EVALUATION OF GROUNDWATER MONITORING METHODOLOGIES IN THE TUCSON COPPER MINING DISTRICT

by

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ABSTRACT

The Upper Santa Cruz Basin Mines Task Force implemented a two year groundwater monitoring program in response to recommendations of an earlier investigation. The work program included monitoring several copper mines' tailing ponds and wells 15-20 miles south of Tucson. ASARCO mine was monitored to determine the source of high sulfates and TDS in the groundwater in the vicinity of the ASARCO ponds. A network of twelve sampling sites was sampled quarterly to look at water quality trends over time. One additional monitor well was drilled at the base of ASARCO's newest pond. The Anamax groundwater monitoring program consisted of investigating changes in water levels and water quality in the vicinity of its two tailing ponds to determine the hydrologic impacts of the ponds. The Duval program consisted of a network of thirteen monitor and seven interceptor wells. It was designed to determine the effectiveness of the interceptor wells as a management practice for preventing migration of mineralized tailing pond seepage to downgradient areas. The programs are compared in relation to their relative merits and their effectiveness in determining the groundwater quality impacts of the tailings ponds.

INTRODUCTION

Studies concerning tailing pond seepage and recharge of tailing pond water south of Tucson began over twelve years ago. Data collected in the early 1970's by the United States Geological Survey indicated recharge of tailing pond water at one mine. Monitoring of groundwater showed increased concentrations of sulfate and total dissolved solids in downgradient wells monitored over a ten year period. Information from a water rights case suggested significant groundwater recharge was occuring through tailing ponds south of Tucson (Thuss, 1978).

Earlier soils and water quality studies of the tailing ponds reached various conclusions. A materials investigation of the tailing ponds south of Tucson characterized the water quality, soil density, particle sizes and permeabilities of the tailings and tailing pond water (Engineers Testing Laboratory, Inc., 1973). The rather high sulfate and total dissolved solids concentrations in the tailing pond water and downgradient wells suggested the ponds were a possible source of degraded water in the wells. Two additional studies (W.A. Wahler and Associates, 1973)(Hail, 1974) completed a drilling exploration program at the mines' tailings ponds. The program included soil sampling and laboratory analyses of the soils. Additionally, these studies included drilling four monitor wells at the base of four different tailings ponds. Water with high total dissolved solids and sulfates, exceeding recommended Arizona State limits, was found at three of the four sites.

The Upper Santa Cruz Basin Mines Task Force completed its first study in 1979. Investigation of water levels and groundwater quality in the Sahuarita-Continental-Green Valley area was generally inconclusive regarding the impact of tailings ponds on groundwater since there were few monitor wells to sample near the tailings ponds and only one round of samples was obtained. The Mines Task Force recommended further studies in the tailing ponds areas to determine the effects of tailings ponds on the local groundwater. The three groundwater monitoring programs to be discussed in this paper were conducted as a result of the Task Force's 1979 recommendations (Upper Santa Cruz Basin Mines Task Force, 1979).

An independent study of the ASARCO tailings ponds effects on groundwater recharge and contamination was conducted during the same period as the Mines Task Force study of the ASARCO ponds (Thurnblad, 1982). The independent study evaluated the effectiveness of stable isotopes of hydrogen and oxygen as tracers of tailings pond recharge and subsurface movement. Isotope information coupled with

sulfate, calcium and total dissolved solids data suggested localized tailings pond recharge as the source of degraded downgradient monitor and industrial well water.

PEDCo Environmental, Inc. has just finished a groundwater and source monitoring study of the Cyprus-Pima tailing ponds area south of Tucson. The study followed the Resource Conservation and Recovery Act guidelines. Five wells were constructed for the program: three wells immediately downgradient, one well upgradient, and one well further downgradient of the suspected source. Results from this study are not yet available, but they will be used for recommendations to the Environmental Protection Agency as to what kinds of regulations are necessary for tailings pond disposal (PEDCo, 1983).

An evaluation of the monitoring programs performed as part of the Upper Santa Cruz Basin Mines Task Force Program is presented in this paper. These programs include the ASARCO, Anamax, and Duval study areas. The Task Force consists of various public entities and includes, or included, the four mining companies operating south of Tucson. Recommendations will be formulated by the Task Force for future activities in each site-specific area.

MONITORING PROGRAMS

ASARCO Program

The purpose of the ASARCO program was to determine the source of increased sulfates and total dissolved solids in the groundwater in the vicinity of the ASARCO ponds, and to develop, as necessary, recommendations for the future (Upper Santa Cruz Basin Mines Task Force, 1980).

The program included wells in Figure 1. All of these wells were measured for water levels in 1981 and 1982 and the underlined wells were sampled for water quality quarterly over a two year period. Two monitor wells at the base of ASARCO Tailings Ponds #1 and #2 were sampled. The City of Tucson monitor well was redeveloped after two years of non-use (since the 1979 Baseline Report). The Bureau of Indian Affairs' well was drilled during the monitoring program and was sampled during two subsequent sampling runs. M-6, M-7, M-8, M-10, M-11, SX-1, SX-2, and SX-3 are ASARCO industrial wells which are downgradient of the ASARCO tailings ponds. Beginning with M-6, the wells range from about one to two miles downgradient of the ponds. Two other water quality sampling sites were established at the ASARCO pits about one to two miles upgradient of the ponds.

The quarterly sampling was sufficient to obtain temporal trends for any plume movement into the wells. From both a monetary and a data interpretive viewpoint, the frequency was more than sufficient.

Constituents that were analyzed included all the major cations and anions, copper, molybdenum, total dissolved solids, electrical conductance (lab and field), pH (lab and field), and field temperature. Analyses were done by BC Laboratories of Bakersfield, California, an Arizona State Certified lab. Ten percent of the samples were split between BC and Arizona Department of Health Services Labs for verification.

Deficiencies of the monitoring program included: the lack of monitoring wells to the east and northeast of the tailings ponds, the need for sampling the tailings ponds, and the need for sampling additional constituents used in the copper milling process. It is difficult to describe the flow regime and water quality to the northeast of ASARCO Pond #1 since there are no monitor wells in that area. There is a known cone of depression described in earlier studies (Upper Santa Cruz Basin Mines Task Force, 1979) which is centered about the ASARCO and Cyprus-Pima well fields and defining the northern influence of the cone is difficult. Table 1 presents pond water quality data for ASARCO. Pond water quality is significantly different temporally and points to the necessity for more frequent pond sampling to obtain better understanding of variations in water quality. Finally, because of the addition of flotation agents, and the type of ore being processed, there is a need to analyze the ponds and wells for selenium, cyanide, and chemicals used in the copper and molybdenum flotation processes.

Anamax Program

The purpose of the Anamax tailings pond monitoring program was to determine the hydrologic impacts of the ponds, and to develop recommendations, as necessary, for future activities (Upper Santa Cruz Basin Mines Task Force, 1980).

The program included wells in Figure 2. Underlined are the wells sampled for water quality while the others were checked only for water levels.

Water quality samples were taken on a quarterly basis. This frequency was again sufficient for observation of seasonal trends and plume movement. Three wells sampled for water quality parameters were at the base of tailings ponds: P-1225, P-1758, and P-1759. The other two wells sampled were public supply wells ST-5, one-half mile east of Tailings Pond #3; and ST-6, about one mile east of the

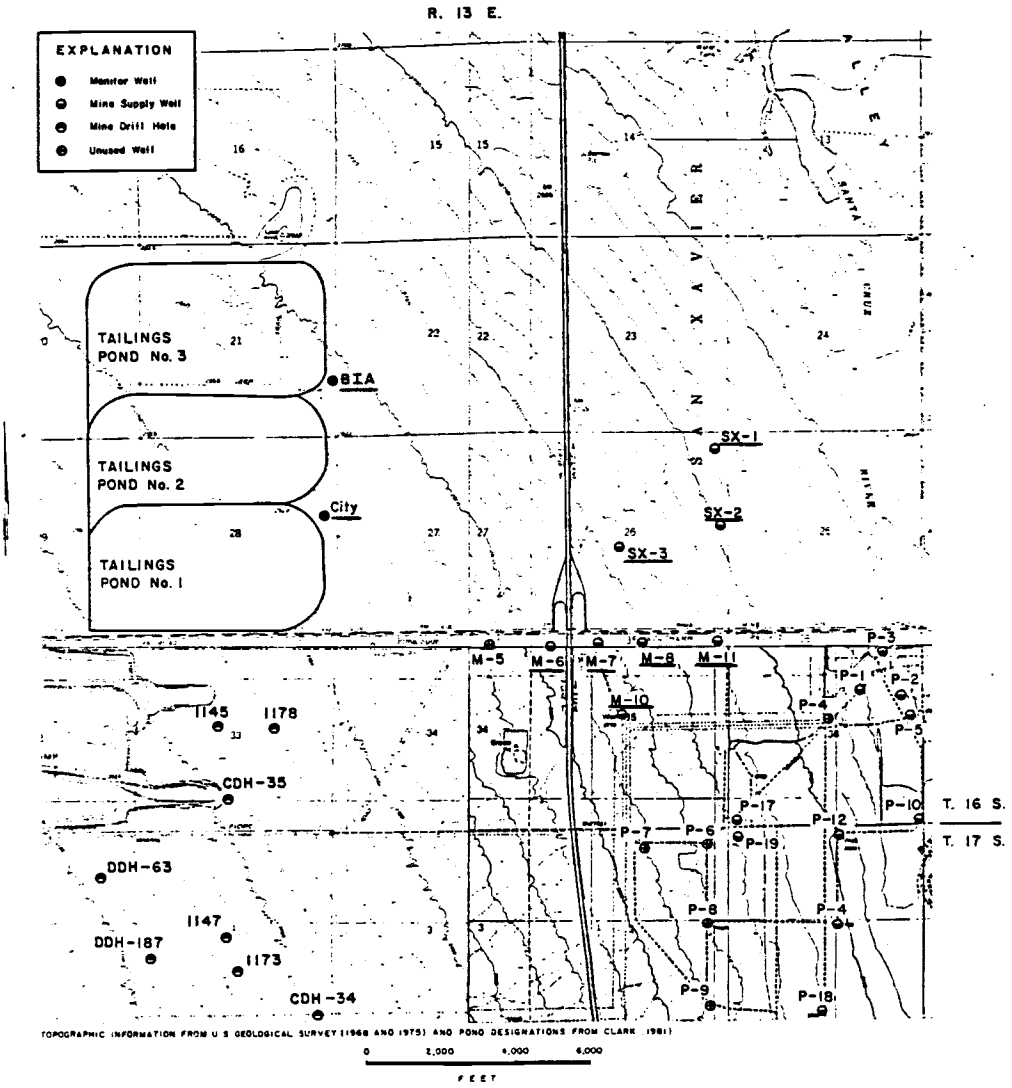

FIGURE 1 - LOCATION OF WELLS AND DRILL HOLES IN THE VICINITY OF THE ASARCO PONDS

TABLE 1 - CHEMICAL COMPOSITION OF WATER FROM ASARCO TAILINGS PONDS

Constituent (mg/l)	Pond No. 1	Pond No. 2		
Calcium	530	552	615	760
Magnesium	<1	5	2	1
Sodium	190	163	166	240
Potassium	49	70	-	72
Carbonate	35	0	0	0
Bicarbonate	0	39	41	18
Chloride	43	26	38	32
Sulfate	1,600	1,558	1,745	2,400
Nitrate	2	2	<1	2
Flouride	2.0	3.7	0.6	2.3
Iron	<0.08			0.05
Manganese	<0.04	-	-	0.08
Arsenic	<0.005	-	-	<0.01
Chromium	<0.04	-	-	<0.01
Selenium	0.013	-		<0.01
Molybdenum	1.9	5.5	16	2.0
Lead	-	-	-	<0.01
Copper	-	-	-	0.01
Zinc	-	-	-	0.14
Cadmium	-	-	-	<0.01
Boron	-	0.4	-	0.13
Vanadium	-	-	-	<0.1
Electrical Conductivity (micromhos at 25°C)	2,993	-	-	3,351
Total Dissolved Solids	3,500	-	2,629	3,333
Total Organic Carbon	7.8	-	-	6.7
Field pH	-	-	-	5.5
Lab pH	10.1	6.7	5.0	6.5
Date	5/4/81	2/17/71	10/18/71	8/20/81
Lab	U of A	ETL	ETL	BC Labs

1971 analyses from Engineers Testing Laboratory, Inc. (1973) and 1981 analyses from Thurnblad (1982).

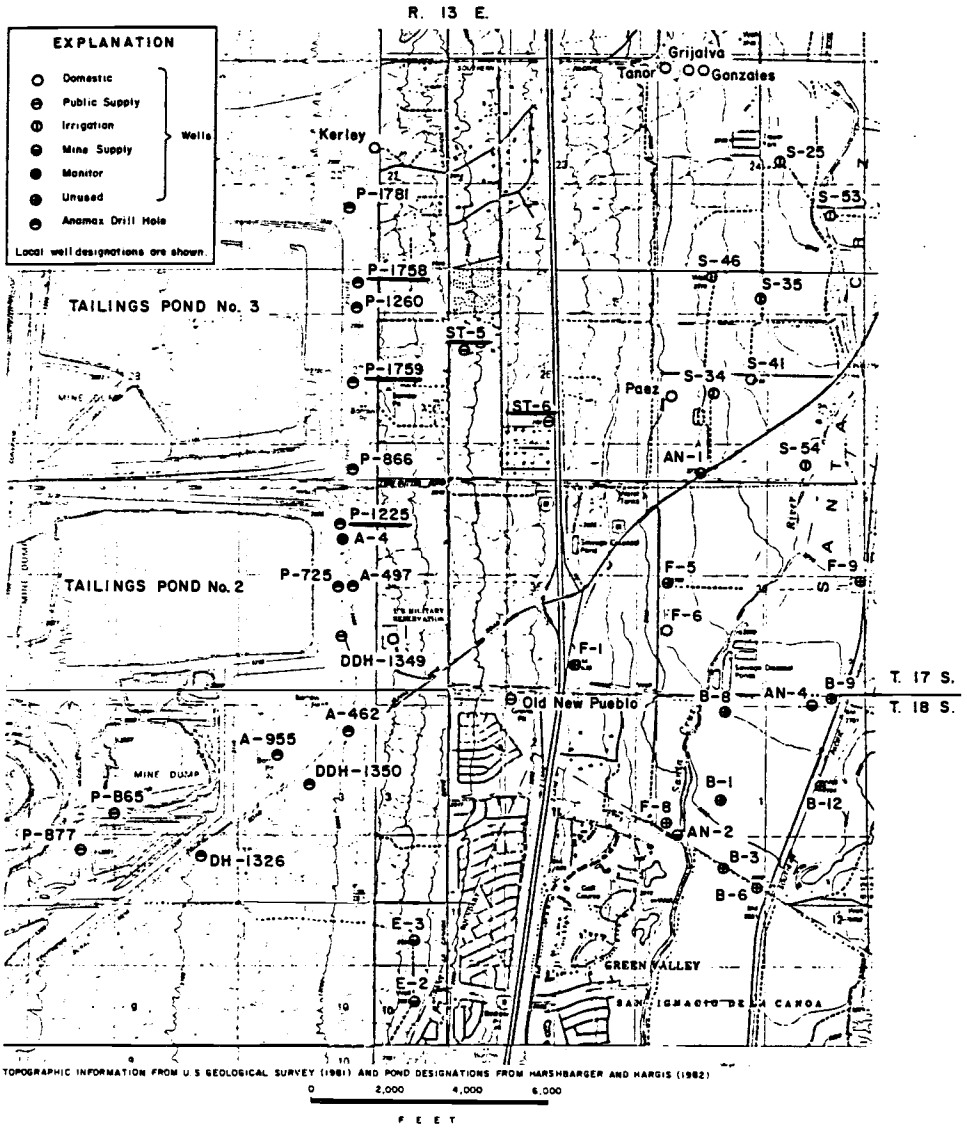

FIGURE 2 - LOCATION OF WELLS AND DRILL HOLES IN THE VICINITY OF THE ANAMAX PONDS

southeast toe of Tailings Pond #3. Constituents analyzed included all the ones sampled in the ASARCO program and also trace constituents such as selenium, arsenic, silver, mercury, zinc and lead. Well P-1225 showed a marked increase in sulfate and total dissolved solids over time indicating tailings pond recharge.

The program's additional needs, which will be recommended for future investigation, include: tailings pond water quality sampling, including products used in the flotation process and radiologic analyses, and placement of additional monitor wells between the wells next to the ponds and the public supply wells. The latest available data for pond analyses is from the early 1970's (Engineers Testing Lab, Inc., 1973) and if trends follow the ASARCO pond water quality trends, Anamax pond water quality could be substantially different. The number of wells in the Anamax program is not sufficient to define the areal extent of subsurface sulfate movement. In comparison to the ASARCO or Duval programs, the areal coverage of the Anamax area is minimal and could benefit by expansion. Water level data suggest an area of depressed groundwater elevation due to pit dewatering (Upper Santa Cruz Basin Mines Task Force, 1979). The necessity of wide areal coverage for water quality monitoring under altered flow directions is evident.

Duval Program

The purpose of the Duval monitoring program was to determine the effectiveness of the Duval interceptor well system as a management practice for mitigating downgradient groundwater degradation, and to develop recommendations concerning the Duval interceptor and water quality monitoring systems.

Figure 3 delineates the Duval monitoring system. Underlined wells were sampled for water quality parameters. Ten three-inch diameter monitor wells ring the Duval tailings ponds. Additionally, three three-inch diameter monitor wells are in a line from north to south about one mile east of the northeast part of the tailings pond. These wells were bailed with a mechanical stainless steel bailer. Seven interceptor or barrier wells also ring the pond. Interceptor wells were constructed to alter the direction of groundwater movement to mitigate potential water quality degradation of downgradient public supply wells. Two Green Valley supply wells were sampled for water quality parameters, CW-3 and GV-1. These wells are about one and one-half miles east of the ponds. Additionally, two Duval industrial wells, E-1 and E-4, were sampled for water quality. These wells are about one and one-half miles northeast of the pond. Finally, tailings pond water samples were also obtained and analyzed.

Sampling frequency varied from once per week for the interceptor wells, to once per month for the monitor wells and CW-3, to once per year for the other wells. Constituents analyzed included all the ones mentioned in the ASARCO program. The laboratory analyzing the water samples was the Duval lab. Ten percent of the samples were split between the Duval and Arizona State Health Labs for verification.

The Duval program was probably the most comprehensive of the three programs described. Over twenty-five wells were sampled for water quality, covering twelve square miles. Sampling frequencies were more than adequate and close monitoring enabled correlations between well water quality and interceptor well pumpage to be described. Monthly water level measurements in the monitor wells allowed examination of the effects of interceptor well pumpage on the direction of groundwater movement. Suggestions for improvements to the monitoring program include: addition of monitor wells between existing monitor wells and the public supply wells to better define the sulfate plume; additional analysis of constituents in the pond water which are used in the flotation processes, including cyanide, selenium, molybdenum, and selected organics; and installation of a pumping system for the monitor wells in order to flush adequate amounts of well water prior to sampling. Finally, it appears that the interceptor well pumping regime could be improved by additional pumping capacity northeast of the ponds.

CONCLUSIONS

1. Evidence from previous investigations suggest tailings pond recharge as the source of degraded water in wells downgradient of the ASARCO and Duval ponds. Evidence from this current study corroborates this observation and also suggests a similar situation for Anamax tailings pond #2. There is no reason to believe the situation at Cyprus-Pima is any different.

2. Future monitoring programs at all study areas should emphasize placement of monitor wells upgradient of public supply wells in order to detect problems and prevent supply well degradation.

3. Monitoring of tailings ponds on an annual to semi-annual basis is necessary to determine constituents for analysis in downgradient wells.

4. Sampling frequency for wells and ponds could be reduced to an annual basis for the complete suite of constituents. However, indicator constituents such as sulfate and total dissolved solids should be sampled quarterly. Annual monitoring should include constituents added in the milling process for flotation purposes.

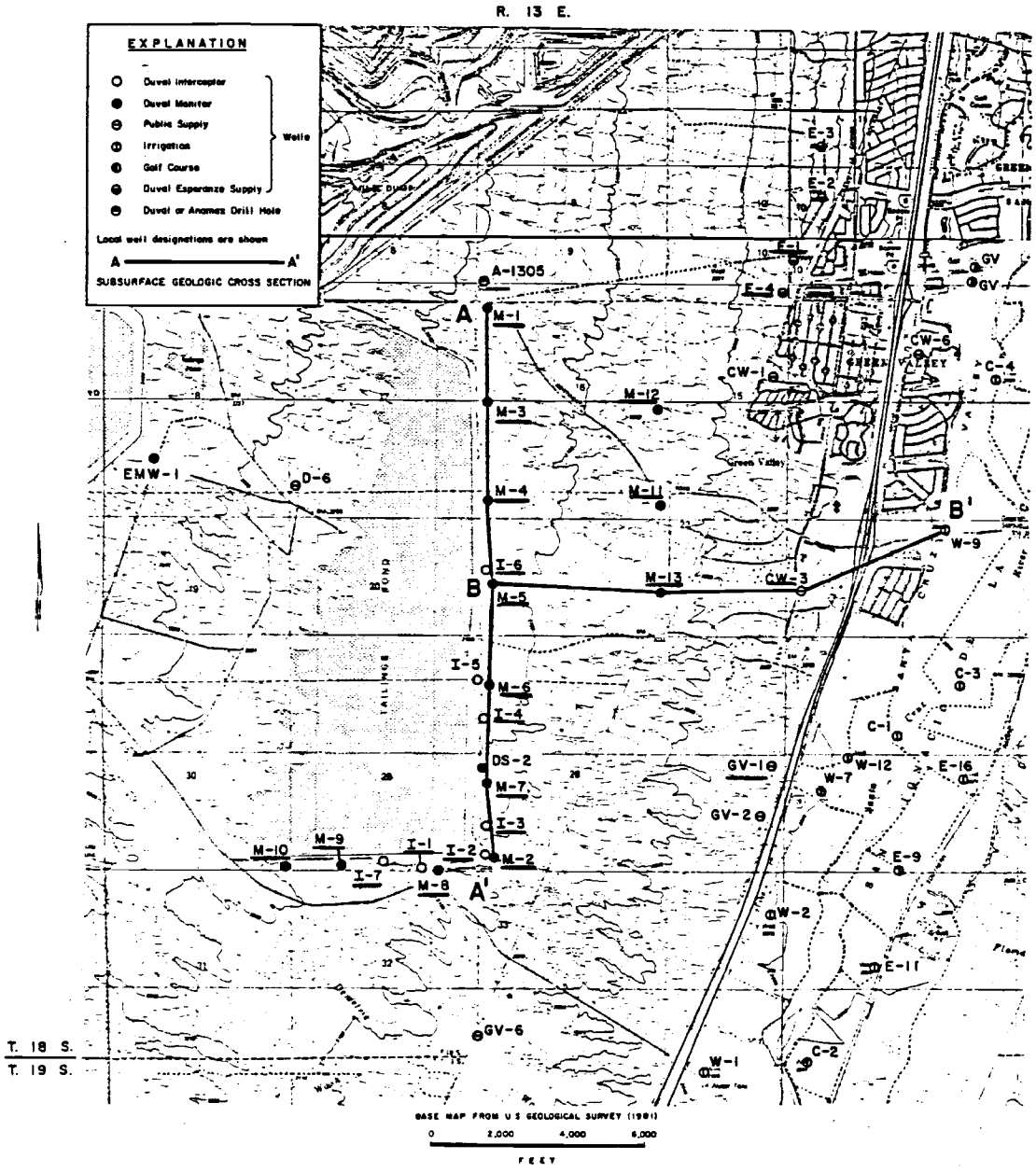

FIGURE 3 - LOCATION OF WELLS, DRILL HOLES AND SUBSURFACE GEOLOGIC CROSS SECTIONS IN THE VICINITY OF THE DUVAL SIERRITA POND

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