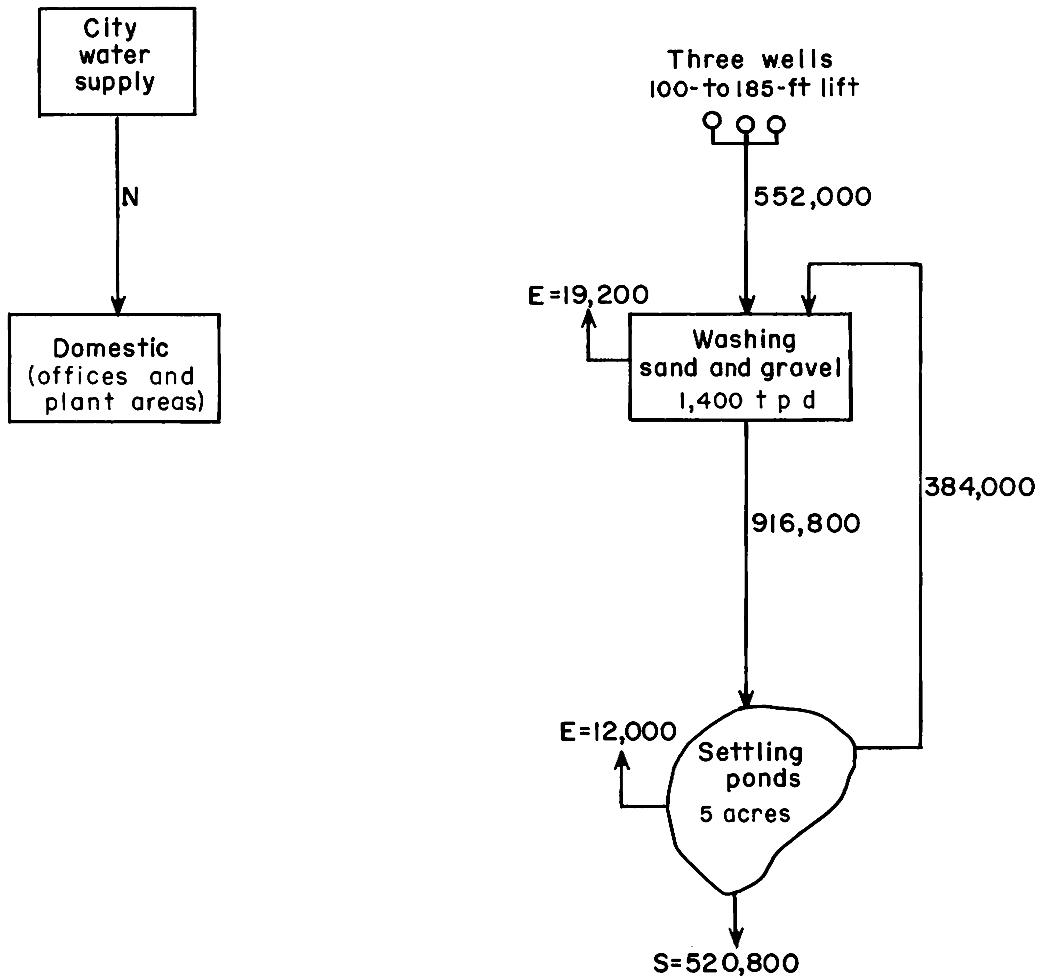
Washing the 5,600 tpd of sand and gravel requires about 1 million gallons of water, ready-mixed concrete 30,000 gpd, and estimated domestic uses only 200 gpd. About 90 percent of the intake is returned to ground water.



WATER BALANCE		
	Subtotal g p d	Total g p d
Water in		138,000
Evaporation	31,000	
Seepage	94,000	
Incorporated in product	13,000	
Water out		138,000
Recirculated	154,000	

E Evaporation
S Seepage
13,000 Gallons per day
N Negligible
P Incorporated in product

FIGURE 43. - Schematic Waterflow Diagram, Two Sand-and-Gravel Plants, Tucson Rock & Sand Co., Pima County, Ariz.



WATER BALANCE		
	Subtotal g p d	Total g p d
Water in		552,000
Evaporation	31,200	
Seepage	520,800	
Water out		552,000
Recirculated	384,000	

E Evaporation
S Seepage
19,200 Gallons per day
N Negligible

FIGURE 44. - Schematic Waterflow Diagram, Two Arizona Sand-and-Gravel Plants, (Name of Company Withheld).

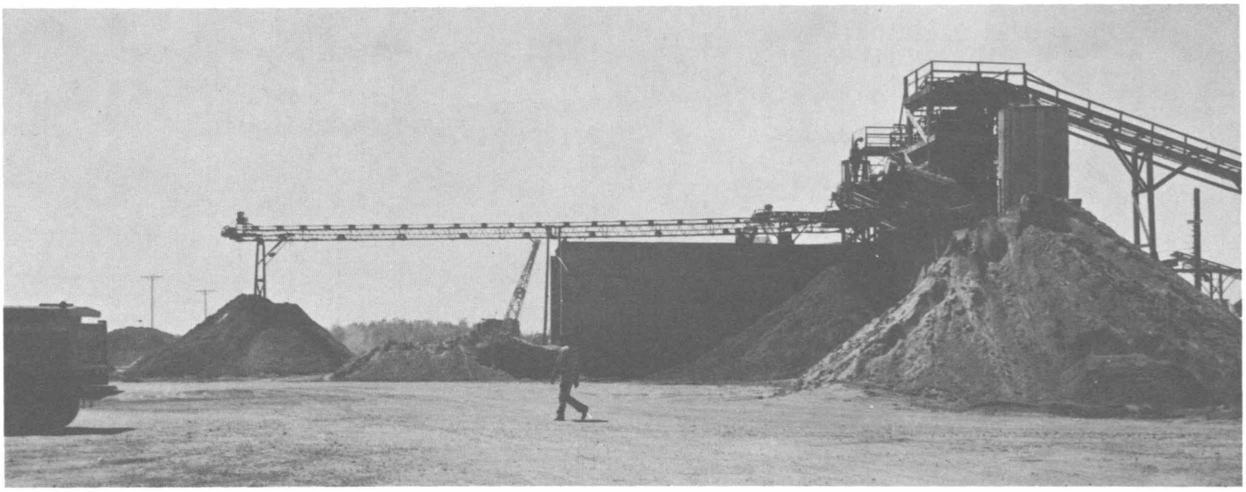


FIGURE 45. - Sand-and-Gravel Washing Plant, Union Rock and Materials Co., Phoenix, Ariz.

Quality presents no problems for these operations, and none of the water is treated. Cost of power for pumping the well water is approximately 1 cent per 1,000 gallons.

United Materials, Inc.

The following data represent three of the plants operated in the Phoenix area by United Materials, Inc. Two plants are operated one shift per day, and the other, two shifts per day; all three are operated 260 days per year. The three plants wash about 4,600 tons of sand and gravel per day and employ a total of 250 persons.

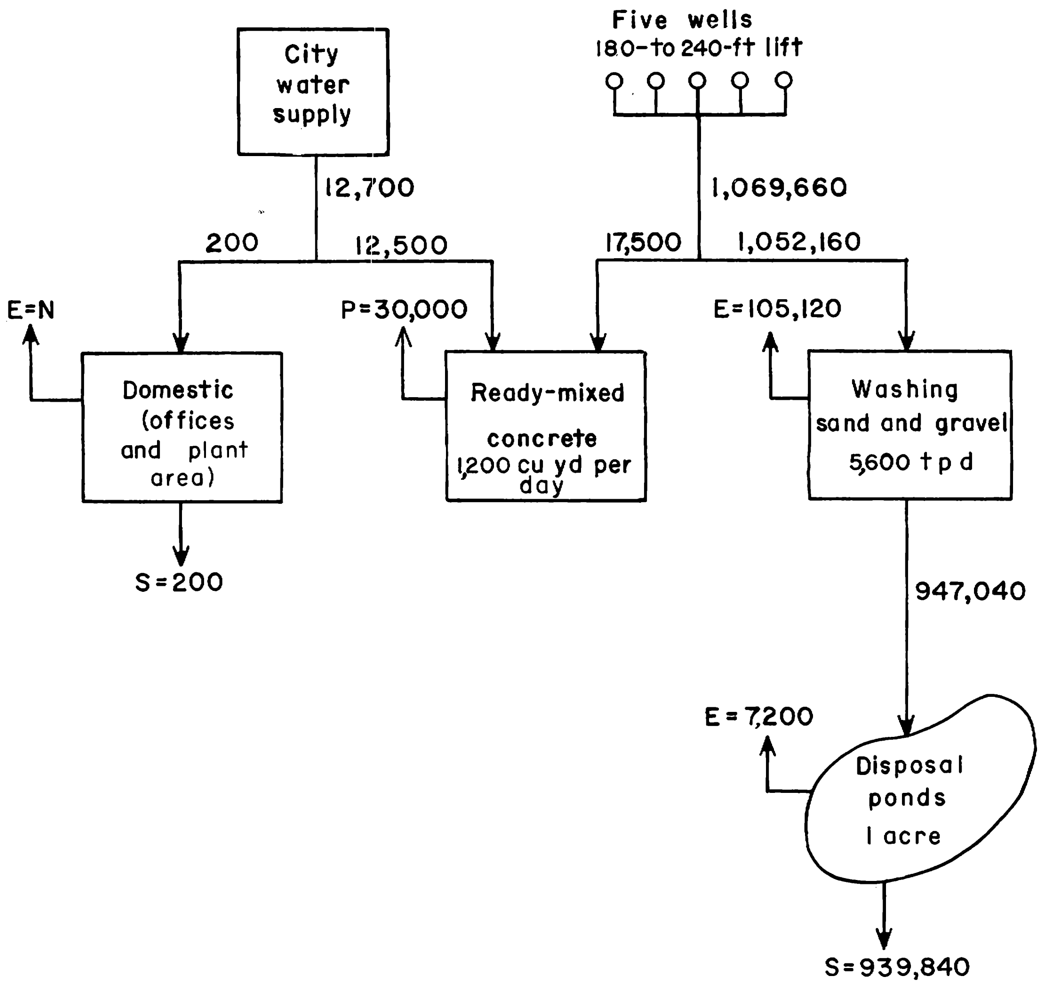
Water for nondomestic uses is pumped from three company-owned wells, each having a lift of 200 feet (fig. 47). A negligible amount of water is obtained from the Phoenix Water Department for domestic use in offices and plant areas.

Sand-and-gravel washing requires more than 2 million gpd; 40,000 gpd is incorporated in ready-mixed concrete. Nearly 90 percent of the intake is returned to ground water by seepage.

The water is of good quality, and none is treated. New-water pumping cost, for power only, is 1.2 cents per 1,000 gallons.

Metal Processing

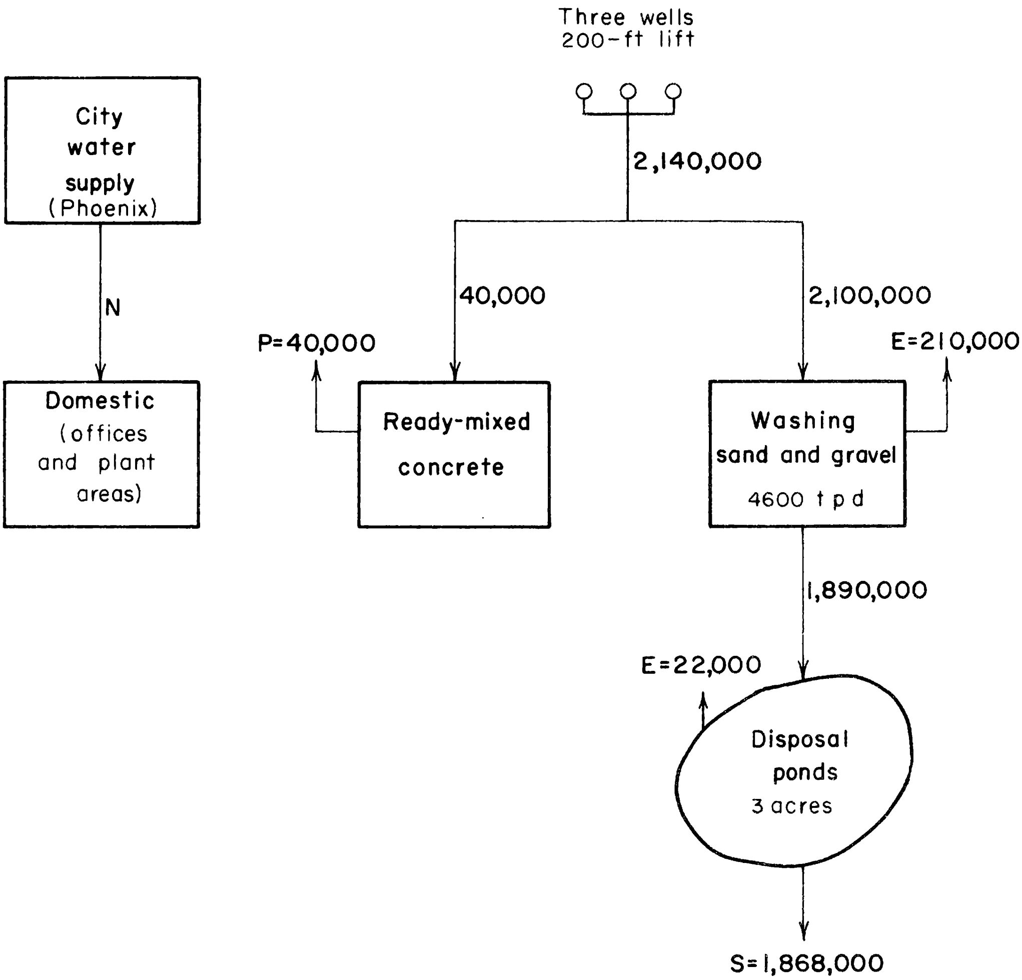
Water has many uses in forming-and-shaping, plating, and fabricating plants. Cooling is the most important use quantitatively in most of these operations. No attempt was made to obtain water-use data at all Arizona plants of these types; those described below are representative.



WATER BALANCE		
	Subtotal g p d	Total g p d
Water in		1,082,360
Evaporation	112,320	
Seepage	940,040	
Incorporated in product	30,000	
Water out		1,082,360

E Evaporation
S Seepage
200 Gallons per day
N Negligible
P Incorporated in product

FIGURE 46. - Schematic Waterflow Diagram, Three Sand-and-Gravel Plants, Union Rock & Materials Co., Maricopa County, Ariz.



WATER BALANCE		
	Subtotal gpd	Total gpd
Water in		2,140,000
Evaporation	232,000	
Seepage	1,868,000	
Incorporated in product	40,000	
Water out		2,140,000

E Evaporation
S Seepage
40,000 Gallons per day
N Negligible
P Incorporated in product

FIGURE 47. - Schematic Waterflow Diagram, Three Sand-and-Gravel Plants, United Materials, Inc., Maricopa County, Ariz.

Forming and Shaping Plants

Described below are several metal-working plants in the Phoenix and Tucson areas.

Foundries that produce metal castings require water for conditioning molding sand and for domestic uses. Rolling mills, which roll metals into desired shapes, use water to cool furnaces, mill rolls, and compressors, and for domestic purposes.

Knight Foundry Co.

This small aluminum and brass foundry in Tucson employs four persons one shift per day, 6 days per week.

The estimated 200 gallons of water required daily for conditioning molding sand is obtained from the public supply at $2.75 per month.

Tucson Iron Works

This plant, in Tucson, is a combination foundry and structural-iron works. Nearly all of the water for the plant is used in the foundry, which employs 15 persons and processes 400 to 600 tons of iron annually. One shift works 5 days per week.

The 900 gpd of new water for the foundry is purchased from the Tucson Water Utility. About 800 gpd, used in conditioning molding sand, is evaporated. Domestic uses in the plant require 100 gpd, nearly all of which reaches the city sewer.

The quality of water for conditioning molding sand is of little importance; no water is treated. The cost of the water is about $60 per year or 25 cents per 1,000 gallons.

Western Rolling Mills

Western Rolling Mills Division, Yuba Consolidated Industries, Inc., 5 miles south of Tempe, has 400 employees and processes 75,000 tons of scrap steel annually. The plant is operated three shifts per day, 7 days per week.

New water, for industrial and domestic use, is pumped from one 600-foot-deep company-owned well in the plant area. The pumping lift is 95 feet. Storage in a 3,000-gallon pressure tank eliminates the need for an elevated tank.

For industrial purposes, which include cooling of furnaces, mill rolls, and compressors, the daily new-water requirement to replace evaporation losses totals 1,000 gpd. Recirculated cooling water amounts to 14,000 gpd.

New water required for domestic uses in the plant area is 1,500 gpd. Ninety percent, or 1,350 gpd, goes to cesspools, from which it seeps back into the ground water supply; the remaining 10 percent, 150 gpd, is evaporated.

Quality characteristics of the new water reported by the company are as follows: pH, 7.3; hardness (as $CaCO_3$), 1,048 ppm; $SO_4^{=}$ (as Na_2SO_4), 1,030 ppm; and Cl^- (as NaCl), 1,250 ppm.

,The industrial water is treated with 1.1 pounds of sulfuric acid (66 Baume) and 0.25 pound of a corrosion inhibitor, per 1,000 gallons.

Estimated cost of the new water, including cost of power and maintenance, is 30 cents per 1,000 gallons.

Three Arizona Metal-Forming and Shaping Plants

Three additional forming and shaping plants in the Phoenix area, employing a total of 375 persons, are represented by the following data.

Source and quantity of new water:	gpd
Public supply	2,000
Company-owned wells	38,000
Total new water	40,000
Uses:	
Industrial (for conditioning molding sand, washing castings, cooling)	35,000
Domestic in plant area	5,000
Consumption (evaporation):	
Industrial	10,000
Domestic	[1]
Return to supply (stream and ground water):	
Industrial	25,000
Domestic	5,000

Treatment: (in one plant only)

New water chlorinated for algae control, and softened.

[1] Negligible.

Plating Plants

A metal surface coat is deposited on a metallic object by electroplating. The coating, for ornamentation or for corrosion resistance, is usually a more expensive metal than the one being covered.

The surface of the object to be plated must first be prepared by polishing and cleaning. After the surface has been prepared, the object is immersed in an electrolyte and connected to the cathode (negative electrode). The electrolyte is usually a solution of a suitable salt of the plating metal. The anode (positive electrode), if soluble, dissolves to replenish the plating-metal content of the solution. The plated objects are rinsed to remove all plating solution carried over from the electroplating process.

Except for rinsing, all operations involving the use of water are conducted on a batch basis, with water being added only to replace evaporative losses. Cleaning and plating baths are used as long as possible to conserve contained chemicals. All recoverable materials are salvaged, and the solution is neutralized before it is discarded.

The following data, collected at 11 electroplating plants in Phoenix, represent most of Arizona's electroplating industry.

Chem Research Co.

This electroplating plant in Phoenix is operated one shift per day, 5 days per week, with 30 employees. The company is engaged principally in subcontracting precision plating of aircraft components. A wide variety of metals, including precious metals, is used in the plating processes.

Nearly all water for the plant is obtained from public supply; requirements include a small amount of distilled water.

The quantity of new city water averages 29,000 gpd; about 10 percent of this, or 3,000 gpd, is used in maintaining ordinary plating solutions. Distilled water is used for solutions having high-quality requirements, such as precious-metal solutions. All of the solution-makeup water is evaporated. About 26,000 gpd of city water is used in cleaning metal surfaces before plating, and in rinsing solution from the plated products. No water is recirculated. Domestic needs are small.

Quality of the new water is brought up to the required standard by ion-exchange.

Most of the 25,000 gpd of waste water, after removal of suspended solids by settling, is discharged to the city sewer system. Highly contaminated waste water is trucked to a disposal area to eliminate the necessity of treating plant effluent.

Master Plating & Metal Finishing Company

Twenty persons are employed in this chromium and precious-metal electroplating plant in Phoenix. The plant is operated one shift per day, 5 days per week.

New water for most purposes is purchased from the Phoenix Water Department. The plant also uses small amounts of distilled water.

Of the 3,000 gpd of city water, about 2,700 gpd is used for cleaning metal surfaces before plating and for rinsing plating solution from the plated product. Makeup for chromium solutions takes the remaining 300 gpd. Little water is needed for domestic purposes, and none is recirculated. The small quantity of distilled water goes into cyanide solutions for precious-metal plating. Evaporation, mostly from solutions, is about 300 gpd.

No new water is treated; for high-quality needs distilled water is used. Before it is discharged to the sewer system, the 2,700 gpd of effluent is chlorinated to break down the contained cyanide. Chromic acid in the effluent is too dilute to be objectionable. The pH of the water discharged is restored to normal by adding sodium hydroxide.

Nine Arizona Plating Plants

The following discussion summarizes information obtained at nine plating plants in the Phoenix area. It is assumed that all are operated one shift per day, 5 days per week. Employees, ranging from 2 to 40 in the individual plants, total 88.

Electroplating processes are employed at all nine plants. One plant also plates by a hot-dipping method. Metals for electroplating in these plants include nickel, chromium, copper, zinc, cadmium, lead, tin, gold, and silver. One case of brass electroplating was reported. Tin is applied in the one hot-dipping operation.

All water, other than a small amount of distilled water, is obtained from public supply. The quantity of new industrial water totals 80,000 gpd. Domestic requirements are insignificant. An estimated 20 percent, or 16,000 gpd, is consumed by evaporation in the plant area and in the Phoenix sewage-treatment plant. The remaining 64,000 gpd is returned to supply.

Water is recirculated at only one plant, where a small amount of rinse water is used a second time.

Disposal of waste water in five plants is by discharge to the city sewer system; four dispose of waste in the plant area by discharging to a septic tank or cesspool, or by surface evaporation and seepage.

New water for plating solutions is deionized at two plants and softened at one. Contamination of discharged rinse water is generally low; at only one plant is the rinse water treated before discharge to the city sewer system.

Gross business reported by six of the nine plants totals $800,000 per year. Little information was available on quantity and value of plating metals and other processing materials. One operator reported consumption of 1,000 pounds of concentrated chromic acid per $35,000 of gross chromium-electroplating business. Another mentioned consumption of 1,000 pounds of 90 percent nickel sulfate per $20,000 of gross nickel-electroplating business.

Fabricating Plants

The five fabricating plants to be described are associated with the mineral industry in that their products are metallic or contain appreciable quantities of metals. Major water uses are for cooling and domestic purposes.

Allison Steel Mfg Co.

The various products made by Allison Steel Manufacturing Co. at its plant in Phoenix include structural steel, farm machinery, rotary kilns, and military defense items. The 500 employees work one shift per day, 5 days per week. Gross business amounts to $12 million annually.

Water for the plant comes from one company-owned well having a 100-foot lift and from the Phoenix Water Department (fig. 48). Well water, amounting to 250,000 gpd, is used for compressor cooling and, in the galvanizing section, for makeup in pickling and rinse solutions. An additional 56,000 gpd for industrial use is obtained from the municipal supply. Approximately 212,000 gpd of compressor coolant is sent to a cooling tower, where evaporation is 28,000 gpd and blowdown is 3,000 gpd. Of the 212,000 gpd sent to the cooling tower, 181,000 gpd is recirculated for compressor cooling.

From the plant, 250,000 gpd is discharged directly into an irrigation system, and 25,000 gpd is discharged into the city sewer system.

Domestic uses in the plant area require 56,000 gpd of municipal water, all of which is discharged into the city sewers. An estimated 10 percent of the sewage is evaporated in the sewage-treatment plant, and the remaining 90 percent is returned to an intermittent stream.

Water obtainable from the company-owned well would be inadequate without the supplemental municipal supply and the 181,000 gpd recirculated.

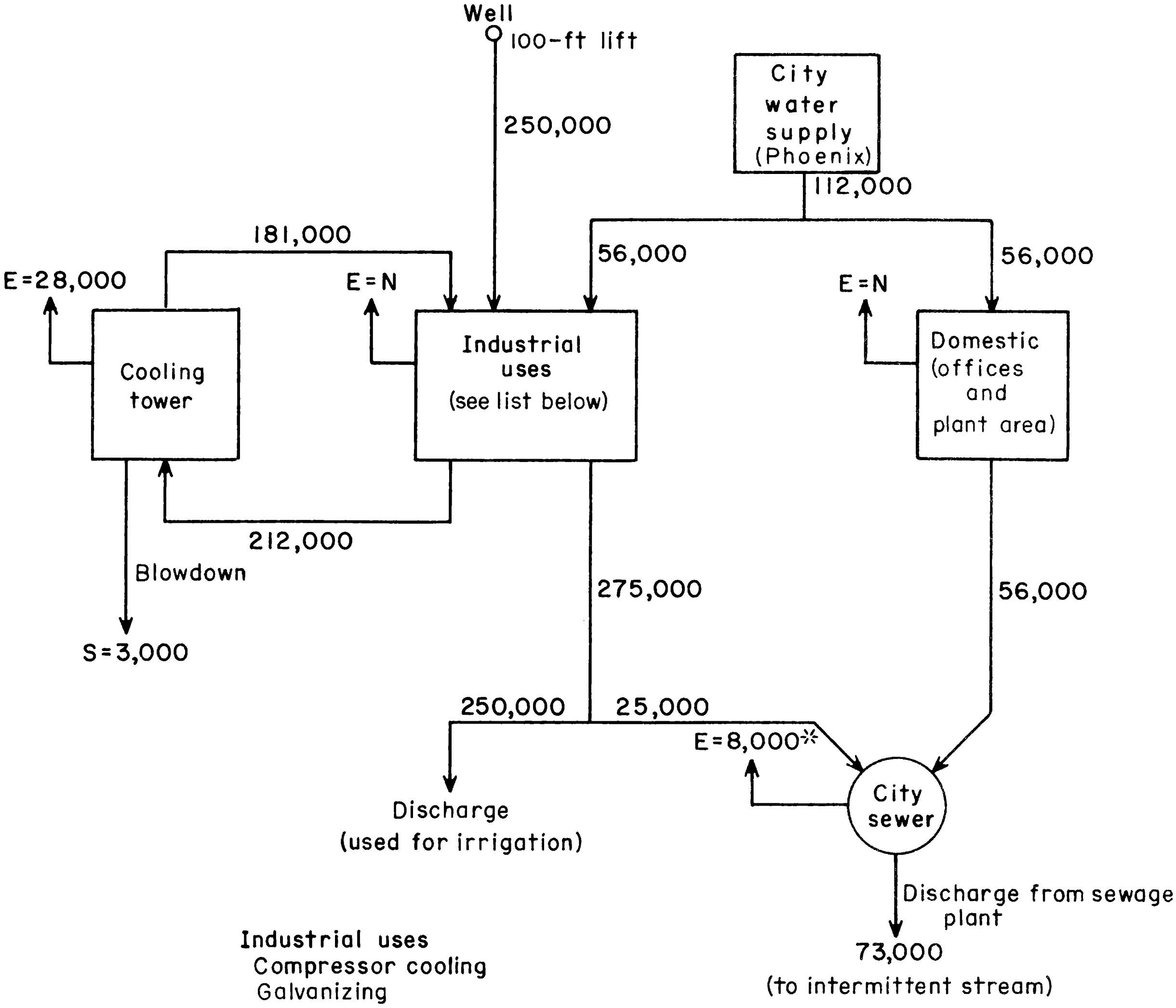
No quality problems have been encountered, and none of the water is treated by the company.

Hughes Aircraft Co.

Electronic components are manufactured at the Tucson Division of Hughes Aircraft Co. Most of the components are made for the Federal Government under Defense Department contracts, and much operational data, such as number of employees and types of products and processes, are classified. The plant is operated two shifts per day, 5 days per week.

Nearly all water used in the plant is pumped from two company-owned wells in the plant area (fig. 49). The wells, 450 and 485 feet deep, have a 100-foot lift.

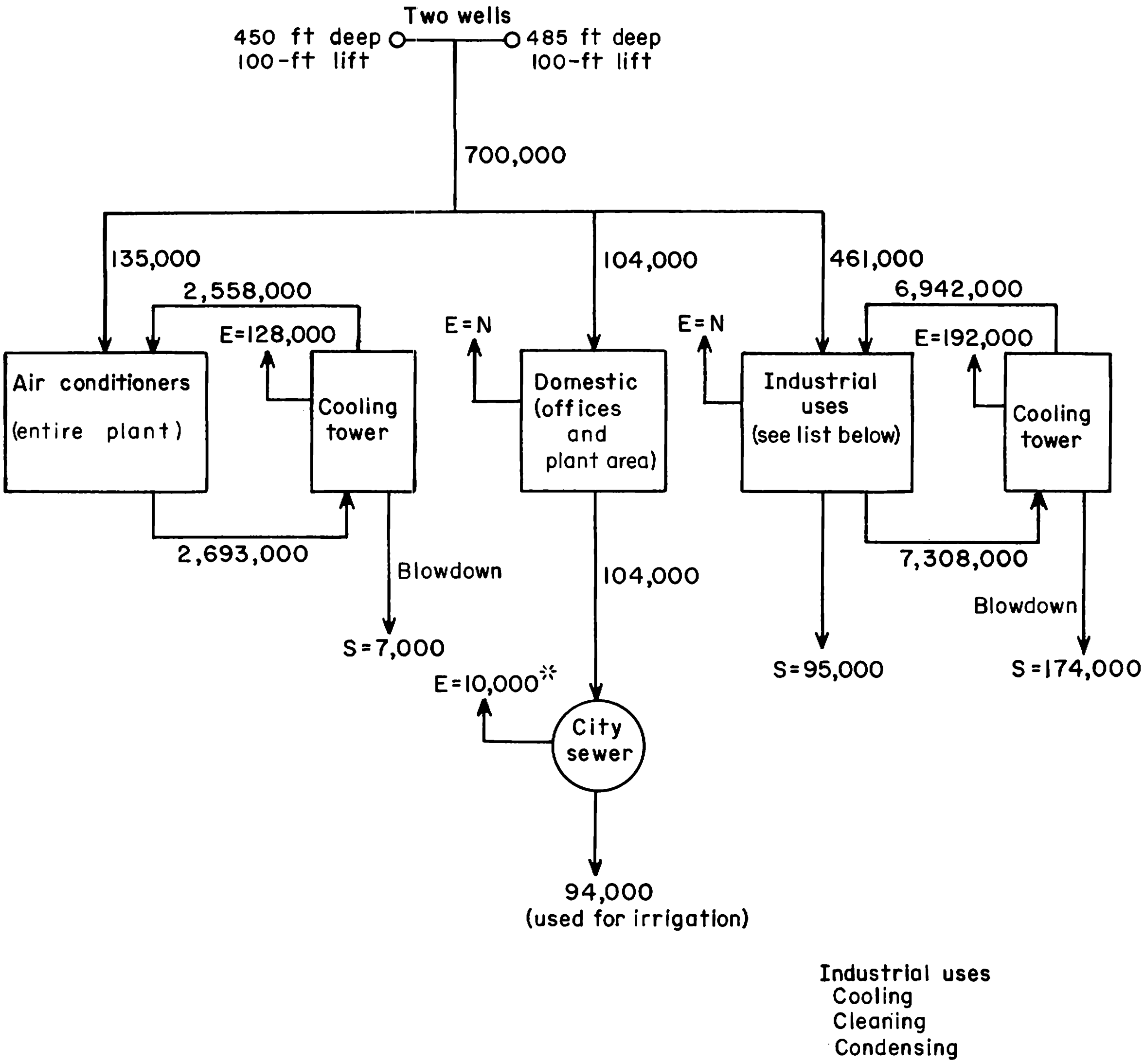
Industrial uses in the plant, including cooling, cleaning, and condensing, require 461,000 gpd of new water and 6,942,000 gpd of recirculated water. Evaporation from the cooling tower is 192,000 gpd, and the blowdown, which returns



WATER BALANCE		
	Subtotal gpd	Total gpd
Water in		362,000
Evaporation	36,000	
Seepage	3,000	
Discharge to streams	323,000	
Water out		362,000
Recirculated	181,000	

E Evaporation
S Seepage
181,000 Gallons per day
N Negligible
* Approximately 10-percent is evaporated in sewage-treatment plant

FIGURE 48. - Schematic Waterflow Diagram, Allison Steel Mfg. Co., Maricopa County, Ariz.



WATER BALANCE		
	Subtotal gpd	Total gpd
Water in		700,000
Evaporation	330,000	
Seepage	276,000	
Discharge to stream	94,000	
Water out		700,000
Recirculated	9,500,000	

E Evaporation

S Seepage

135,000 Gallons per day

N Negligible

* Approximately 10-percent is evaporated in sewage-treatment plant

FIGURE 49. - Schematic Waterflow Diagram, Hughes Aircraft Co., Tucson Division, Pima County, Ariz.

to the ground-water supply by seepage, is 174,000 gpd. An additional 95,000 gpd, not suitable for recirculation, is discharged.

Air conditioning of the entire plant takes 135,000 gpd of new water; 128,000 gpd of the new water replaces evaporation from the cooling tower, and 7,000 gpd replaces blowdown. Recirculation amounts to 2,558,000 gpd.

Water for domestic uses in the plant and offices, totaling 104,000 gpd, is discharged into the city sewer. About 10 percent of the domestic water, or 10,000 gpd, is evaporated in the municipal sewage-treatment plant, and the remaining 94,000 gpd is available for irrigation.

In October 1959, the company lessened the new-water demand 45 percent by reducing excessive flows to various units in the plant.

The new water has a hardness (as $CaCO_3$) of 250 ppm, a pH of 7.9, and 300 ppm of dissolved solids. All water is chlorinated, and boiler feed is softened. The company buys distilled water for extremely high-quality uses.

The cost of pumping new water is 1.95 cents per 1,000 gallons.

Motorola, Inc., Fifty-sixth Street Plant

Motorola, Inc., operates the Fifty-sixth Street Plant in Phoenix with 1,000 employees, one shift per day, 5 days per week. The plant product is printed circuits.

All new water, totaling some 44,000 gpd, is purchased from the Phoenix Water Department.

Industrial use in the plant requires 26,000 gpd. About 1,000 gpd is used in plating, and the remainder is used in other steps in manufacturing printed circuits. Very little is evaporated; the bulk of the water is discharged into dry wells.

Air conditioners in the plant take 5,000 gpd of new water and 818,000 gpd of recirculated water. About 4,000 gpd is evaporated, and 1,000 gpd is discharged into the dry wells.

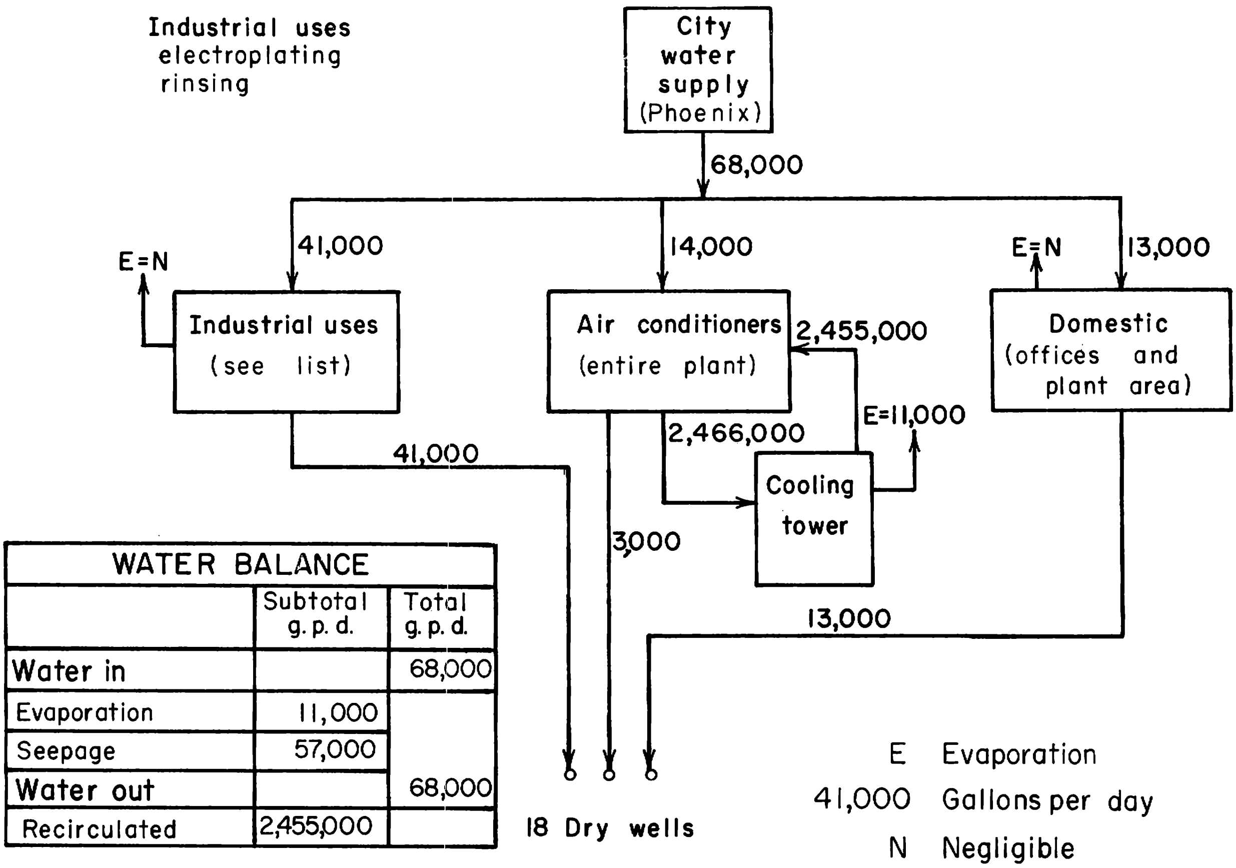
Another 13,000 gpd is required for domestic use in the offices and plant area, including the cafeteria. Nearly all of this quantity is discharged into the dry wells.

New water for air conditioning is treated with a compound to control algae and with polyphosphate to keep sludge in suspension. Water discharged from electroplating is chlorinated to break down the contained cyanide.

Motorola, Inc., Western Military Electronics Center

Motorola, Inc., operates the Western Military Electronics Center (Hayden Plant) in Phoenix. The plant is operated one shift per day, 5 days per week. Employees total 1,200.

All new water is obtained from the Phoenix Water Department (fig. 50). Total plant intake is 68,000 gpd.



WATER BALANCE	Subtotal g. p. d.	Total g. p. d.
Water in		68,000
Evaporation	11,000	
Seepage	57,000	
Water out		68,000
Recirculated	2,455,000	

FIGURE 50. - Schematic Waterflow Diagram, Motorola, Inc., Western Military Electronics Center, Maricopa County, Ariz.

Industrial needs for electroplating and rinsing amount to 41,000 gpd; little of this amount is evaporated. The effluent goes to dry wells.

Air conditioning of the plant, with refrigerative-type coolers, requires 14,000 gpd of new water; 11,000 gpd is evaporated, and 3,000 gpd is discharged into the dry wells. An additional 2,455,000 gpd is recirculated in the system.

Domestic uses in the offices and plant area, including the cafeteria, take 13,000 gpd, nearly all of which is discharged into the dry wells.

The new water has a pH of 7.4 to 7.5 and contains 300 to 600 ppm dissolved solids. Water quality varies as a result of seasonal changes in sources of the city water. Treatment of new water is limited to zeolite softening. Water in the cooling tower is treated with a polyphosphate to keep sludge in suspension, with acid to control pH, and with a nitrite to prevent corrosion. Discharged water is chlorinated to break down cyanide and to neutralize the acid.

New water cost is $485 per month for 200,000 cu ft, equivalent to 32 cents per 1,000 gallons.

Sperry Phoenix Co.

Sperry Phoenix Co. manufactures automatic aircraft controls at this plant in Phoenix.

The plant is operated two shifts per day, 256 days per year. Employees total 1,300.

All water is pumped from one company-owned well 3-1/2 miles west of the plant (fig. 51). The pumping lift is 100 feet. Water is delivered to the plant area through a buried pipeline.

Industrial uses, including degreasing, induction soldering, blueprint processing, and paint spraying, require 25,000 gpd, nearly all of which is sent to disposal areas.

Plant air conditioning takes 10,000 gpd of new water and 2,160,000 gpd of recirculated water. Evaporation from the two cooling towers is 8,600 gpd, and blowdown from the towers is 1,400 gpd.

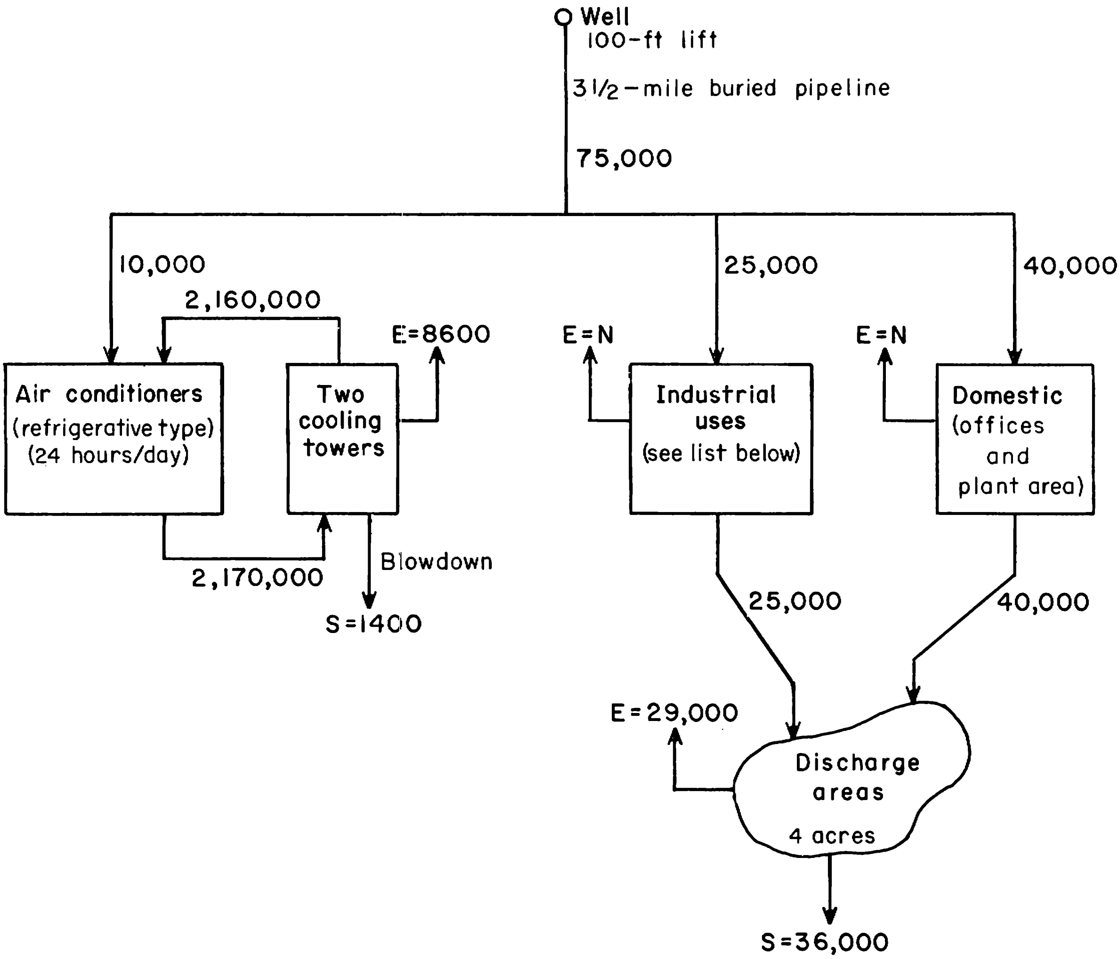
Domestic uses amount to 40,000 gpd. Little of this quantity is evaporated before it reaches the disposal area.

With large-scale recirculation in the plant, the one well provides sufficient water. In emergencies, suitable water is obtained from a privately owned water company.

Water from the well has a pH of 7.3 and contains 98 ppm total hardness (as $CaCO_3$) and 375 ppm total solids. For power, labor, and supplies, the cost of water is about 1 cent per 1,000 gallons. Water for air conditioning is treated with a patented compound to reduce scaling and prevent corrosion. This compound, added in the cooling towers, costs about $3,000 per year. Domestic water is chlorinated to 3.5 ppm residual chlorine for bacteria control.

Public-Utility Powerplants

In 1960 the three public-utility power companies in Arizona used natural gas almost exclusively in generating electricity at their nine powerplants.



E Evaporation
S Seepage
10,000 Gallons per day
N Negligible

WATER BALANCE		
	Subtotal g p d	Total g p d
Water in		75,000
Evaporation	37,600	
Seepage	37,400	
Water out		75,000
Recirculated	2,160,000	

Industrial uses;
- Paint-spray booths
- Blueprint processing
- Vapor degreasers
- Induction soldering

FIGURE 51. - Schematic Waterflow Diagram, Sperry Phoenix Co., Maricopa County, Ariz.

Production at the nine plants totaled 5.5 billion kilowatt hours. Arizona Public Service Company produced nearly one-half of the total.

Water used in 1960 at the four plants of the Arizona Public Service Company was obtained mainly from company-owned wells. The quantity pumped from these wells amounted to about 3.47 billion gallons, and 10.5 million gallons was purchased. Of the purchased water, 6.8 million gallons came from canals and 3.7 million gallons from municipal supplies. Water recirculated in condensing systems totaled 160.4 billion gallons. No data are available regarding the quantities of water consumed or the amounts returned to supply.

All cooling water at the four plants is treated with sulfuric acid to control pH; with chlorine for bacterial protection; and with either sodium hexametaphosphate or a patented compound for sequestering soluble calcium and magnesium salts and for forming a protective coating on pipes. Boiler feed is treated with (1) sodium hydroxide to adjust the pH of boiler brine; (2) with sodium sulfite, sodium phosphite, or a patented additive to scavenge oxygen; (3) with disodium phosphate, trisodium phosphate, or a patented additive to sequester soluble calcium and magnesium salts; (4) with morpholine, an organic compound, or a patented additive to control pH and form a coating on low-pressure parts. At one plant a patented compound is used to adjust pH, and another patented material is added to form a protective film on low-pressure parts in the boiler system. One of the four plants uses a hexamine to control the pH of condensate.

Water Companies

Water data for Phoenix, Tucson, and several mining communities are given in the following discussions.

The average per capita intake given for some areas may be compared with the national average of 134 gallons per person per day.

Bisbee (Warren District)

The towns of Bisbee, Warren, and Lowell are served by Warren District Water Company. This area required 350,863,000 gallons of water during the year ended January 31, 1960.

Water is pumped from several wells near Naco, on the Mexican border, 8 miles south of Bisbee. The wells are 200 feet deep and have a lift of about 80 feet. Recently, the pumps were redesigned to increase capacity.

Rates charged by the company include 57 cents per 1,000 gallons for industrial use, and 50 cents per 1,000 gallons for irrigation.

Douglas

Water for Douglas and vicinity, with a population of 12,300, is pumped from four wells. Two wells are about 2 miles west of the city, one is one-half mile north of the city, and one is within the city. The wells are 400 feet deep and have lifts of 110 to 160 feet.

In 1960, the Douglas Water Department pumped 734 million gallons, averaging 61 million gallons per month. Demand reached 100 million gallons in June and July. Per capita, water used in 1960 was 163 gpd.

Rates for all water used in excess of minimum quantities are 15 cents per 1,000 gallons up to 130,000 gallons, and 10 cents per 1,000 gallons in quantities above 130,000 gallons.

Effluent from the sewage-disposal plant goes into Whitewater Creek, which flows across the international border into Mexico where it is used in agriculture.

Globe-Miami Area

Globe, Miami, and nearby areas, with a combined population of 14,000, are served by three water companies. The water sources, quantities pumped, and other pertinent data are summarized in table 5.

TABLE 5. - Water companies in Globe-Miami area, 1960

Company	Water sources	Treatment	Adequacy	Quantity pumped (million gallons per year)	Rates[1] (cents per 1,000 gallons)
Arizona Water Co.	One 68-foot "dug" well. Six 400-to 800-foot wells.	Chlorine, cold lime, alum.	Occasionally barely adequate.	127	30-to 150
Citizen's Utility	Two 150-foot wells. One 175-foot well.	None	No shortage	75	40-to 80
Globe City Water Dept.	100- to 300-foot wells.	Chlorine	Water shortage at present.	150	60-to 85
Total				352	

[1] Rate depends on quantity used.

The present shortage at Globe should be relieved when two additional wells, now being drilled, are completed.

Phoenix

Water for Phoenix is obtained from several sources. The primary source is a group of wells along the Verde River, 35 miles northeast of the city. During periods of peak demand, output from these wells is supplemented with water from a group of lower quality wells nearer the city and with treated surface water from the Verde and Salt Rivers. Some water is obtained from the Arizona Canal. All water is chlorinated.

The Phoenix Water Department pumped 32 billion gallons, or 88 million gpd, in 1960 to supply about 90 percent of the metropolitan area. Population of the area served was 495,000, and the per capita quantity pumped was 178 gpd.

Rates in Phoenix are about one-half as high as those outside the city. Inside the city a minimum monthly quantity of 1,000 cubic feet (7,500 gallons), on the smallest meter, costs $2.40, or 32 cents per 1,000 gallons. The first 60,000 cubic feet in excess of the minimum, for any size of meter, costs 14.5 cents per 100 cubic feet, or 19 cents per 1,000 gallons. In excess of 300,000 cubic feet, the rate drops to 9 cents per 100 cubic feet, which is about 12 cents per 1,000 gallons.

Batch discharge of waste by some industrial plants is detrimental to sewage treatment; concentrations of certain wastes are toxic to the bacteria necessary in the treatment process. Eleven billion gallons of sewage was treated in 1960, an average of 30 million gpd in the two municipal treatment plants. One plant, with a capacity of 30 million gpd, uses the "activated sludge" method of treatment. The other plant, with a capacity of 5 million gpd, uses the biological filter method. Effluent from the treatment plants goes into the Salt River. An estimated 10 million gpd of the effluent is used for irrigation.

Superior

Superior, with a population of 4,875, purchases water from the Arizona Water Company at $1.00 per 1,000 gallons. The water is pumped from two 700-foot-deep wells in the desert 19 miles west of the town. Because the water is delivered through a surface pipeline, in summer the water arrives at Superior at temperatures as high as 140° F. It is cooled by reservoir storage.

No information is available regarding the quantity pumped per year, or per capita demand. Some septic-tank effluent is used for lawn irrigation.

Tucson

The Tucson Water Utility pumps water from 190 wells to supply a metropolitan area of 227,000 people. The wells, all in the 50-square-mile metropolitan area, have an average lift of 250 feet. The maximum lift is 300 feet and the minimum 150 feet. A total of 13.7 billion gallons was pumped during the year ended February 1, 1961. An estimated 50 percent of this amount was used for watering lawns.

Water quality varies considerably, depending on the source; treatment is limited to adding a small amount of chlorine. Water rates per 1,000 gallons range from about 20 cents, for large quantities within the city limits, to 85 cents, for small quantities in remote areas.

Sewage is treated in two municipal treatment plants, each with a capacity of 12 million gpd. One uses the activated-sludge method of treatment and the other the trickling-filter method. Treated effluent from these plants, now 14 to 15 million gpd, is used for irrigating a 2,500-acre farm.

Per capita demand for water in Tucson averaged 140 gpd for the 10-year period, 1949-59. In fiscal year 1959-60, the per capita demand increased to 157 gpd. As a result of pumping in excess of the recharge rate, the water table is dropping an average of 1.5 feet per year. (In some residential areas this situation has caused measurable subsidence). A 10-year program is now underway to bring more water into the Tucson area.

Agriculture

Reportedly, about 90 percent of the water withdrawn from surface and ground-water sources in Arizona goes to agricultural uses.

Table 6 shows water requirements, acres irrigated, value of product, and value per 1,000 gallons of water. The value of product per 1,000 gallons of water ranges from 6 cents for hay to $4.52 for lettuce. For cotton, the most extensively cultivated crop, the value of product per 1,000 gallons is $0.46.

The economic importance of water and its indispensability in certain industrial processes are strikingly demonstrated in Navajo County: After many years of search for an adequate water supply, Southwest Forest Industries is building, about 30 miles northwest of Show Low, a 32-million-dollar papermill that will require 8 million gpd of new water. Annual production from the plant, which will employ 375 workers, will be 75,000 tons of newsprint and 65,000 of kraft. Pulpwood will come from the nearby Sitgreaves National Forest, the largest stand of ponderosa pine in the United States.

Water for the mill was found some 17 miles east of the millsite. Three wells have been drilled to a depth of 750 feet. Testing has indicated that the underground source could provide as much as 30 million gpd. Near the millsite is a dry lake bed to be used for disposal of waste water.

WATER USE AND MINERAL-PRODUCT VALUE

A measure of the importance of water in industrial processes is the "value added" to the materials processed, per unit quantity of water used. In some industrial operations, such as producing metals from the low-grade Arizona ores, value added constitutes much of the "value of product." As value

TABLE 6. - Value of Arizona agricultural production in 1958, by water used[1]

	Water needed inches	Acres in use	Product unit value	Product total value, thousands of dollars	Value per 1,000 gallons of water
Winter wheat.............	21	130,000	$ 1.75/bushel	$ 6,800	$0.09
Barley....................	21	203,000	1.07/bushel	10,100	.09
Sorghum grain............	21	93,000	1.25/bushel	6,000	.11
Hay......................	52	262,000	25.00/ton	23,400	.06
Potatoes.................	16	9,600	2.64/cwt	4,700	1.13
Cotton...................	32	377,000	.38/pound	150,000	.46
Cantaloup................	22	12,000	5.83/cwt	8,400	1.17
Lettuce..................	6	64,000	5.00/cwt	47,200	4.52
Livestock with forage....	--	([2])	93.37/head	88,700	.30

[1] Source: Michaelson, S. D., B. H. Ensign, S. J. Hubbard, and A. W. Last. Water, a Raw Material for the Production of Copper. AIME Preprint 60H98, 1960, 17 pp.

[2] 950,000 head.

added information is not available for 1960, the authors have used value of product to measure the importance of water at copper and lead-zinc operations and at all mineral-industry operations listed in table 7.

The copper and lead-zinc operations accounted for about 99 percent of the total 1960 Arizona production of copper, lead, zinc, molybdenum, gold, and silver. The smelter-product value of production from these operations was $357,424,000. This figure includes value of metals recovered at 7 integrated operations, as well as value of recoverable metals in concentrates and precipitates shipped from 13 nonintegrated operations.

New water used at these operations, in mining and processing, in powerplants, and for domestic and miscellaneous purposes totaled 23,409 million gallons. This amount includes an estimated 891 million gallons required in smelting concentrates and precipitates shipped from the 13 nonintegrated operations.

Computed from the totals just given, the value of product for each 1,000 gallons of new-water intake was $15.27. The unit value of production per 1,000 gallons consumed is obtained similarly. Total consumption amounted to 13,593 million gallons, and the value of product per 1,000 gallons consumed was $26.29.

Further economic benefit from the use of water is the large-scale employment resulting from such use: 13,619 persons were employed in 1960 in the operations just considered.

For all mineral industries listed in table 7, the value of production was $13.54 per 1,000 gallons of new-water intake and $26.69 per 1,000 gallons consumed. These unit values are computed from a total production value of $379,073,000, new water amounting to 27,995 million gallons, and consumption to 14,205 million gallons.

FUTURE SUPPLY AND DEMAND

Future water supply and demand depend on many factors - economic, technologic, and political.

In Arizona most of the water required by the mineral industry is used in copper operations. At the present rate of production, the State has a 30-year reserve of copper ores of economic grade. Tending to compensate for depletion is the occasional discovery of additional ore comparable in grade with that of ores now being utilized. Probably of much greater importance, however, in extending the life of the copper industry will be a progressive lowering of the economic grade by changes in processing methods.

Some of the factors affecting adequacy of the water supply and quantities required for the Arizona mineral industry in general are discussed under the Supply and Demand sections. Obviously, because of the interdependence of the factors involved, the supply-demand situation is highly complex.

TABLE 7. - Total new water required and consumed, major Arizona mineral-industry operations, 1960

Commodity	Production	Value, thousands of dollars	New water millions of gallons	Water consumed millions of gallons	New water, consumed, percentage
Metals:					
Copper, Lead, zinc	1,154,811,700....pounds..	[1] $357,424	[2] 23,409	[2] 13,593	58.1
Uranium	283,684....tons (ore)..	6,219	111	64	57.6
Total	-	363,643	23,520	13,657	58.1
Nonmetals:					
Cement	[3] 5,300,000...barrels..	([4])	(200)	(103)	51.5
Lime	150,000......tons..	2,430	30	18	60.0
Sand and gravel	[5] 12,668,600......tons..	[5] [6] 13,000	4,445	530	11.9
Total[7]	-	15,430	4,475	548	12.2
Grand total[7]	-	379,073	27,995	14,205	50.7

1 Value after smelting, including byproducts.
2 Includes estimated water necessary for smelting ore and concentrates shipped from nonintegrated operations.
3 Annual capacity.
4 Figure withhelt to avoid disclosure of individual-company data.
5 Includes only washed sand and gravel.
6 Estimated.
7 Excluding cement.

Supply

The supply of water available to the mineral industry would be favorably affected by allocation based on economic considerations, including value of product and employment.

In competition for water, the industry as a whole is able to pay a higher price than are agricultural users. Also tending to increase the amount available to the industry would be an increase in the overall supply resulting from the development of successful methods of weather modification or discovery of additional ground-water reservoirs. Improvement in conventional water-treatment practices and development of economic methods of converting saline or brackish water offer possibilities.

The supply of usable water available to the mineral industry is adversely affected by such factors as a decrease in the overall supply resulting from the drop in the water table, deterioration of quality in some well areas, and increase in demand by other users.

Demand

Development of additional water-using mineral industries, for example, one to utilize the large titaniferous iron deposits of the State, would raise the water needs. New mineral-processing methods may, in some cases, involve higher demand. In flotation, the quantity of water needed is generally proportional to tonnage processed; therefore, a drop in grade of ores processed by this method tends to increase demand. Population increase, with consequent market expansion, results in greater demand for water by industries such as the sand-and-gravel industry. Many mineral-industry operations would use more new water if the cost of water were lower.

Demand may be decreased by technical changes in mineral processing, by improvements in water-treatment methods to permit more recirculation, or by improvements in methods used to control evaporation. Demand may also be lessened as a result of substitutions, such as plastics for certain metals used in construction, or aluminum for copper.

In table 8, water-demand data are projected from 1960 to 1980 for the mining-flotation-smelting and leaching-smelting methods of recovering copper. The data do not include water for powerplants or for domestic and miscellaneous uses. The projection is based on certain assumptions, listed as footnotes, that seem reasonable at this time. No attempt was made to project water requirements of other Arizona mineral-extraction industries because their requirements are relatively small and the data necessary for projection were not readily available.

Estimating on the basis of data given in table 8, the total 1980 intake (new, recirculated, and transferred water) by the copper industry will be 50 percent greater than in 1960, and the demand for new water will increase by 20 percent.

TABLE 8. - Water requirements for Arizona copper production in 1960 and 1980

	Quantity	1960	1980
Copper production:			
By mining-flotation-smelting method	million pounds	1,001	[1]1,150
By leaching-smelting method	do	66	[1]130
Total	do	1,067	[2]1,280
Water demand:[3]			
By mining-flotation-smelting method:			
Average total intake per pound of copper produced	gallons	58.2	[4]75
Total intake	million gallons	58,258	86,250
New intake (percent of total intake)	percent	27	[5]20
New intake	million gallons	15,730	17,250
By leaching-smelting method:			
Average total intake per pound of copper produced	gallons	30.8	[6]34
Total intake[7]	million gallons	2,051	4,420
New intake (percent of total intake)	percent	85	85
New intake	million gallons	1,743	3,757
Totals:			
Total intake	do	60,309	90,670
New intake	do	17,473	21,007

[1] Greater proportion is assumed to come from leaching; in 1960 leaching accounted for 6 percent of total copper; in 1980, 10 percent.

[2] Total copper production in 1980 is assumed to be 20 percent greater than in 1960.

[3] Demand excludes powerplants, domestic uses, and miscellaneous uses. The figures for 1980 are projected from 1960 data for operations that accounted for 99 percent of State copper production.

[4] This assumes a decrease in grade of ore treated by flotation. In 1960, grade averaged about 0.90 percent and recovery about 81 percent. With an estimated average decrease of 0.01 percent per year, 1980 grade will average 0.70 percent. The water required per pound of copper produced was increased on the assumption that the water required per ton of ore and the percentage of copper recovered would remain constant.

[5] This assumes that some increase in reuse will be made possible by better water-treatment methods and made necessary by higher water costs.

[6] This assumes a decrease in grade of material being leached and a consequent 10-percent increase in losses per pound of copper produced.

[7] Leaching in the LPF (leaching-precipitation-flotation) process is excluded.

APPENDIX

TABLE A-1. - RESULTS OF WATER ANALYSES

ppm. (except pH)

No.	Operation and description	Total solids	Dissolved solids	Total hardness as $CaCO_3$	Temporary hardness as HCO_3^-	Organic N	Organic C	Ca^{++}	Mg^{++}	Cl^-	F^-	Na^+	K^+	$CO_3^=$	$SO_4^=$	Total S	pH
1	Magma-Reclaimed from smelter pond.	4,685	3,791	2,079	2,069	0.5	7.1	624	124	226.0	8.6	255.0	48.0	1.4	2,492	848	3.2
2	Magma-New from Arizona Water Co.	463	441	223	220	1.0	3.9	57	19	110.0	3.7	60.0	4.0	118.0	60	21	8.05
3	Inspiration-New from Pringle.	1,820	1,814	1,213	1,185	1.5	2.3	364	67	23.6	1.9	60.0	6.0	119.0	1,072	366	7.6
4	Inspiration-New from Pinal and Well 31.	1,583	1,545	1,047	1,037	2.4	1.2	318	59	24.0	.7	53.5	6.0	170.0	860	285	8.4
5	Miami-New from Old Dominion.	585	574	396	391	6.0	5.0	107	30	26.0	.9	45.5	4.0	143.0	183	65	8.2
6	Miami-Waste from precipitation tanks.	15,653	15,643	2,495	2,470	5.6	9.4	414	349	24.0	35.0	35.0	13.0	17.7	9,676	3,265	2.75

TABLE A-1. - RESULTS OF WATER ANALYSES (Con.)
ppm. (except pH)

No.	Operation and description	Total solids	Dissolved solids	Total hardness as $CaCO_3$	Temporary hardness as HCO_3^-	Organic N	Organic C	Ca^{++}	Mg^{++}	Cl^-	F^-	Na^+	K^+	$CO_3^{=}$	$SO_4^{=}$	Total S	pH
7	Copper Cities-New from Solitude and Employees' Garden.	1,481	1,434	869	865	.4	5.1	282	39	28.8	1.2	80.0	26.5	68.2	901	319	7.8
8	Copper Cities-Reclaimed from tailings thickener.	1,925	1,915	1,110	1,080	.3	3.5	421	7	42.0	3.0	118.0	60.5	53.2	1,173	424	8.0
9-14	Confidential data.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Pima-New from wells.	428	426	180	179	4.3	4.2	55	10	9.2	5.0	54	3	146	135	45	8.50
16	Pima-Reclaimed from tailings pond.	1,334	1,326	691	682	4.5	1.4	268	3	26.4	5.6	78	30	34	780	266	7.85

17	Banner-New from Mineral Hill mine.	1,715	1,695	1,079	1,075	.5	4.3	303	77	33.6	1.9	45	18	112	979	332	8.35
18	Esperanza-New from wells.	298	295	115	111	1.7	<1.0	38	4	5.6	1.6	35	3	164	39	14	8.60
19	Esperanza-Reclaimed from tailings thickeners.	470	425	132	129	.1	5.7	50	1	6.8	6.0	45	37	19	204	76	9.05
20	Silver Bell-New from wells.	268	244	98	97	1.0	<1.0	34	3	4.4	1.4	34	3	140	23	8	8.50
21	Silver Bell-Reclaimed from tailings thickeners.	1,772	1,731	935	929	1.0	5.5	370	1	26.0	3.7	125	35	85	969	337	10.45
22	Silver Bell-Reclaimed from tailings pond.	2,033	1,997	1,053	1,051	1.0	4.7	391	18	43.2	3.5	158	45	76	1,191	405	8.00

TABLE A-1. - RESULTS OF WATER ANALYSES (Con.)
ppm. (except pH)

No.	Operation and description	Total solids	Dis-solved solids	Total hard-ness as $CaCO_3$	Temp-orary hard-ness as HCO_3^-	Org-anic N	Org-anic C	Ca^{++}	Mg^{++}	Cl^-	F^-	Na^+	K^+	$CO_3^=$	$SO_4^=$	Total S	pH
23	Douglas-New from wells.	1,295	1,291	33	29	1.0	12.9	7	3	333.0	5.6	432	5	177	309	109	8.80
24	Copper Queen-New from Copper Queen Mine.	1,081	969	685	682	1.5	<1.0	193	46	12.4	2.5	20	3	158	529	185	7.90
25	Copper Queen-Reclaimed from tailings pond.	1,402	1,395	856	850	1.3	2.2	337	2	24.0	1.5	33	27	19	872	297	7.65
26	Johnson Camp-New from well.	945	925	14	14	1.0	1.2	4	1	210.0	9.7	325	2	240	126	43	8.90
27	Johnson Camp-New from underground mine.	406	391	248	245	1.2	<1.0	62	22	10.4	1.1	28	2	230	24	8	8.45

28	Johnson Camp-Waste.	990	968	295	291	1.4	9.1	105	7	148.0	6.1	200	14	128	356	136	8.45
29	Atlas-New from well.	2,208	2,197	1,373	1,248	0.65	1.8	455	27.5	26	5.5	51	3	82	1,329	460	7.9
30	Atlas-New and reclaimed from mill reservoir.	2,366	2,195	1,399	1,280	.81	1.1	467	28.1	28	16.0	51	3	72	1,356	464	7.9
31	Iron King-Reclaimed from tailings thickener.	825	611	165	154	2.6	2.4	61	.5	19	5.5	133	18	46	187	91	11.5
32	Iron King-Waste before final settling.	1,359	995	418	341	3.1	4.3	105	19.1	51	3.3	157	6	175	492	172	7.7
33	Iron King-New from wells.	669	663	36	35	.84	.8	9	4.1	17	7.6	268	6	545	31	12	8.4
34	Bagdad-New from Burro Creek.	379	313	160	146	.18	<.1	41	10.6	16	2.2	34	5	278	14	8	8.55

TABLE A-1. - RESULTS OF WATER ANALYSES (Con.)
ppm. (except pH)

No.	Operation and description	Total solids	Dissolved solids	Total hardness as $CaCO_3$	Temporary hardness as HCO_3^-	Organic N	Organic C	Ca^{++}	Mg^{++}	Cl^-	F^-	Na^+	K^+	$CO_3^=$	$SO_4^=$	Total S	pH
35	Bagdad-Reclaimed from tailings pond.	911	825	356	341	.30	.9	132	2.7	51	3.4	80	24	61	469	166	10.0
36	Bagdad-New from well (domestic).	334	319	162	147	.62	<.1	48	6.5	13	5.1	45	3	270	12	5	8.4
37	Old Dick-New from mill building.	323	300	169	148	0.30	<0.1	41.0	11.2	15.0	1.2	32	5.0	225	21	10	8.6
38	Old Dick-Reclaimed from zinc tailings thickener.	1,795	1,300	618	575	.45	1.3	228.0	1.6	38.0	2.8	118	39.0	45	755	326	6.1
39	Old Dick-Waste (in tailings pond).	1,333	1,321	570	562	.74	2.5	211.0	8.8	42.0	3.5	140	36.0	19	815	321	6.5
40	Mission-New from wells.	325	321	142	117	.6	4.7	42.8	7.1	.36	5.8	38	4.0	131	74	25	8.1

41	Lakeshore-New from well.	640	630	136	121	2.4	3.1	32.1	9.6	93.2	7.3	175	4.0	172	140	47	8.4
42	Tuba City-New from well.	196	195	103	97	2.5	<.1	35.7	1.6	.40	15.3	14	3.0	112	21	8	8.0
43	Tuba City-Waste to tailings pond.	127,570	9,474	5,025	2,949	168.0	4.9	503.4	411.0	19.6	5.4	68	10.5	48	5,489	1,865	2.5
44	Tuba City-Moenkopi, Wash, 3 miles up-stream.	601	515	194	194	.3	4.4	58.9	11.2	4.0	1.9	85	4.0	204	210	72	8.3
45	Tuba City-Moenkopi, Wash, 7 miles down-stream.	900	545	207	191	.3	2.7	5.4	10.6	6.0	1.6	118	4.0	176	284	95	8.5

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