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ASARCO

Southwestern Exploration Division

JHC

April 5, 1977

J. H. C.

APR 7 - 1977

file
Silver Bell

TO: S. A. Anzalone

FROM: F. T. Graybeal

Uranium in mill water

I understand that Westinghouse is so desperate that they have approached a number of copper mining companies with respect to solvent extraction of uranium from mill water. Dick Ahern of Kerr-McGee tells me that Westinghouse is about to go on-stream with one of these plants in a porphyry copper mine he would not name. Silver Bell is well-known for its torbernite and, if Westinghouse has not already approached the Mining Dept., I wonder whether such an arrangement might be of interest to Asarco.

F. T. Graybeal

F. T. Graybeal

FTG:lb

cc: WLKurtz

ASARCO

Mining Department

March 3, 1977

J. H. C.

MAR 4 - 1977

Silver Bell

Mr. F. T. Graybeal
Building

Attached is an interesting, though somewhat speculative, paper by Jim Galey concerning a possible gravity slide at the Silver Bell mine and the resultant exploration potential in the West Silver Bell Mountains.

In view of the publication of the Vaca Hills Quadrangle geological map and the exploration activity it may generate, I believe Galey is correct to suggest that the area be studied in more detail. If his hypothesis is correct, some of the gravel covered areas adjacent to the West Silver Bell Mountains might be worth considering as exploration targets.

You may wish to discuss this further with Jim Galey and then assign someone from the Exploration Department to carry out some work in the region.

S. A. Anzalone

SAA:ka
Attach.
cc: JHCourtright

Harold:

Please return the attachment to me, as it is the original and my only copy.

S-10.10

original returned to SAA 3/4/77

J.H.C.
MAR 4 - 1977 → SAA

SILVER BELL UNIT

February 24, 1977

MEMO TO: MR. D.R. JAMESON

FROM: J.L. GALEY

SUBJECT: A POSSIBLE GRAVITY GLIDE AT SILVER BELL

Summary

In a regional and comprehensive evaluation of the Silver Bell District, evidence has suggested that the upper portion of the Silver Bell deposit could have been removed by gravity gliding at an age of less than 17 m.y. ago. The West Silver Bell Mountains may represent the upper portion of the deposit. The gravity glide hypothesis demands urgent attention and extensive geologic mapping is indicated.

Background

After touring several mines in Arizona in the spring of 1976, it became apparent that many of the deposits have one feature which was common among them; that being major post mineral faulting. The more notable deposits are:

San Manuel - Kalamazoo
Mission - Pima - Twin Buttes
Florence
Lakeshore
La Caridad
Sacaton

Silver Bell became more and more of an exception. Therefore, I considered that if post-mineral faulting had occurred, where would it be visible at Silver Bell. The obvious solution was that because we see no major displacements, a low angle fault and removal of the upper part of Silver Bell could be a possibility. This memo is the results of this hypothesis.

Silver Bell Geology

Before listing the criteria for a gravity glide at Silver Bell, a brief description of Silver Bell geology is necessary.

The Tertiary stratigraphy consists of older Tertiary gravels and sediments designated as Unit I. They are characterized by regional tilting. Interbedded and overlying Unit I is the northeast tilted Tertitary volcanics and dated at 19.5 - 22 m.y. Overlying the volcanics, is a sequence of gravels and sediments with horizontal attitudes designated as Unit II. The angular unconformity between the volcanics and Unit II displays the Basin and Range structural activity in the area. Inspection of the dips of bedding and foliations in Unit I and the volcanics surrounding Silver Bell give an approximate average dip of 30° toward the northeast. The resulting conclusion is that the Silver Bell deposit also is tilted 30° from its original position. Therefore, Watson reached an incorrect assumption when he concluded the dip of the Silver Bell Complex and the Mount Lord Ignimbrite were a result of withdrawl of the ignimbrite and doming by the monzonite. Most of the dip is a result of a regional tilting of the entire area during the Basin and Range uplift at 12 to 17 m.y. ago. *as in Tucson mts*

A detailed inspection of the Silver Bell Mountains shows that the stratagraphic highs (Mount Lord) occupy the topographic highs, and the intrusives occupy the topographic lows. This results in a 10° cross section. Thus, the 30° tilt combined with the 10° section from topography gives a 40° cross section into the Silver Bell alteration system.

Two basic conclusions are immediately recognized. First, the problem of why the ENE trending monzonite and syenodiorite dikes disappear as the alaskite is approached can be hypothesized. That being the fault system is either associated with, or a result of intrustion of the monzonite, and the steeply dipping faults are located above and peripheral to the intrusive body. Also, the monzonite becomes more of a stock in the pit area as would be expected as the top of a pluton is approached. The large stock west of Oxide Pit becomes less of an egnima because the larger portions of the pluton are being exposed with increasing depth into it. The second conclusion is that the propylitic alteration becomes more explicable. The widespread alteration in the northeast would be more noticable because of the 40° cross section and because it occurs higher in the porphyry system. The southwest propylitic zone is not as pronounced because it is lower in the porphyry system and thus not as prominent and less intense.

Discussion

The following is a list of evidence for a possible gravity glide and resulting displacement of the upper portion of the Silver Bell ore body. The data suggests that the West Silver Bell Mountains are the displaced portion.

1. The stratagraphic similarities between the West Silver Bell Mountains and the Silver Bell Mountains are notable. The Claflin Ranch, Silver Bell Complex, and the Mount Lord are present in both areas. The Paleozoic and Mesozoic sediments are present, but their relationship from one area to the other is not completely understood.

2. The youngest Paleozoic formation in the Silver Bell Mountains is the Sherrer, and the oldest exposed stratagraphic formation in the West Silver Bell Mountains is Sherrer. This simply suggests that the youngest Paleozoics (Sherrer and Concha) are encountered in the upper portion of the proposed faulted section as would be expected.

3. Of major importance is the northeast trend of linears in the West Silver Bell Mountains as noted by J.R. King (1970). Also, the granodiorite-syenodiorite-monzonite dikes strike in this same general direction. In the Silver Bell Mountains the trend of the dikes are N70E. Thus, it is suggested that the upper faulted portion, which would be the West Silver Bell Mountains, was rotated 20° to 30° during gliding. Also, the regional dip of bedding and foliations is slightly greater in the West Silver Bell Mountains, which could suggest some vertical tilt associated with the rotational gravity gliding.

4. The presence of granodiorite-syenodiorite-monzonite dikes suggest similar intrusive rocks as compared to those at Silver Bell. As stated previously, these dikes could represent the peripheral or upper portions of the porphyry system. The presence of a fine grained granite (?) in the western portion of the West Silver Bell Mountains might suggest an upper fine grained equivalent of the Silver Bell alaskite. Such a possibility needs further investigation. Also, a fine grained granite texturally similar to alaskite was noted south of section 35,T11S,R7E.

5. The gravity glide is suggested to have occurred during the 12 to 17 m.y. time interval which is dominated by Basin and Range tectonics and regional tilting.

6. The change to an E-W strike of the Ragged Mountain Fault in the West Silver Bell area could be the result of gravity gliding with rotation. Thus the rotation of the fault would be compatable with the proposed rotation for the northeast linears and the strikes of the granodiorite-syenodiorite-monzonite dikes.

7. Reconnaisance of the West Silver Bell area revealed a breccia pipe in section 25 of T11S, R7E. The pipe is oval in shape with approximate dimensions of 300' in the long axis and 100' in the short axis. The clasts consist of granodiorite, Mount Lord, and a coarse grained granite (the major constituent). Examination of the granite shows a texture similar to alaskite. Only one large feldspar phenocryst (approximately three-fourths inch in size) was found. Also, several pieces of schist were found. This would tend to suggest Precambrian Oracle. No notable mineralization was found except for one piece of massive quartz approximately three inches in diameter.

8. Drill hole #KK-1 from West Silver Bell contains Precambrian Oracle from 915' to 946' (EOH). The presence of the Precambrian Oracle at these shallow depths is unexpected and could possibly suggest gravity gliding. Also, it should be carefully examined to insure it is Precambrian Oracle and not the Silver Bell alaskite.

9. Of note is the occurrance of skarn in the Paleozoics in the El Tiro Hills area, and an apparent decrease in propylitization toward the north. This is highly suggestive of the situation in the Silver Bell deposit. Thus the inference is an increase of alteration toward the SSW.

10. Of note is that El Tiro Pit is possibly lower in a porphyry system than Oxide Pit. The grade of copper from chalcopyrite in the protore is 0.25% Cu in El Tiro and approaches 0.40% Cu in Oxide. Therefore, the suggestion is that the upper portion of the proposed faulted deposit could attain much higher values of chalcopyrite than is found in Oxide and El Tiro pits. It should be noted that petrographic examination of thin sections from several deep holes in Oxide and El Tiro show a noted decrease in alteration at depth. Also, a corresponding decrease in copper assays with less vein sulfides accompanies the decrease in alteration. Thus, the suggestion is that the pits are in the lower portion of the porphyry system.

11. If the faulting occurred after the 12 to 17 m.y. interval that would suggest that the chalcocite blanket is younger than the Tertiary volcanics. It is interesting to note that there is no evidence that the blanket has been tilted. As it is certain that the Silver Bell deposit has been tilted, the conclusion is that the blanket was readjusted after tilting, or it is a relatively young blanket. If it is a young blanket, the possibility exists that it started to form after the proposed gravity glide occurred.

Concluding Remarks

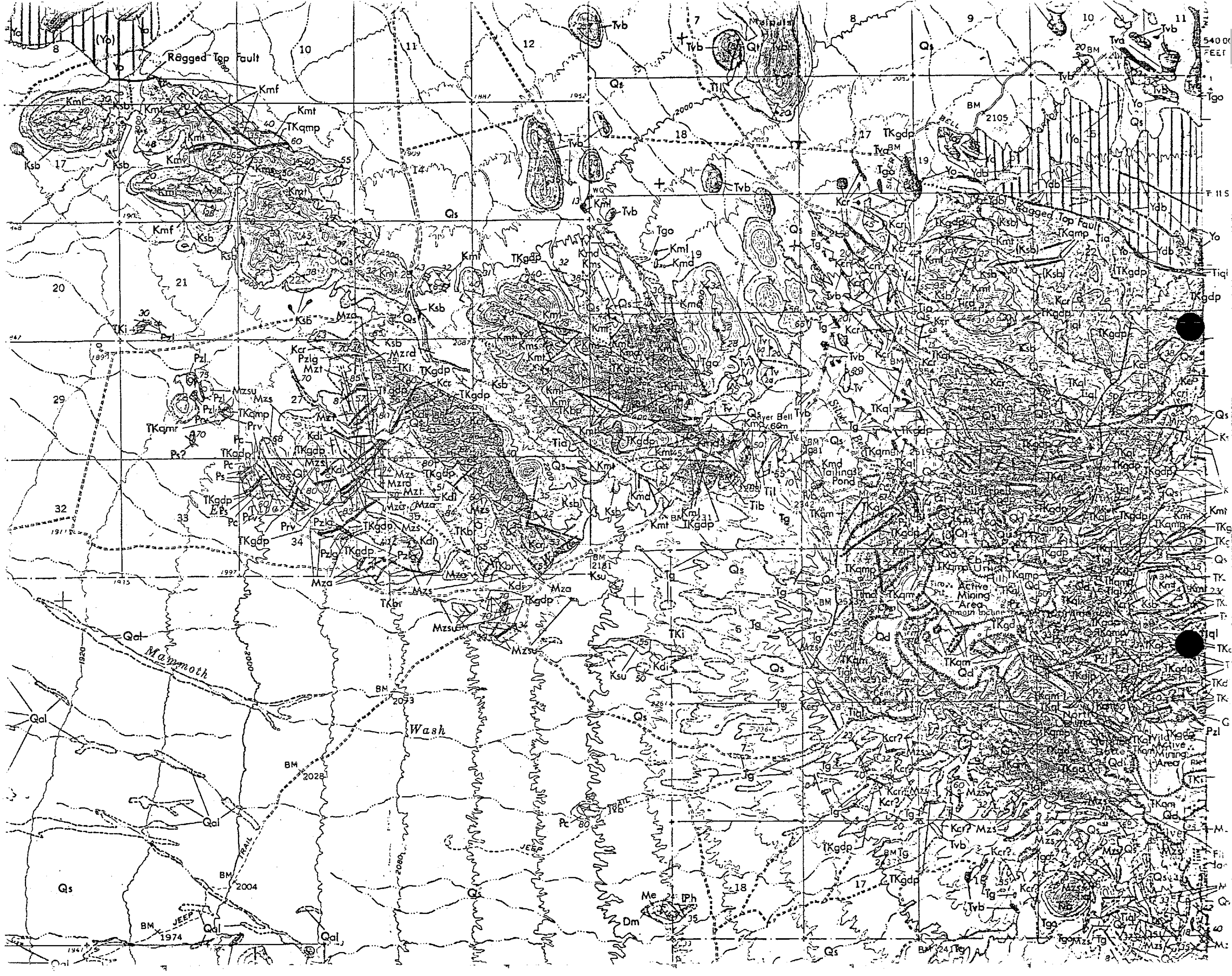
The above data are suggested as evidence for a possible gravity glide. I am not totally convinced that such an occurrance has taken place at Silver Bell. I believe there are spatial and structural data which would suggest no faulting has occurred. However, I think the accumulation of the above data warrants an extremely detailed investigation of the greater Silver Bell District. The matter should be considered as soon as possible. With the publication of the geologic map of the Vaca Hills Quadrangle, many of the above similarities between the West Silver Bell Mountains and the Silver Bell Mountains are readily available to everyone. Also, the map depicts the location of the breccia pipe. This will undoubtedly cause interest when noted. Therefore, it is imperative that the matter be given immediate attention.

I believe that the relationship between the tilted alteration system and the Atlas Fault has not been completely investigated. The alteration system is displaced either toward the south or north depending upon whether the Atlas fault is pre or post Basin and Range tilting. Also if a gravity glide has occurred, the structural relationships become more complex depending upon relative ages of the gravity glide and the Atlas Fault.

J. L. Galey
J. L. GALEY
Resident Geologist

JLG/me

cc: SAAnzalone w/attach.


Ragged Top Fault
Malpais Hill
Silver Bell
Tailings Pond
Active Mining Area
Mammoth Wash
Qs
Qal
540 00 FEET
T 11 S

SILVER BELL UNIT

February 23, 1977

J. H. C.
FEB 28 1977

TO: MR. J.H. COURTRIGHT

FROM: J.L. GALEY

SUBJECT: LEACHING PROCESS AT SILVER BELL

Persuant to your verbal request, the following information should answer most of your questions concerning the dump leaching process at Silver Bell. If you have any further questions do not hesitate to ask.

Attached is a revised copy of a speech given to AIME, Tucson in 1967. It contains general information concerning the process at Silver Bell. The following is a summary of the paper and other data which was gathered from the mill superintendent, chief metallurgist, and the metallurgist in charge of the leaching process.

General Process

A series of ponds are constructed on each dump and the ponds are progressively flooded. As the percolation of water is restricted due to the accumulation of ferric sulfate, other ponds are opened to accomodate the continued influx of water. The process continues until the dump has been flooded.

The flooding period of each dump varies from three to six months followed by a period of drying for a period of three to six months. The length of flooding depends upon the grade of the pregnant solution and production requirements.

Assays from an idealized cycle would show high values of 1.5 to 1.0 grams per liter copper at the start of the flooding. However, the assays drop rapidly within the first few weeks to an average value of 0.8 grams per liter. This value may vary considerably, and the values start to decline toward the end of the cycle. Values of 0.4 grams per liter are expected toward the close of the cycle. The above assay values are idealized. They vary considerably from dump to dump. The variation of assays are attributed to mineralogy within the dumps as well as channeling of percolating water. Also, the longer periods of drying give higher assays and longer flooding intervals before the assays start to decline below the 0.8 grams per liter average.

The cycles of flooding and drying are the ideal conditions for optimum recovery. The flooding cycle takes the copper ions into solution, decomposes the acid soluable copper minerals, and creates the acidic

Depr. 1976 Precip. Plant $31,727.
8837066 lbs. produced
.0037 /lb.

operation 76 $ .14.12 ¢
maint .063
$ .1443
indirect .0573
.2018

environment for the drying period. The drying period gives oxidizing conditions for the formation of copper and ferruginous salts principally from the sulfides.

Reserve Figures

For convenience of explanation the production and reserve figures have been combined for the four leach dumps at Silver Bell. The total (to date) assay and tonnage figures are 56,954,100 tons at an assay of 0.393% copper. From approximately 16 years of leaching, the average recovery is 23% to date. Expected recovery by present leaching processes and current cost to price of copper ratios is estimated to be 40%. However, this could probably be increased by considering blasting of dumps or by inserting perforated pipe into the dump. A cross section of the dumps shows extensive channeling and areas untouched by acid solutions. Also, the sides of the dumps are not being leached. Therefore, the final total recovery is not known.

The mineralogy of the dumps is unknown. Only total copper assays have been compiled. (Non-sulfide data could be collected, but it would require months of compilation). An "educated (?)"guess on the amount of copper occurring as sulfide would be 50-60% as chalcocite and chalcopyrite. Probably 3-7% of the total copper occurs as chalcopyrite. However, more of the chalcopyrite and chalcocite are disseminated than the non-sulfide copper minerals, so that the recovery is higher on the non-sulfides.

Cost and Production Figures

Leach = ±20% of total production

Major direct cost items are the tin cans, sulfuric acid and wages. Average monthly tin can consumption for the period from September, 1976 thru January, 1977 was 592 tons of cans at a cost of $111.04 per ton (total cost of $65,736 per month). Average consumption of sulfuric acid to maintain a 2.5 Ph is 216 tons per month at a cost of $20 per ton ($14 for acid and $6 for freight) which gives a total cost of $4,320 per month.

Production of precipitate copper varies from month to month but average production is 350 tons per month. Thus it requires 0.62 pounds of sulfuric acid and 1.69 pounds of cans to produce one pound of copper.

Cost of cans, acid and wages are approximately $0.11 per pound of copper produced. Cost figures per pound of copper produced for 1976 were as follows:

$	0.146	Direct
$	0.058	Indirect
$	0.204	Total cost
	.076	fr., smelt Ref
	.280	/lb

J. L. Galey
J.L. GALEY
Resident Geologist

JLG/me
1 Attachment
cc: DRJameson w/ attachment
SAAnzalone "
File "

Total operating cost $.28 /lb Cu
Plus cost of water — ?
Plus amortization of plant — ?

To: SRH
Initials:

Read and Return ______ File ✓
Prepare ans. ______ Priority ______

COPPER DUMP LEACHING AT ASARCO'S SILVER BELL UNIT, ARIZONA

By: Kenneth L. Power, Metallurgist, 1967

Revised by: Kenneth W. Deter and
Rollin W. Roberts,
Metallurgists, 1972

American Smelting and Refining Company
Silver Bell, Arizona

Members AIME

Revised speech given by K. Powers on 12/67 for AIME; Tucson, Ariz.

Dump leaching at Silver Bell started in January, 1960. The dumps now being leached are the results of selective mining during the stripping and active mining phases of the development of the two pits. Barren cap-rock is segregated and dumped separately in waste dumps. The copper bearing material in the leach dumps consists of oxide copper minerals and low grade sulfide copper minerals. Neither of these two classes of material could be profitably treated by flotation in the concentrator. The copper values are amenable to dump leaching in closed circuit with iron launder precipitation.

The more basic criteria for dump leaching are: (a) copper mineralization capable of dissolution in leaching solutions within reasonable lengths of time; (b) a host rock which will not consume inordinate quantities of acid, or decrepitate to prevent proper passage of solutions; and (c) a suitable site for placement of the dumps to insure minimal losses of pregnant solution to seepage and good drainage to a central recovery dam.

Additional advantages which are desirable, but not basically necessary are: (a) sufficient pyrite present in the dump material to generate enough free acid and ferric sulfate to dissolve the copper minerals without acid having to be added to the leaching solutions; and (b) not too much ferric sulfate produced in the dumps, which would make subsequent precipitation of the copper difficult or costly.

All of the above basic criteria are realized in the dump leaching operations at Silver Bell. However, H_2SO_4 is added to the leach solutions to aid in dissolving the copper minerals.

LEACH DUMPS AND DAMS

At the present time, there are four dumps undergoing leaching, (Figure 1). The original dump, upon which the leaching plant started operations, is in a canyon adjacent to the Oxide Pit. This is now called the Upper Oxide Leach Dump (Ox. II). The ravine underlying this dump runs directly to the main pregnant solution dam near the precipitation cells.

The main pregnant solution dam is of concrete construction, abutting in solid rock on both walls of the canyon. It has a storage capacity of about 750,000 gallons.

The lower Oxide Leach Dump (Ox. I) was started in another ravine west of the Upper Dump (Ox. II). It has been formed mainly with leach material developed by stripping and mining after ore production for the concentrator was started in the Oxide Pit. In fact, leach material is still being added to its north-western end while the rest of the dump is being leached. The pregnant solution collecting in the ravine under the northern two-thirds of this dump is diverted with an earth-fill dam and a 16-inch pipeline some 250 feet long, to the main pregnant solution dam.

The diversion dam has a 12-inch thick concrete key and the earth face is sealed and protected with gunite. The footings of this dam are in conglomerate but there has been very little leakage. The inlet to the diversion pipe is provided with slots for weir boards so the dam can be used as emergency storage of about 100,000 gallons of pregnant solution in case of trouble with the pumps at the main pregnant solution dam.

The southern one-third of Oxide I dump drains to the same canyon as the Ox. II dump and the solution goes directly to the main pregnant solution dam.

About 250 yards below the diversion dam and the pregnant solution dam the two ravines from the Oxide Dumps joins as one (Fig. 2). Below this junction another 50 yards lies the barren solution dam, another earth-fill dam with a tamped-earth key. The footings of the key are in solid rock on one side and conglomerate on the other. The storage capacity of this dam is roughly one and one-half million gallons.

In early 1961, the west leach dumps being prepared adjacent to the El Tiro Pit (E.T. I) were ready for leaching. In order to accomplish this, it was necessary to put in a pump and a pipeline from the barren solution dam to the El Tiro #I dumps, construct a dam across the canyon below, and provide pumps and a pregnant solution return line to the main pregnant solution dam. Also, the additional amount of copper to be precipitated required an increase in the number of cells and in drying area at the precipitation cells. Construction was completed and leaching started on the El Tiro #I dumps in July, 1971.

The El Tiro I dumps overlie four branches of a main canyon which drains the area. These four join under the dumps and there is only a single underflow. The pregnant solution dam is about 500 feet downstream from the toe of the dumps. It is of concrete, tied into solid rock and has a storage capacity of about 100,000 gallons.

In 1965, the El Tiro South Dumps (E.T. II) were large enough to allow starting several rows of ponds on the established area while the crest was continuously being advanced by additional leach material. This required a third barren solution pump installation at the barren solution dam, a pipeline to the dump, a pregnant solution and diversion dam across the drainage canyon, pumps and return lines to the main plant, as well as additional drying pad area at the plant to allow for the anticipated additional production. As is explained later, only modest changes were necessary on the precipitation cells, with no increase in number. The construction work was completed and leaching of the El Tiro II dumps started in December, 1965.

The concrete pregnant solution dam for the El Tiro II dumps is tied into solid rock and has a storage capacity of about 350,000 gallons.

LEACHING SOLUTION DISTRIBUTION

At the barren solution dam, there are two 6-inch vertical centrifugal pumps of type 304 stainless, driven by 100 HP motors, for pumping the solution to the Oxide area and El Tiro #I. The pump to El Tiro #II is an 8-inch pump, driven by a 150 HP motor. They are floated on rafts to maintain constant submergence regardless of the rise and fall of the water level in the dam. The raft for Oxide and El Tiro #I is made up of a wooden deck floating on 24 sealed ten-foot lengths of 12-inch I.D. PVC plastic pipe. The separate raft for El Tiro #II is floated on polystyrene flotation billets. The pumps are connected to their respective discharge lines by flexible hoses. The rate of the flow of barren solution from each of the pumps is measured and recorded by orifice plate meters.

The Oxide dumps receive their leaching solution through a 10-inch pipeline approximately 3950 feet long, with a static head of 260 feet. On the Upper Ox. II dump, the solution was initially distributed from ten lateral pipes six inches in size. These laterals were provided with one and one-half inch plastic valves on each side of the pipe every 50 to 60 feet. The valves regulated the flow of solution to small, irregular ponds which averaged about 50 to 60 feet square.

When the Ox. #I dump was being readied for leaching, it was decided to try a less elaborate method of distribution. In this system, the solution was simply delivered through an open-end 10-inch pipe to a high point and discharged to an open ditch. From the ditch, the solution was cut into one or more 100' square ponds as desired. This "irrigation system" has proven quite successful and the same method is now in use on all dumps. The barren solution is being distributed at a rate of 1 gal/min. to 200 square feet of dump surface.

El Tiro #I barren solution is delivered through 16,940 feet of 8-inch pipeline with a static head of 165 feet to the upper benches. El Tiro II solution travels two miles through a 14-inch line, against a static head of 260 feet.

The El Tiro #I pregnant solution used to be pumped the full 16,940' back to the main plant in its own separate 8-inch line. Since the installation of the El Tiro II pregnant solution dam, however, the E.T.I Pregnant solution is simply pumped by two 4-inch pumps to the new dam where it joins the underflow of the E.T.II dump. The combined underflows are then pumped by two 6-inch and one 8-inch, Type 316 stainless steel pump through an 8-inch and a 12-inch pipeline to the main pregnant solution dam. Magnetic type flow meters on the two lines measure and record the flow rates.

On all ponds, every effort is made to get the solution to spread out and cover as much area as possible and not short-circuit through the dump. In some rocky areas, it has been necessary to bring in concentrator tailings and crusher fines, to be spread in thin layers over the pond's surface, to reduce the porosity. The whole purpose is to gain as wide a distribution base as possible to get drop-by-drop penetration into the dump. This gives maximum expectation of wetting every rock in the dump, maximum contact time for leaching, minimum of channeling, and above all, a higher grade pregnant solution.

There is a practical limit, however, to these large pond areas, because of the high evaporation rate in the desert country which creates an appreciable loss of water. The percent recovery of leaching solutions varies widely but averages 90 to 95 percent. Most of the loss cam be attributed to evaporation, with minor losses to seepage and seeping into the pores of the rock in the dump.

CHEMICAL REACTIONS OF LEACHING

The chemical reactions involved in leaching of copper minerals were thoroughly studied by John S. Sullivan and others, about 1930. From this source and others, the following overall reactions are given for the dissolution of the principal minerals in Silver Bell dump leaching.

reaction rates?

Chrysocolla: $Cu\ SiO_3.2H_2O + H_2SO_4 \rightarrow Cu\ SO_4 + SiO_2 + 3H_2O$

Azurite: $Cu_3(OH)_2(CO_3)_2 + 3H_2SO_4 \rightarrow 3CuSO_4 + 2CO_2 + 4H_2O$

Malachite: $Cu_2(OH)_2CO_3 + 2H_2SO_4 \rightarrow 2CuSO_4 + CO_2 + 3H_2O$

Cuprite: $Cu_2O + H_2SO_4 + Fe_2(SO_4)_3 \rightarrow 2CuSO_4 + 2FeSO_4 + H_2O$

Chalcocite: $Cu_2S + 2Fe_2(SO_4)_3 \rightarrow 2CuSO_4 + 4FeSO_4 + S$

In vat leaching or agitated leaching, chalcopyrite is usually considered to be insoluble in leaching solutions or, at best, has a reaction requiring such an extremely long time that the amount dissolved is negligible. For these methods of leaching this is true. However, in dump leaching, time of reaction is measured in years. It is probable, then, that a small amount of chalcopyrite does dissolve slowly but inexorably over the years due to the action of ferric sulfate, oxygen, and water.

reaction rates?

Chalcopyrite: $CuFeS_2 + 2Fe_2(SO_4)_3 + 2H_2O + 3O_2 \rightarrow CuSO_4 + 5FeSO_4 + 2H_2SO_4$

At Silver Bell, extra acid is added to the barren solution when it is pumped to the dumps as leaching solution. Experiments indicated that the extra acid addition helped/to keep Iron scale from forming in the pipelines; and the leaching mechanisms previously described. A minor source of sulfuric acid and ferric sulfate required by the above reactions is the reaction of pyrite in the dump with water and oxygen to form these solvents, probably

How much

assisted by iron-based bacterial action. - how much at SB. rates of rxn?

Pyrite: $4FeS_2 + 15O_2 + 2H_2O \rightarrow 2Fe_2(SO_4)_3 + 2H_2SO_4$

Table I shows typical flow data and analysis of solutions to and from the dumps. Assays are reported in grams per liter.

TABLE I

Dump Leaching Data

Barren Solution to Dumps

		Oxide	El Tiro I	El Tiro II	TOTAL
GPM		700	500	1500	2700
Cu	gms/liter				.030
H_2SO_4	" "				.15 - .30
Fe^{++}	" "				1.0 - 1.5
Fe^{+++}	" "				.05
pH	" "				2.70

Pregnant Solution from Dumps

		Oxide	El Tiro I	El Tiro II	TOTAL
GPM		690 - 700	410 - 500	1400	2500 - 2600
Cu	gms/liter	0.6 -.800	1.0 - 1.60	.5 - .700	.6 - .900
H_2SO_4	" "	.40	1.00	.15	.50
Fe^{++}	" "	.01	.01	.01	.01
Fe^{+++}	" "	.15	.30	.15	.20
pH	" "	2.50	2.00	3.05	2.3 - 2.50

As can be seen from the above data, the barren solution consists mainly of a slightly acidic solution of iron salts, most of which is in the ferrous form. In passing through the dumps, the pregnant solution has accumulated copper, gained in acidity, and converted its remaining iron content almost entirely to the ferric state. Some of the original iron content was precipitated in the distributing ponds and some in the dump itself. There has been some indication that the iron precipitated in the dump may have a deleterious effect on the leaching of the dump material in the form of an iron coating which seals off rock from additional leaching.

? This can be miniumized by periodic working of the dumps and additions of acid to the leach solution.

PREGNANT SOLUTION GRADE CONTROL

The copper content of the pregnant solution underflow is maintained by gradual, progressive changes from one pond to another on the surface of the dumps. Usually, several small ponds are being leached at the same time. As the grade of copper in the underflow tends to fall, a new pond is cut in, and the pond which has been leaching the longest is cut out. The length of time during which a particular pond may be covered by solution varies from a few days up to several weeks. Since this time is dependent only on the copper being extracted, it follows that the depth of the leaching column, the copper content of the rock, the type of mineralization, and the efficiency of the leaching solution distribution are all factors in its determination.

still applicable

After a pond is cut out of the leaching cycle and the excess solution has drained, the material in the leaching column underneath this pond will remain unwetted until the pond is again cut in for leaching in its turn in the progression from pond to pond to maintain copper grade. The time of this drying or rest period varies from six months to a year at the present rate of operation.

3-6 mo now

During this rest period, there is still enough moisture in the rock to maintain the humid, oxidizing conditions required by serveral of the chemical reactions to create additional solvents and to dissolve the copper minerals. By diffusion, capillary action, and evaporation, these salts concentrate at the surface of the rocks and are readily dissolved by the leaching solutions during the next wetting cycle.

PRECIPITATION OF COPPER

To precipitate the copper from solution, detinned scrap cans, supplied by Proler Steel Corp., of El Paso, Texas are used. The main advantage of cans is the large surface area presented to the solutions per pound of metal. This large surface area promotes more efficient precipitation per unit of cell volume, than with heavier pieces of iron.

Cans are prepared for use in precipitation by burning in kilns to remove the tin plating and paint from the surface, and the solder from the seams. After this, they are passed through a hammer mill, a toothed roll or some other shredder of suitable design to make them more compact and less bulky to handle, and less wasteful of space in the cells.

Untreated cans will weigh only 8 to 12 pounds per cubic foot. After shredding and compacting, they will weigh 20 to 30 pounds per cubic foot. The limiting factor of the compaction is that if it is carried too far, there will not be enough porosity remaining to get adequate solution penetration and efficient precipitation. Baled cans have never been widely used for this reason.

CHEMICAL REACTIONS OF PRECIPITATION

There are three principal reactions taking place simultaneously in the iron launders. Only one of these is profitable. The other two represent a necessary operating loss to achieve the first; the precipitation of cement copper. The overall reactions are:

2 $$CuSO_4 + Fe \rightarrow Cu + FeSO_4$$

3 $$H_2SO_4 + Fe \rightarrow H_2\uparrow + FeSO_4$$

1 $$Fe_2(SO_4)_3 + Fe \rightarrow 3FeSO_4$$

There is also a fourth reaction, between ferric sulfate and metallic copper, which undoubtedly takes place, but yields the same net effect as the overall reactions given.

$$Fe_2(SO_4)_3 + Cu \rightarrow CuSO_4 + 2FeSO_4$$

The copper sulfate formed in this reaction is reprecipitated on metallic iron as in the first equation. The overall effect is that at equal concentrations, the reduction of ferric iron to ferrous iron is the fastest of the three basic reactions. The reduction of copper is the next in rapidity, followed by the reaction between acid and iron.

PREGNANT SOLUTION PUMPING TO CELLS

At the main pregnant solution dam there are three five-inch vertical centrifugal pumps of 316 stainless, two are driven by 50 HP motors and the third by a 30 HP motor, to pump the solution to the cells. A magnetic type flow meter in the main header of the three pumps measures and records the rate and quantity of flow. The discharge pipe is ten inches in diameter, and about 300 feet long from dam to cells.

Sulfuric acid is being added to the pregnant solution ahead of the precipitation cells. The amount of acid added is small; only enough to lower the pH to about 2.3. The purpose of this addition is to gain better copper precipitation conditions in the cells by preventing hydrolysis and precipitation of hydrous iron salts in the lower cells where the acid concentration is low. About half of the acid is being added to the pregnant solution at the El TiroI dam to prevent scale forming in the 3-1/2 miles of pipe which return this pregnant solution and combined El Tiro underflow to the main plant. The other half of the acid is added at the pumps on the feed to the precipitating cells.

Sulfuric acid is stored in a 10,400 gallon tank at the plant's office and in a 4,090 gallon tank on a dump above the El Tiro I pregnant solution dam. Deliveries from the tanks are metered by variable-stroke diaphragm acid pumps. In the warmer months all the acid is 98% H_2SO_4 or 66.4° Baume'. In the Winter months 93% or 66.0° Baume' is used, to prevent the acid from freezing in the lines. In the near future plans are being made

Is it used now { to use a ~~75%~~ H_2SO_4 or 55.1° Baume', which will be more plentiful and cheaper to buy than the ~~98%~~ or 93% acid.

CEMENTATION CELLS

The original plant consisted of six precipitating cells. This number was increased to ten in 1961 to gain the needed capacity for the precipitation of the El Tiro solutions.

However, an economic analysis of the precipitating cell operations is 1964 showed that not all of these ten cells were needed. The study made clear that the iron consumed in the lower cells was costing more than the copper precipitated there was worth. As a result of this investigation, five of the cells were cut out of operation and only the remaining five were used to precipitate the copper from the 1000 GPM of solution flow.

Then, when the El Tiro II dump was brought into production in late 1965, with nearly another 1000 GPM of solution to be treated, it was only necessary to cut these five cells back into operation, with minor modifications, to have adequate capacity to handle the flow rate. The economic study of 1964, therefore, has paid off in continuing savings of can consumption and in preventing an unnecessary over-capitalization during the plant expansion of 1965. The present flow rates of 2500 - 2600 GPM are at times too much for the 10 cells, especially when the heads are high in copper. Therefore, plans are being made for a needed expansion in 1974, in the form of new precipitation cones in service along with the 10 precipitation cells. Each cell is eight feet wide by five feet deep and is divided into two compartments, each twelve feet long, by a dividing center wall. The tops of the concrete walls are protected by 6" x 10" timbers. At the five-foot depth in the cells is a perforated screen made of 3/4 inch polypropelyne which has been locally drilled with one and a quarter inch holes on one and one-half center. The poly-propelyne screens are supported by type 316 stainless steel grids which have approximately two inch by four inch openings. The grids rest on two 6" x 8" timbers which are keyed into the side walls in each compartment. Beneath this screen bottom, the concrete floor of the cells slopes to a twelve inch drain valve. This valve is operated by a bell crank and handwheel from the walkway on top of the cells. Stainless steel grates with 1" x 2" openings were tested, but allowed too many scrap cans to escape into the final precipitate during washing and caused an increase in can consumption and lowering of the grade of the precipitate.

CELL OPERATION

Feed solution to the cells passes through cells 1, 2, 3 and 4 in parallel flow from the feed launder and then returns, in parallel, back through cells 5, 6, 7 and 8. The advantage of parallel flow on these first cells is that the heavy precipitation from the strong solutions is divided and there is less back-pressure or resistance built up to flow of solution. After these cells, the solution passes through cells 9 and 10 in parallel. The discharge of cells 9 and 10 is tailings solution which returns through a sump and a 16-inch pipeline to the barren solution dam by gravity.

In each cell (Fig. 3) the solution enters through a gateway from a launder into the upstream compartment. Most of the solution flows down through the cans in that compartment and through the holes in the screen bottom. The majority of it then passes under the center dividing wall, up through the screen bottom and through the cans in the second compartment before overflowing the discharge gate. Some of the solution will pass longitudinally through the top section of the cans in both compartments by way of the gateway in the center dividing wall. Especially, when the gallonage is extremely high or the cells are full of precipitated copper.

Detinned and shredded cans are delivered to the plant by Proler Steel Corp, in side-dump semi-trailers. The loads are dumped off the side of a ramp about eight feet above the stockpile area. The cans are placed in piles by a diesel-driven mobile rubber-tired crane with a 65 foot boom and a five foot diameter electromagnet. The cans are transferred from the stockpile to the cells as needed, by the crane and magnet. Each magnet load of cans weighs about 650 pounds.

Table II shows typical precipitation cell data. Assays are reported in grams per liter.

TABLE II

PRECIPITATION CELL DATA

		Cell Feed	Cell Tailings
Cu	gms/liter	0.717	.018
H_2SO_4	" "	.67	.06
Fe^{++}	" "	.01	1.00
Fe^{+++}	" "	.05	Tr.
pH		2.32	3.28

Lbs. Acid/Lb. Cu Pptd.	.50 - .80
Lbs. Iron/Lb. Cu Pptd.	1.3 - 1.5
Manshifts/week	18

The above data illustrates the salient features of the precipitation cell operations. 97.5 percent of the copper is stripped from the solution, the acid content is decreased, and the ferric iron content is reduced to ferrous iron.

A comparison of the cell tailings solution which returns to the barren solution dam with the barren solution being pumped to the dumps, shown in Table I, demonstrates that a certain amount of the iron content is precipitated in the barren solution dam. This is advantageous in preventing an excessive build-up of iron in the leaching solutions. Unfortunately, some iron precipitates out in the lines and pump intakes in the form of scale. This can be readily controlled by descaling of the barren solutions lines twice a month with chain-covered, rubber balls and the use of acid, which is added to the barren solution.

CELL WASHING

The first four cells always receive the strongest solution and must be washed the most often. They precipitate about 70 percent of the total production and at present are being washed twice a week. The next group, cells 5, 6, 7 and 8, make about 25 percent more of the total and are washed once a week. Cells 9 and 10, producing the remaining 5 percent, are washed once a week.

Situated below the ten drain valves from the cells are five settling tanks, each 16 feet, 10 feet square by four feet deep. When the cells are being washed, the slurry of copper precipitate and wash water flows to these tanks. After allowing time for the copper to settle, the clear water is decanted, and pumped, by a three inch vertical centrifugal pump of 316 stainless, from a recovery sump back to the cells, to entrap any fine particles of copper.

When a cell is to be washed, wooden gates cut the flow of solution, and the drain valve is opened to the settling tanks. The magnet transfers any loose cans which were not covered by solution to an adjoining cell. When the mass of copper and partially consumed cans is exposed, the copper is washed off the cans through the polypropelyne screen bottom and out the drain valve. Washing is done with two one and one-half inch high pressure hoses equipped with quick shut-off fire nozzles. Water for washing is furnished from the tailings solution sump by a two and one-half inch vertical centrifugal pump of 316 stainless. Driven by a 350 RPM, 25 HP motor, this pump can deliver 200 GPM to the wash hose at 100 pounds pressure.

As the cans are washed clean, the magnet lifts them to the next cell. When the cell is empty, the screen bottoms are inspected and repaired, if needed. Earlier in the plant's operation, drilled, plywood sheets were used, but the polypropelyne sheets proved to have a much longer life with less maintenance troubles and eventually replaced them. The polypropelyne sheets have an infinite life and have to be replaced only when accidently broken or cracked by the magnet. When repairs are complete, the washed cans are replaced, new cans are added, the drain vlave is closed, and the gates are removed to put the cell back in the circuit. Ordinarily, a cell can be washed in 1-1/2 to 2 hours by two men on the hoses and one crane-man.

The operating crew consists of two operators, one helper, and a crane-man. All operations, from leaching solution distribution changes to cell washing, are performed on day shift only. Shift bosses from the concentrator check the plant on afternoon and night shifts to see that the pumps are running properly.

Beside dump work and cell washing, the operators are responsible for sampling of the solutions, controlling the acid addition by pH measurements, and miscellaneous oiling and maintenance around the plant.

PRECIPITATION DRYING AND SHIPMENT

In order to reduce the weight of the cement copper shipped to the smelter and more importantly, to improve its handling characteristics, a drying pad of concrete has been provided on the opposite side of the settling tanks from the cells. The original pad was 35 feet by 105 feet and at times was not quite adequate for the amount of precipitate to be dried. With the extension for the El Tiro west production (E.T.I), the pad was enlarged to 60 by 145 feet. For the El Tiro South dump production (E.T.II), it was enlarged to its present size of 115 by 195 feet.

Once each week, the settling tanks, which have copper in them from washing the cells, are bailed out with the crane and a clamshell bucket.

When first placed on the pad, the precipitate will contain 35 to 40 percent moisture. It is placed in an irregular pile and allowed to drain for a day and a half. It is then picked up in small bucket-loads with a front-end loader and laid out in rows about eight to ten inches deep. Occasionally, especially in the winter, there is further drainage of free water from these rows. The drying pad is sloped toward the settling tanks to help in the drainage.

The precipitate is left in rows for 2-3 days in summer and up to 5 or 6 days in winter until the desired shipping consistency is reached. In winter, it is sometimes reworked with the loader to turn the material over and hasten the drying process. When dry enough, the precipitate is placed in a stockpile for ease of loading for shipment.

Carload lots of cement copper average 80 to 82 percent copper and 10 to 15 percent moisture.

The Company railroad siding is a spur off the Southern Pacific mainline at Plata, near the Tucson Casa Grande Highway, a distance of 23 miles from Silver Bell. The same trucks and trailers which haul the concentrates from the mill are used to haul the precipitate to the siding. Usually three trailers, each hauling 35,000 to 40,000 pounds of precipitate, are sufficient to fill a carload. At the siding, the end-dump trailers are unloaded by means of a head-frame and winch into a hopper. From there, conveyor belts deliver the material to open gondolas. The loaded cars are sampled for moisture and copper assay, weighed, and sent to ASARCO's Smelters at Hayden or El Paso.

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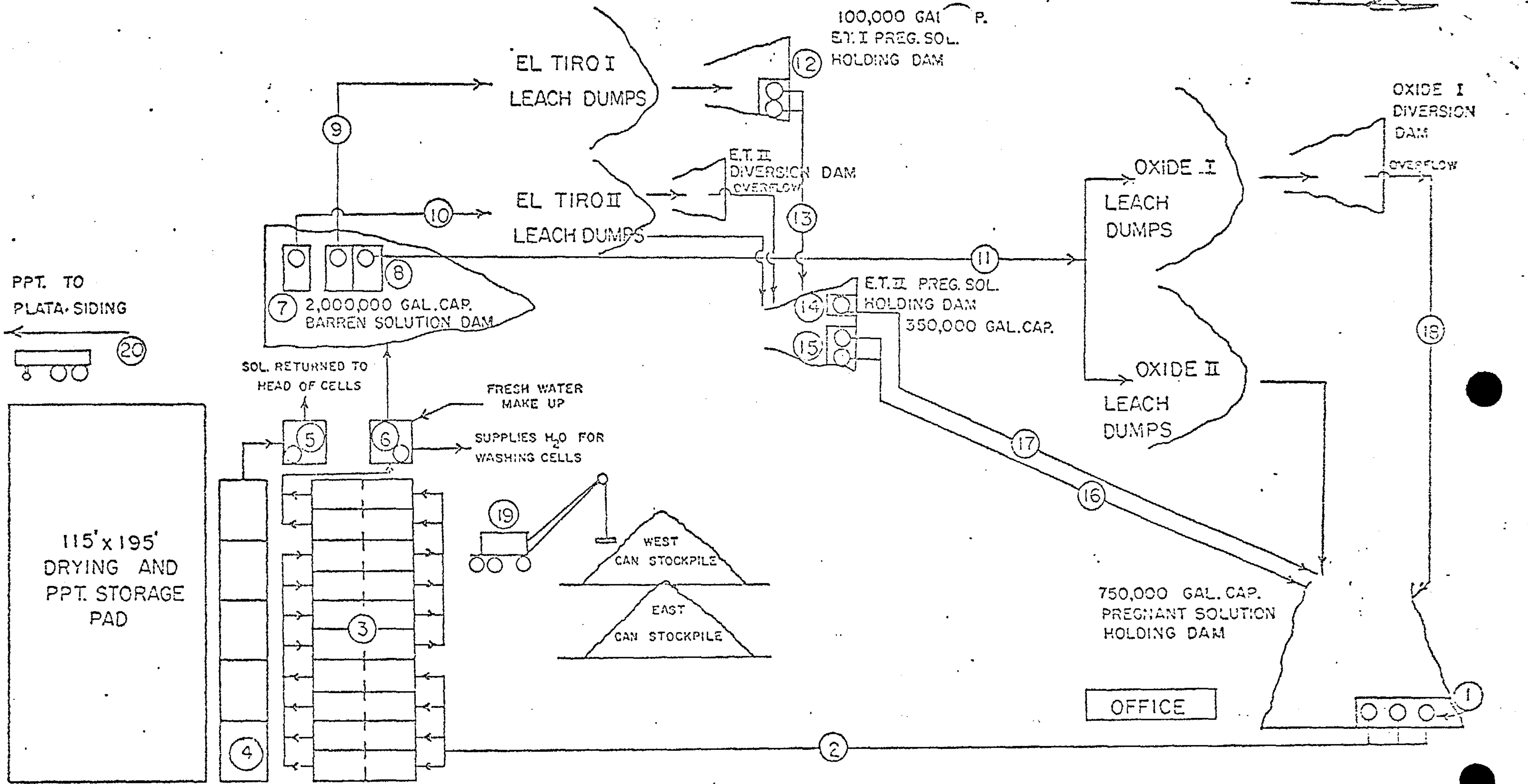


1. 3 B-H 5" VERT. PUMPS 316 SS.
2. 10" EPOXY LINED C-A PIPE.
3. 10 8'X 24' CONCRETE PRECIPITATION CELLS.
4. 5 6'X 10' X 4' DEEP DRAIN SUMPS.
5. 3" B-H VERT. RECOVERY PUMP 316 SS.
6. 2 1/2" B-H VERT. WASH DOWN PUMP 316 SS.
7. 8"-H B-H VERT. RAFT MOUNTED PUMP 316 SS.
8. 2 6"-C B-H VERT. RAFT MOUNTED PUMPS 304 SS.
9. 3.5 MILE 8" EPOXY LINED C-A PIPE.
10. 2.0 MILE 14" EPOXY LINED C-A PIPE.
11. 10" EPOXY LINED C-A PIPE.
12. 2 4"-C B-H VERT. PUMPS 316 SS.
13. 8" EPOXY LINED C-A PIPE.
14. 8"-E B-H VERT. PUMP 316 SS.
15. 2 6"-C B-H VERT. PUMPS 316 SS.
16. 2.0 MILES 8" EPOXY LINED C-A PIPE.
17. 2.0 MILES 12" EPOXY LINED C-A PIPE.
18. 16" EPOXY LINED C-A PIPE.
19. UC 78-A LINK BELT CRANE (30 TON CAP) WITH 5' SHRADER MAGNET.
20. 20 TON CAP. PPT. TRAILERS.

B-H = BARRET HAENTJENS
C-A = CEMENT ASBESTOS (JOHNS MANSVILLE TRANSITE) PIPE

SILVER BELL FLOWSHEET

FIG. I

PRECIPITATION PLANT

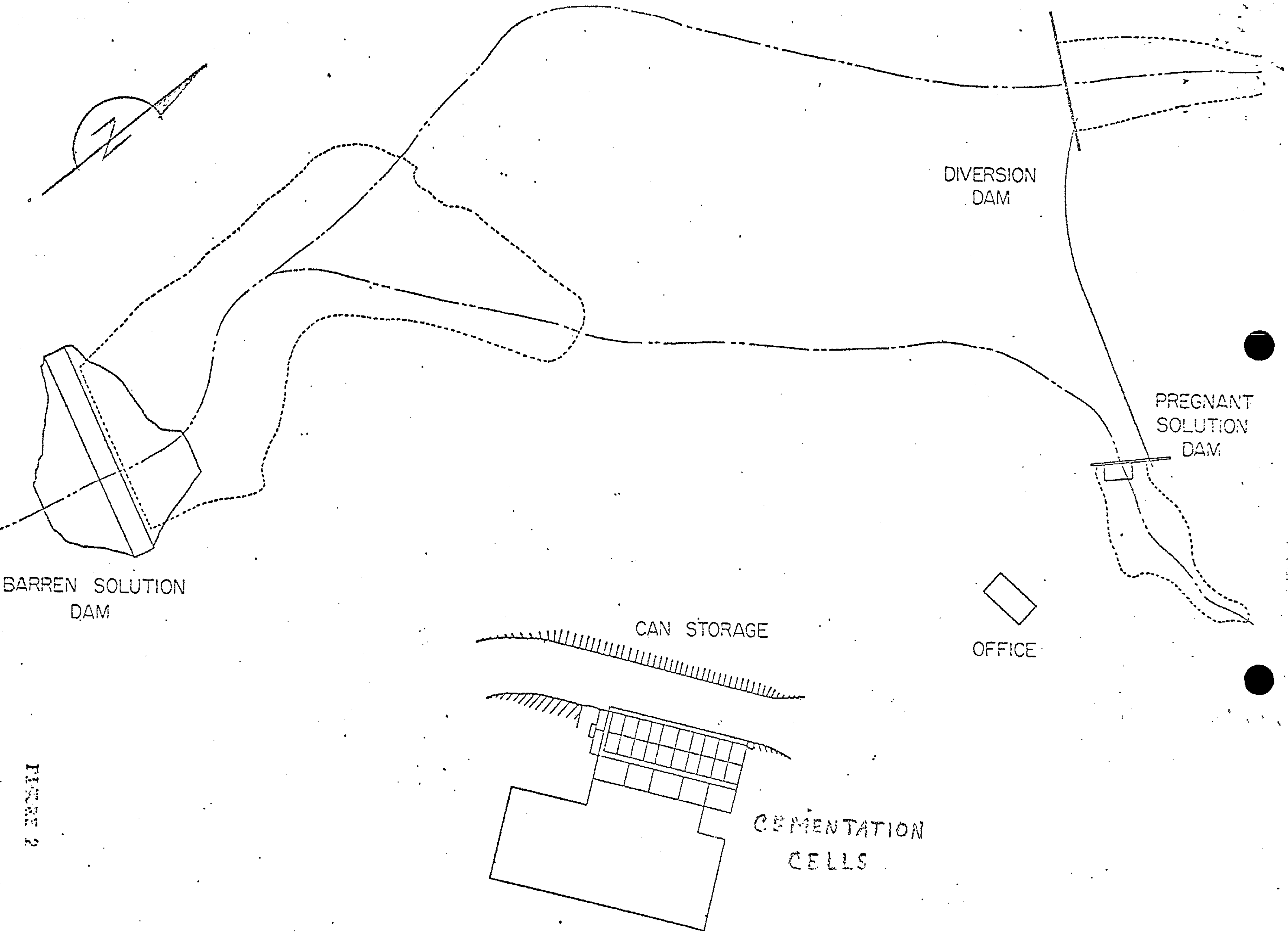

DIVERSION DAM
PREGNANT SOLUTION DAM
BARREN SOLUTION DAM
CAN STORAGE
OFFICE
CEMENTATION CELLS

FIGURE 2

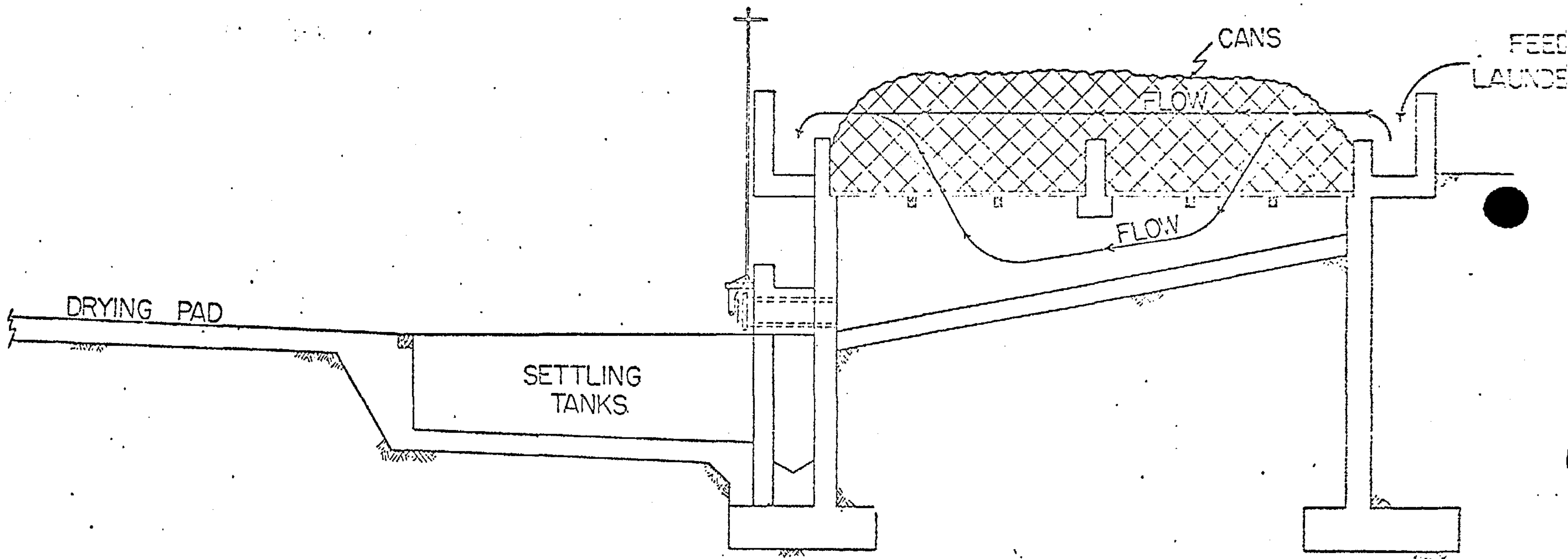
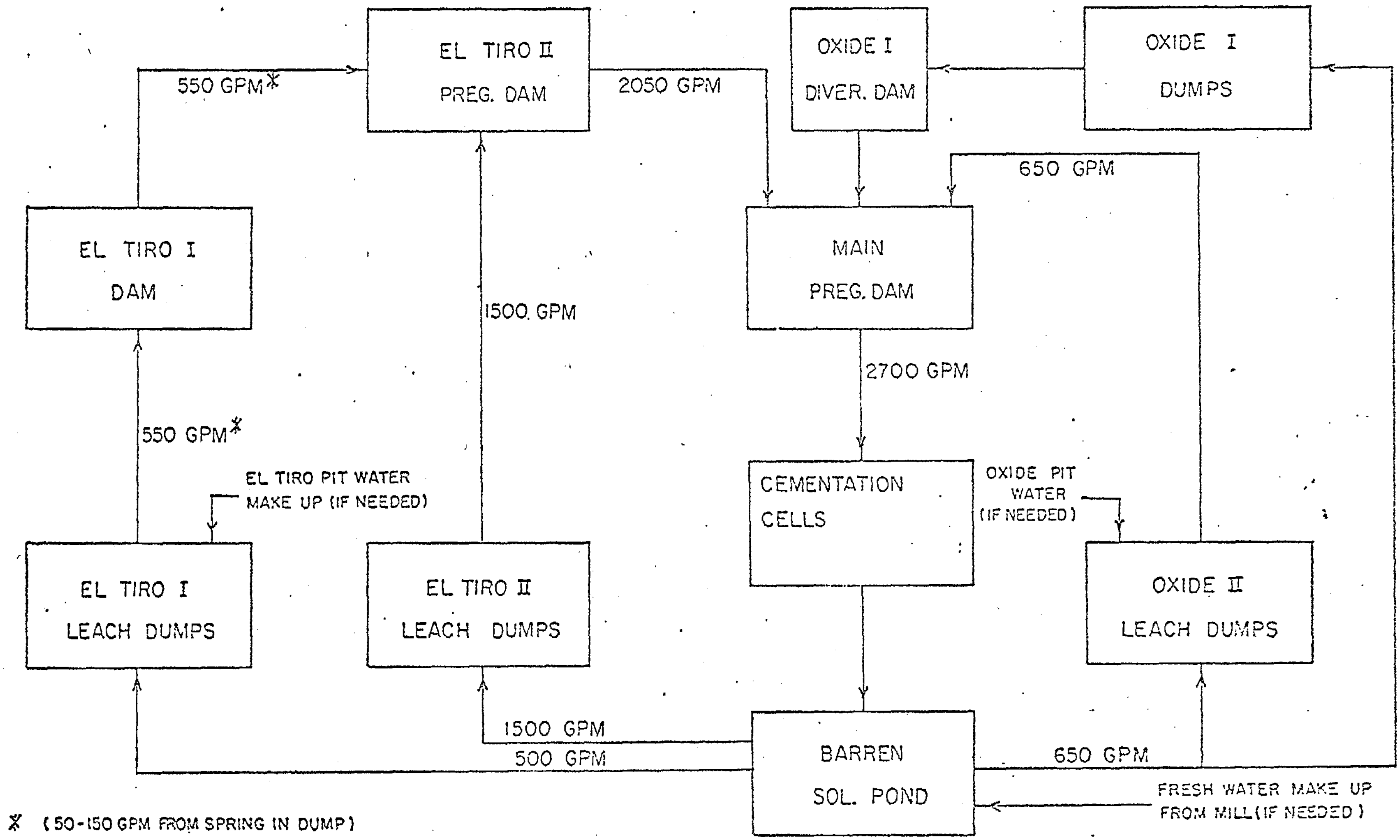


FIGURE 3



SILVER BELL FLOWSHEET

FIG. 4

PRECIPITATION PLANT FLOW RATE

DIAGRAM