Rumrill, Nancy

From:	John Anderson <jla@johnlanderson.com>
Sent:	Monday, January 26, 2015 8:41 AM
To:	Rumrill, Nancy
Subject:	Florence Copper Project
Attachments:	epa tenorm 402-r-99-002.pdf

Ms. Rumrill,

It was so nice to meet you at the EPA meeting, here in Florence, on January 22.

I was elated to hear you say that the EPA decision for granting a permit to Florence Copper would be based on facts. I, immediately thought, the permit would be denied that this was a done deal! There is so much negative data and facts on the EPA website concerning in-situ mining. A lot of the data refers to in-situ mining for other commodities such as uranium and oil. But there are also articles about the in-situ copper mines in Arizona and specifically the pilot testing that was done at the Florence Copper site by BHP in 1996. Your report, see attached, states "There are several in-situ solution copper mines in the Arizona mining belt. High levels of TENORM have been found in the PLS of tow in-situ leach operations in Arizona." The two mines listed in the report are the BHP mine on the Florence Copper site and Santa Cruz site in nearby Casa Grande.

I bring this to your attention because when I had a discussion with some of the members of your staff, one being a mining engineer, he
was not aware on any in-situ copper mining in Arizona. I ask about the contamination of the aquifer and the flow to the public drinking water wells within two miles of the proposed test site. The response was that he had "modeled" the data and that based on his model, contamination would not reach our wells for about a hundred years. I ask why he was using a model rather than the BHP pilot which showed specific contamination and aquifer migration. He said he was not aware of any copper in-situ mining in Arizona. There are several in-situ mines currently in use in Arizona, your people are not aware of these mines?? Your mine engineer was more confident in his "model" that actual facts. This was rather disappointing.

Modeling is where you take a few knowns and attempt to project an answer when you do not have a complete set of facts or data to determine an outcome or future event. The weather forecasters do this daily, and are fairly accurate. The weather forecaster have been modeling for years and adding more known facts to their models but they are still occasionally wrong. The casinos love the people who have a model on how to win. These gamblers have fewer facts and lose more than they win. There are too many unknowns to adequately model now our aquifer will react to the in-situ process. There is no data on the flow rates, geological structures or vertical and horizontal flows outside of the test area. Even the data of flow rates is either not known or not being shared on the land within the PTS. The bottom line is that we do not have too model this project. Also, you do not have to inject acid into the aquifer to determine flows and flow rates. You have tons, (no put intended) of data concerning the impact in in-situ mining; all being negative. The testing done in 1996 proves the acid caused unacceptable TENORMS. Why allow this again?

The few people I spoke with from you staff, all appeared to be focusing on ways to support the approval of the pending permit. I was surprised and disappointed that there was not anyone on your staff that was a proponent of protecting the environment. The EPA people I met seemed to have backgrounds in mining and were promoting mining. If the EPA wants to model an experiment on a mining process, I commend them for doing so. Please do not allow such an experiment to go on where there is ANY risk to an aquifer that is used for drinking water now, a hundred years from now, or two hundred years from now. If the experiment fails, there is no recovery.

Again, thank you for coming to Florence and please, please, make your decision on the facts, not a model.

Regards,

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Environmental Protection
Agency

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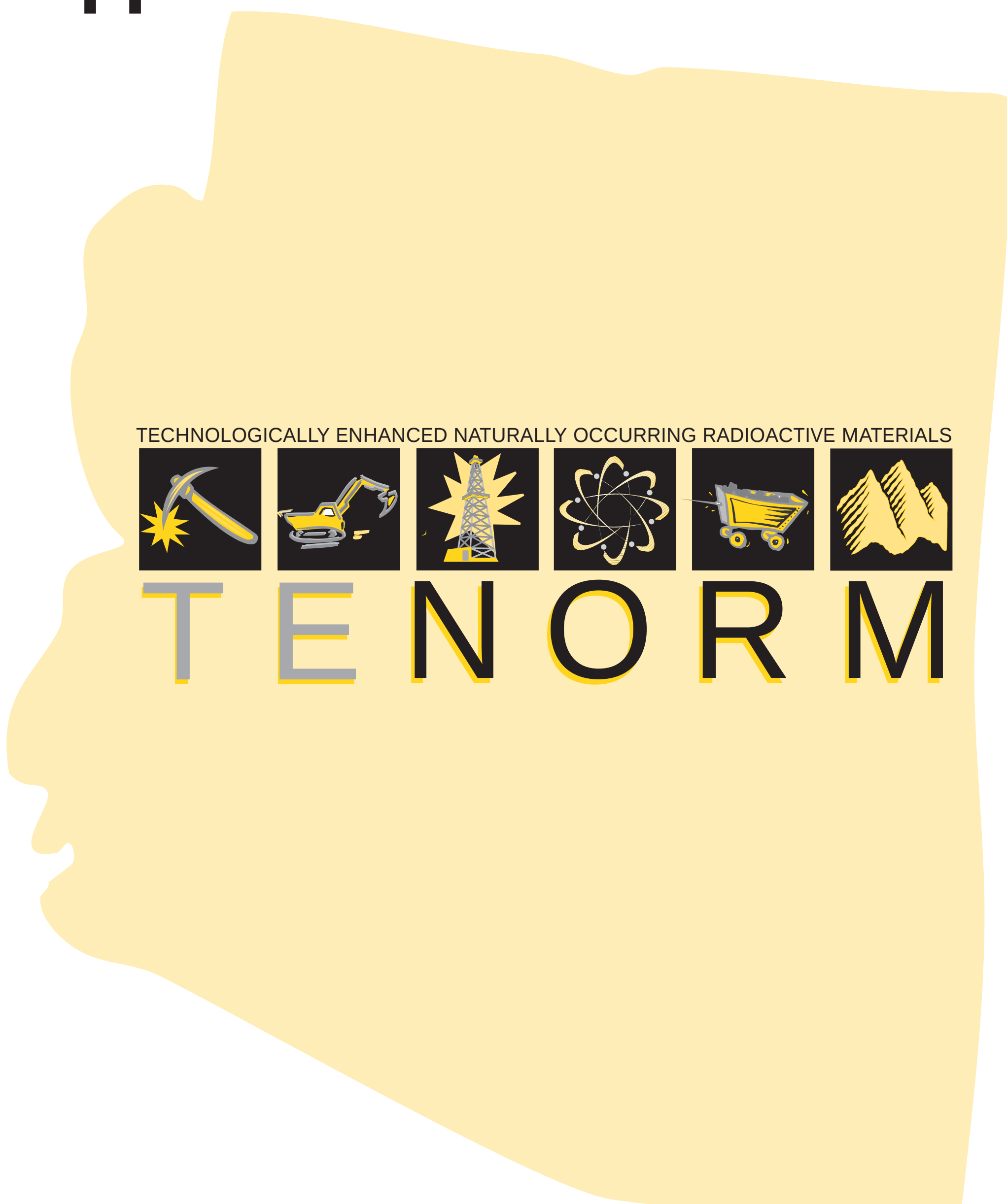
Technologically Enhanced Naturally Occurring Radioactive Materials in the Southwestern Copper Belt of Arizona



TECHNICAL REPORT

ON

TECHNOLOGICALLY ENHANCED
NATURALLY OCCURRING RADIOACTIVE MATERIALS

IN THE SOUTHWESTERN
COPPER BELT OF ARIZONA

U.S. Environmental Protection Agency,
Office of Radiation and Indoor Air,
Radiation Protection Division
401 M St. SW,
Washington, D.C. 20460

October 1999

DISCLAIMER

The mention of company or product names in this document is not to be considered an endorsement by the U.S. Environmental Protection Agency. The use of the terms "extraction," "beneficiation," and "mineral processing" in this document are not intended to classify any waste stream for the purposes of regulatory interpretation or application. Rather, these terms reflect common industry usage.

This report should be viewed only as a compilation of existing data on technologically enhanced naturally occurring radioactive materials (TENORM) in the copper industry of Arizona. It does not attempt to draw conclusions regarding the risks to human health and the environment, extrapolate data to other facilities, or define what actions may be taken regarding TENORM.

PREFACE

In mid-1992, the Arizona Department of Environmental Quality shared with the U.S. Environmental Protection Agency data on technologically enhanced naturally occurring radioactive materials (TENORM) emanating from copper mines. EPA developed this report to provide a better understanding of the nature and extent of TENORM at copper mining and mineral processing sites. This report compiles the data relevant to the occurrences and distribution of TENORM at mines in the southwestern copper belt of Arizona. The data show that dump leaching operations and solvent extraction-electrowinning procedures, as well as the practice of recycling raffinate at copper mines, may extract and concentrate soluble radioactive materials. The results show increases of up to two orders of magnitude over background levels for all radiochemicals tested except Rn-222.

ACKNOWLEDGMENTS

This document was prepared by the EPA, Office of Radiation and Indoor Air, Radiation Protection Division, Ariel Rios Building, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460. The author of this report is Mark R. Schuknecht, who worked for the Office of Radiation and Indoor Air, and is presently with the Office of Solid Waste. The text was distributed for review to the following EPA offices: ORD-NERL-Characterization Research Division, Las Vegas; Office of Radiation Programs, Waste Standards and Risk Assessment Branch; Office of Water, Water Quality and Industrial Permits; and EPA Region IX, Water Management Division, Permits and Enforcement. Comments from these offices have been incorporated into the document. EPA would like to thank the following external reviewers: Dr. Erling Brostuer, Colorado School of Mines, Energy, Minerals, and Environment Program; Dr. Glen Miller, University of Nevada, Reno; and Diann Gese, U.S. National Park Service.

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LIST OF ACRONYMS

ADEQ	Arizona Department of Environmental Quality
ABM	Arizona Bureau of Mines
ADHS	Arizona Department of Health Services
AEA	Atomic Energy Act
AMD	Acid Mine Drainage
APPA	Aquifer Protection Permit Application
ARRA	Arizona Radiation Regulation Agency
AWQS	Aquifer Water Quality Standards
AZMILS	Arizona Mineral Industry Location System
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DWR	Drinking Water Regulations
EPA	Environmental Protection Agency
HBGL	Human Health Based Guidelines
MCL	Maximum Contaminant Level
MW	Monitoring Well(s)
NORM	Naturally Occurring Radioactive Material
ORIA	Office of Radiation and Indoor Air
OX-EW	Oxide and Electrowinning
PLS	Pregnant Leach Solution
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SX-EW	Solvent Extraction-Electrowinning
TDS	Total Dissolved Solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
UIC	Underground Injection Control
USGS	U.S. Geological Survey

Mines Referred to by Acronym

AL	American Legion
CB	Cyprus Bagdad
CQ	Phelps Dodge Copper Queen
CS	Cyprus Sierrita
DF	De la Fontaine
HS	Hillside
MF	Magma Florence
MM	Phelps Dodge Morenci
MP	Mineral Park
NC	Phelps Dodge New Cornelia
PV	Pinto Valley
SC	Santa Cruz
SM	Magma San Manual
TB	Cyprus Twin Buttes
TR	Three R's

Mine Specific Facility Acronyms

LOS	Lean Ore Stockpiles (Phelps Dodge)
SACLOG	Sacramento Low Ore Grade Stockpiles (Copper Queen Mine)
SWRRD	Southwestern Railroad Dumps (Phelps Dodge)

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency has been working over the past several years to better understand the nature and extent of TENORM that may become concentrated at copper mining sites. This document presents the information that EPA has compiled on this issue to date. The literature on the subject indicates the presence of uranium and thorium in minerals associated with porphyry copper deposits in Arizona. Copper extraction and beneficiation operations may concentrate these radioactive materials. Samples taken by the ADEQ from several copper mines indicate that TENORM has been found to occur above background levels in surface water and in some mining process and waste streams. The data also show evidence of TENORM in surface water, groundwater and soils. The data suggest that dump leaching operations and solvent extraction-electrowinning procedures, as well as the practice of recycling raffinate at copper mines, extract and concentrate soluble radioactive materials. The results show increases of up to two orders of magnitude over background levels for samples of all radiochemicals tested except Rn-222. Radiological data in this report represent a sampling of mine wastes at specific facilities and do not necessarily represent other copper operations. Based on the data presented herein, there is an increased likelihood that copper leach operations and their associated solvent extraction-electrowinning circuits in Arizona concentrate TENORM.

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I. INTRODUCTION

Nearly all rocks, soils, and water contain small amounts of radioactive materials such as uranium, thorium, radium, radioisotopes of potassium, lead, polonium, and their decay products. When naturally occurring radioactive materials in their undisturbed natural state (NORM) become purposefully or inadvertently concentrated either in waste byproducts or in a product, they become technologically enhanced naturally occurring radioactive materials (TENORM). TENORM is defined as any naturally occurring radioactive materials whose radionuclide concentrations or potential for human exposure has been increased above levels encountered in the natural state as a result of human activities (NAS, 1999).

The U.S. Environmental Protection Agency (EPA) and other regulatory entities have become increasingly aware of the immense volume of TENORM produced annually throughout the United States and the world. TENORM wastes often include byproducts from industrial activities such as thorium and uranium mining/milling; niobium, tin, and gold mining; water treatment; oil and natural gas production; and phosphate fertilizer, coal fire ash, and aluminum production. The potential threat posed by these wastes cannot be dismissed as below radiological concern or below exempt concentration levels. TENORM concentrations often reach levels comparable to typical low-level radioactive waste (Paschoa, 1998). The scientific community has been concerned for some time with the issue of exposures to these materials. EPA's Office of Radiation and Indoor Air (ORIA) is currently examining the potential environmental implications of TENORM wastes from various sources and is looking at disposal methods as well as exposure risks.

EPA has studied sources of radiation since the mid-1970s. Because radioactivity is not a "characteristic" of hazardous waste, as defined in Subtitle C of the Resource Conservation and Recovery Act (RCRA), the regulation of radioactive wastes has generally been limited to the Atomic Energy Act (AEA), the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

EPA evaluated radioactive materials in its 1985 Report to Congress on Special Wastes from Mineral Processing (USEPA, 12/1985). In this report, the Agency indicated that it would continue to study radioactive waste and waste with the potential to form sulfuric acid to determine if they posed a threat to human health and the environment; however, sufficient data were not available to make such a determination. The Agency stated that it would continue gathering relevant information, and if it became necessary to regulate these wastes, the Agency would develop appropriate measures of hazard and waste management standards (USEPA, 12/1985). The Agency subsequently made several regulatory determinations as to the appropriateness of RCRA Subtitle C regulation under the Bevill Amendment. Natural radioactivity was identified as a concern for several of the Bevill wastes. To date, the Agency has received no statutory direction in this area. However, under the Clean Air Act (40 CFR Part 61), EPA has developed regulations to control the emissions of radon from phosphate production (phosphogypsum stacks), elemental phosphorous plants, and uranium mill tailings. Additionally, under the Safe Drinking Water Act (40 CFR Part 141), maximum contaminant levels for radiation have been established, and standards for radioactivity in liquid discharges from uranium, thorium and vanadium mills were developed under the Clean Water Act (40 CFR part 440). In areas with radioactively contaminated soils, EPA has established guidance for clean-up levels for its field offices under authority of the Comprehensive Environmental Response, Compensation and Liability Act.

As mentioned above, TENORM is found in many metal mining and mineral processing wastes. For example, the 1985 Report to Congress reported elevated uranium and thorium concentrations in various copper mining and processing operations. In the early 1980, EPA s Office of Air and Radiation studied Rn-222 and uranium particulate releases from copper processors, but did not find significant releases. However, these studies are at least ten years old and radiological characterization of the wastes was not their primary goal. In addition, technological advances in dump leaching and solvent extraction-electrowinning (SX-EW) procedures, as well as the practice of recycling raffinate, have created new waste streams not assessed in previous EPA studies. The purpose of this report is to characterize and document TENORM from copper mining. It should be noted, however, that it addresses only a subset of mines in Arizona.

To address radiation protection issues, EPA has initiated programs under the authority of the Clean Water Act, SDWA, CAA, and Toxic Substances Control Act. ORIA is concerned about the public health implications of TENORM, and has received inquiries from state radiation protection agencies and EPA regional offices for guidance in this area. In response, ORIA is developing a series of technical reports that will be used to assess risks of the various sectors where TENORM has been found. Concern about elevated levels of TENORM at several mine sites prompted the development of this report.

EPA has been working with the Arizona Department of Environmental Quality (ADEQ) to assemble the available data on TENORM at metal mining sites in Arizona. As part of its groundwater and surface water protection programs, ADEQ requires mining companies to submit Aquifer Protection Permit Applications (APPA) that include facility-specific radiological characterizations. EPA continues to seek information from all interested parties to increase its knowledge and ability to characterize TENORM at mining sites. A secondary goal of this study is to bring scientifically-sound and well-documented data to light, and to assist stakeholders in assessing radiochemicals relative to background levels and federal and state radiation protection standards.

II. FINDINGS

In 1992, ADEQ shared with EPA data on TENORM emanating from copper mines. EPA has continued to work with ADEQ to assemble the available data. As part of its groundwater and surface water protection programs, ADEQ requires mining companies to submit APPAs containing facility-specific radiochemical characterizations. As a result, ADEQ and EPA have accumulated in excess of 3200 analyses of radionuclides at 15 mining sites in the copper industry. This report reviews the current information on the occurrence and distribution of TENORM at mines in Arizona and contains tables of all the available data as of 1997.

Tables 1 through 5 summarize the data according to media, including: groundwater, surface water, soil-sediment, process solutions, and process wastes. Instances when the average levels of radioactivity exceed the federal maximum contaminant levels (MCLs) or Arizona guidelines are shown in bold. The groundwater media included about 2220 analyses from about 176 wells at nine mines. The surface water media included about 197 analyses from nine mine adits, eight washes, and six creeks at seven mine sites. As many as 25 soil samples were taken from four mines to support 110 analyses.

Levels in excess of the federal MCLs and state guidelines were found in groundwater and surface water samples, as well as soil and sediment samples at abandoned and active copper mines. TENORM exceedences were also found in groundwater at active and inactive copper mines. Uranium byproducts were recovered from heap leach dumps and in-situ operations that feed SX-EW and ion exchange circuits at several copper mines. Radioactivity was discovered in copper mineral processing waste streams. Elevated levels of radioactivity were also found to occur in the process solutions and process wastes. The average radiochemical composition of five pregnant leach solution (PLS) samples, in pCi/L, can be characterized as 3642 gross alpha, 1974 gross beta, 929 U-238, 999 U-234, 304 U-235, 51 Ra-226, and 1701 total uranium (see Table 1, Average column). The average activity of six raffinate solutions are 2943 and 1228 pCi/L gross alpha and beta, respectively. The average activity of 22 sump solutions is slightly less   1331 and 811 pCi/L gross alpha and beta, respectively. It should be noted that all available data, from both contaminated and uncontaminated samples, was used in preparing Tables 1-5 below. Consequently, the statistical results on radioactivity levels are significantly lower than if only contaminated samples were used.

The data indicate that the solvent extraction process acts to concentrate TENORM. Technological advances in SX-EW procedures have created new waste streams that were not assessed in earlier EPA studies. Also, the practice of recycling raffinate that contains elevated levels of TENORM from SX-EW facilities and using delisted waste streams such as KO64 as lixivent acids at the leach dumps may exacerbate the occurrence of TENORM at copper processing sites. KO64 is smelter acid blowdown or sulfuric acid produced from the air emissions scrubber circuits. However, the uranium-enriched raffinate might also be considered a resource that can be exploited at relatively low cost through eulex-ion exchange technology, thereby removing the potential contaminants from the environment and contributing to the long-run profitability of the mining operation (i.e., by reducing potential remediation costs).

The radioactivity appears to be associated with copper mineralization that contains traces of uranium. The natural leaching process tends to extract and concentrate radioactive materials in the acid mine drainage or leachate at waste dumps. Dump or heap leaching operations also extract and concentrate the soluble radioactive materials in the PLS. If TENORM is present at the waste dump, it may be found in the drainage or the leachate. These solutions are then concentrated by the SX process and sent to the electrowinning plant for copper recovery. TENORM is also concentrated at the SX units since the PLS is concentrated by those units. Because uranium is not recovered in the electrowinning process, the TENORM may stay in the raffinate, which is recycled back to the leach dumps as lixivents. Many copper mining companies have reclassified their waste dumps as leach operations within the last decade. Recycling of the raffinate solutions from the SX-EW circuit to the leach dump may also contribute to the buildup of TENORM at the leach dumps. The limited data presented in this report indicate a potential for TENORM to be concentrated in the soil, surface water, groundwater at abandoned mine dumps, and active copper mines. Preliminary findings also suggest that it is concentrated in the soils, surface water, and groundwater at leach dumps in the leach circuit of active copper mines. The data also show that TENORM is concentrated in copper beneficiation and processing waste streams.

Data presented within this report represent a sampling of copper mines and facilities, and may not necessarily represent all copper operations in the state. The impacts of copper mining are noteworthy because of unique conditions, such as the presence of trace uranium minerals and the mining and extraction methods that unintentionally extract radioactive materials and enhance its environmental mobility. Tables 1-5 present data on the mining sites where TENORM has been documented by ADEQ. These sites are: Cyprus Bagdad (CB), Cyprus Twin Buttes (TB), Cyprus Sierrita (CS), Phelps Dodge Copper Queen (CQ), Pinto Valley (PV), Mineral Park (MP), Phelps Dodge Morenci (MM), Phelps Dodge New Cornelia (NC), American Legion (AL), De la Fontaine (DF), Hillside (HS), Three R s (TR), Magma Florence (MF), Santa Cruz (SC), and Magma San Manual (SM). Groundwater, surface water, process solution and process waste data in Tables 1-5 are expressed in pCi/L, while soil and sediment data are expressed in pCi/g.

Table 1

Groundwater Statistical Data (except Morenci) (pCi/L)

Radiochemical	Mine Sites	Number	Min.	Max.	Avg.	Std. Dev.
Gross Alpha	CB,TB,CS,CQ,PV,MP,NC	129	0	1500	60.3	150.8
Gross Beta	CB,TB,CS,CQ,PV,MP,NC	116	0	500	44.4	72.6
U-238	CB,CQ,NC	63	0.06	38.6	5.9	7.6
U-234	CB,CQ,NC	63	1.3	60.4	12.8	14.8
U-235	CB,CQ,NC	56	0	2.9	0.4	0.5
Total Ra	PV	16	0.8	122	10.8	30.5
Ra-226	CB,TB,CS,CQ,PV,NC	117	0	130	3.0	13.4
Ra-228	CB,TB,CS,CQ,PV,NC	111	0	122	4.1	12.7
Total-U	IB,CB,CS,CQ,PV,NC	119	0	209	12.0	24.9
Rn-222	CB,CQ,PV	23	16	3980	1216	1309
Total	7 MINES	813				

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Table 2

Surface Water Statistical Data (pCi/L)

Radiochemical	Mine Sites	Number	Min.	Max.	Avg.	Std. Dev.
Gross Alpha	MP,MM,CB,TR,AL,DF,HS,NC	54	0	1240	83.5	188.4
Gross Beta	CB,MP,MM,TR,NC	32	0	128	27.1	34
U-238	CB,TR,AL,HS,NC	19	0.1	678	83.8	168.2
U-234	CB,TR,AL,HS,NC	19	0.2	577	80	141.8
U-235	CB,TR,NC	9	0.04	2.9	1.1	0.9
Ra-226	CB,MP,NC	29	0	71.8	6.4	13.8
Ra-228	MP,CB,TR,AL,DF,HS,NC	18	0	55.5	5.6	13.1
Total-U	MP,CB,TR,NC	12	0.01	32.9	6.6	10.9
Rn-222	MP	3	39	120	68.3	44.9
Total	8 MINES	195				

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Table 3

Sediment and Soil Statistical Data (pCi/g)

Radiochemical	Mine Sites	Number	Min.	Max.	Avg.	Std. Dev.
Gross Alpha	AL,DF,HS,MM	25	0.5	395	63.1	90.0
Gross Beta	AL,DF,HS,MM	25	22	248	69.4	52.3
U-238	AL,DF,HS	20	0.7	63.3	7.9	14.2
U-234	AL,DF,HS	20	0.9	60.8	10.0	16.6
Ra-226	AL,DF,HS	20	0.7	82.6	10.4	19.7
Totals	4 Mines	110				

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Table 4

Process Solutions Statistical Data (pCi/L)

Radiochemical	Mine Sites	Number	Min.	Max.	Avg.	Std. Dev.
Gross Alpha	MP,MM,MF,SC	43	1.3	8649	1841	1850
Gross Beta	MP,MM,MF	41	3.0	3683	975.6	881.7
U-238	MF	2	248	1611	929.5	963.8
U-234	MF	2	254	1745	999.5	1054.3
U-235	MF	2	11.6	598	304.8	414.7
Ra-226	MF,SC	4	19.5	193	86.3	79.1
Ra-228	MF,SC	4	2.0	19	7.8	8.0
Total-U	MF,CS,TB	6	0.8	4362	1895.9	1532.9
Rn-222	MF,SC	4	243	3760	1805.7	1593.5

Total	5 MINES	108

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Table 5

Process Wastes Statistical Data (pCi/L)

Radiochemical	Mine Sites	Number	Min.	Max.	Avg.	Std. Dev.
Gross Alpha	MM,PV,CQ,SM	21	0	4100	246.9	894.4
Gross Beta	MM,PV,SM	20	5.4	4400	301.5	968.5
U-238	CQ	1		156		
U-234	CQ	1		131		
U-235	CQ	1		6.8		
Total Ra	PV	1		2.2		
Ra-226	PV,CQ	4	0.3	20	5.4	9.7
Ra-228	PV,CQ	4	0.7	7.1	3.0	2.8
Total-U	PV,CQ	2	0.2	0.7	0.4	0.4
Rn-222	PV,CQ	2	10	57	33.5	33.2
Total	4 MINES	57				

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold
= No data

III. GEOLOGIC EVIDENCE

A. Background Levels and Standards of TENORM

Uranium is associated with many different minerals and rock types. The average abundance (background level) of uranium (total uranium) in crustal rocks ranges from 0.5 parts per million (ppm) (0.34 pCi/g) to 5.0 ppm (3.4 pCi/g), depending on rock type. In sedimentary rocks, such as sandstones and carbonates, the average background concentration is relatively low, ranging from 1.0 ppm (0.69 pCi/g) to 2.0 ppm (1.37 pCi/g). Shales average 3.2 ppm (2.20 pCi/g). In extrusive and intrusive igneous rocks, average crustal abundance is relatively high. Intrusive rocks, such as granite, average 4.8 ppm (3.30 pCi/g), while extrusive rocks are more variable. Basalt ranges from 0.5 ppm (0.34 pCi/g) to 1.0 ppm (0.69 pCi/g), while rhyolite is around 4.0 ppm (2.75 pCi/g) (NCRP, 1987). Rocks that contain more than 10 ppm (6.87 pCi/g) are considered rich in uranium.

The literature typically reports uranium in ppm, while the mining industry usually reports it as a percentage. Naturally occurring uranium contains 99.2800 percent U-238 by weight, 0.7110 percent U-235, and 0.00546 percent U-234. The specific activity for uranium is 0.6866 Ci/g (56 FR 33068). Since the units used in this report are pCi, whenever possible, the data have been converted to pCi/L or pCi/g using this specific activity. The international community uses Becquerels (Bq), for which the conversion factor is 27 pCi = 1 Bq. In some cases, the percentages of naturally-occurring isotopes vary (CRC, 1979). Table 6 shows the average range of background levels of uranium in rocks expressed in pCi/g. Researchers have reported slightly different values, which may be due to differences in measurement techniques or because their samples were taken from different locations. Table 6 is a collection of background level data from the National Council on Radiation Protection and Measurements (NCRP, 1987), Arizona Department of Environmental Quality (ADEQ, 9/1989) and EPA (USEPA, 1994).

Table 6

Average Background Levels of Uranium in Crustal Rocks (pCi/g)

Rock Type	U-Total Range	U-238 Range
Mafic Basalt	0.34-0.61	0.17-0.30
Salic Basalt	2.67-3.22	1.29-1.55
Granite	2.06-3.30	0.99-1.58
Rhyolite	2.75	1.32
Shale	2.20	1.06
Clean Sandstone	0.68-1.37	0.33-0.66
Dirty Sandstone	1.38-2.06	0.66-0.99
Carbonates	0.68-1.37	0.33-0.66
Soils avg.	1.23	0.59
Crustal avg.	1.92	0.92

References: NCRP, 1987; ADEQ 9/1989; USEPA, 1994
1.0 ppm = 0.69 pCi/g
All values convert from ppm to pCi/g

Additional data on background radionuclide concentration in surface soils are summarized in the EPA Technical Background Document, *Review of Radionuclide Concentrations in Rocks, Soils, Mining Materials, and Coal Ash,* July 1994. As cited in this document, Myrick conducted a study that analyzed 356 samples. The analysis calculated the geometric mean for U-238 to be 0.96 pCi/g. The data ranged from a low of 0.12 to a high of 3.8 pCi/g. Myrick also analyzed another 327 samples for Ra-226. They ranged from 0.23 to 4.2 with a mean value of 1.0 pCi/g. Another study done by Shacklette and Boerngen in 1984 analyzed 354 samples for U-238. Their results produced an average value of 0.89 pCi/g with a range of 0.096 to 3.63 pCi/g (USEPA, 1994).

The background level of radionuclides in Arizona is highly variable due to the widespread occurrence of uranium-rich source rocks. The most frequent source of radionuclides in Arizona is granitic rocks associated with Precambrian outcrops and Laramide intrusive rocks (ADEQ, 9/1989). The Precambrian Lawler Peak Granite, which outcrops extensively throughout the Bagdad Mining District, is considered to be one of the two most uranium-rich granites in the United States. The Lawler Peak Granite near Bagdad contains up to 51 ppm uranium, with an average concentration of 14.6 ppm uranium. Another Lawler Peak Granite contains up to 551 ppm uranium, with an average concentration of 269 ppm (ADEQ, 9/1989; Pewe, 1989; AGS, 1990). These data have been converted to pCi/g in Table 7 below.

Table 7

Uranium Levels in Arizona Rock Formations (pCi/g)

	Total U Range	
Formation	Low	High
Hopi Buttes Lamproproyres	2.75	-
Wilderness Granite near Santa Catalina Mts.	0.80	1.99
Oricale Granite near Santa Catalina Mts.	2.40	5.56
Turkey Track Andesite near Tucson	2.27	-
Dells Peak Granite near Prescott	5.63	18.06
Lawler Peak Granite near Bagdad	10.02	35.02
Lawler Peak Granite	184.7	378.3

Reference: ADEQ, 9/1989
- = No data
All values convert from ppm to pCi/g

The radioactivity of the southwestern copper belt appears to be related to Laramide porphyry intrusive and Precambrian granitic rocks that contain trace amounts of residual radioactivity.

Background levels for gross alpha and beta, Ra-226, U-238, U-234, and Rn-222 in groundwater are presented in the report, *Natural Occurrence of Radon and Other Natural Radioactivity in Public Water Supplies*, which was prepared by EPA s Office of Radiation Programs, now ORIA, in 1985 (USEPA, 10/1985). Table 8 below shows the data for public groundwater systems in selected locations in Arizona. The systems were selected to provide background radiation levels in groundwater for the nearest watershed to the mines discussed in this paper.

The 1985 EPA study sampled finish water collected as near to the source as possible. Small public groundwater systems, like many of those presented in Table 8, tend to have higher radon levels than larger systems. Larger water systems, such as in Tucson, tend to use aerators with higher holdback capacity that may reduce radon levels due to decay and dilution. Many of the larger systems may also chemically treat their water to improve quality. Many of the water samples below were untreated, although specific information on the types of treatment used by each system is unknown. The analytic methods used in the 1985 EPA study were discussed in previous papers. In general, the precision and accuracy of these analytic methods were maximized, while counting errors were minimized. These aspects were also discussed in detail in these papers (USEPA, 10/1985). ADEQ also sampled public drinking water wells in the Bisbee/Naco area to establish background levels of radionuclides. ADEQ analyses were the same as the EPA results shown in Table 8 for the Bisbee area.

Table 8

Natural Radioactivity in Public Groundwater Systems in Arizona (pCi/L)

Sample Location	Alpha	Beta	Ra-226	U-238	U-234	Rn-222
Apache Junction	0.2	7.0	-	-	-	135.8
Bisbee	3.0	2.0	0.1	0.3	2.0	487.4
Casa Grande	20.0	6.0	0.1	9.8	12.8	544.2
Florence-High	3.0	14.0	0.1	-	-	236.0
Florence-Low	1.0	4.0	-	-	-	197.8
Globe	1.0	2.0	-	-	-	310.5
Miami	3.0	5.0	0.1	-	-	291.7
Nogales	4.0	5.0	0.1	3.3	4.2	396.4
Prescott	1.9	1.1	0.1	0.4	1.3	859.9
Sierra Vista-High	2.0	2.0	-	-	-	1153.0
Sierra Vista-Low	1.0	0.3	-	-	-	313.3
Superior	0.5	3.0	-	-	-	30.9
Mammoth	2.0	2.0	-	-	-	580.9
Oracle	0.3	2.0	-	-	-	210.8
Tucson - Low	0.1	0.1	0.2	1.0	2.1	19.7
Tucson - High	4.9	1.7	0.2	1.5	2.6	460.7

Reference: USEPA, 1985
- = No Data

EPA established federal water quality standards for radionuclides in SDWA and Interim Drinking Water Regulations (DWR). The Agency uses MCLs, established under SDWA, as reference points for water resource protection efforts when the groundwater is a potential source of drinking water. The MCLs for most radioactive materials are usually measured in pCi/L. Beta/photon emitters are dose-limited (4 mrem), while gross alpha Ra standards are expressed in pCi/L. Table 9 identifies the current and proposed federal and Arizona drinking water standards for gross alpha and beta, total radium, Ra-226, Ra-228, total uranium, and radon.

Table 9

Current and Proposed Radionuclide Standards (pCi/L except as noted)

Radionuclide	Federal 1976 Current MCL	Federal 1991 Proposed MCL	Arizona State HBGL[1]
Alpha	15	15	None
Beta and Gamma	4 mrem/yr.	4 mrem/yr.	(50)
Total Radium (Ra 226+Ra 228)	5	None	None
Ra 226	if > 5	20	None
Ra 228	if > 5	20	None
Uranium	None	30[2]	7[3]
Rn 222	None	300	None

References: 40 CFR /141.15; 56 FR 33050
if > 5 = if the individual component of Ra-226 or Ra-228 is greater than five pCi/L it will exceed the total radium standard.

[1] HBGL is Arizona Human Heath Based Guidelines

[2] Natural uranium contains three isotopes: U-234, U-235, and U-238. The corresponding percentages of occurrence in rocks for these isotopes are 0.006, 0.72 and 99.27 percent by weight, respectively. However, the percent occurrence of these isotopes relative to each other is not constant in drinking water. U-238 and U-234 are responsible for most of the uranium in natural waters. The overall activity-to-mass of uranium ratio for the three natural isotopes of uranium in rocks is .68pCi/ug and is frequently used to estimate the activity of total uranium measured as mass (EPA1988b; EPA/ORNL 1981). The 0.68pCi/ug value is based on the natural crustal abundance of isotopes. The U-234/U-238 activity ratio of one, that is inherent in the assumption, may not be appropriate for samples taken from water. The National Radon Survey (EPA, 10/1985) which measured uranium as well as radon, reported a range of U-234 to U-238 activity ratios in water of 0.7 to 32 with a geometric mean of 2.7. Using the U-234 to U-238 activity ratios of 2.7, an overall activity to mass ratio of 1.3 pCi/ug was calculated for uranium as it occurs in drinking water (EPA 1990h; 1991o). The 1.3 factor was applied to the NIRS results to convert those data from mass (ug/L) to activity (pCi/L) for total uranium (56 FR 33068). Note the 20 ug/L is the MCL standard not the conversion. In the 1994 Regulatory Impact Analysis, cost impacts were estimated based on a revised best estimate of the activity to mass ratio of 0.9.

[3] ADEQ assumes that the dominant isotope in total uranium is U-238. Then the specific activity for U-238 or total uranium is = 0.338 uCi/g. Then (0.338uCi/g x 21ug/L) = 7 pCi/L. ADEQ uses this value as an indicator of TENORM contamination. Note the 21ug/L is the guideline, not the conversion.

Gross Alpha and Beta

In the July 1976 regulations (41 FR 8404) and the 1991 proposed regulations, EPA set the MCLs for the gross alpha emitters at 15 pCi/L, and gross beta emitters at 4 mrem/yr (40 CFR /141.15). The MCL for beta and photon radionuclides is determined by the annual dose equivalent to the total body or any internal organ from the average annual beta particle and photon radioactivity in drinking water shall not be greater than 4 mrem/yr. The concentration of radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in *Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure*, NBS Handbook 69, as amended, August 1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year (40 CFR /141.16).

Compliance with 40 CFR /141.6 requirement for radioactivity in community water systems is achieved if the gross beta particle activity is less than 50 pCi/L, and if the analysis of tritium and Sr-90 are less that 4 mrem combined dose. If the gross beta particle activity exceeds 50 pCi/L, an analysis of the sample must be performed to identify the major radioactive constituents present. The concentrations shall be compared to the picoCurie levels calculated from NBS-69 to determine compliance with 40 CFR /141.16 (40 CFR /141.26 (b)(1)(i)). Arizona uses the gross beta value of 50 pCi/L (calculation based on 40 CFR /141.16 applying the 4 mrem/g standard) as a guideline to trigger analyses for other radiochemicals.

Radium

The 1986 amendments to the Safe Drinking Water Act also established the MCL standard for total radium (226+228) at 5 pCi/L (40 CFR /141.15). Thus, if any single isotope of radium exceeds 5 pCi/L, it will also violate the total radium standard. In 1991, EPA proposed to increase the MCL for both Ra-226 and Ra-228 to 20 pCi/L (56 FR 33050). Because of the controversy surrounding the proposed standard, Congress prevented the proposal from being promulgated. After passage of the Amendments of 1996, new deadlines were established by a stipulated agreement between the court, EPA, and parties to previous consent decrees. The agreement set November 2000 as the date for EPA to finalize the rules for uranium, and to either finalize new levels or justify maintaining current levels for radium, alpha, and beta/photon emitters.

For surface contamination, radium is very often the key radionuclide of concern (in terms of exposure) for tailings or waste. Radium is found in equilibrium with natural unaltered uranium. Although they were developed to address uranium mill tailings, the cleanup standards established under the Uranium Mill Tailings Radiation Control Act (40 CFR Part 192) are often used as a general guide for the cleanup of radium contamination. They call for a limit of 5 pCi/g total radium over background in the top 15 cm soil, and 15 pCi/g average over background in any layer below that. The 5 pCi/g limit addresses external exposure, while the 15 pCi/g limit allows for the identification of mill tailings (which usually exhibit concentrations of several hundred pCi/g) with a hand held instrument so that buried contamination can be reduced to about 5pCi/g. This should maintain the indoor radon levels below 4 pCi/L, the EPA Action Level.

Uranium

There are no current federal MCLs for uranium or isotopes of uranium. Although in 1991, EPA proposed a total uranium standard at 20 ug/L (56 FR 33050). The proposed 20 ug/L is equal to 30 pCi/L. For an explanation of conversion see Note 2 at the bottom of Table 9. The Arizona Human Health Based Guideline (HBGL) action level for total uranium was set at 35 ug/L in 1990 and then lowered to 21 ug/L in 1992 (ADEQ, 1992). See Note 3 at the bottom of Table 9 to explain the difference between the proposed federal and Arizona guidelines. Since the Arizona HBGL is for total uranium, any isotope that exceeds the total uranium guideline will surpass the HBGL as well.

Radon

The measured concentration of radon in public groundwater systems ranges from 200 to 600 pCi/L (ADEQ, 9/1989). The background level of radon in Arizona is highly variable. The average concentration of radon in public groundwater supplies in Arizona is 250 pCi/L (ADEQ, 9/1989). In 1991, EPA proposed a drinking water standard for radon at 300 pCi/L (56 FR 33050). EPA withdrew the proposed radon standard in August of 1997.

Section 1412(b)(9) of the Safe Drinking Water Act, as amended in 1996, states: each revision shall maintain or provide for greater protection of health of persons. Thus, it appears that EPA will maintain the standards for these radionuclides established in 1976, except for adjustments for some nuclides that represent a greater risk than originally believed. Also, in the 1996 amendments, Congress directed EPA to propose a radon regulation by 1999 and subsequently finalize it within a year.

In summary, the average crustal abundance of total uranium in rocks is 1.92 pCi/g. Uranium-rich rocks contain greater than 7 pCi/g, usually ranging between 7 to 400 pCi/g while mineable uranium deposits are greater than 600 pCi/g. The Arizona guideline for total uranium that leaches into water is 21ug/L which is approximately equal to 7 pCi/L. See Note 2 on Table 9. The background level of radionuclides in Arizona is highly variable due to the widespread occurrence of uranium-rich source rocks. Likely sources of the radionuclides in Arizona are the Precambrian granite and Laramide intrusives (ADEQ, 9/1989).

B. Quality Assurance/Quality Control

The data in this report were obtained from ADEQ as part of its permitting and enforcement processes. The author has identified several potentially unresolved issues due to data limitations. Most of the data on TENORM were provided by Arizona mining interests in response to specific requests for information from ADEQ. The level of quality control between mines varied, depending on the sampling methodology used, the laboratory conducting the analyses, the sample size, TDS concentration, and elapsed time; although all analyses for radiochemical parameters were conducted by EPA-certified labs. The samples contained quality splits, blanks, duplicates, and counting errors that were taken and analyzed with each of the samples. All data in this report have been reviewed by ADEQ and met the quality assurance quality control (QA/QC) standards of ADEQ s Quality Assurance Project Plan of 1991, which provides guidelines for ensuring the quality of geological samples for radiochemicals. This document is referenced as part of all APPA permit requirements and regulations of ADEQ. It should be noted that it is in the best interest of the mining industry to maintain high-quality information and results. There were two instances (as noted in the text) that showed large counting errors. ADEQ and the respective mines agreed to re-sample and re-analyze the questionable results with lowered error values (ADEQ, 5/1991).

Although the data met QA/QC standards, the precision of the data provided by Arizona mining interests (i.e., the number of counting errors and significant figures) was not always consistent. It was not possible, therefore, to establish a uniform level of significance for data presented in this report. Moreover, a comprehensive presentation of error limits and precision levels in the gathering of the data is beyond the scope of this report. Complete laboratory results, including chain-of-custody from data collection to laboratory analysis, QA/QC documentation, and margins of error, may be found in the original reports cited in the references.

All water laboratory results for radiochemicals presented in the tables in the remainder of this report are expressed in pCi/L. All sediment sample laboratory results are reported in pCi/g. International readers note that 1 Bq = 27 pCi (or 1 pCi = .037 Bq).

C. Regional Geologic Literature and TENORM

Uranium minerals are found in association with many primary metal deposits in Arizona. They are associated with the copper porphyry deposits and with vein deposits of copper, lead, and precious metal sulfide ores (USEPA, 1990). Uranium has been mined at many precious metal, copper, and base metal sulfide mines in Arizona as a primary or secondary mineral. In many cases, during the development of a mineral deposit, the primary mineral classification of a mine (e.g., gold mine or copper mine) will change. This is because the classification system is based on factors that affect the profitability of the mine, such as: the mineral value, size of deposit, and its location. The majority of copper mines in Arizona were mined for other metals at some time during their development. Geologists generally agree that the presence of NORM within a particular ore deposit depends on the regional geology, the mineral assemblage, and the geologic formation, rather than on mine type or classification. Figure A shows the locations of the TENORM sites discussed in this document.

The Arizona Department of Mines and Mineral Resources maintains a computerized database known as the Arizona Mineral Industry Location System (AZMILS) that lists all known mineral occurrences in Arizona. A section of the AZMILS database, as of 1998, identifies 421 records of old miner. . .primary occurrences of uranium and another 161 records of byproduct occurrences of uranium, for a total of 582 known occurrences of uranium in Arizona. About 14 percent or 80 of these old miner records of uranium are associated with copper minerals. See Figure A for the location of these occurrences. The majority of the old miner records came from Keith s 1970 work on uranium in the Arizona Bureau of Mines Bulletin 182, entitled Coal, Oil, Natural Gas, Helium, and Uranium in Arizona (ABM, 1970). A list of all the old miner records of uranium occurrences associated with copper are presented in Appendices A and B of this report. Appendix A contains sites that were verified by sample analyses, while Appendix B contains sites that were not verified with laboratory analyses.

The mining industry usually reports the percentage of total uranium, or U, to indicate the concentration of uranium in a sample. The estimated percentage of uranium, or eU, is based on field readings from hand-held scintillation or Geiger counters. Note that 0.1 percent uranium is equal to 582.2 pCi/g. Exploration geologists usually consider deposits containing greater than 0.1 to 0.2 percent total uranium as economic or potentially mineable.

A band of uranium-bearing minerals appears to extend from 10 miles (16 km) northwest of Twin Buttes and Esperanza, across the Sierrita Mountains, to the Black Dike mine. Esperanza and Twin Buttes are large open-pit porphyry copper-molybdenum mines about 25 miles (40 km) south-southwest of Tucson and 10 miles (16 km) southwest of Sahuarita. Twin Buttes is 4 miles (6.4 km) northeast of Esperanza. The New Year s Eve underground mine at Esperanza contains uraninite (U3O8) in veinlets of molybdenite and copper minerals in the porphyry copper deposit. Assays of ore stockpiles indicate that uraninite contains between 0.11 to 0.18 percent eU. Uranium was found along the contact of a vein of copper and fluorite minerals at the Black Dike underground mine. Radionuclides also occur in the pitchblende with manganese oxides in fractures, copper sulfides, and fluorite minerals in contact metamorphosed zones between the granite and basalt dike. Assays showed that uranium minerals contain about 0.11 to 0.16 percent uranium (Keith, 1970).

Uranium has also been found at the Gismo Group in the Las Guijas Mountains, southwest of the Esperanza. The Gismo Group consists of several underground mines that produced precious metals. Sooty uraninite, kasolite, and schroeckingerite are found in association with copper minerals and iron gossan deposits in fault-veins in the granite. Assays range from 0.012 to 0.30 percent eU (Keith, 1970).

The King mine is an old silver and copper underground operation south of Tucson. The mine is situated in a contact alteration zone, where pitchblende occurs with sulfide ores in quartz-calcite gangue in pockets along a limestone/quartz monzonite contact. Assays show uranium ranging from 0.14 to 0.93 percent. The Copper Squaw underground copper mine is on the Papago Indian Reservation west of Tucson. Uranium with oxide copper and iron minerals occurs in veins in altered andesite and contains from 0.76 to 1.4 percent uranium (Keith, 1970).

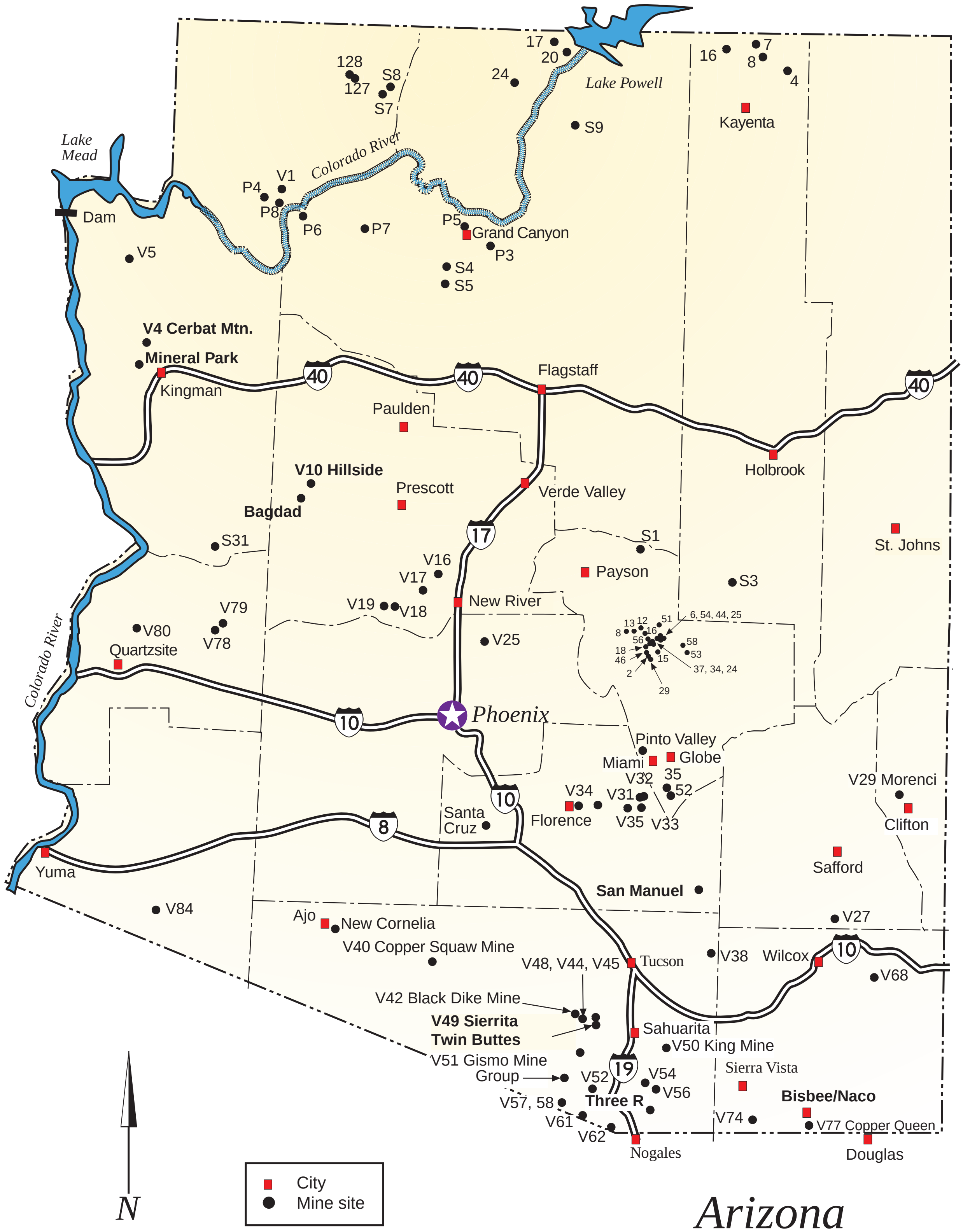
Other mines where uranium has been found within the southwest copper belt are the Hillside, De La Fontaine, and Cerbat Mountain Range group of mines. The Hillside mine, also known as the Seven Star claim, was extensively mined for gold, silver, and base-metal sulfides. Pitchblende and secondary uranium carbonates were found in association with precious and base metals and fluorite in open veins crosscutting the Precambrian Yavapai Schist. Samples showed trace levels to 0.11 percent of uranium. The De La Fontaine mine is an underground operation that was mined for base metals. It contains uranium mineralization in quartz and base-metal sulfide minerals that fill the fractures and shear breccia in granite and schist. The Cerbat Mountain Range mines are a cluster of several underground mines that includes the Detroit group, Summit mine, Bobtail mine, Jim Kane, Monitor group, J. C. and Fort Lee, and unnamed mines in the area. These mines were worked for base and precious metals that contained uranium mineralization that ranged between 0.01 to about 0.50 percent uranium. Finely disseminated uranium mineralization was found with base metal sulfides in a shear zone that crosscuts the granite at these mines (Keith, 1970).

Uranium occurs in, or near, other large copper mines in Arizona. Uranium was reported in the sulfide ore at Bisbee, where it is associated with quartz and hematite in slip planes or as crusts. Trace amounts of uranium were also reported in the copper mineralization at Morenci (Keith, 1970) and in the Miami-Globe mining district, east of Phoenix. In addition, uranium was found in copper sulfide ores in schists near Globe and in the porphyry copper deposits at Miami. The average grade of uranium was 0.0055 percent at the Miami deposits (Still, 1962).

Radionuclides also have been found in groundwater in Arizona. In 1992, ADEQ and the Arizona Geological Survey investigated radon concentrations in the groundwater. They sampled wells in eight areas in geologic formations known to have high uranium concentrations. Thirty-two samples were collected from Kingman, New River, Paulden, Payson, Sierra Vista, Safford, Verde Valley, and Yuma. The mean value for radon was 1148 pCi/L, and the median ranged between 677 to 777 pCi/L. Payson s five wells had radon ranging from 1750 to 6310 pCi/L. One sample out of three from New River s wells contained 1340 pCi/L, and one sample of four wells in the Verde Valley contained 2560 pCi/L. One sample out of four wells in Yuma contained 1450 pCi/g, and two samples of four wells in Sierra Vista contained 1450 and 1120 pCi/L. One sample out of four from Safford s wells contained 1020 pCi/L of radon. The occurrence of radon appears to be associated with the uranium-rich granites in Payson and the Sierra Vista area, but no other clear relationship is evident between the presence of high radon and other radiochemicals tested in Arizona (Duncan, 1992).

Granitic rocks northwest of Prescott are known to contain radionuclides. Therefore, it would be expected that radionuclides would be found in aquifers downgradient of the Lawler Peak Granite. Water samples from the public water supply systems of two subdivisions in Prescott Village had gross alpha ranging from 38 to 83 pCi/L, although uranium was not detected, and an air sample

Figure A: Location Map of TENORM Sites



NOTE: Points in the area between Payson and Miami-Globe are not to scale.

Reference: ADEQ 1990

analyzed for radon showed 11000 pCi/L in a Prescott house (ADEQ, 9/1989).

D. TENORM Field Studies at Abandoned Mines

Acid mine drainage (AMD) occurs at abandoned mines in Arizona. Often, several mines or waste dumps contribute to the total concentration of AMD affecting the watershed in a mining area. AMD is leachate produced from the natural decomposition of sulfide minerals at a mine. The acids produced in this process mobilize the metals within the waste piles. Uranium is highly soluble in acid, and is mobilized along with the other metals in the waste dumps or piles. AMD has been detected discharging from the adits of closed underground mines and seeping from the base of waste dumps and tailings piles of abandoned mines in Arizona.

1. Hillside Mine/Boulder Creek

Uranium occurs in the Bagdad mining district, some 35 miles west of Prescott (Figure A). The Hillside mine, a gold, silver, zinc, and lead mine situated in a fissure-type vein, is northeast of Bagdad. Uranium was reported to be as high as 2.3 percent at this mine in 1955, when it was closed (USGS, 1955). See Figures A and B for the site locations and Tables 10 and 11 for analytical results. A 1970 study found that the average concentration of uranium at the Hillside mine was about 0.1 percent (Keith, 1970). Samples taken by ADEQ confirmed that TENORM occurs at high concentrations in surface water emanating from the Hillside mine. Two of the three waste piles at the mine were also investigated: the upper tailings and middle tailings areas. Boulder Creek passes near both waste piles and drains the area where the Lawler Peak Granite is extensively exposed at the surface upgradient of the Hillside mine. Background radiochemical levels in this area may be high. The nearest background surface water samples analyzed for TENORM in this area were taken in Prescott (Table 10). ADEQ personnel observed discharge with an iron-red color flowing into Boulder Creek from an open mine adit in the middle tailings area. ADEQ also observed that surface water runoff had severely eroded all the tailings piles and washed out mine wastes into Boulder Creek.

Table 10 shows radiological analyses of surface water samples. Site 5 is mine water discharge from the adit. It contained 678 pCi/L of U-238 and is believed to be representative of the groundwater in the mine area. Site 6 was taken at Boulder Creek below the adit. It contained 383 pCi/L of U-238. Site 2.1 is upgradient of Sites 5 and 6 and was taken as a background sample (ADEQ, 4/1993). Lawler Peak Granite is known to be present and it may be high in radionuclides. It also may be influencing the radiochemistry of the background sample.

Table 10

Radiological Analyses of Surface Water Samples, Hillside/Boulder Creek, April 1993 (pCi/L)

Site	Gross Alpha	U-238	U-234	Ra-226
5	1240	678[1]	577	71.8
6	644	383[1]	330	18.5
2.1 upgradient[2]	6.9	11.6	3.8	<0.1
Bgd Prescott[3]	1.9	0.4	1.3	0.1

Reference: ADEQ, 4/1993

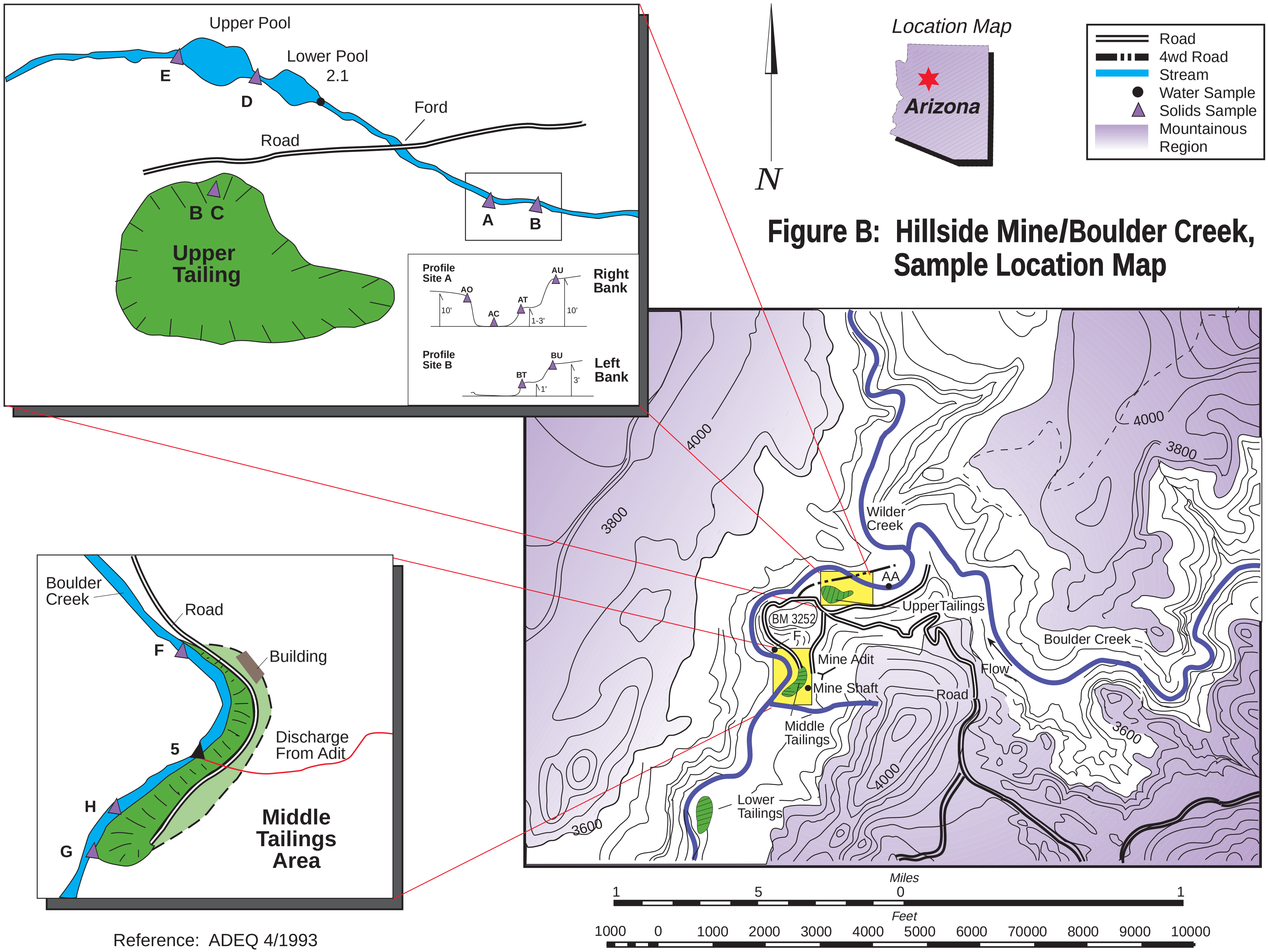
[1] The results have been converted from ug/L to pCi/L.

[2] Background concentration of TENORM may be high in the Lawler Peak Granite in this area

[3] Background data from Table 8, Prescott, Arizona

The waste dumps at the Hillside mine consist of three piles of red-orange, very fine-grained silts and clays. Thirteen sediment samples were taken from the site. Table 11 shows the sediment sample results. Figure B shows the sample locations. For purposes of comparison, the average crustal background level of total uranium and U-238 in soils is 1.23 and 0.59 pCi/L, respectively. Sites A and B are the two profiles shown in the upper left corner of Figure B. At Sites A and B, samples were taken from the terraces (AT, BT), channel (AC), and upland areas of the upper tailings (AU, BU). Sample BC100 is a surface grab sample of the actual tailings that may have leached out. Sample D is the control sample for the lower tailings area. Samples E through H were taken from the middle tailings. Sample H was taken near water sample number 6. Sample AA1 is upgradient from the upper tailings area. These samples were also analyzed for metals. The results showed that the sediment and water samples were acidic and contained high concentrations of arsenic, cadmium, aluminum, beryllium, copper, cobalt, and mercury (ADEQ, 4/1993). At least one sample of water collected from the

Figure B: Hillside Mine/Boulder Creek, Sample Location Map



Reference: ADEQ 4/1993

tailings pile by the ADEQ in February 1991 had a field pH of 2.8. The pH measurements of Boulder Creek were slightly alkaline and the adit discharge was slightly acidic.

Table 11

Sample	Gross Alpha	Gross Beta	U-238	U-234	Ra-226
A-Opposite bank	9.6	33.2	0.70	0.88	0.69
A-Terrace	20.1	31.5	2.50	2.70	1.90
A-Channel	21.1	53.0	0.97	1.08	0.94
A-Upland	19.4	34.5	1.23	1.23	2.00
B-Terrace	60.1	68.4	5.90	6.10	9.40
B-Upland	35.9	46.9	3.90	4.10	4.30
BC100- Upper Tails	17.3	22.0	1.79	1.82	0.89
D-Lower Tails	20.9	45.4	1.49	1.90	1.74
E-Middle Tails	26.7	48.1	2.30	2.20	1.40
F-Middle Tails	16.0	45.3	1.70	2.46	0.77
G-Middle Tails	261	185	25.60	51.30	44.00
H-Middle Tails	395	248	63.30	60.80	82.60
AA1-Up grade[1]	57.4	54.3	5.90	2.90	5.50

Radiochemical Analyses of Sediment Samples, Hillside/Boulder Creek, April 1993 (pCi/g)

Reference: ADEQ, 4/1993

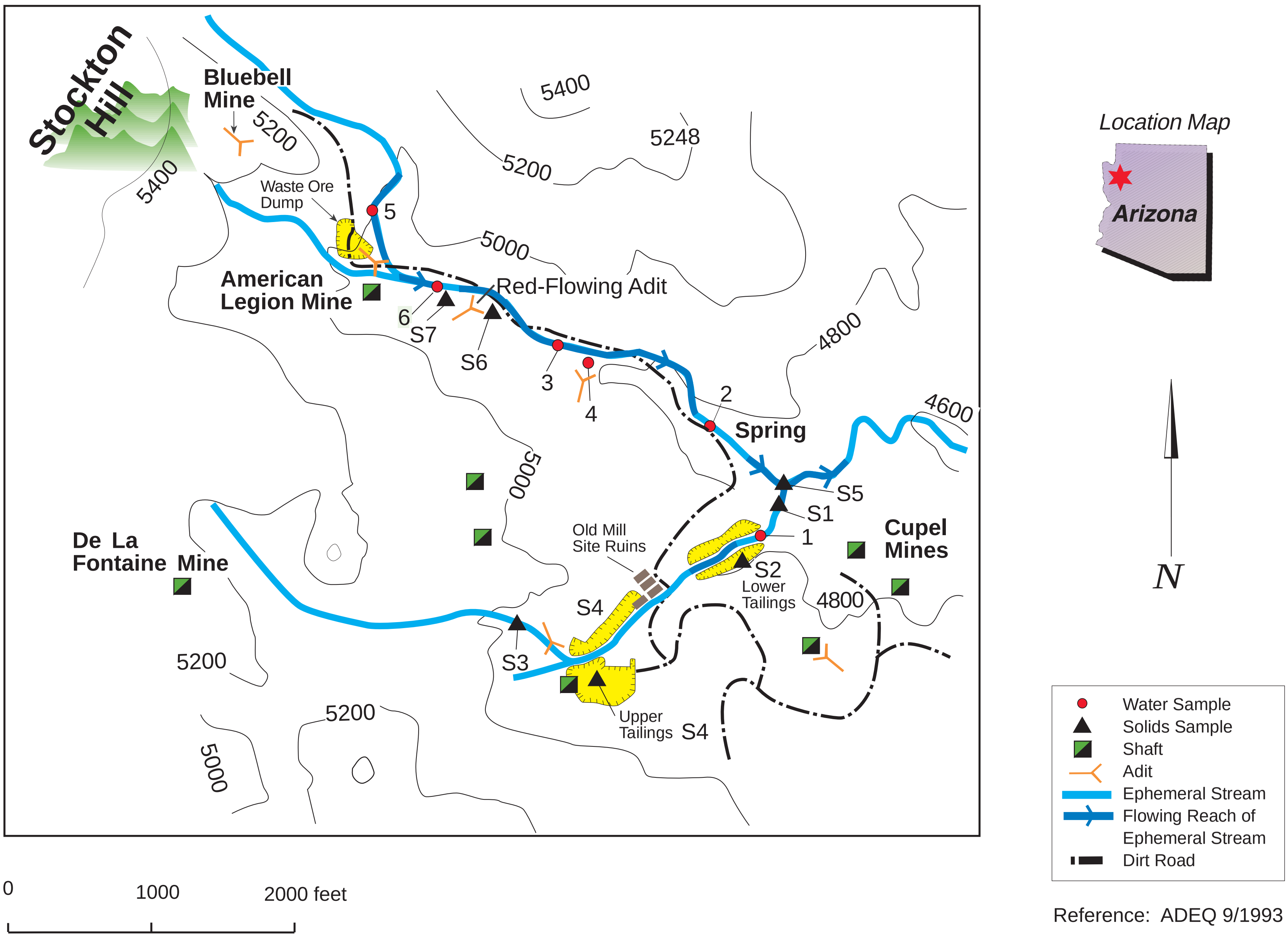
[1] Background concentration of NORM may be high in the Lawler Peak Granite in this area

2. Cerbat Mountains Mines

In 1992, the Surface Water Enforcement Section of ADEQ found two more mines where TENORM had affected surface waters in Arizona s Cerbat Mountains (ADEQ, 8/1993). The De La Fontaine and the American Legion mines are located northwest of Kingman, in the Stockton Hills or Hualapai Pines mining district (Figure C). The mines are on different branches of the same stream and are both free-flowing sources of AMD that are impacting surface water. The nearest background surface water sample analyzed for TENORM in this area was taken in Prescott.

The American Legion mine is an abandoned, underground gold operation that was worked in the 1860s. ADEQ personnel observed a reddish-orange discharge flowing from this mine into surface water during a site visit. Six samples and one background sample were collected at this site (Table 12). Samples 1 and 2 were taken above the confluence of the De La Fontaine and American Legion Creeks. Samples 3 and 4 of the American Legion mine were slightly acidic (ADEQ, 8/1993). Sample 5 was a background water sample collected in the watercourse upstream of most of

Figure C: Cerbat Mountains Mines, Sample Location Map



Reference: ADEQ 9/1993

the mine workings, tailings, and waste piles. Sample 6 was taken in the ephemeral section of American Legion Creek below the confluence of Bluebell Creek. The Bluebell mine lies upstream of sample location 5, but the workings are quite small. Table 12 shows the results of the sample analysis.

Sample	Gross Alpha	U-238	U-234	Ra-226
1A (De La Fontaine)	55.7	-	-	3.4
1B (De La Fontaine)	43.6	-	-	-
2A (American Legion)	53.3	23.5	26.6	1.1
2B (American Legion)	54.8	25.3	27.1	0.8
3A (American Legion)	55.9	22.3	23.8	20.3
3B (American Legion)	67.4	-	-	16.7
4A (American Legion)	154	112	110	16.8
4B (American Legion)	297	115	117	12.8
5A (American Legion)	158	-	-	<0.5
5B (American Legion)	159	73.7	77.1	<0.6
6A (American Legion)	66.8	-	-	-
6B (American Legion)	68.3	30.0	33.6	<0.5
Bgd Prescott[1]	1.9	0.4	1.3	0.1

Table 12

Radiological Analyses of Surface Water Samples
Cerbat Mountains, August 1993 (pCi/L)

Reference: ADEQ, 8/1993

- = No Data

In the water sample identification, A denotes unfiltered and B denotes filtered

[1]Background data from Table 8, Prescott, Arizona

Table 13 identifies the analytical results for the sediment samples taken from both mines. The De La Fontaine mine, worked in 1943, produced lead, gold, zinc, silver, arsenic, uranium, and associated metals. During their 1992 site visit, ADEQ personnel observed a red and white powdery sediment discharge flowing from the mine into surface water.

Sample	Gross Alpha	Gross Beta	U-238	U-234	Ra-226
S1 (De La Fontaine)	44.3	52.5	4.9	4.8	5.3
S2 (De La Fontaine)	95.8	134	9.9	10.8	12.8
S3 (De La Fontaine)	8.2	30.8	0.99	0.87	0.71
S4 (De La Fontaine)	73.0	94.2	6.9	7.8	18.4
S5 (De La Fontaine / - American Legion Confluence)	171	57.2	6.6	6.7	7.2
S6 (American Legion)	62.3	93.4	4.2	22.8	7.4
S7 (American Legion)	15.1	23.4	6.8	7.0	0.94

Reference: ADEQ, 8/1993

Table 13

Radiological Analyses of Sediment Samples Cerbat Mountains, August 1993 (pCi/g)

All the soils data from the Cerbat Mountains and Boulder Creek were aggregated and plotted on the bar graph shown in Figure D. To show the magnitude of the high and low variations between background and the data, a logarithmic scale was used for the abscissa and on the ordinate, the radiochemical species were plotted. For each radionuclide, a bar was plotted representing each site. The spread of the data or (minimum to maximum values) is the highlighted area. The total number of data points is shown at the base of each bar. The background and federal and state guidelines were also plotted when available. Comparison of the soils data from the mines in the Cerbat Mountains and the Hillside mine are remarkably similar to the background levels of U-238 and Ra-226 found in each area. This may mean that the waste piles are unmineralized rock, mined during drift development to the ore deposits, or that the samples have been leached to within background levels.

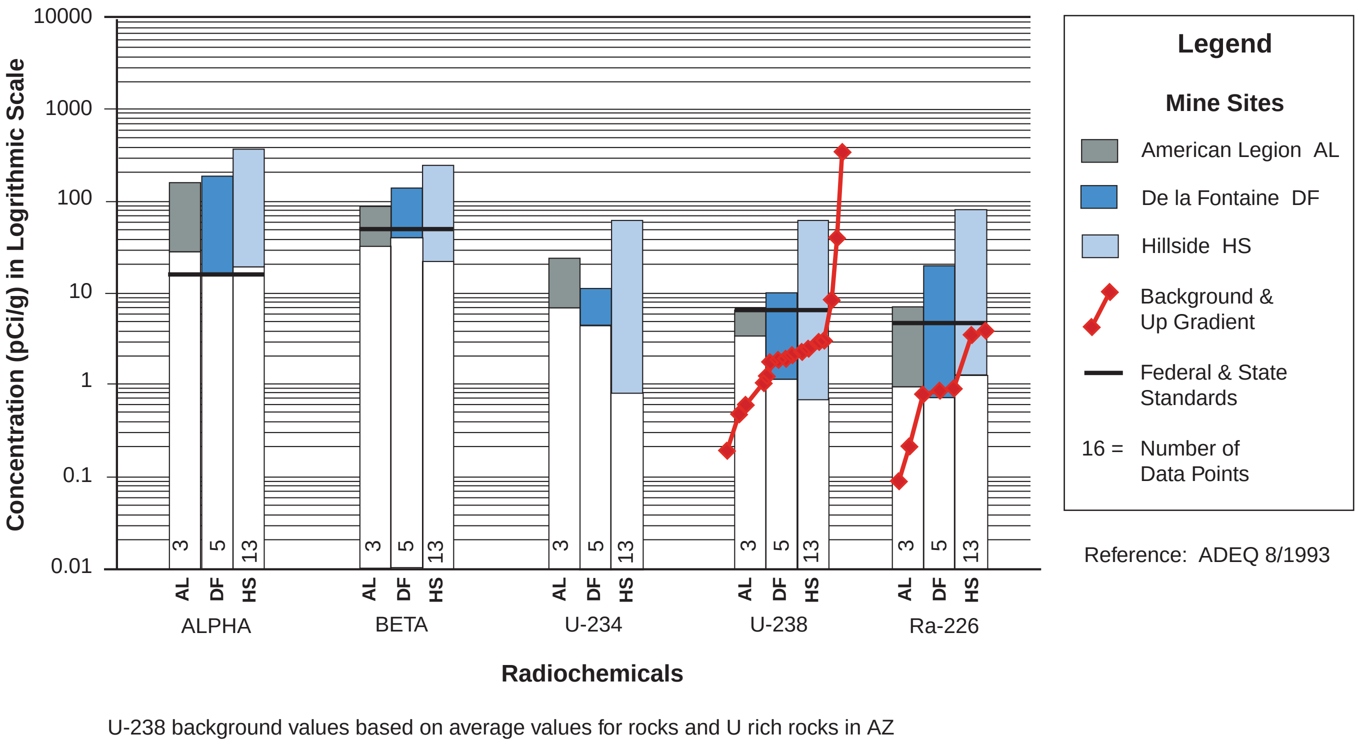


Figure D: Bar Graph of All Soil Sample Data

3. Three R Mine

ADEQ, Water Quality Division personnel found TENORM in water discharging from the Three R underground silver mine near Patagonia in the Patagonia Mountains (Figure E). This deposit is a nearly vertical lense of chalcocite in a northwest-trending fault zone. It contains uranium (ranging from 0.02 to 0.07 percent uranium) associated with copper sulfides (ABM, 1970).

Six water samples were collected during site visits in 1992-93. Samples 1 and 4 were taken 2 miles (3 km) downstream at the confluence of Three R and Maggies Canyon. Sample 1 was not tested for radiochemicals, but analytical results showed high concentrations of Cu and Fe, as well as low pH. Sample 2 was collected downgradient of the Three R mine in the canyon. Samples 3 and 6 were taken from stope water near the 400-foot (122-meter) adit (Three R, 1992). Sample 5 was taken at the first emergence of groundwater flow in the canyon below the 600-foot (183-meter) adit (ADEQ, 7/1993). Table 14 summarizes the results.

During the Three R mine investigation, ADEQ collected a background sample at Maggies Tank, a manmade impoundment used for watering livestock that lies in the Maggies Canyon watershed south of Three R Canyon watershed. The sample had gross alpha and beta values which may be somewhat elevated because the tank is shallow and is not a flow through water body. Consequently, constituents may be concentrated through evaporation. The reported total dissolved solids (TDS) for the sample collected from Maggies Tank is higher than other samples in the area, which may indicate that some concentration has occurred. The nearest background surface water samples analyzed for TENORM in this area were taken at Nogales to the west and Sierra Vista to the east of Patagonia.

Sample	Gross Alpha	Gross Beta	U-238	U-234	U-235	Ra-226	Ra-228
2 (6/92)	139	128	-	-	-	-	-
3 (6/92)	35	37	-	-	-	-	-
4 (7/93)	53.7	54.33	30.98	52.13	1.36	<0.67 (BDL)	<1.70
5 (7/93)	131.6	126.74	23.02	34.10	1.42	10.38	(BDL)
6 (7/93)	(BDL)	10.24	22.60	32.74	0.98	-	55.45
MT (7/93)	5.61	49.91	0.12	0.19	<0.04	0.10	-
Bgd Nogales[1]	4.0	5.0	3.3	4.2	-	-	-
Bgd Sierra Vista Low[1]	1.0	0.3	-			-	-

Table 14

Radiochemical Analyses of Water Samples from the Three R Mine, July 1993 (pCi/L)

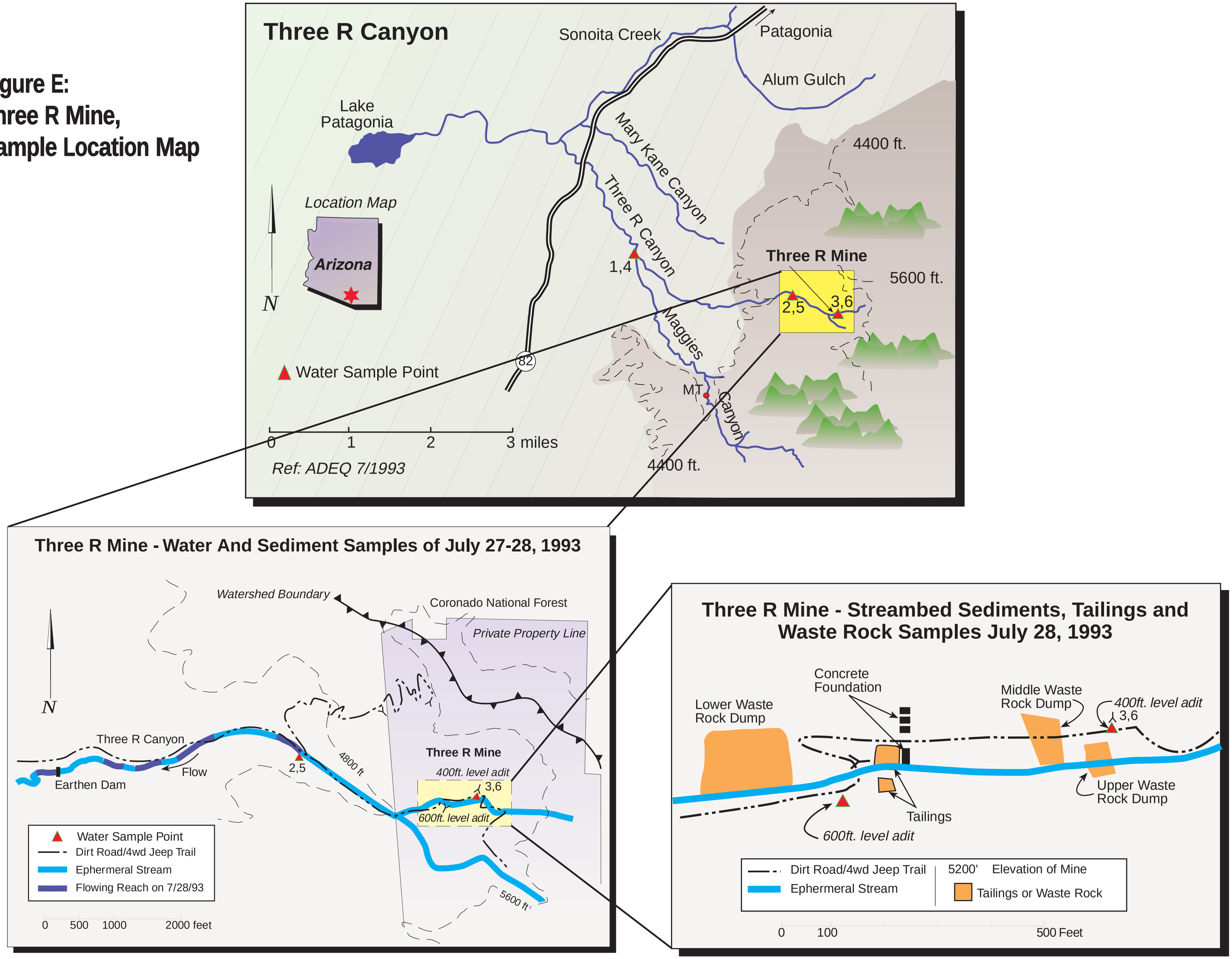
Reference: ADEQ, 7/1993

- = No data, BDL = Below Detection Limits

[1] Background data from Table 8, Nogales and Sierra Vista Hi and Low

In summary, field observations, water samples, and soil and sediment samples clearly show that uranium mineralization is associated with some copper deposits in Arizona.

Figure E:
Three R Mine,
Sample Location Map



IV. URANIUM RECOVERY AT COPPER MINES

New technology emerged in the 1980s that significantly changed copper mining operations. SX-EW processes made it profitable to process low concentrations of naturally occurring AMD that were seeping from many copper waste dumps. Additional technologies were developed to expedite the natural process of leaching. For example, the production of AMD can be increased by adding lixivent solutions. These solutions are typically acids produced either in the air scrubber units at the smelter, or raffinate produced from the SX-EW operation. The leachate is then recovered at the base of the dump in sumps and pumped to holding ponds for processing at the SX-EW plant. When the leachate is recovered for processing, it is referred to as PLS, which, by definition, is a process solution and is therefore not regulated by EPA. If low-grade ores contain any TENORM minerals, they will be leached out along with the other metals.

A. Cyprus Sierrita Corporation, Twin Buttes Mine

It is common knowledge within the mining community that uranium was produced as a byproduct of copper leaching operations prior to the 1980s, although documentation of this production has been difficult to obtain. Uranium was produced in the southwestern copper belt near Sahuaita, Arizona, at the Twin Buttes Anamax uranium plant. The mine producing the ore for the plant is located due south of Tucson, near Sahuaita. The ore body contains both sulfide and oxide zones. Trace levels of uranium, typically at levels approaching 10 ppm (6.87 pCi/g), were found in the oxide ore zone. The source of the radioactive mineralization was residual radioactivity from the Tertiary intrusions. Hydrothermal fluids from these intrusions mineralized the nearby Paleozoic quartzites, limestones, and siltstones, creating vein deposits of sulfide ore in the Mesozoic volcanoclastics. The oxide ore was formed as a result of surface oxidation of the sulfide ore body prior to being covered by alluvial deposits. Supergene enrichment of the ore body concentrated the copper and radionuclides in the oxide zone (ADHS, 1985; Hopkins, 1977).

Uranium was produced as a byproduct of the oxide ore SX-EW operation at the Twin Buttes mine. Operations at Twin Buttes consisted of a mill and vat leaching and electrowinning plant with a single tailings pond. In the early 1970s, during the development of the copper oxide plant, low levels of uranium were discovered in the PLS. At that time, the uranium was not considered economically extractable. Later in 1975, when the copper oxide plant was brought on line, uranium prices had increased considerably, making uranium extraction economically feasible. An eluex-ion exchange unit extraction process was built to extract the uranium and the plant was commissioned in February 1980. After the uranium was extracted from the PLS, the remaining copper-rich solution was pumped back to the SX plant where the copper was recovered. In 1981, 118 tons of yellow cake were produced. The yellow cake contained 73.19 percent uranium, 22.34 percent ammonium, 3.38 percent sulfur, 0.2 percent iron, 0.86 percent water, and 0.03 percent insolubles. The secondary uranium plant was believed to have operated between 1980 to 1986 (Hopkins, 1977; Lorenz, 1982; C. AMAX, 1987; AMAX, 1988).

Samples of the oxide tailings liquid taken from the Anamax uranium plant in January and February of 1984 showed Th-230 concentrations in the 1500 to 2500 pCi/L range. The total uranium concentrations of the same samples were in the 1020 to 1300 pCi/L range (ADHS, 1985 see Table 15).

Table 15

Radiological Analyses of Twin Buttes Oxide Tailings Pond, 1985 (pCi/L)

Sample	Th-230	Total U
Oxide tailing pond 1/95	1500	1020
Oxide tailing pond 2/95	2500	1300

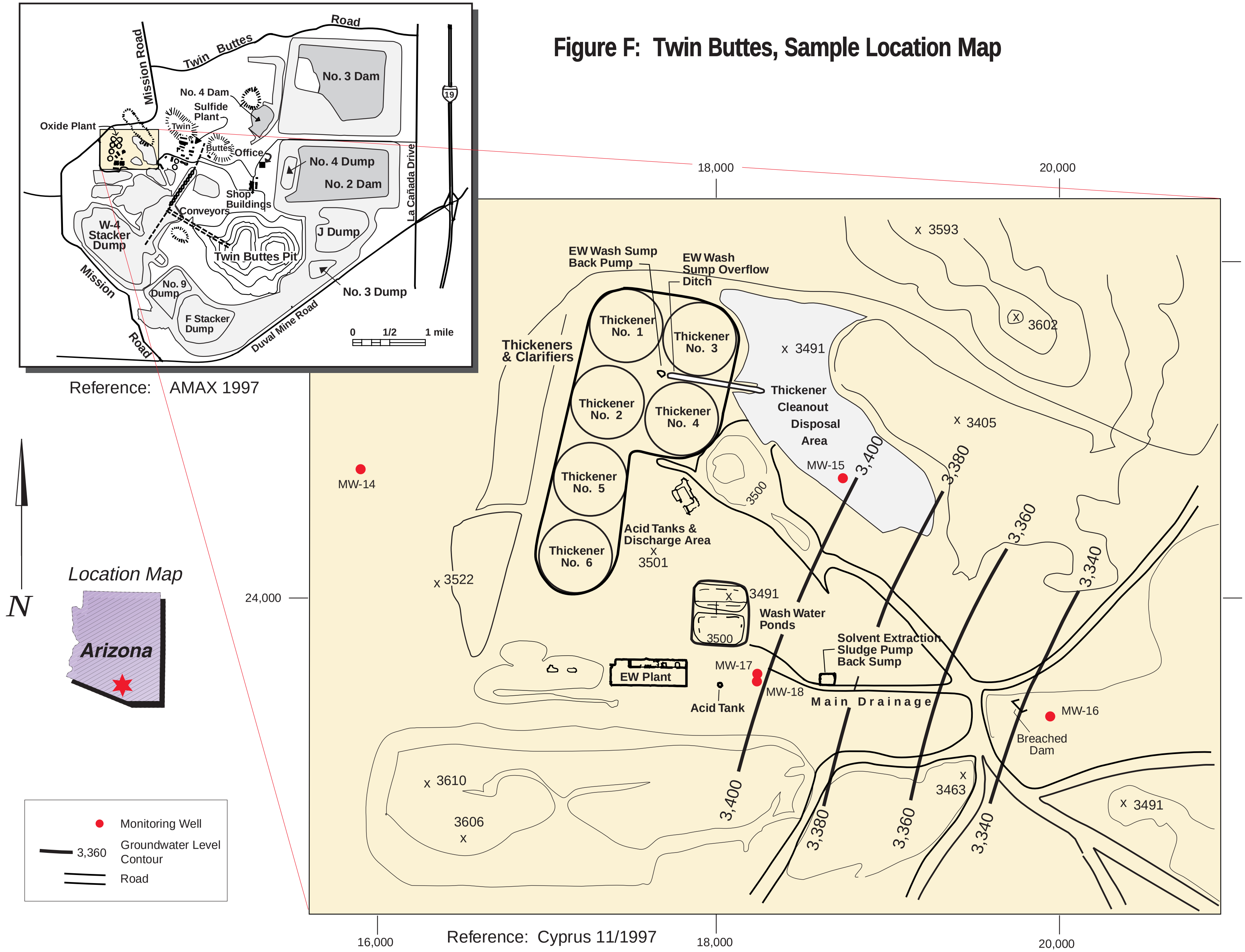
Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold
Reference: ADHS, 1985

The Arizona Radiation Regulation Agency (ARRA) regulated the recovery of secondary uranium and licensed the facility (Lic. No. 10-72). The facility license required that the throughput not exceed 600 lbs/day (273 kg/day) and that storage would not exceed 63630 kgs of U3O8. During the facility s operating period it was inspected, and soil, groundwater, and air were monitored at the yellow cake drier. The uranium processing unit did not produce tailings, although organic acid wastes were produced as a result of the solvent extraction operation. The disposition of these liquid wastes (petroleum-based chemicals) is unknown to the author of this report. No elevated levels of radionuclides were detected during quarterly environmental sampling by the ARRA (ARRA, 1987). Due to the drop in price of uranium in the early to middle 1980s, most of these units have been shut down and dismantled. The solvent extraction ion exchange uranium plant at Anamax has been decommissioned for almost a decade. In 1994, the secondary uranium recovery circuit at Twin Buttes was dismantled. The author does not know the disposition of the wastes in the oxide tailing pond nor the type of closure.

In 1997, Cyprus Sierrita Corporation submitted an APPA to ADEQ that covered the oxide and the electrowinning (OX-EW) plant area of the Twin Buttes mine. The mine and tailings pond are not covered in this permit. Five monitoring wells were installed and sampled at the OX-EW plant. See Figure F for the location of the monitoring wells. Analyses of the groundwater beneath the OX-EW plant showed radiochemicals. The plant is located on the margin of the Santa Cruz basin that forms a trough to the southeast of the mine. The two stratigraphic units underneath the plant are alluvial basin fill deposits of interbedded sand and gravel with silts and clays, and intrusive granodiorite. The basin fill deposits thicken from 10 to 130 feet beneath the plant and are saturated. Underlaying the basin fill deposits is the Ruby Star Granodiorite Tertiary intrusive. All the monitoring wells are completed within the intrusive unit, which is saturated. The water table conforms to the bottom of the basin and locally thickens from 5 to 10 feet and dips to the southeast. Groundwater flow is to the southeast, as indicated by the hydraulic heads (Figure F).

Radiological analyses of groundwater samples from the five monitoring wells are shown in Table 16. Monitoring wells MW-14 and 15 are upgradient of the OX-EW plant and may be used to establish background levels. Monitoring wells MW-17 and MW 18 are located about 400 feet due east of electrowinning plant and 250 feet south of the wash water ponds. Both are directly downgradient of the OX-EW plant. Samples from monitoring well MW-17 contained gross alpha ranging

Figure F: Twin Buttes, Sample Location Map



Reference: AMAX 1997

Reference: Cyprus 11/1997

from 144 to 268 pCi/L and gross beta ranging from 123 to 234 pCi/L. Similarly, samples from monitoring well MW-18 contained gross alpha ranging from 157 to 163 pCi/L and gross beta ranging from 113 to 131 pCi/L. MW-16 is also downgradient of the plant, but appears to be relatively unaffected.

Table 16

Radiochemical Analyses of Monitoring Well Samples Twin Buttes Mine, November 1997 (pCi/L)

Monitoring Wells	Gross Alpha	Gross Beta	Total U	Ra-226	Ra-228
MW-14 12/23/97	41	36	0.27	3.6	6.2
4/6/98	70	8	0.39	3.2	3.3
MW-15 7/10/97	30	42	0.27	0.0	1.2
8/26/97	42	28	0.30	0.0	0.0
MW-16 7/11/97	62	29	0.56	0.1	0.5
8/21/97	53	35	0.65	0.3	1.7
MW-17 7/31/97	268	234	3.64	0.0	1.3
8/25/97	144	123	3.43	0.3	0.1
MW-18 7/24/97	163	131	1.51	4.6	0.0
8/25/97	157	113	3.30	0.0	0.8

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Cyprus, 11/1997a

The U.S. Atomic Energy Commission explored for uranium at Bisbee in 1948. Then in 1977, Phelps Dodge Corporation was granted a permit by the Arizona Atomic Energy Commission to store and process a limited amount of radioactive material at the Copper Queen facility in Bisbee. The Copper Queen facility was leaching the Lavender Pit low-grade ore at the Number 7 waste dump. This leach solution was pumped to a cementation leach plant near the Campbell shaft, where Phelps Dodge installed a secondary resin-type ion-exchange pilot plant to test the feasibility of uranium recovery (Az Pay Dirt, 1979).

This information confirms that at least two copper mines in the southwestern copper belt of Arizona operated secondary uranium recovery units and produced yellow cake.

V. TENORM DATA FROM ACTIVE COPPER MINES

A. Magma Processing Waste Streams

The records of the ADEQ, Aquifer Protection Permit section, provide two examples of TENORM concentrations that were found at Magma Copper Company s smelter and concentrator operations at San Manual. All of Magma s facilities were sold to BHP in 1995. TENORM was discussed in Magma Copper s 1991 permit modification that requested permission to process non-indigenous copper sulfate solution through their SX-EW facility at San Manuel. The resultant stripped acid-leach solution (raffinate) would be mixed in the existing raffinate pond and recycled to the leach operations. Analyses showed that the copper sulfate solution contained 75 pCi/L gross alpha and 104 pCi/L gross beta (Magma, 1991). If procedures were conducted as planned, an additional source of TENORM would have been introduced into the leach circuit and recycled back to the heap leach operation.

Another example of TENORM was discussed in Magma s 1992 permit modification request to process flash furnace and convertor vessel flue dust from the smelter. Analyses of the indigenous flue dust leachate showed that it contained 4100 pCi/L gross alpha with 4400 pCi/L gross beta (Magma, 1992 see Table 17). The permit proposed to process the flue dust by agitated vat-leaching methods. The resultant PLS would be processed in its own separate solvent extraction unit.

Table 17

Radiological Analyses Magma Copper Process Streams, 1992 (pCi/L)

Sample	Gross Alpha	Gross Beta	Ra-226	Ra-228
CuS04 Solution	75	104	<1	<2
Flue Dust Leachate	4100	4400	20	7.1

References: Magma, 1992; Magma, 1991

The source of the radiation in the flue dust may originate from the ore concentrates, or the natural gas used in the smelter, or it may come from some other source. The 1991 and 1992 permit modifications were proposed with the addition of a lime precipitator unit at the end of the SX-EW unit. The solids from the precipitator unit were proposed to be disposed of in the tailings pond at the mill, and the resulting raffinate was to be recycled in the leach circuit. The flue dust reprocessing unit is fully constructed but not operating, awaiting resolution of other permit issues. To date, the flue dust is being reintroduced into the smelter along with the feed stocks.

ADEQ has divided Magma s facilities into two APPAs: the smelter and concentrator area, which includes the tailings ponds and the mill, and the mine and heap leach area. Nine monitoring wells were installed in the smelter/concentrator plant area. Water quality data have been collected at several monitoring points up- and downgradient of the tailings impoundments on San Padro River. The ADEQ Mining Unit suggested that the Surface Water Section perform radiochemical analyses on future samples. New groundwater monitoring data from these wells is expected in 1999.

Based on the information above, radionuclide concentrations in some of the copper processing waste streams may be significantly above the natural crustal abundance.

B. In-Situ and Solvent Extraction Operations

Several Arizona copper ore bodies are either too deep or are too low-grade to be mined by conventional surface or underground methods. However, in-situ solution mining may be an economical option. There are several in-situ solution copper mines in the Arizona copper mining belt. High levels of TENORM have been found in the PLS of two in-situ leach operations in Arizona.

Typically, an in-situ copper mining company will be required to undergo a joint ADEQ-EPA permitting process. EPA issues a federally-administered Class III Underground Injection Control (UIC) permit and an aquifer exemption permit that focus on the subsurface injection and restoration activities. ADEQ initiates an APPA process that focuses on both subsurface activities and the surface facilities and impoundments.

A proposed operation must meet both of the following two criteria for an aquifer exemption: 1) the aquifer must not currently serve as a source of drinking water and 2) the permit applicant must demonstrate that the deposit contains minerals that are expected to be commercially producible. The permit covers the construction, operation, and eventual closure of the injection and recovery wells system and surface facilities and impoundments. The permit also defines the lateral and vertical boundaries of the proposed aquifer exemption.

A typical in-situ facility contains raffinate impoundments and processing facilities for the injectate (a lixivent solution of sulfuric acid with a pH of 2), a PLS impoundment, a SX/EW plant, surface run-on/run-off facilities, an evaporation impoundment, a non-storm water containment impoundment, and ancillary facilities. The mining area is usually divided into discrete mining units. Injection mining proceeds on a unit-by-unit basis until the ore zone is depleted. Injection occurs within the screened interval throughout the ore zone. The recovery wells are constructed 50 feet to 200 feet from the injection wells, depending on the permeability of the formation, and are screened in the same zone. Once the ore zone has been depleted, it will be rinsed with fresh formation water until the aquifer meets Aquifer Water Quality Standards (AWQS) and Primary MCLs.

1. BHP Copper Florence In-Situ Project

BHP Copper Florence (formerly Magma Florence) was granted a UIC permit (No 396000001) and aquifer exemption to operate an in-situ copper mine located two miles northwest of Florence, Arizona. The Gila River flows southwest and its floodplain is about 1/4 mile south of the mine. The copper ore body is between 400 feet and 1600 feet deep in highly fractured Precambrian granite, gneiss, and schist. The ore zone is about 250 acres wide. The water table is 130 feet below the surface and the ore body is within the saturated zone. The local stratigraphy consists of four hydrogeologic units. The uppermost alluvial unit is an upper basin fill that consists of interbedded gravels, sands, and silt lenses. The second unit is a middle silt and clay fine grained formation. A lower alluvial unit consists of conglomeratic gravel and sand. The basin fill are underlain by fractured igneous and metamorphic rocks that contain the ore body. ADEQ is currently in the process of reviewing BHP s APPA.

In January of 1996, BHP (Magma) conducted a column leach test to characterize the leachability of the mineralized zone and determine the chemical composition of the resultant PLS. Samples of ore-bearing quartz monzonite and granodiorite were leached for 58 days with 10 liters of sulfuric acid and maintained in a closed system at a pH of 1.5 to 1.7. The PLS was analyzed for common ions, metals and radiochemicals. The TDS and sulfate concentration at the end of the test was 26000 to 37000 mg/L for the quartz monzonite and 18000 to 23000 mg/L for the granodiorite. The gross alpha and beta activities for the quartz monzonite were 8649 and 3683 pCi/L, respectively. Similarly, the gross alpha and beta activities for the granodiorite were 897 and 612 pCi/L, respectively. The Ra-226 concentration of both samples was 33.6 pCi/L for the quartz monzonite and 19.5 pCi/L for the granodiorite. The total uranium, U-234, U-235, U-238 for the quartz monzonite were 4362, 1745, 598, and 1611 pCi/L and for the granodiorite 0.835, 254, 11.6, and 248 pCi/L, respectively (Table 18).

Subsequently, the raffinate from the PLS was recirculated into the leach system for another 19 days. Then the samples were drained and washed with groundwater for another 14 days in an open system. At the end of the wash test, the solution was tested for radiochemicals. The gross alpha and beta activities for the quartz monzonite and granodiorite were reduced to 11 and 3 (alpha) and <8 and <8 (beta) pCi/L for both the quartz monzonite and granodiorite. The Ra-226 and Ra-228 concentration was also reduced in both samples. The total uranium, U-234, and U-238 were 10, 27.3, 20.7 and 1.2, 6.8, and 4.82 pCi/L, respectively (Magma, 1/1996). The analytic results are shown in Table 18 (Magma, 1/1996). In all cases the quartz monzonite showed higher levels of radiochemicals than the granodiorite. The range of background levels alpha and beta activity and Ra-222 are shown at the bottom of the Table 18.

Table 18

Radiochemical Analysis of Leach Test Samples
Magma Florence In-Situ Copper Project, January 1996 (pCi/L)

Sample	Gross Alpha	Gross Beta	Total-U	U-234	U-235	U-238	Ra-226	Ra-228	Rn-222
Leach Test									
quartz monzonite	8649	3683	4362	1745	598	1611	33.6	<2	810
granodiorite	897	612	0.84	254	11.6	248	19.5	<2	243
Wash Test									
quartz monzonite	11	3	10	27.3	0.6	20.7	2.5	4	5.3
granodiorite	<8	<8	1.2	6.8	<0.6	4.82	<0.6	<3	7.9
Bgd Florence[1]									
High	3.0	14.0	-	-	-	-	0.1	-	236
Low	1.0	4.0	-	-		-		-	197.8

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Magma, 1/1996

= No data

[1] Background data from Table 8, Florence, Arizona

These data indicate that the PLS produced from the Magma Florence in-situ projects contain very high levels of radionuclides and that they are leachable.

2. Santa Cruz In-Situ Copper Project

On October 30, 1994, ADEQ and EPA granted ASARCO Santa Cruz Inc. an EPA-issued UIC permit (No 397000001) and an Aquifer Protection Permit (No P-101431) to operate an in-situ copper mining research facility. The site is seven miles west of Casa Grande and consists of a five spot well field containing four recovery wells and one injection well. The permit approved plans for down hole perforation of well casing and hydraulic fracturing of the aquifer test area, followed by injection testing using sulfuric acid for development and redevelopment and sodium bromide tracer testing during the mining phase. Surface treatment facilities included four evaporation ponds, one PLS pond, and one raffinate reservoir.

There are three geologic units beneath the Santa Cruz site. Six hundred feet of basin-fill deposits overlie 600 to 650 feet of Tertiary age conglomerate that lie upon the Precambrian granite. The basin-fill deposits comprise the principal aquifer in the mining area and the groundwater level in the basin-fill aquifer is about 490 feet below the surface. The copper mineralized zone begins at about 1100 feet. It includes a cap rock and an oxide and sulfide zone that extends to over 2360 feet.

The 4th Quarter 1996 monitoring report included radiochemical analyses of the raffinate and PLS. Total uranium of the raffinate and the PLS is 4.1 and 2.6 mg/L with 6800 and 4410 pCi/L gross alpha and 193 and 99 pCi/L Ra-226 (Table 19).

Table 19

Radiochemical Water Sample Results, ASARCO Santa Cruz In-Situ Copper Project, January 1997 (pCi/L)

Sample	Gross Alpha	Total U	Ra-226	Ra-228	Rn-222
Raffinate	6800	2870	193	19	2410
Pregnant Leach Solution	4410	1823	99	8.3	3760
Bgd Casa Grande[1]	20	6.0	0.1	—-	544.2

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: ASARCO, 1997

= No Data

[1] Background data from Table 8, Casa Grande

These results confirm that uranium occurs in the PLS and raffinate of the process streams at the Santa Cruz in-situ copper operation.

C. Groundwater Monitoring

1. Cyprus Bagdad Copper Corporation

The Cyprus Bagdad mine is located in Yavapai County about 64 miles due west of Prescott, Arizona, along Highway 69. It is a porphyry copper deposit being mined by open pit methods. The major components of the operation are the mine, the sulfide flotation concentrator that recovers copper and molybdenum sulfide concentrates, and the leach dump that recovers oxide ore solutions using SX-EW. Facilities at the mine site include the open pit mine, the concentrator, ore and concentrate stockpiles, the SX-EW facility, the active and inactive leach dumps, mine waste rock dumps, and active and inactive tailings ponds. The Cyprus Bagdad site is divided into ten hydrogeologic drainage areas that are addressed in separate sections of the APPA. Three of these areas have been found to contain TENORM   the Copper Creek leach dump, Lawler Peak, and the Hillside Loadout area (Cyprus 6/1993).

a) Copper Creek

In May 1991, during routine monitoring, Cyprus Bagdad discovered surface water contamination in Boulder Creek. Samples showed lowered pH and elevated copper levels in Boulder Creek. Further investigation revealed that the contaminants originated from leaks in the PLS pond into Copper Creek. Cyprus Bagdad initiated remedial response measures. Sumps were excavated into the alluvium of Copper Creek and extracted contaminated groundwater migrating down Copper Creek before entering Boulder Creek. In January of 1992, samples taken from these sumps were found to contain radiochemicals (Figure G). Samples from four sumps (S), two monitoring wells (MW), and three surface water stations on Boulder Creek were collected and analyzed for TENORM (Cyprus, 1992). MW-1 and MW-2 are located near the PLS pond at the base of the leach dump. No samples were taken directly from the PLS pond or the flood basin. Table 20 summarizes these water sample results. Subsequently, Cyprus Bagdad installed two compliance monitoring wells for the remediation of the remaining contaminated groundwater in the lower Copper Creek area.

Table 20

Radiochemical Water Sample Analyses of Cyprus Bagdad Copper Creek Leachate Dump Area, 1992 (pCi/L)

Sample	Gross Alpha	Ra-226	Ra-228
Boulder Creek 2 UG	19	BDL	BDL
Boulder Creek 1 DG	84	BDL	2
Boulder Creek 0 DG	20	BDL	BDL
Sump 4	18	BDL	BDL
Sump 3	<2	0.8	BDL
Sump 2	27	BDL	7
Sump 1	10	0.6	2
Monitor Well-1	58	10.8	31
Monitor Well-2	8	12.9	2
Bgd Prescott[1]	1.9	0.1	-

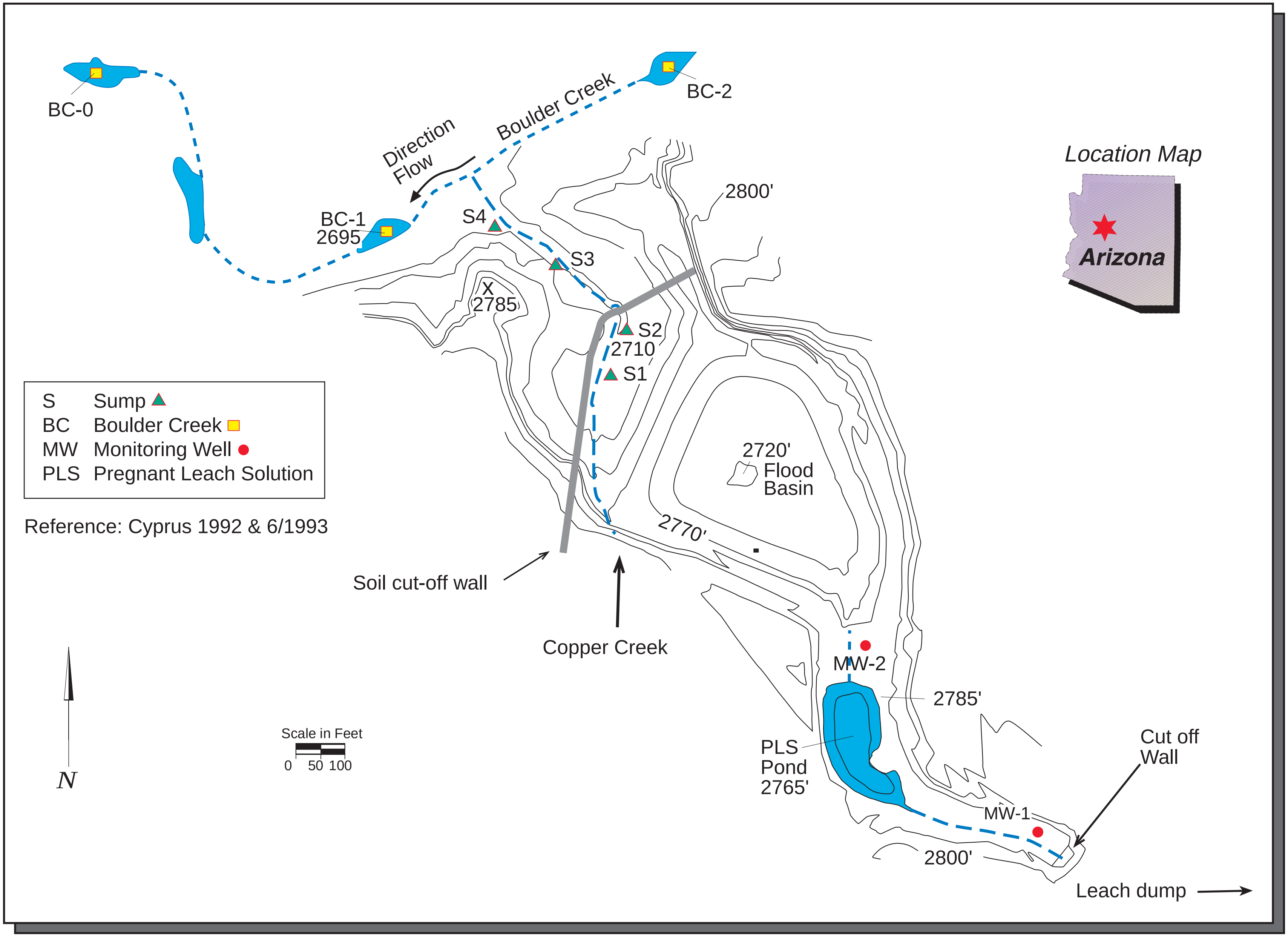
Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Cyprus, 1992

BDL = Below detection limits, - = No Data, DG = downgrade, UG=Upgrade,

[1] Background data from Table 8, Prescott, Arizona

Figure G: Copper Creek, Sample Location Map



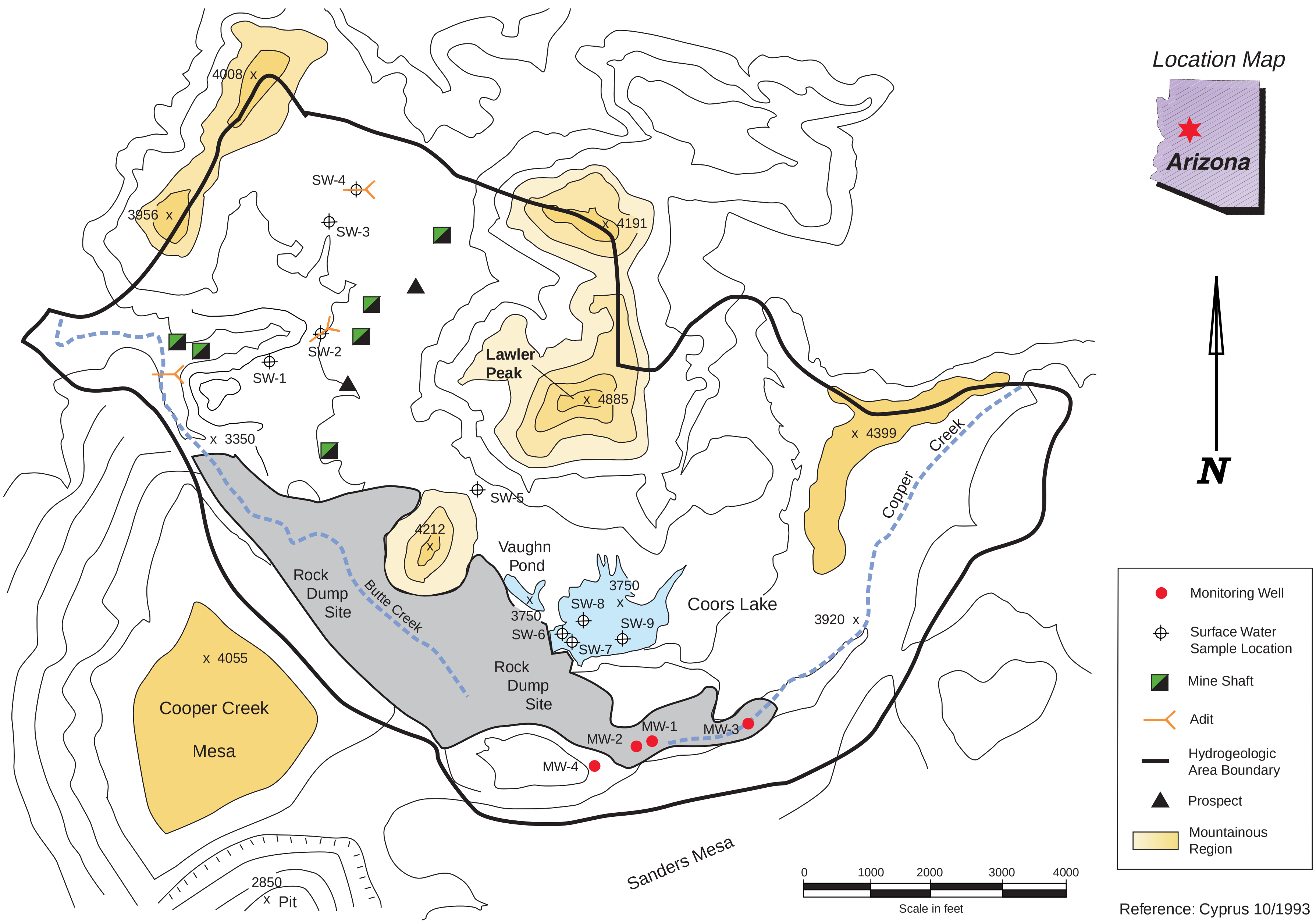
b) Lawler Peak

The Lawler Peak drainage basin forms a well-defined hydrogeologic area that encompasses part of the Bagdad open pit and Copper and Butte Creeks. Mine waste dumps fill the former channels of Copper and Butte Creeks with Coors Lake in the middle. The Lawler Peak area also contains a sanitary landfill, a stockpile of hydrocarbon-contaminated soil, a proposed solid waste management facility, and various mine facilities, in addition to the waste rock dumps. In October 1993, Cyprus Bagdad submitted a groundwater investigation of the Lawler Peak drainage basin that contained radiochemical data showing elevated levels of TENORM in the surface and groundwater (Cyprus 10/1993).

Five surface water samples were collected from springs and adits in the Lawler Peak Granite. Samples SW-2 and SW-4 were taken from standing water in mine adits. Samples SW-1 and SW-3 were taken from pools of standing water in springs near mining areas. Sample SW-5 was taken at the base of Little Lawler Peak and is not associated with historical mining areas. See Figure H for the location of these samples. The data are summarized in Table 21. The analytical results of the surface water samples show elevated radiochemical activities. Cyprus Bagdad suggests that this may be due to high background levels from the Lawler Peak Granite at the site. The adit samples and SW-5 show lower levels of radiochemicals than the other two springs. The data show that SW-3 exceeds federal MCLs and ADEQ HBGL for both uranium and radium, while SW-1 exceeds only uranium guidelines. The four water samples collected from Coors Lake are unremarkable with respect to alpha and beta activities, indicating the groundwater leaching from the Lawler Peak Granite or the leach dumps has not affected the lake.

Four ground water monitoring wells were installed, sampled, and analyzed for radiochemicals. Groundwater occurs in the waste dumps and flows generally to the southwest. All four monitoring wells were completed in the Copper Creek alluvial deposits buried beneath the waste rock dumps at 127 to 132 feet below surface. The radiochemical data show that the groundwater is high in U-234 and U-238 exceeding the ADEQ HBGL. Cyprus Bagdad suggests that the clay layer beneath the Copper Creek channel sediments is the source of the elevated radionuclides, rather than leachate from the waste rocks, since the clay may be a host for heavy metals like uranium and its daughter isotopes because of the high cation exchange capacity. The author believes that further investigation is needed to resolve this issue.

Figure H: Lawler Peak, Sample Location Map



Reference: Cyprus 10/1993

Table 21

Radiochemical Water Sample Analyses of Cyprus Bagdad Lawler Peak Area, October 1993 (pCi/L)

Site -Well ID	Gross Alpha	Gross Beta	Total-U[2]	U-234	U-235	U-238	Ra-226	Ra-228
Groundwater Samples								
MW 1	18.3	72.7	12.6	6.8	0.4	6.0	1.4	2.0
MW 2	13.2	ND	14.0	8.0	0.3	6.8	0.7	0.1
MW 3	52.8	19.9	26.6	14.4	1.2	15.3	4.2	1.9
MW 4	33	4.1	30.1	16.6	0.7	15.1	1.2	1.5
Surface Water Samples								
SW-1 Spring	23.5	6.7	18.9	33.9	0.8	12.0	0.4	1.9
SW-2 Adit	13.7	3.1	19.6	16.2	1.2	9.1	0.2	0.2
SW-3 Spring	57.1	59.8	32.9	21.9	2.9	18.7	19.3	17.8
SW-4 Adit	1.1	6.6	0.7	1.1	ND	0.8	0.3	4.4
SW-5 Spring	3.3	ND	2.1	2.1	0.1	1.3	0.2	3.1
Coors Lake Samples								
SW-6	3.0	11.4	0.7	-	-	-	-	-
SW-7	1.5	8.7	1.4	-	-	-	-	-
SW-8	0.6	7.7	1.4	-	-	-	-	-
SW-9	2.8	5.7	0.7	-	-	-	-	-
BDG Prescott[1]	1.9	1.1		1.3	-	0.4	0.1	-

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Cyprus, 10/1993

ND = Not Detected, - = No Data

[1] Background data from Table 8, Prescott, Arizona

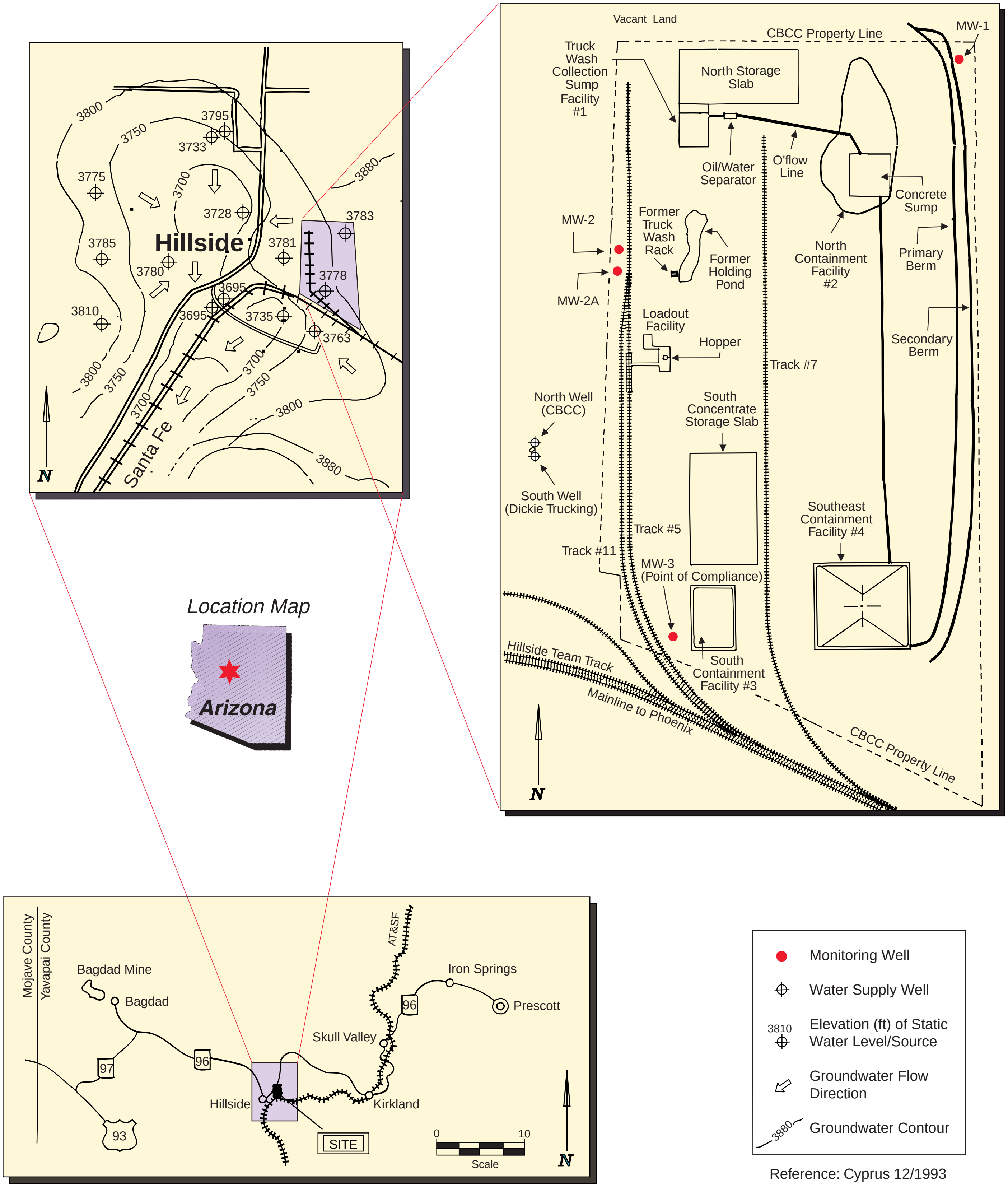
[2] Converted from mg/L to pCi assumes equilibrium condition for Tot-U=(mg/L)(701.000pCi/L)(10-6 g/ug)=pCi/L

c) Hillside Loadout Facility

The Hillside Loadout property is near the small town of Hillside, Arizona, approximately 18 miles southeast of Bagdad on Highway 96 (Figure I). The property handles the transfer of copper sulfide from the Cyprus Bagdad mine concentrator. Concentrates are hauled by truck from the mine at Bagdad to Hillside, where they are temporarily stockpiled and reloaded into railroad cars. In December of 1993, Cyprus Bagdad submitted a groundwater investigation of the Hillside Loadout property that contained radiochemical data showing high levels of TENORM in the groundwater (Cyprus 12/1993).

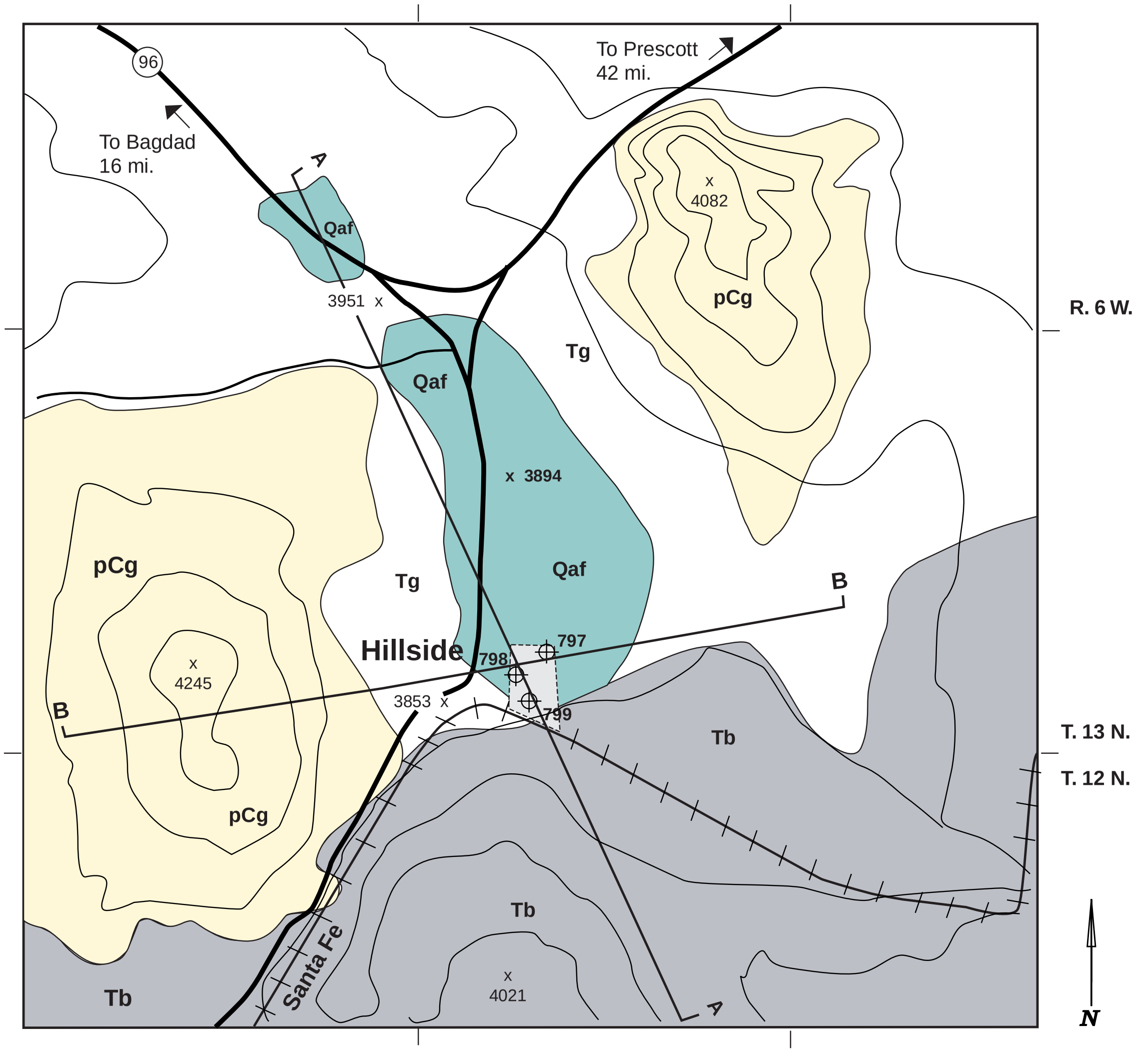
The property is underlain by a northeast trending paleochannel that was eroded in the Precambrian crystalline basement rocks. The paleochannel is filled with interbeded sedimentary and volcanic rocks consisting of Tertiary alluvial gravels and Tertiary basalt. A thin Quaternary alluvial fan deposit overlays the Tertiary deposits. Both the alluvial sediments and Tertiary gravels are interbeded with clay rich layers that reduce the vertical hydraulic conductivities of the units. All units are saturated beneath the surface with the Tertiary gravels forming an artesian aquifer (Figure J). Elevated copper

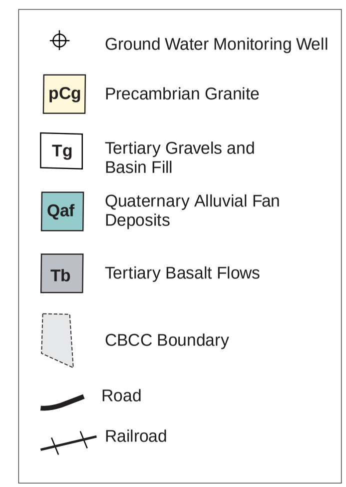
Figure I: Hillside Loadout Facility, Sample Location Map



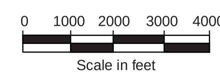
Reference: Cyprus 12/1993

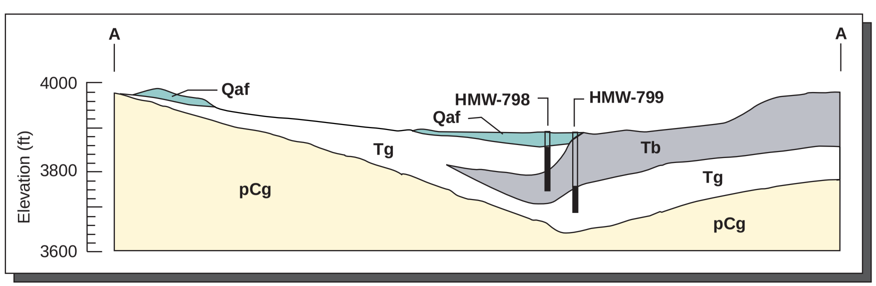
Figure J: Hillside Loadout Facility, Geologic Map

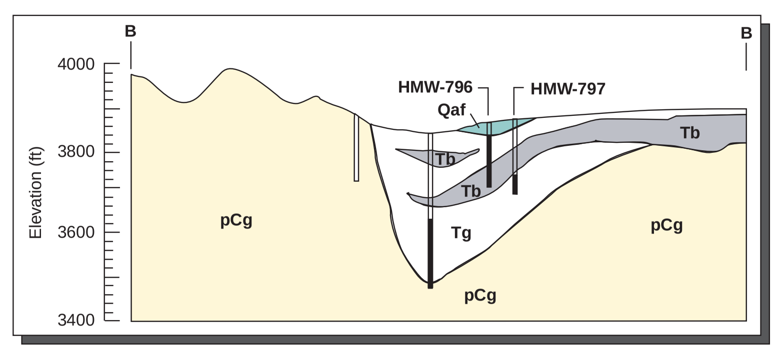




Reference: Cyprus 12/1993







concentrations were found in the soils at the site. Four groundwater monitoring wells were installed and sampled to characterize the water quality. Monitoring wells MW-1 and MW-3 were completed in the Tertiary gravels, monitoring well MW-2 was screened in the Tertiary basalt, and monitoring well MW-2A was completed in the alluvial fan deposits.

The gross alpha and beta values from monitoring well MW-2 are 100 and 136 pCi/L and the gross beta activity for MW-2A is 215 pCi/L. This may be due to an unknown isotope other than the uranium or radium. Both the U-234 and Ra-228 in MW-1 exceed the Arizona 7pCi/L HBGL and the federal radium standard of 5pCi/L. Remarkably, its gross alpha and beta activity are low. Radon values of all four samples are very high. The source of all the radionuclides at the Hillside Loadout facility is unknown. Analytical results are presented in Table 22.

Table 22

Radiochemical Water Sample Analyses of Cyprus Bagdad Hillside Loadout Facility, December 1993 (pCi/L)

Site -Well ID	Gross Alpha	Gross Beta	Total-U[2]	U-234	U-235	U-238	Ra-226	Ra-228	Rn-222
MW-1	5.5	3.6	3.5	**8.2**	0.1	2.3	1.6	**6.2**	3540
MW-2	100	136	<0.7	1.8	0.1	0.4	1.4	ND	3680
MW-2A	0.8	215	<0.7	1.3	ND	0.5	0.5	0.5	2690
MW-3	3.1	7.5	<0.7	2.5	0.1	0.6	0.5	ND	2910
MW-3 Dup	2.5	8	<0.7	1.9	0.1	0.4	0.8	2.2	3180
BDG Prescott[1]	1.9	1.1	-	1.3	-	0.4	0.1	-	859.9

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Cyprus, 12/1993

ND = Not Detected, - = No Data

[1] Background data from Table 8, Prescott, Arizona

[2] Converted from mg/L to pCi assumes equilibrium condition for Tot-U = (mg/L)(701.000pCi/L)(10-6 g/ug) = pCi/L

2. Cyprus Sierrita Corporation, Sierrita Mine

The Sierrita mine is located 62 miles due south of Tucson, Arizona on Highway I-19 near the town of Green Valley. The mine encompasses approximately 20000 acres, and lies on the eastern flank of the Sierrita Mountains and the western margin of the upper Santa Cruz basin. Operations consist of three open pit copper/molybdenum mines, a 115000 ton-per-day concentrator, two molybdenum roasting plants, a ferromolybdenum plant, a rehenium plant, a dump leaching operation, and an SX-EW plant. In 1996, Cyprus Sierrita started mining a 70-million-ton oxide deposit. Construction has begun on a new in-pit crusher and conveyor system to reduce haulage costs. The heap leach operations and the waste rock dumps and collection ponds overlie fractured bedrock. A thick sequence of deposits fills the basin and comprises the principal aquifer. Tailings from the mill are discharged to the tailings impoundment which overlies the basin-fill deposits aquifer. Cyprus Sierrita presently operates an interceptor wellfield to capture tailings impoundment seepage water containing increased concentrations of sulfate and total dissolved solids. Cyprus Sierrita began preparing its APPA in 1986 The APPA was submitted to ADEQ in September of 1994. At the time this report was prepared, negotiations with ADEQ were proceeding (Cyprus 1997b).

In 1997, Cyprus Sierrita sampled six monitoring wells and nine piezometers for TENORM at the Sierrita and Esperanza mine, mill, and concentrator facilities (Figure K). The results of these sampling events were submitted to ADEQ on November 13, 1997 as part of its APPA. The samples were analyzed for radiochemicals and the results are summarized in Table 23. Monitoring wells MW 21, 22, 23 and piezometers 3, 4, 5, 6 are located near the mills and concentrators.

Some of these wells show elevated levels of gross alpha and beta activity, in addition to elevated Ra-226 and Ra-228. Monitoring wells MW 18, 19 and piezometers 1, 2, 13, 14, are located to the south of the leach dumps and are downgradient of them. Monitoring well MW-17 is located near Tinaja Wash and it appears to be upgradient of the leach dumps. It shows elevated Ra-226 at 9.3 to 130 pCi/L and Ra-228 at 15 to 19 pCi/L in groundwater.

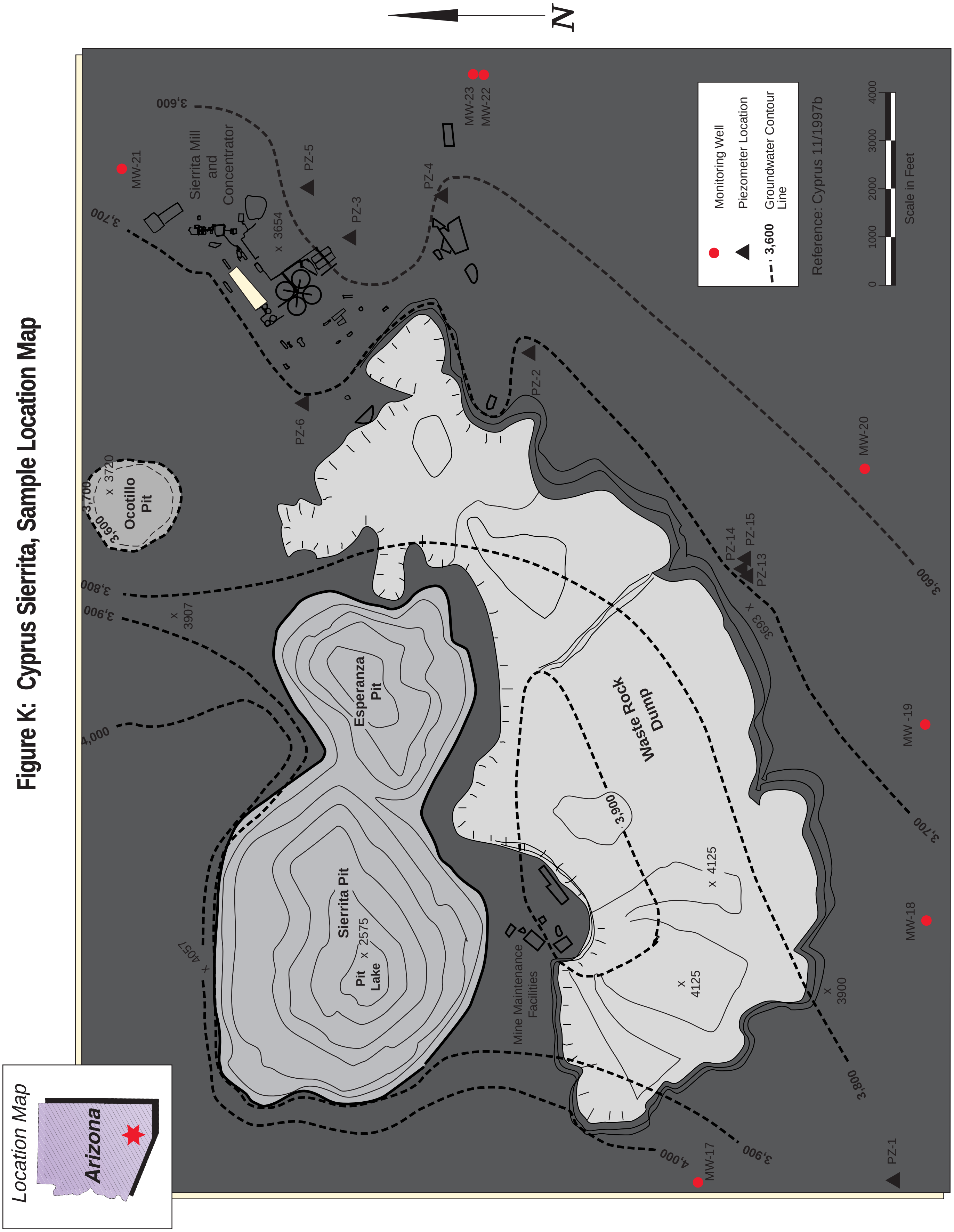
Table 23

**Radiochemical Analyses of Monitoring Well Samples
Cyprus Sierrita Mine, November 1997 (pCi/L)**

Monitoring Wells and Piezometers	Gross Alpha	Gross Beta	Total U[1]	Ra-226	Ra-228
MW-17 6/26/97	85	56	0.82	9.3	15
8/15/97	85	57	0.07	130	19
MW-18 6/19/97	14	13	0.13	0.9	0.0
8/14/97	12	4.7	0.12	0.0	0.9
MW-19 7/31/97	23	0.2	0.14	0.1	0.6
8/25/97	23	21	0.16	1.5	1.2
MW-21 7/16/97	557	334	7.55	7.3	9.1
8/15/97	406	299	5.01	15	6.2
MW-22 6/24/97	262	122	3.43	0.0	1.7
8/19/97	117	132	2.61	0.4	1.1
MW-23 7/02/97	70	71	0.37	0.4	5.6
8/21/97	17	8.0	0.51	0.5	1.0
PZ-1 6/18/97	7.5	8.2	0.03	0.0	0.1
8/12/97	9.7	9.5	0.02	0.0	0.0
PZ-2 6/27/97	48	40	0.12	1.2	10
8/13/97	14	59	0.14	2.2	10
PZ-3 6/26/97	61	49	0.51	2.0	1.7
8/13/97	32	50	0.49	4.5	13
PZ-4 6/23/97	63	49	0.82	0.6	0.8
8/20/97	56	70	0.82	0.5	1.6
PZ-5 6/26/97	232	150	3.84	1.4	5.8
8/19/97	245	129	2.40	3.1	7.1
PZ-6 7/02/97	26	27	0.12	2.7	30
8/20/97	19	44	0.14	3.2	8.3
PZ-9* 7/11/97	137	50	1.44	0.0	1.5
8/26/97	186	37	1.17	0.2	0.0
PZ-13 8/06/97	15	47	0.21	0.0	2.1
8/25/97	29	1.0	0.23	0.0	0.9
PZ-14 8/01/97	53	14	0.14	0.1	0.0
8/22/97	14	4.0	0.16	0.1	1.1

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold
Reference: Cyprus, 11/1997b
* = Not shown on Figure K
[1] Converted from mg/L to pCi assumes equilibrium condition for Tot-U = (mg/L)(701.000pCi/L)(10-6 g/ug) = pCi/L

Figure K: Cyprus Sierrita, Sample Location Map



3. Phelps Dodge, New Cornelia Mine at Ajo

The New Cornelia mine is located in Ajo, Arizona, 42 miles due south of Gila Bend on Highway 85. It is one of the oldest copper mines in Arizona, having been opened in 1854. It was closed in 1985, although Phelps Dodge Corporation reopened the mine in May of 1997. The facilities at the mine are to be upgraded to a semi-autogenous grinding mill and concentrator. Concentrates will be hauled off site for processing at Phelps Dodge s smelter at Douglas, Arizona.

During groundwater monitoring at the New Cornelia mine, radionuclides were found in several monitoring wells. Phelps Dodge installed a monitoring well system consisting of 35 wells (Figure L). During the winter of 1997, Phelps Dodge sampled 16 of these monitoring wells to characterize water quality (Table 24). Samples collected exceeded background radiation levels in the Prescott area. Nine wells exhibited radiochemicals that exceeded either federal MCLs or Arizona HBGL guidelines. Monitoring well MW 3 is located near the east stockpiles and shows high values for U-234 and U-238 (12 and 7 pCi/L). Monitoring well MW 14 is located south of the west stockpiles and shows high values for alpha activities of 33 pCi/L and U-234, U-238, and Ra-228 for 24, 21, and 6.8 pCi/L, respectively. Monitoring wells MW 8-B5, 9-B5 are located at the waste water treatment facility. They show high levels of U-234 and U-238 at 10 and 8.5 pCi/L. Monitoring well MW 5 is slightly south of the plant process area and shows high values of alpha and Ra-228 (17 and 7.3 pCi/L). Monitoring wells MW 13 and 16 are north of the tailing impoundments and show high alpha and beta activities of 35 and 66 pCi/L. Lastly, monitoring wells MW 17 and 18 are south of the tailings impoundments and show high values of U-234, U-238, and Ra-228 (14, 7.8 and 6.0 pCi/L, respectively).

Phelps Dodge has questioned the accuracy of these data because of large counting errors that were reported. They are currently in the process of validating the data through resampling and analyses with lowered error values.

Figure L: Phelps Dodge, New Cornelia Mine, Sample Location Map

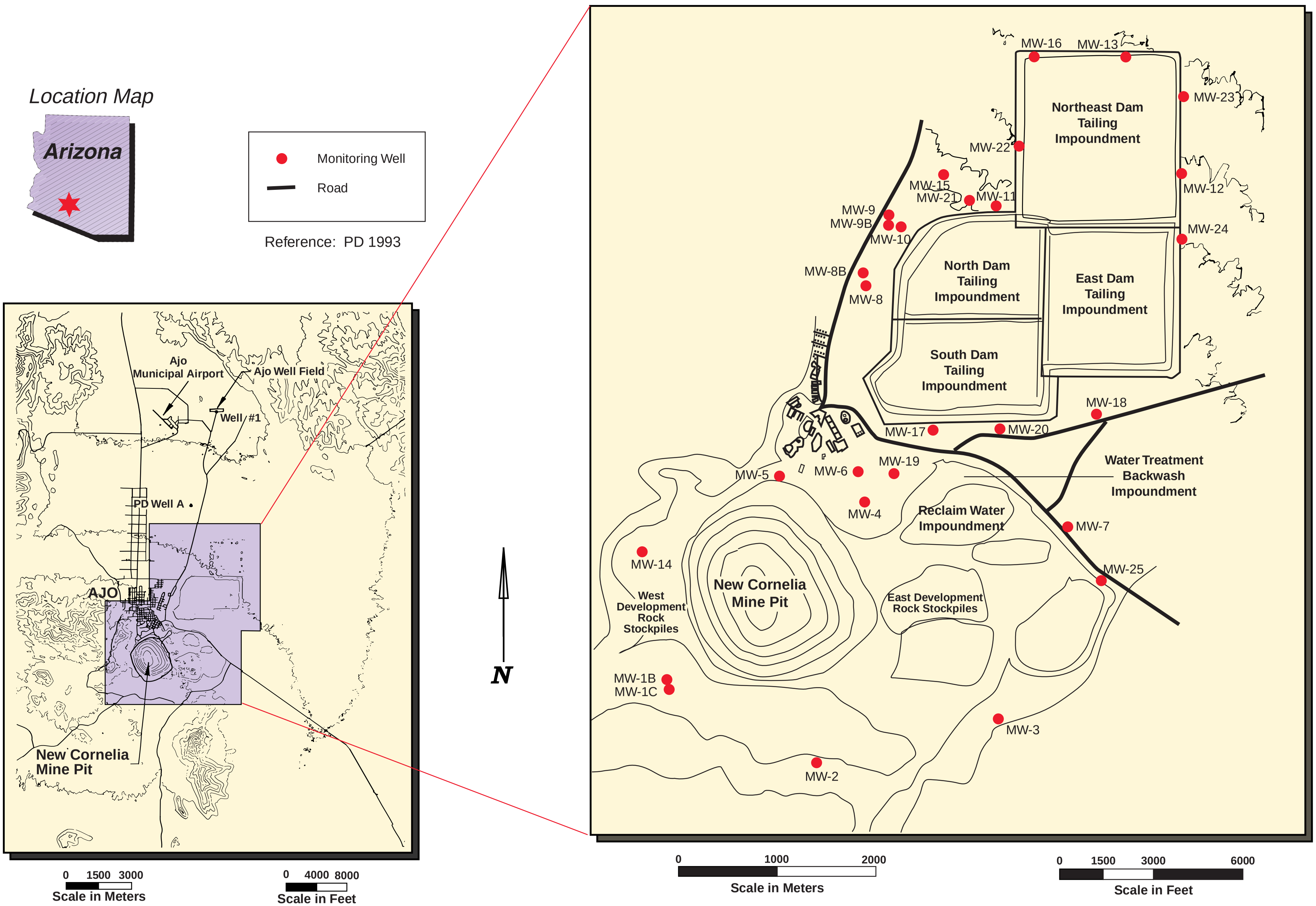


Table 24

Summary of Radiochemical Monitoring Well Water Sample Results at Phelps Dodge, New Cornelia Mine, March 1993 (pCi/L)

Site -Well ID	Gross Alpha	Gross Beta	Total-U[3]	U-233 + 234	U-235	U-238	Ra-226	Ra-228
MW 2-1	9	8	4.9	5.3	0.1	2.6	0.7	1.3
MW 2-2	6	6	5.6	5.5	0.3	2.8	0.8	1.0
MW 3-1	28	22	9.8	11	0.4	5.6	0.7	2.0
MW 3-2	10	5	9.8	12	0.7	5.0	0.6	0.6
MW 3-3	14	9	11.9	11	0.6	7.0	0.8	1.9
MW 4-2	8	5	<3.5	5.3	0.1	1.1	0.6	0.9
MW 4-3	6	5	<3.5	6.1	0.1	1.4	0.4	0.9
MW 5-2	17	14	4.2	4.2	0.2	2.1	3.0	7.3
MW 5-3	13	31	4.2	4.0	0.0	2.0	3.5	6.7
MW 6-5	5	13	<3.5	5.3	0.4	1.3	0.2	0.5
MW 7-2	6	6	4.2	5.8	0.3	2.1	0.2	0.7
MW 7-3	9	5	4.2	6.5	0.0	2.5	0.1	0.1
MW 8-B5	6	8	5.6	9.0	0.8	2.4	0.0	0.2
MW 8-B Dup	8	11	5.6	8.0	0.1	3.4	0.2	0.4
MW 9B5	12	10	15.4	10	0.8	8.5	0.2	0.0
MW 10-5	3	5	4.2	2.4	0.1	2.3	0.0	-0.4
MW 12-2	4	4	4.9	5.9	0.1	3.0	0.1	0.2
MW 12-3	5	3	4.9	5.1	0.2	2.5	0.2	-0.1
MW 13-1	33	66	3.5	3.1	0.0	2.0	1.2	2.3
MW 13-2	15	27	3.5	3.6	0.0	1.6	0.6	1.8
MW 13-3	-11	11	3.5	3.1	0.2	1.7	0.6	1.0
MW 14-1	33	25	15.4	9.2	0.1	10	3.1	6.8
MW 14-2	37	17	37.1	24	1.1	21	0.2	4.6
MW 14-3	43	15	38.6	24	1.1	21	0.4	0.3
MW 15-1	3	38	4.2	1.8	0.1	2.0	0.2	0.2
MW 15-2	6	8	4.2	2.2	0.3	2.5	0.1	0.8
MW 15-3	2	2	4.2	2.2	0.1	2.1	0.0	-0.4
MW 16-1	7	31	4.2	4.2	0.3	2.3	0.8	1.8
MW 16-2	35	50	5.6	4.6	0.3	2.9	1.8	1.0
MW 16-3	-5	4	<3.5	3.0	0.1	1.6	1.2	2.9
MW 17-1	10	12	9.1	14	0.3	6.0	0.3	0.7
MW 17-2	18	25	8.4	10	0.3	4.7	0.7	6.0
MW 17-3	6	5	9.1	13	0.2	5.7	0.3	0.1
MW 18-1	5	18	6.3	5.5	0.4	3.1	0.4	0.6
MW 18-2	31	35	12.6	13	0.5	7.7	2.5	-0.2
MW 18-3	7	17	11.2	13	0.4	7.8	0.5	0.7
Rinsate[2]	0	4	<3.5	0.9	0.0	0.9	0.1	0.1
Bgd Prescott[1]	1.9	1.1	-	1.5[2]	-	0.4	0.1	-

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold
Reference: PD, 1993
- = No Data,
[1] Background data from Table 8, Prescott, Arizona
[2] Background for U-234 only, not combined U-233 & U-234
[3] Converted from mg/L to pCi assumes equilibrium condition for Tot-U = (mg/L)(701.000pCi/L)(10-6 g/ug) = pCi/L

4. BHP Copper, Pinto Valley Mine

TENORM also contaminated groundwater at the BHP Copper Pinto Valley mine. The Pinto Valley mine is approximately eight miles west of Miami, Arizona, in the Salt River drainage and groundwater basin. The Pinto Valley mine is an open pit copper and molybdenum mine with dual processing facilities for dump leach and SX-EW circuit, and a conventional sulfide crusher and concentrator operation. Facilities include tailings impoundments, waste dumps, process solution ponds, and stormwater runoff ponds. The facility mines low-grade copper and molybdenum ore that feed the sulfide mill and leach circuits. High-grade ore is processed at the sulfide mill, while low-grade ore is deposited in the dump leach at Gold Gulch. Raffinate solution consisting of sulfuric acid is sprayed over the low-grade ore to extract copper. The resulting PLS is collected in a double-lined leach pond with leak detectors and pumped to the SX-EW plant.

The records of the ADEQ, Aquifer Protection Mining section show that TENORM was found at the Pinto Valley mine. The 1996 APPA (No P-100329) showed relatively high radon levels in the majority of the compliance monitoring wells. Three of these wells (APP-3A, APP-3B, and APP-6) also showed high levels of gross alpha and beta. Additionally, all eight of the open pit dewatering wells exceeded one or more of the state or federal standards (Table 25). The data suggest that the groundwater is discharging into the pit as a result of the dewatering operations. The disposition of the produced mine water is unclear to the author of this report.

The Pinto Valley mine experienced multiple tailing dam failures, one in September of 1997 and another in 1993. The most recent failure occurred when 200000 tons of tailings were washed into Miller Canyon and Pinto Creek. All three catchment basins were destroyed. The author is uncertain of the environmental effect on the Pinto Creek watershed. However, the data confirm that TENORM is present in the ore at the Pinto Valley mine and that it has leached, in concentrations above federal standards and state guidelines, into the groundwater.

Table 25

Radiochemical Analyses of Dewatering and Monitoring Well Samples Magma s BHP Copper, Pinto Valley Mine, April 1996 (pCi/L)

Pit Perimeter-Dewatering Wells	Gross Alpha	Gross Beta	Total -U	Total -Ra	Ra-226	Ra-228	Rn-222
W14B	11.6	5.6	12.2	1.2	<0.7	<0.5	530
W12	179	68	209	<1.6	<1.2	<1.6	150
W11	67.4	22	84	2.2	0.6	2.2	300
W17	48	33	—-	5.23	2.8	5.2	2680
W15B	19	11.8	22	<0.8	<0.3	<0.8	190
W19	7.0	5.8	6.0	<1.1	<0.6	<1.1	120
NW24	25.3	164	2.2	122	61	122	2000
NE26	35	39	5.1	29.7	14.9	29.7	3980
Tailings	<53	150	0.17	<2.2	<0.4	<2.2	10
Monitoring Wells	**Gross Alpha**	**Gross Beta**	**Total -U**	**Total -Ra**	**Ra-226**	**Ra-228**	**Rn-222**
APP-1A	<17	<14	1.3	<1.3	<0.3	<1.0	300
APP-2	<15	<12	1.1	<1.1	<0.3	<0.8	427
APP-3A	85	14	80	<0.9	<0.2	<0.7	520
APP-3B	38	7.6	50	<1.6	<0.4	<1.2	140
APP-4	<24	<17	0.84	<1.1	<0.3	<0.8	940
APP-5A	<14	<12	7.2	<1.2	<0.3	<0.9	150
APP-5B	<8	<7	4.6	<0.9	<0.2	<0.7	16
APP-6	10.4	6.3	25	<0.9	<0.2	<0.7	2000
Bgd Globe[1]	1.0	2.0					310.5
Bgd Miami[1]	3.0	5.0	-		0.1	-	291.7

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: Magma, 4/1996

[1] Background data from Table 8, Globe and Miami, Arizona

= No Data

D. GROUNDWATER CONTAMINATION

1. Phelps Dodge, Copper Queen Mine

TENORM contamination of groundwater has been documented south of Bisbee, Arizona, at the Phelps Dodge Copper Queen mine. The facility is known as the Concentrator Tailings Storage Area; the contamination did not actually emanate from the concentrator, but from the tailings piles, surface impoundments, conveyance channels, and irrigation area of the Warren Ranch (Figure M). The facility includes a closed underground copper mine and an operating leach dump. In June of 1987, the U.S. Geological Survey (USGS) investigated and reported a plume of contaminated groundwater containing high concentrations of sulfate and total dissolved solids. The citizens of Bisbee alleged that the plume also contained radionuclides. The plume of contaminated groundwater extend-ed southwestward from the concentrator tailings storage area, over seven square miles (18 square km), and is moving toward the Bisbee and Naco municipal well fields and the Mexican border at a rate of 0.5 to 0.8 feet/day (150 - 240 centimeters/day). The plume has contaminated private drinking water wells in the area. In the late 1980s, ADEQ requested that Phelps Dodge prepare an APPA for the Copper Queen mine. The USGS and the ADEQ have identified the site as the source of the contamination, although the presence of radionuclides was not documented until 1991 (USGS, 1987; ADEQ, 7/1991).

The Copper Queen site has two tailings piles that contain between 100 and 200 million tons of mining overburden and mill tailings that cover 566 acres (226 hectares). The piles are 45 to 85 feet thick (14 to 26 meters) and contain uranium and other toxic residues from the metal processing operations. The site consists of seven surface impoundments and the irrigation area used to dispose of mine water from the underground mining operations. One large impoundment is located immediately south of and adjacent to the south tailings pile and was used for the disposal of mine waters and mine process solutions. The other six impoundments are located north of the north tailings pile and were used to contain seepage/leachate from former leach dumps that contained waste rock/ore. These dumps were referred to as SACLOG #1 and #2 (Sacramento Low Ore Grade Stockpiles No 1 and 2).

All seven impoundments are now closed. SACLOG #1 and #2 and the Crawford Mill tailings pile were relocated to the top of the north tailings impoundment. The waste rock dumps and the Lavender pit are also potential sources of contamination since much of the waste at the site came from the pit. Contaminated mine water was used for agricultural irrigation and was discharged into farmlands surrounding the site (ADEQ, 5/1989; 1990; 1991; 2/1992; 7/2/1992; 7/6/1992; PD 1990; Maest 1991; ATIG, 1992; Margolla, 1992).

In July 1991, ADEQ collected radiochemical water samples at a depth of 24 feet (7.3 meters) from five wells located within the contaminated groundwater plume. See Figure N for the location of the wells and Table 26 for the analytical results of the sampling. Three out of four of these samples exceeded either the federal MCLs or Arizona HBGLs. Samples 8 Surface and 4 Surface exceeded the Arizona 1992 HBGL for total uranium. Samples 4 Surface and 8 Deep also exceeded the federal MCL for gross alpha and sample 4 Deep showed significantly increased levels of Rn-222. (Table 26)

Table 26

Radiochemical Water Sample Analyses, Phelps Dodge Copper Queen Concentrator Tailings Storage Area, July 1991(pCi/L)

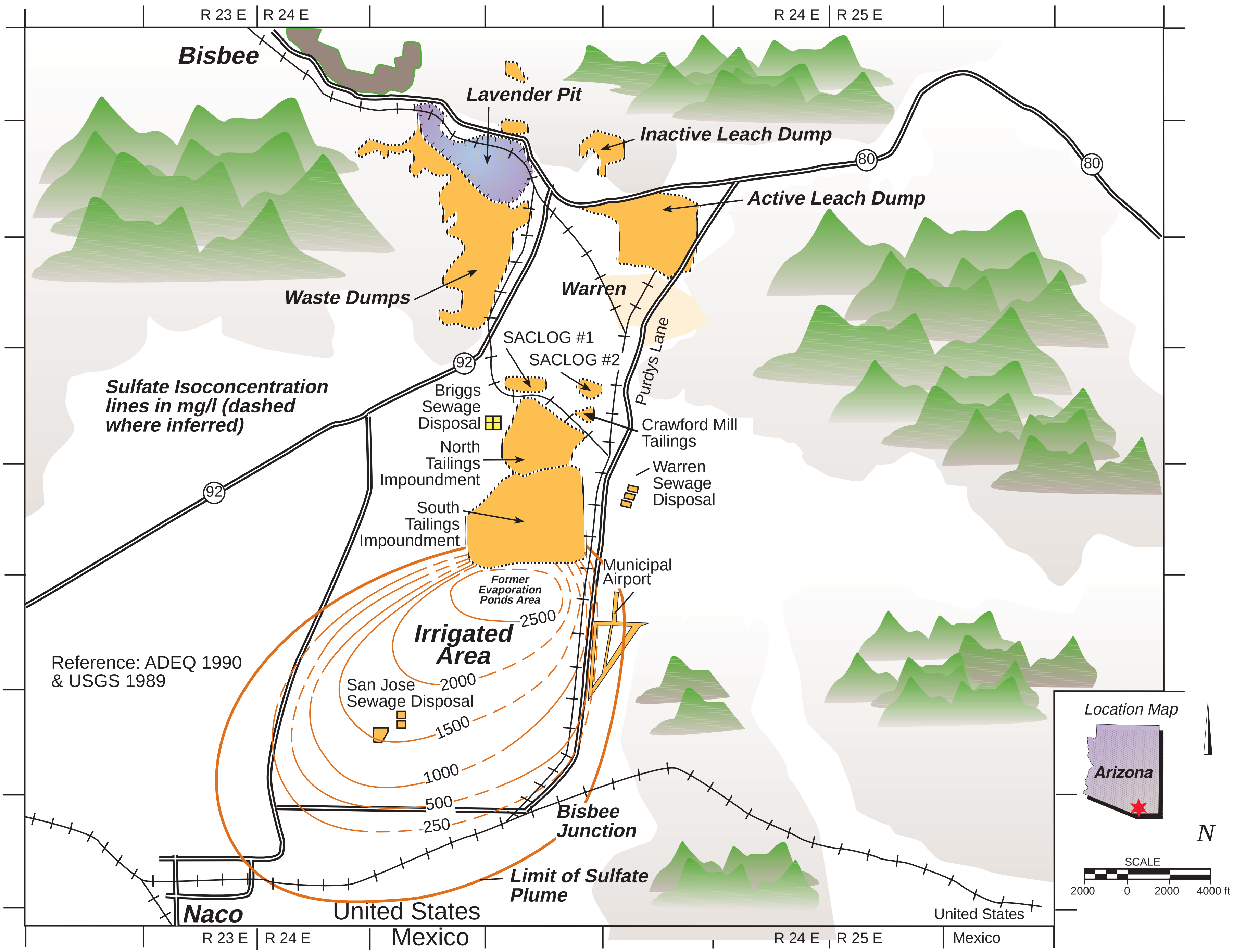
Sample	Gross Alpha	Gross Beta	U-238	U-234	Ra-226	Ra-222
8 Surface	5.1	7.5	0.06	16	0.14	521
8 Deep	72	5	<.40	4.3	0.27	332
4 Surface	34	35	35	58	0.13	542
4 S Duplicate	3.9	33	35	60	<.10	586
4 Deep	3.0	4.9	0.52	1.9	0.16	1330
Bgd Bisbee[1]	3.0	2.0	0.30	2.0	0.10	487

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: ADEQ, 7/1991

[1] Background data from Table 8, Bisbee, Arizona

Figure M: Isoconcentration Map of Sulfate in the Shallow Zone, Phelps Dodge Copper Queen Mine



The radon concentrations are highest in wells screened in the deeper part of the aquifer and lowest in the shallow wells, with the exception of well 8S (shallow) and 8D (deep), which contained 521 and 332 pCi/L, respectively (ADEQ, 7/1991). This appears to be opposite of the trend for uranium, possibly suggesting that the radon may originate from natural sources, such as deeply buried granitic basement rocks or Cretaceous sedimentary rocks that underlie the basin fill deposits. Alternatively, radon could be more readily off-gassing out of shallow wells, thereby escaping detection.

In 1992, Phelps Dodge Corporation submitted an APPA to ADEQ. In response, ADEQ required additional studies, including groundwater monitoring and characterization for all radionuclides. Phelps Dodge installed and sampled eight monitoring wells and tested these samples for radiochemicals (Figure N). In June 1994, the corporation submitted its results (Table 27) to ADEQ (PD, 1994). The results indicated that the radioactivity was correlated with the sulfate plume.

Table 27

**Radiochemical Water Sample Results,
Phelps Dodge Copper Queen Concentrator Tailings Storage, 1994 (pCi/L)**

Well	Alpha	U-238	U-234	U-235	Ra-226	Ra-228	Total-U	Rn-222
Basin Fill BF-1 10/93	13.15	10.19	32.84	0.45	<0.30	<0.83	46.56	60.0
Basin Fill BF-1 11/93	14.48	9.98	33.76	0.67	<0.27	<0.92	49.73	-
Basin Fill BF-2 10/93	44.27	1.88	39.80	0.50	<0.37	<0.65	46.83	240.0
Basin Fill BF-2 11/93	54.04	11.86	38.65	0.47	<0.27	<0.80	60.99	-
Basin Fill TM-2	59.48	24.56	60.37	2.54	<0.38	<0.72	72.78	-
Basin Fill TM-19	4.97	0.78	4.72	<0.01	<0.34	<0.76	4.21	-
Glance conglomerate TM-2A	22.18	3.58	15.40	<0.01	<0.35	<0.98	19.99	-
Morita Formation TM-19A	2.45	1.10	2.80	<0.01	<0.28	<0.74	6.16	-
Glance conglomerate GL-1	17.48	3.44	17.55	<0.01	<0.27	<0.70	23.77	-
Glance conglomerate GL-3	3.35	0.47	1.98	<0.01	<0.29	1.50	2.36	-
North Tailings Water NTW-1	75.60	156.76	131.53	6.87	<0.28	0.70	106.36	57.0
Bgd Bisbee[1]	3.0	0.3	2.0	-	0.1	-	-	487.4

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: PD, 1994

- = No Data

[1] Background data from Table 8, Bisbee, Arizona

BF-1, BF-2, and TM-2, are shallow monitoring wells screened in the upper aquifer of the basin fill deposits south of the two tailings impoundments. Samples from these wells show that these deposits are contaminated by radiochemicals. Sample TM-2A is from a deep monitoring well screened in the lower aquifer of the Glance Conglomerate located next to TM-2. It is also clearly contaminated with high gross alpha activities and total uranium concentrations exceeding the federal MCL and Arizona HBGL. Sample TM-19 is from a shallow monitoring well screened in the upper aquifer of the basin fill deposits 12000 feet (3660 meters) southwest of the two tailings impoundments. The total uranium content of TM-19 is 4.21 pCi/L. This appears to be slightly higher than background levels for this area. Consequently, this sample may be marginally impacted and may have represented the outer limit of contamination in 1994. Sample TM-19A is a deep monitoring well screened in the lower aquifer of the Morita Formation next to TM-19. The total uranium content of TM-19A also exceeded background levels, hence it may have defined the lower limit of contamination in 1994. Monitoring wells GL-1 and GL-3 are both screened in the Glance Conglomerate, which is geologically separated by a pair of faults that offset the units in this area. Monitoring well GL-1 is a deep monitoring well located in the center of the south tailings impoundment (Figure N). It is clearly contaminated by radiochemicals. Monitoring well GL-3 is a deep monitoring well located just southwest of the north tailings impoundment and is hydraulically upgradient of GL-1. It is relatively unaffected and defines the outline of the plume. See Figure O for a pentiometric surface map of the site.

A surface water sample of the north tailing impoundment (NTW-1) was analyzed for radon and radionuclides. Its radon and radium levels are relatively low, although its gross alpha, U-238, U-234, U-235, and total uranium are the highest levels found at the sites. The samples taken at Bisbee typically appear low in radium and U-235, except for the U-235 level of sample NTW-1, which is 6.87 pCi/L. This is generally consistent with the statement by Robin Jenkins of ADEQ that the oxidation-reduction potential is an important control factor on the Ra-226 solubility in groundwater. Field studies confirm that gross alpha due to Ra-226 activities are elevated in reducing conditions where the pH is approximately 4.4 and dissolved oxygen values are <1.0 mg/L. Conversely, in oxidizing water, gross alpha activity due to uranium is elevated. Elevated uranium and radium are therefore rarely found concurrently in the same groundwater samples because of their opposite geochemical behavior. The concentration of radon in groundwater depends largely on the concentration of the parent nuclide Ra-226. . .in underlying rocks of aquifer material (ADEQ, 9/1989).

Phelps Dodge collected samples from two shallow monitoring wells (TM-2 and TM-19) in June of 1996. These samples were analyzed for total uranium and three of its species, U-234, U-235, and U-238. Monitoring well TM-2, located near the source of the plume, showed slightly decreased concentrations of uranium, while monitoring well TM-19, located near the southwest side of the plume, showed slightly increased concentrations of uranium isotopes. Phelps Dodge speculates that the plume is sinking due to density separation.

ADEQ collected samples from public and private monitoring wells in the plume at the Copper Queen mine site in August of 1996. The samples were analyzed for total uranium content only (Table 28). As part of this effort, ADEQ collected eight additional samples, five of which were taken from the Arizona Water Company and Naco Water Company public supply wells downgradient of the plume. The results (Table 28) indicate that these wells are not presently contaminated. They also establish the background level range for total uranium to be between 0.5 and 3.4 pCi/L. In addition, these wells will serve as detection monitoring wells in the event the plume affects Naco s water supplies. The locations of these wells are not shown on Figure N.

Figure N: Monitoring Well Location Map, Phelps Dodge Copper Queen Mine

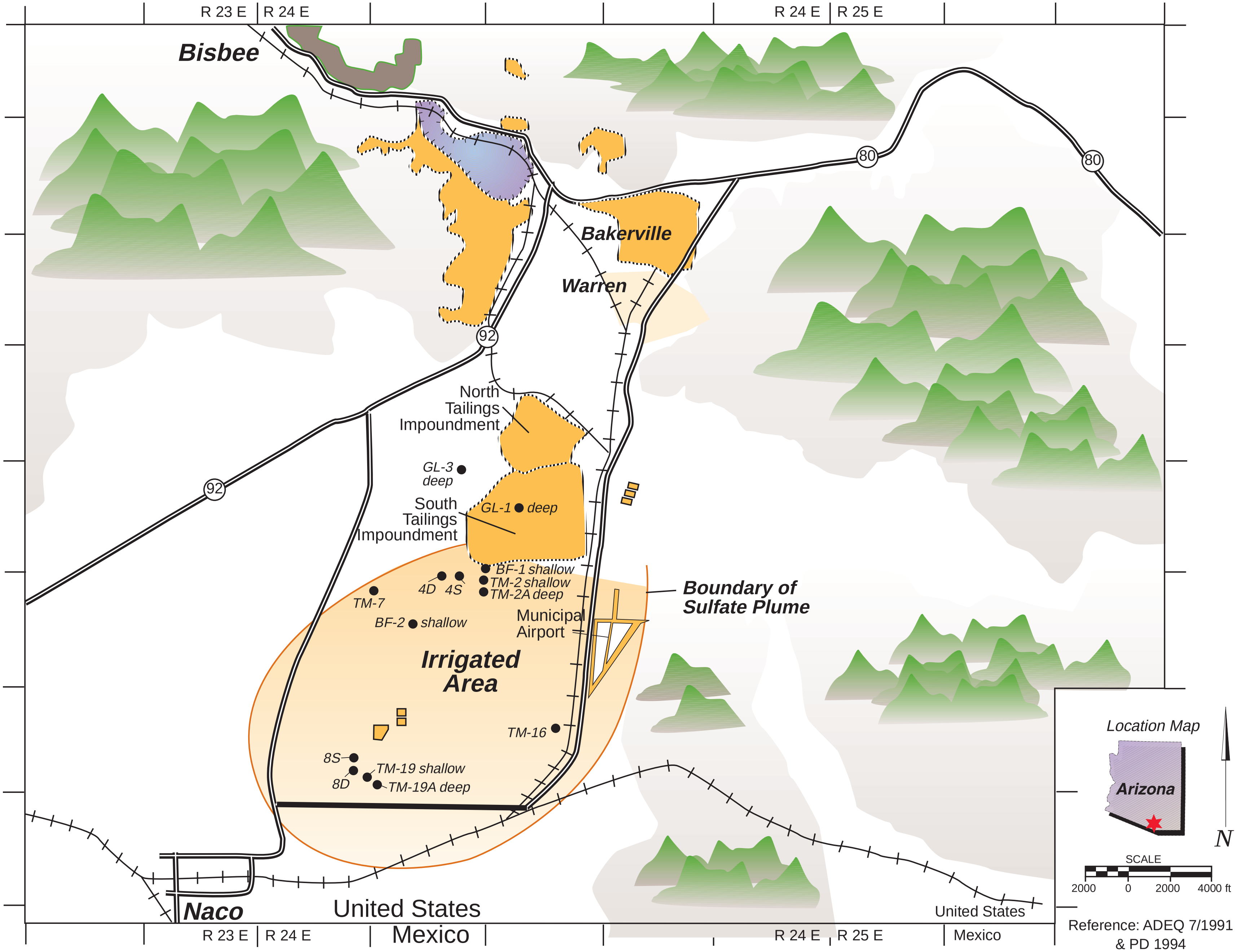


Table 28

Radiochemical Groundwater Sample Results, Phelps Dodge Copper Queen Concentrator Tailings Storage Area, 1996 (pCi/L)

Well ID	Total-U	U-238	U-234	U-235
Phelps Dodge Samples 6/20/96				
TM 2	66	13	51	2.0
TM 19	23.2	3.9	19	0.3
ADEQ Samples 8/8/96				
BF 2	17.5			
TM 2	18.4			
TM 19	6.6			
TM 16	2.5			
TM 7	4.3			
(D-24-24)05acc*	5.7			
(D-24-24)17bbb*	4.1			
(D-23-24) 29bcb*	1.2			
Background Samples				
AWC. PSW2*	0.5			
AWC. PSW3*	0.6			
NWC. PSW5*	1.3			
NW C. PSW4*	0.7			
NWC. PSW3*	3.4			

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

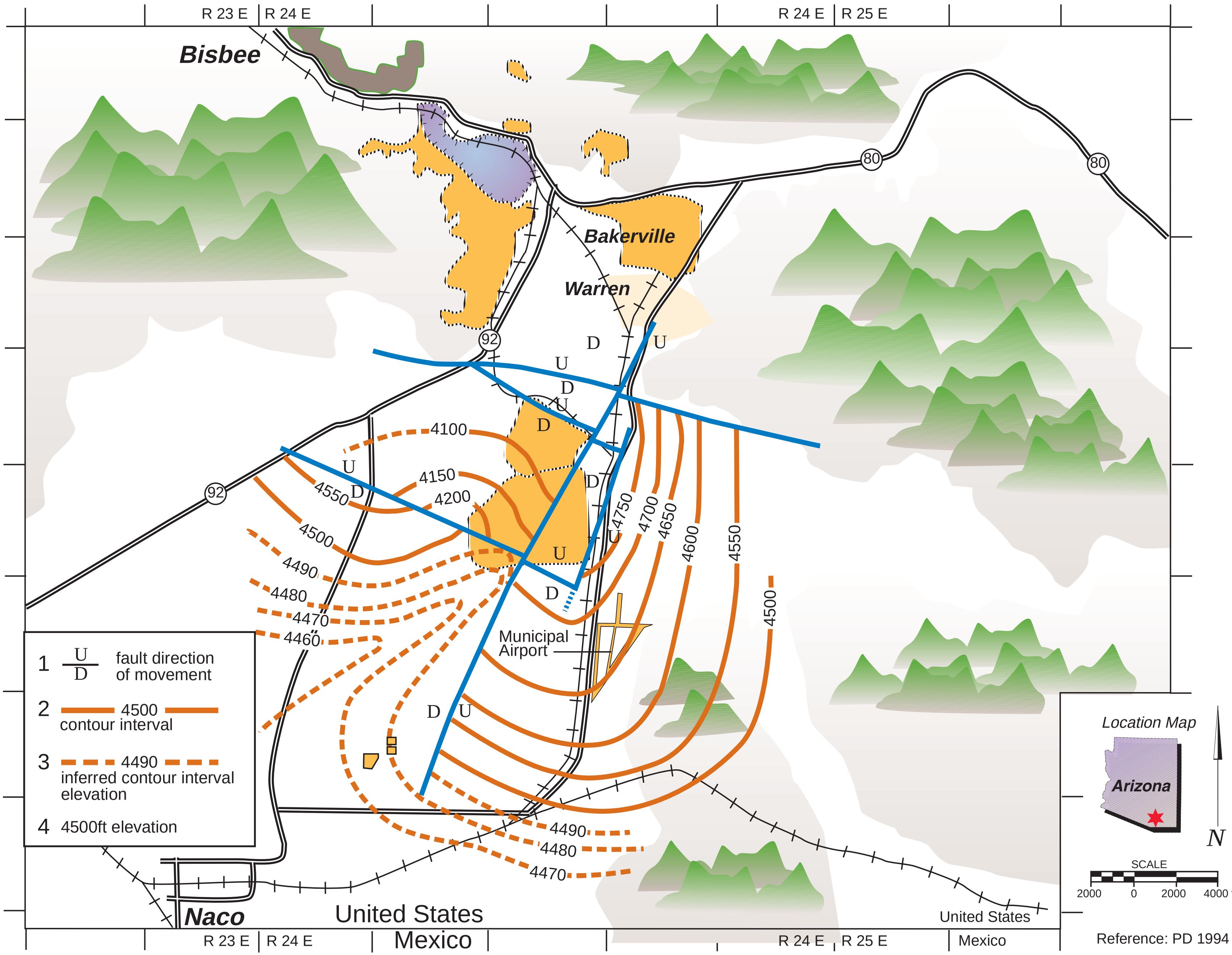
* = Not located on Figure N

Reference: PD, 1996

Phelps Dodge recently installed four monitoring wells north of the tailing impoundments at the Copper Queen mine. Submission of additional sampling and analyses was received by ADEQ in the spring of 1998, although it has not been included as part of this report. Phelps Dodge is preparing new groundwater modeling of the hydrologic flow at the site.

The data in Tables 26 - 28 show that TENORM has been found in process waste streams and in the leach circuit of a closed mine. They also indicate that TENORM from process units has affected groundwater resources at active copper mining operations. The existing data also suggest that the contaminant plume continues to migrate toward Naco, Mexico.

Figure O: Hydrogeologic Map, Phelps Dodge Copper Queen, Concentration Storage Area



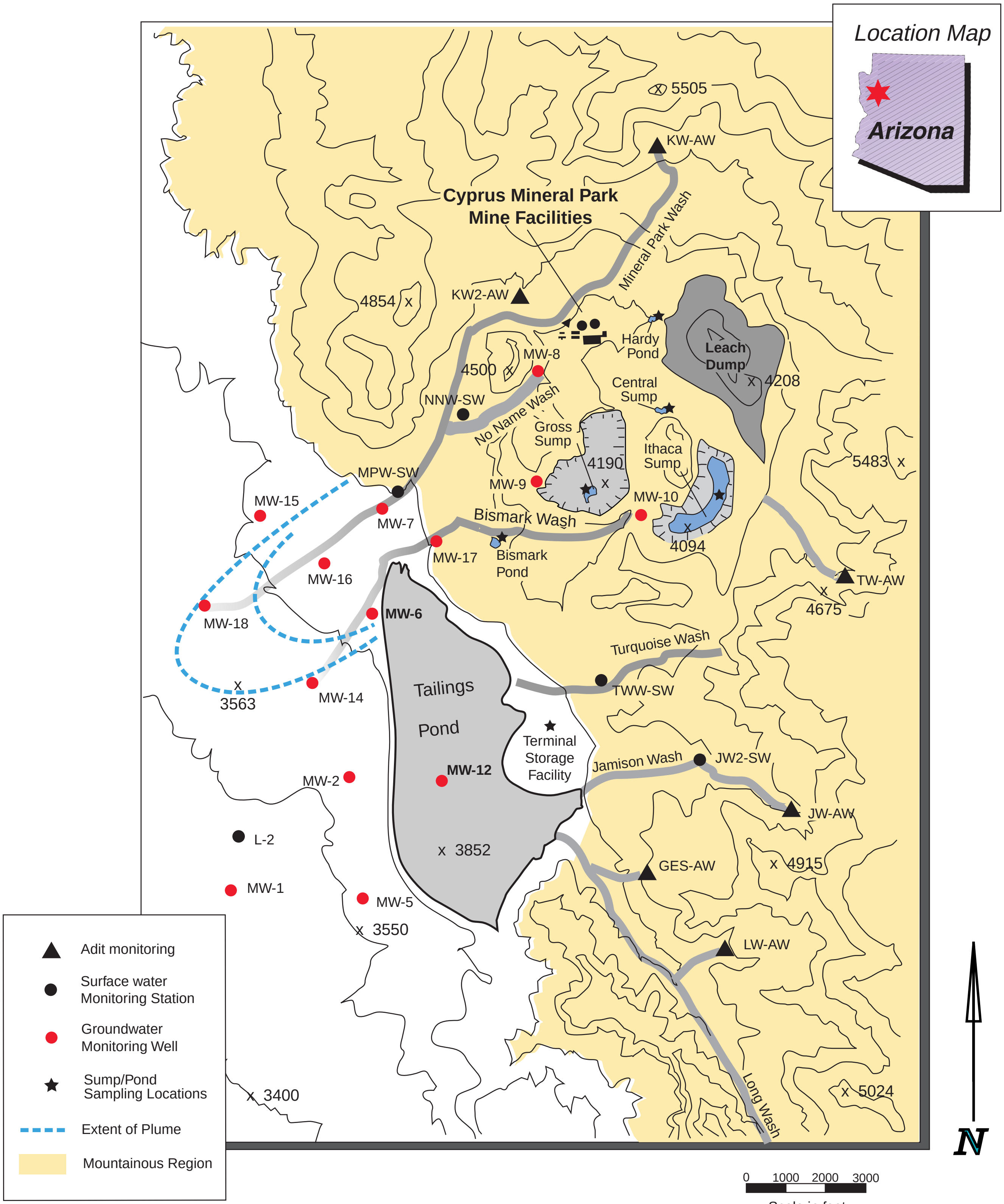
2. Cyprus Mineral Park Mine

In 1996, Cyprus Mineral Park submitted an APPA that contained radiochemical data. The Mineral Park mine is 17 miles northwest of Kingman in the Cerbat Mountains. The mine consists of three coalescing open pits that have been in operation since the 1860s. The mine contains one closed 560 acre tailing impoundment and seven leach dumps. The Ithaca, Central, and Gross leach dumps are currently active and drain into the bottom of the open pit where the sumps are located. PLS is processed at the central SX-EW plant.

Cyprus collected surface water samples from seven drainage areas and analyzed them for metals and radiochemicals. All of these drainages, except for Golden Eagle Spring, exceeded either the federal MCLs and/or state guidelines for gross alpha or gross beta. Gross alpha activities ranged from 11 to 150 pCi/L. Gross beta activities ranged from 18 to 62 pCi/L, with only one monitoring well exceeding the state beta guideline of 50 pCi/L. The results are shown in Table 29. Five of these eight washes had mine adits located within them. Samples from all the mine adits exceeded the federal standard for gross alpha emissions of 15pCi/L.

Cyprus sampled nine sumps and their raffinate and the terminal storage facility pond. Eight of these sumps had gross alpha and beta levels ranging from 260 to 1700 pCi/L, and 190 to 880 pCi/L, respectively. The raffinate and the terminal storage facility pond contained 1100 and 750 pCi/L, and 660 and 370 pCi/L gross alpha and beta, respectively (Figure P).

Figure P: Cyprus Mineral Park Mine, Sample Location Map



Reference: Cyprus 1994

Table 29

Radiochemical Surface Water Sample Results
Cyprus Mineral Park, 1996 (pCi/L)

Sample ID		Description		Gross Alpha	Gross Beta	Total U	Ra-226	Ra-228	Rn-222
GES-AW	8/4/95	Golden Eagle Spring	Adit Water	16	18	-	-	-	-
JW-AW	8/4/95	Jamison Wash	Adit Water	68	35	-	-	-	-
TW-AW	8/4/95	Bismark Wash	Adit Water	11	20	-	-	-	-
KW-AW	8/3/95	Keystone Wash	Adit Water	20	10	-	-	-	-
KW2-AW	8/4/95	Keystone Wash	Adit Water	43	22	-	-	-	-
KW2-AWC	8/4/95	Keystone Wash	Adit Water	BDL	6	-	-	-	-
LW-AW	8/4/95	Long Wash	Adit Water	36	26	-	-	-	-
LW-SW	4/5/93	Long Wash	Surface Water	62	-	0.10	0.8	1.4	120
JW-SW	4/5/93	Jamison Wash	Surface Water	47	-	0.05	0.5	1.8	46 to 30
JW2-SW	8/4/95	Jamison Wash	Surface Water	37	24	-	-	-	-
MPW-SW	8/3/95	Mineral Park Wash	Surface Water	140	BDL	-	-	-	-
NNW-SW	8/4/95	No Name Wash	Surface Water	150	90	-	-	-	-
TWW-SW	8/4/95	Turquoise Wash	Surface Water	37	43	-	-	-	-
TWW-SW	4/5/93	Turquoise Wash	Surface Water	27	-	0.01	0.4	1.6	39
B-1	7/31/95	Bismark	Sump	1200	600	-	-	-	-
C-1	8/2/95	Central	Sump	730	590	-	-	-	-
G-1	8/2/95	Gross	Sump 1	780	480	-	-	-	-
G-3	8/2/95	Gross	Sump 3	1700	880	-	-	-	-
H-1	7/31/95	Hardy	Sump	1100	370	-	-	-	-
I-1	7/31/95	Ithaca	Sump 1	260	190	-	-	-	-
I-2	7/31/95	Ithaca	Sump 2	410	290	-	-	-	-
I-3	7/31/95	Ithaca	Sump 3	820	430	-	-	-	-
S-27*	8/4/95	Sump 27		28	56	-	-	-	
RAFF	8/2/95	Raffinate Pond		1100	750	-	-	-	-
TSF/TP-1	8/3/95	Treatment Storage Facility Pond -1		660	370	-	-	-	

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

References: Cyprus, 1994; Cyprus, 1996

- = Not Sampled, * = Not shown on Figure P

BDL = Below Detection Limit

During its review of the Cyprus Mineral Park APPA, ADEQ observed that surface water runoff emanating from the drainages in the mine area were affecting the water quality of the alluvial pediment. Data from the APPA showed that the plume contained high levels of beryllium, cadmium, fluoride, and nickel. Further review of the APPA revealed that the plume contained high alpha and beta activity levels as well (Table 30).

Monitoring well 9 is located slightly west of the Gross sumps and shows very high levels of gross alpha activity at 1500 pCi/L and gross beta activities at 500 pCi/L, similar to the PLS in the sumps. Monitoring well 10 is located at the foot of the hill between the Gross and Ithaca pits and is marginally affected by the PLS in the sumps. Monitoring well 8 is located at the head of No Name Wash and is also marginally affected by the nearby leach dumps. Monitoring wells 7 and 6 are located at the mouth of Mineral Park and Bismark Washes, and are influenced by the absorption of surface water drainage into the sediments. Monitoring wells 14 and 15 are located on the northwest and southeast fringes of the plume, while monitoring wells 16 and 18 are near the centerline of the plume and are marginally impacted. Monitoring well 12 is in the center of the tailings pond and monitoring well 17 is near the tailings retention dam.

Table 30

Radiochemical Monitoring Well Sample Results
Cyprus Mineral Park, 1996 (pCi/L)

Sample ID		Description	Gross Alpha	Gross Beta
MW-2A	8/20/95	Monitoring Well	BDL	BDL
MW-6	8/1/95	Monitoring Well	220	170
MW-7	8/1/95	Monitoring Well	140	BDL
MW-8	8/2/95	Monitoring Well	50	40
MW-9	8/2/95	Monitoring Well	1500	500
MW-10	8/2/95	Monitoring Well	19	42
MW-12	8/4/95	Monitoring Well	BDL	60
MW-14	8/1/95	Monitoring Well	BDL	BDL
MW-15	8/1/95	Monitoring Well	BDL	BDL
MW-16	8/1/95	Monitoring Well	80	BDL
MW-17	8/19/95	Monitoring Well	80	29
MW-18	8/19/95	Monitoring Well	73	BDL

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

References: Cyprus, 1996; Cyprus, 1994

BDL = Below Detection Limits

The data show that TENORM is discharging from abandoned mine adits and is impacting surface water and that mining operations have impacted groundwater. In addition, TENORM is concentrated in the process solutions and waste streams associated with the leach circuit. The data also indicate that very high levels of TENORM are being concentrated in the raffinate and recycled within the leach circuit at Cyprus Mineral Park mine. TENORM also has impacted groundwater within the alluvial pediment below the mine.

3. Phelps Dodge Morenci District

Phelps Dodge at Morenci submitted an APPA in 1995 that showed TENORM was present in several monitoring wells. The mine is in the southwestern copper porphyry belt, 20 miles west of New Mexico and 100 miles north of Mexico. It is the largest operating copper mine in the United States. The mineral deposits in the Morenci district are: the Coronado, Shannon Mountain, Metcalf, Northwest Extension, Western Copper, and Morenci mines. See Figure Q for the location of the these features.

The Morenci open pit mine is approximately one mile across from east to west and five miles across from the Morenci pit to northern end of Metcalf mine. The mine contains dual processing facilities for oxide and sulfide ores. Facilities include the leach dumps, SX-EW units, and two sulfide ore concentrator circuits. Sulfide (chalcocite) ore is transported by conveyor to the concentrator for flotation. There are seven in-pit crushers with conveyors for transporting ore to the Morenci and Metcalf flotation concentrators. Concentrates are shipped offsite for refining. The mine has 11 tailing impoundments, eight of which are active. These ponds cover 18000 acres. Forty two million tons of tailings are disposed annually in the tailing ponds.

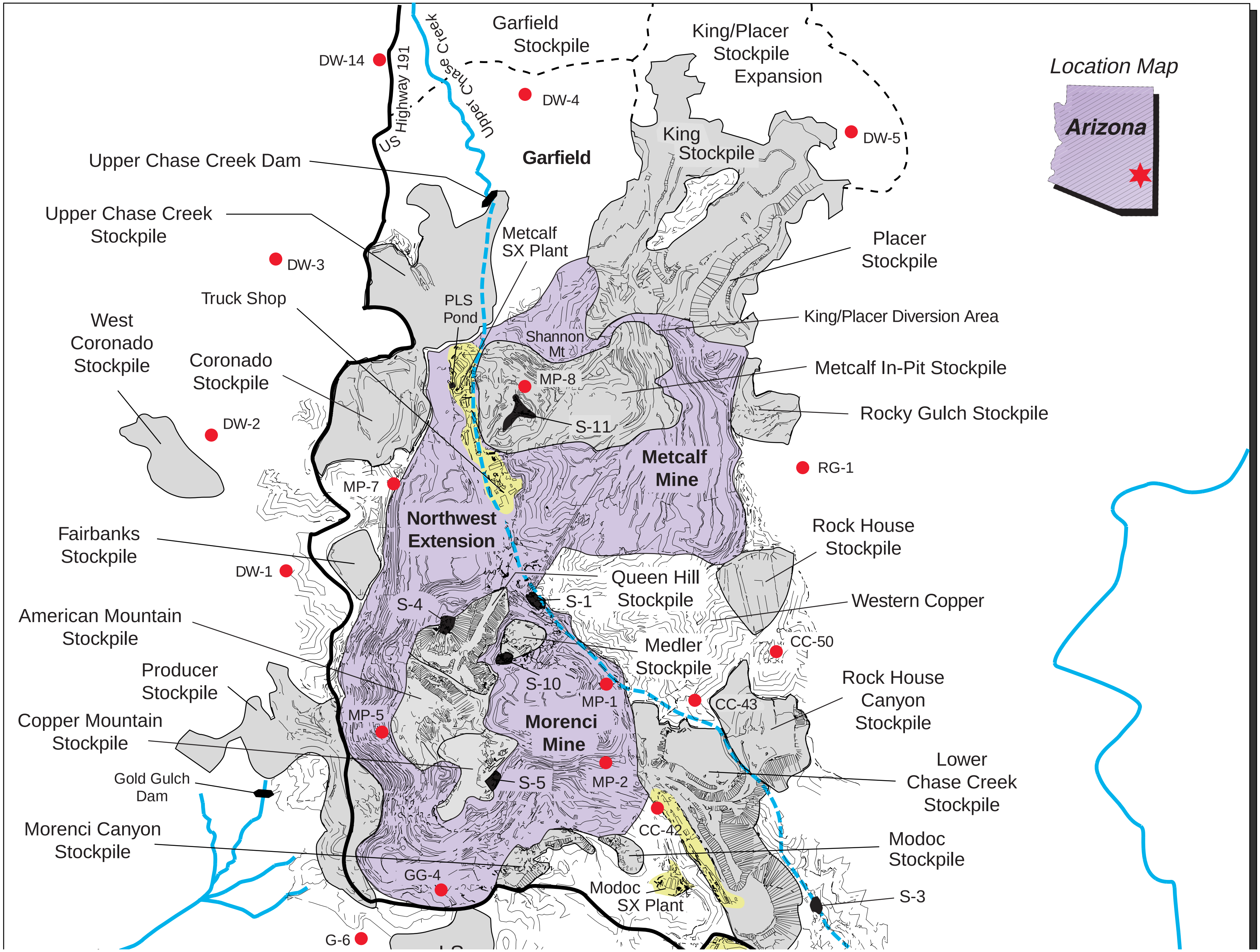
Paleozoic sedimentary rocks, covered by tertiary volcanics and quaternary Gila conglomerate, overlie the formations that are mineralized. Both the overlying and mineralized rocks have been eroded to expose the underlying Precambrian granite, forming a window. The intrusive rocks are monzonite and granite porphyry. The crystalline rocks are relatively impermeable. The local hydrogeologic flow mimics the impermeable basement floor topography. Water balance estimates indicate that there is about a 6.0 percent loss, which is probably due to evaporation. The concentrator and tailing facilities are located to the south of the mine on the Gila conglomerate.

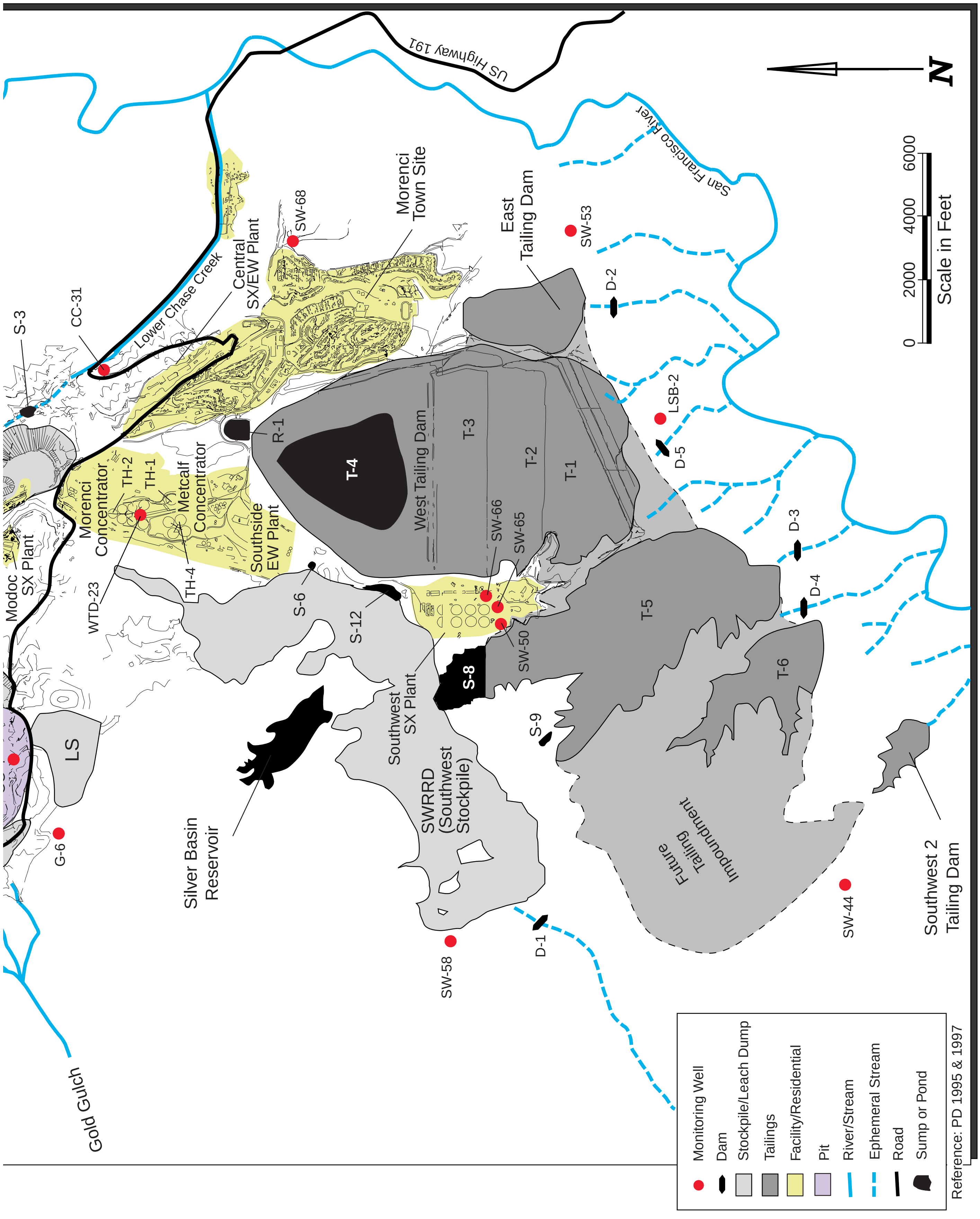
Low-grade sulfide and oxide ore is transported by 70-ton trucks to leach dumps, which Phelps Dodge refers to as lean ore stockpiles (LOS). Oxide ore (azurite, malachite) goes to these LOS for leaching. The resulting PLS is processed by electrowinning. There are three operating leach dumps within the Chase Creek drainage system. The largest active leach dump is the Lower Chase Creek (LCC) dump. It was constructed by damming the Chase Creek Canyon, completely cutting off any natural drainage. The Metcalf and Coronado dumps are located within the Metcalf sideslope mine. They were constructed by backfilling the upper Metcalf Canyon. The Morenci pit is being backfilled as mining progresses, creating a leach dump. There are also eight other old (greater than 30 years) LOS outside the Chase Creek drainage area and the pit. These dumps are referred to as the Southwestern Railroad Dumps (SWRRD). According to Phelps Dodge, they are inactive, meaning that no lixivent solutions are being introduced onto the dumps, although PLS is recovered as natural precipitation generates leachate. Several ponds are located at the base of the SWRRD. No basement preparation of any of the leach dumps was conducted due to the age of the dumps and the rough terrain.

There are four SX plants located in different sections of the mine. The central SX plant is located with the EW tankhouse and plant area above Lower Chase Creek leach dump. The Metcalf SX plant is located at the base of the Metcalf operations. The Southwest SX plant is located on the west side of the tailing ponds by the SWRRD and the Morenci SX plant is located in the pit.

Phelps Dodge installed, sampled, and tested approximately 86 monitoring wells as part of its APPA. Particle activity analyses of gross alpha and gross beta were conducted for all monitoring wells. Gross alpha activity ranged from zero to 136 pCi/L. Fourteen samples exceeded either the gross alpha or gross beta federal MCLs or Arizona HBGL guideline (Table 31). Two monitoring wells (RG-01

Figure Q: Morenci Mine, Sample Location Map




US Highway 191
N
San Francisco River
0
2000
4000
6000
Scale in Feet
Lower Chase Creek
S-3
CC-31
Central
SX/EW Plant
SW-68
Morenci
Town Site
East
Tailing Dam
SW-53
D-2
R-1
T-4
West Tailing Dam
T-3
T-2
T-1
LSB-2
D-5
Modoc
SX Plant
Morenci
Concentrator
TH-2
TH-1
Metcalf
Concentrator
Southside
EW Plant
WTD-23
TH-4
S-6
S-12
SW-66
SW-65
SW-50
T-5
D-3
D-4
T-6
S-8
Southwest
SX Plant
S-9
LS
G-6
Silver Basin
Reservoir
SWRRD
(Southwest
Stockpile)
Future
Tailing
Impoundment
Southwest 2
Tailing Dam
SW-44
SW-58
D-1
Gold Gulch
Monitoring Well
Dam
Stockpile/Leach Dump
Tailings
Facility/Residential
Pit
River/Stream
Ephemeral Stream
Road
Sump or Pond
Reference: PD 1995 & 1997

and SW-44) exceed the federal MCLs and state guidelines for both gross alpha and beta activity and seven others are close to exceeding these levels. Nine samples exceeded or equaled the gross alpha standard of 15pCi/L. Four of these samples ranged between 30 to 136 pCi/L; five samples ranged between 15 and 17 pCi/L. The gross beta activity ranged from 2 to 347 pCi/L with seven samples exceeding the 50 pCi/L HBGL guideline. The data indicate that TENORM has been detected in the Phelps Dodge monitoring wells and that it has impacted groundwater in at least six monitoring wells.

Table 31

Radiochemical Monitoring Wells Sample Results that Exceed Federal or State Radiochemical Guidelines

Sample ID		Monitoring Wells	Gross Alpha	Gross Beta
CC-42	11/1/95	Chase Creek	4.5	74.3
CC-43	11/1/95	Chase Creek	30	47.8
CC-31	6/26/95	Chase Creek	<1.5	347
GG-04	3/7/96	Gold Gulch	9	57
MP-07	2/14/96	Morenci Pit	5.6	56.1
MP-8	11/14/95	Morenci Pit	81	40
RG-01	9/26/95	Rocky Gulch	117	149
WTD-23	2/15/96	West Tails Dam-23	16	5.4
SW-44	2/21/96	South West	136	254
SW-58	8/9/95	South West	1.4	237
SW-50	7/31/95	South West	15.3	8.6
SW-65	10/30/95	South West	17	7
SW-66	10/30/95	South West	15.2	5
SW-68	1/25/96	South West	15	2

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

All Morenci data is presented in Appendix C

Reference: PD, 1995

Phelps Dodge Morenci District, March 1995 (pCi/L)

Phelps Dodge also sampled 55 other process or waste streams at Morenci. Forty-two of these samples exceeded either federal or state guidelines for gross alpha and beta activity. They are shown in Table 32. Four of these samples were taken from the PLS pond and another four were taken from the raffinate pond. The gross alpha ranged from 1250 to 3700 pCi/L for the PLS samples and the gross beta ranged from 1110 to 2390 pCi/L. The gross alpha ranged from 670 to 3550 pCi/L for the raffinate pond samples and the gross beta ranged from 660 to 2010 pCi/L. Eight samples were tailings samples. The gross alpha ranged from zero to 102 pCi/L for these samples and the gross beta ranged from 66 to 214 pCi/L. Another 12 samples were sump samples that showed gross alpha ranging as high as 3970 pCi/L and gross beta ranging as high as 3060 pCi/L.

Table 32

Loc. No.	Sample ID	Description	Gross Alpha	Gross Beta
S-1	4250SUMP	4250 Sump 8/8/95	3970	1930
S-2*	4500SUMP	4500 Sump 8/9/95	1030	600
S-3	HDRSHOSUMP	HORSESHOE Sump 8/9/95	3800	3060
S-4	QNHILLSUMP	Queen Hill Sump 8/17/95	202	162
S-5	CPMTNSUMP	Copper Mountain Sump 8/17/95	2080	1290
S-6	STARGOSUMP	Stargo Sump 8/24/95	1760	1040
S-7*	MORPITSUMP	Morenci Pit Sump 8/21/ 95	21	76
S-8	2325MMSUMP	23/25 Morenci Mine Sump 8/23/95	1590	1100
S-9	27MMSUMP	27 Morenci Mine Sump 8/23/95	720	280
S-10	MEDLERSUMP	Medler Sump 8/17/85	1050	710
S-11	METCASUMP	Metcalf Sump 8/17/95	3060	1630
S-12	5XSUMP	5X Sump 8/25/95	1930	930
P-29*	POND-29	Pond-29 8/6/95	1060	1150
R-1	COLUMBINE RES	Columbine Reservoir 8/8/95	0.60	81
R-2	KNGPCRDIVR	King Placer Diversion Reservoir	3450	2390
D-1	DAMBC 5	Dam BC5 8/8/95	1530	840
D-2	TSRDAM2B	Treatment Storage Res. Dam 2B 8/21/95	160	140
D-3	TSRDAM6	Treatment Storage Res. Dam 6 8/22/95	46	10
D-4	TSRDAM7B	Treatment Storage Res. Dam 7B 8/22/95	313	169
D-5	TSRDAM4B	Treatment Storage Res. Dam 4B 8/21/95	1210	610
TH-1	METCONTH1	Metcalf Concentrator Thickener 1 8/8/95	-2.3	80
TH-2	MORTAILTH1	Morinci Tailings Thickener 1 8/10/95	-0.2	86
TH-4	METTAILTH4	Metcalf Tailings Thickener 4 8/10/95	1.5	93
T-1	1WTAILPD	1 West Tailings Pond 8/24/95	81	80
T-3	3WTAILPD	3 West Tailings Pond 8/25/95	102	214
T-4	4 WTAILPD	4 West Tailings Pond 8/24/95	3.4	121
T-5	SBITAILPD	Silver Basin I Tailings Pond 8/23/95	-0.3	66
T-6	SWITAILPD	South West I Tailing Pond 8/23/95	0.3	68
PD*	PDM-L-2016-X	Pond Mine Leval[1] 2016-X 9/2/95	0.5	82
LS	LONSTRSTCK	Lone Star Stockpile 9/23/95	86	100
GG	GGSPRING	Gold Gulch Spring 8/28/95	36	17
GR*	GRASVX	GRA- SV-X Soil 2/15/96	18.7	49.5
GA-1*	GAROXX	GARFIELD Oxide-X Soil 2/15/96	24.4	57.3
GA-2*	GARDVX	GARFIELD DV-X Soil 2/15/96	16.8	45.4
PLS-1	MODOCSXPLS	Modoc Solvent Extraction Pregnant Leach Solution 8/16/95	2990	1910
PLS-2	METCFSXPLS	Metcalf Central Facility Solvent Extraction Pregn. Leach Sol. 8/16/95	3600	2140
PLS-3	CNTRLSXPLS	Central Solvent Extraction Pregnant Leach Solution 8/95	3700	2390
PLS-4	SWSXPLSTK4	South West Solvent Extraction Pregnant Leach Solution Tank 4 8/9/95	1250	1110
RAF-1	MODOCSXRAF		3550	2010
RAF-2	METCFSXRAF	Modoc Solvent Extraction Raffinate 8/16/95	3480	1810
RAF-3	SWSXRAFTK3	Metcalf Central Facility Solvent Extraction Raffinate 8/14/95	670	660
RAF-4	CNTRALSXRAF	South West Solvent Extraction Raffinate Tank 3 8/9/95	2060	910

Radiochemical Process Water Sample Results that Exceed Federal or State Radiochemical Guidelines,

Phelps Dodge Morenci District, March 1995 (pCi/L)

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

Reference: PD, 1995

[1] Uncertain translation of abbreviation, * = Not shown on Figure Q

The data show that the process solutions and wastes steams associated with the leach circuit contain very high levels of TENORM. It also documents that very high levels of TENORM are being concentrated in and recycled back to the leach circuit (LOS), since the raffinate is used for leach dump lixivent. ADEQ has questioned the quality of this data. (March 28,1996) Due to the large counting errors reported. We [ADEQ] have requested 2-3 additional groundwater sampling rounds that will include: gross alpha, gross beta, Ra-226, Ra-228, and uranium, all with lowered error values. The Mining Unit anticipates receiving this data in late January or February [of 1998] (ADEQ, 1997).

In response to ADEQ s request of March 1995, Phelps Dodge conducted additional sampling and analyses of their monitoring wells. Seventy-one monitoring wells were sampled and analyzed for gross alpha, gross beta, Ra-226, Ra-228, and uranium species, all with lowered error limits. Samples were collected from well locations upgradient of the mine areas, within the mine, downgradient of the tailings dam, and from Lower Chase Creek, Rocky Gulch, and Gold Gulch areas. Twenty of these wells sampled showed elevated levels of one or more radiochemicals that exceeded either federal MCLs or state HBGL guidelines. Due to improved data quality of the 1996 sampling events, the total number of impacted wells increased from 14 to 21. All but two (CC-31 and SW-68) of the 14 monitoring wells sampled during the 1995 sampling event showed elevated radiochemicals in the subsequent 1996 analyses (PD, 1997). The samples that exceeded either federal MCLs or state guidelines for radionuclide levels are shown in bold in Table 33.

Elevated levels of gross alpha and beta, total uranium, and total radium activities were found in four upgradient wells at the mine. District wells DW-02, 03, 04, 05, 10, 14 can be used for background wells for comparison. Four wells located in the Morenci pit area were found to show elevated gross alpha and beta, total uranium, and total radium activities. Elevated gross alpha and beta, and total radium activities were also found in three of the Lower Chase Creek wells. Another three wells located at the southwest SX plant showed elevated gross alpha and total uranium activities. Elevated levels of radionuclides also were found at the wells at Metcalf Drop cut sump, which feeds the Metcalf SX plant. Wells near the dams at Rocky Gulch and Gold Gulch also exhibited high levels of radionuclides. Another well in the southwest stockpile showed elevated gross beta activities. Finally, three downdradient wells of the tailings area showed elevated gross alpha and beta activities.

Phelps Dodge Morenci mine is in the process of collecting 12 new data sets of quarterly monitoring data for radiochemicals. The results are expected to be completed in late 1999.

Site -Well ID	Gross Alpha	Gross Beta	Calculated Total-U	U-234	U-235	U-238	Calculated Total-Ra	Ra-226	Ra-228
Gold Gulch MW									
GG-4 10/31/96	27	56	10.6	6.3	0.3	4	9.7	2.6	7.1
GG-4 12/11/9	13	47	27.6	18	2.6	7	8.3	3.7	4.6
Chase Creek									
CC-42 11/2/96	7	60	4.9	2.4	0	2.5	4.9	1.0	3.9
CC-43 11/2/96	21	61	0.1	0.1	0	0	34.0	13	21
CC-43 11/30/96	28	52	0.4	0.2	0	0.2	19.3	0.3	19
CC-50 12/19/96	23	39	8.1	6.7	0	1.4	22.1	17	14

Table 33

Site -Well ID	Gross Alpha	Gross Beta	Calculated Total-U	U-234	U-235	U-238	Calculated Total-Ra	Ra-226	Ra-228
Morenci Pit									
MP-1 11/5/96	150	140	250	130	10	110	42.0	28	14
MP-1 11/21/96	240	160	249.9	150	-0.1	100	37.6	28	9.6
MP-2 11/21/96	7	30	1.4	1.0	0.1	0.3	6.6	3.2	3.4
MP-5 11/5/96	79	100	123.1	61	1.1	61	2.0	0.7	1.3
MP-5 11/22/96	96	68	129.5	67	0.5	62	1.4	0.6	0.8
MP-7 11/6/96	4	27	1.7	1.5	0.1	0.1	7.8	1.6	6.2
MP-7 11/22/9	3	31	0.1	0	0.1	0	6.7	1.5	5.2
Metcalf DCSumps									
MP-8 11/6/96	51	51	42[1]	21	0.4	12	18.0	8.5	9.5
MP-8 11/22/96	40	38	29.6	18	1.6	10	16.3	8.5	7.8
S.W. SX Plant									
SW-50 10/15/96	19	6	21.9	18	1.0	2.9	1.5	0	1.5
SW-50 11/19/96	18	7	21.9	19	0.6	2.3	0.2	0.2	-0.1
SW-65 10/1/96	35	-2	66.2	54	2.2	10	0.3	0	0.3
SW-65 11/13/96	66	11	93.4	77	2.4	14	0.5	0.2	0.3
SW-66 10/11/96	20	8	20.9	17	0.2	3.7	0.3	0.2	0.1
SW-66 11/13/96	19	4	23.2	20	0.2	3.0	0.5	0.3	0.2
S.W. Stockpile									
SW-58 10/9/96	2	170	0	0	0	0	1.6	0.8	0.8
SW-58 11/13/96	2	110	0	0	0	0	0.3	0.2	0.1
RockyGulchDam									
RG-1 12/4/96	190	190	102	64	0	38	117.7	7.7	110
Downgradient of the TailingsDams									
LSB-2 10/11/96	17	41	1.9	1.4	0	0.5	2.3	0.8	1.5
SW-44 11/15/96	27	53	3.3	2.3	0	1	4.4	0.7	3.7
SW-53 10/8/96	18	25	5.2	3.2	0	2	1.7	0.9	0.8
Upg District Wells									
DW-3 11/2/96	10	59	6.9	4.7	1.7	0.1	2.6	0.9	1.7
DW-3 12/16/96	17	50	33.5	23	8.7	0.5	2.9	1.3	1.6
DW-14 11/30/96	9	5	12.6	10	3.7	0.4	14.2	13	1.2
DW-1 11/22/96	28	66	5[1]	2.8	0	1.2	11.6	4.9	6.7
DW-19 12/12/96*	12	5	13.1	11.0	0.3	1.80	0	0	0
Bgd District Wells									
DW-02 9/19/95	6.3	17.5							
DW-02 10/31/96	5	13	2.7	1.3	0	1.4	1.2	0.6	0.8
DW-02 11/30/96	4	22	1.2	2.2	0	1.1	0.4	0.2	0.2
DW-03 2/21/95	13.4	42.3							
DW-04 2/22/95	7	4							
DW-04 12/03/96	4	8	2.4	1.4	0	1	1.8	0.4	1.4
DW-04 12/12/96	5	9	4.4	3.3	0.1	1	0.7	0.4	0.3
DW-05 12/3/96	4	7	2.4	2	0	0.4	1.2	0.2	1
DW-05 12/12/96	4	7	3.5	3	0	0.5	0.5	0.1	0.4
DW-14 10/17/95	0.4	8.4							
DW-14 2/12/95	5.6	3.9							
DW-14 10/26/96	9	5	8.3	6.5	0	1.8	1.3	0.4	0.9

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold
All Morenci data is presented in Appendix C
Reference: PD, 1997
Upg = Upgradient, Bgd = Background, * = Not shown on Figure Q
[1]Reported total-U

Summary of Radiochemical Monitoring Well Water Sample Results that Exceed Federal or State Radiochemical Guidelines, Phelps Dodge Morenci District, 1996 (pCi/L)

Table 33 (continued)

The data from Phelps Dodge Morenci mine comprises about 40 percent of the total analyses. It is summarized in Table 34. About 10 percent of the total analyses exceeded either federal MCLs or state HBGL guidelines for radiochemicals (see the Exceeds Standards columns). Phelps Dodge has installed, sampled, and tested about 86 monitoring wells as part of its APPA. Of these, 21 wells showed levels of at least one radiochemical that exceeded either federal or state guidelines. Phelps Dodge also sampled about 55 other process or waste streams at the Morenci process operation   41 of these samples exceeded either federal or state guidelines for gross alpha and beta activity.

Table 34

Morenci Groundwater Statistical Data (pCi/L)

	Overall					Exceeds Standards		
Radiochemical	Total	Min.	Max.	Avg.	St. Dev.	Total	Avg.	Std. Dev.
Gross Alpha	230	0	240	10.7	27.1	31	53.9	76.3
Gross Beta	230	0	347	22.3	40.6	24	110.7	70.7
U-238	141	0	110	3.6	14.6	10	42.4	22.5
U-234	141	0	150	7.2	20.2	16	47.9	37.3
U-235	141	0	10	0.3	1.2	2	9.4	2.1
Total Ra	144	0	118	3.2	11.4	15	24.8	17.6
Ra-226	144	0	28	1.2	4.0	8	15.5	5.4
Ra-228	144	0	110	2.2	9.6	12	19.2	7.7
Total-U	141	0	250	11.3	34.9	18	70.3	26.3
Total	1456					136		31

Levels of radioactivity in excess of federal MCLs or Arizona guidelines are shown in bold

MM GT 1430 = 60 percent

MM > Exceeds Standards 136 = 10 percent

VI. REFERENCES

(ABM, 1970) Arizona Bureau of Mines, "Coal, Oil, Natural Gas, Helium, and Uranium in Arizona, *Arizona Bureau of Mines Bulletin 182*, 1970.

(ADEQ, 1997) Arizona Department of Environmental Quality, letter from Dennis L Turner, Water Protection Approvals and Permits Section, Mining Unit, MY97:0010, January 8, 1997.

(ADEQ, 1996) Arizona Department of Environmental Quality, sample analyzed by Arizona Radiation Regulatory Agency, August 8, 1996.

(ADEQ, 1995) Arizona Department of Environmental Quality, *Human Health-Based Guidance Levels (HBGLs) for the Ingestion of Contaminants in Drinking Water and Soil*, September 1990, updated June 1992, January 1995, and March 1995.

(ADEQ, 8/1993) Arizona Department of Environmental Quality, Water Quality Management Survey, Cerbat Mountains, WQMS-212.243. August 20, 1993.

(ADEQ, 7/1993) Arizona Department of Environmental Quality, analyses of samples taken from the Three R mine, July 28, 1993.

(ADEQ, 4/1993) Arizona Department of Environmental Quality, Water Quality Management Survey, Hillside mine, WQMS-212.260, April 20, 1993.

(ADEQ, 7/6/1992) Arizona Department of Environmental Quality, letter to Director, Arizona Toxic Information, July 6, 1992.

(ADEQ, 7/2/1992) Arizona Department of Environmental Quality, letter to Environmental Coordinator, Phelps Dodge Corporation, July 2, 1992.

(ADEQ, 2/1992) Arizona Department of Environmental Quality, analyses of sample taken from Naco Well No 4, Arizona Water Company, February 1992.

(ADEQ, 7/1991) Arizona Department of Environmental Quality, letter to Phelps Dodge, Copper Queen mine, regarding analyses of five samples with location map from Phelps Dodge, July 30, 1991.

(ADEQ, 5/1991) Arizona Department of Environmental Quality, Office of Water Quality, Quality Assurance Project Plan, May 1991 ID# 10666, ADEQ-WQAPP-5/91.

(ADEQ, 1990) Arizona Department of Environmental Quality, analytical data provided by E.M. Schern in support of Aquifer Protection Permit Application, submitted by Phelps Dodge s Copper Queen Branch Concentrator Tailing Storage Area, April 4, 1990.

(ADEQ, 9/1989) Arizona Department of Environmental Quality, Radionuclides in Groundwater and their Occurrence in Arizona, paper presented by Robin Jenkins at Arizona Hydrological Society annual symposium, Water Quality and Water Quantity Issues into the 1990s Adaptation to Current Realities, Casa Grande, AZ, September 1989.

(ADEQ, 5/1989) Arizona Department of Environmental Quality, Notice of Disposal, Bisbee Plant, Phelps Dodge Corporation, May 16, 1989.

(ADHS, 1985) Arizona Department of Health Services, Notice of Disposal, Cyprus Twin Buttes, Environmental Monitoring Anamax Uranium, Plant License 10-72, January 17, 1985.

(AGS, 1992) Arizona Geological Survey, *List of Publications*, July 1992.

(AGS, 1990) Maps Showing Areas in Arizona with Elevated Concentrations of Uranium: Tucson, *Arizona Bureau of Geology and Mineral Technology (now the Arizona Geological Survey), Open File Report 86-11*, 1990.

(AMAX, 1988) AMAX Mineral Resources Company, Twin Buttes Post-Closure Monitoring Program Annual Summary for 1988, February 1988.

(AMAX, 1987) AMAX Mineral Resources Company, CERCLA Site Inspection Report of Twin Buttes mine: EPA Site ID Number: AZDO64946742, Inspection ID Number: F9-8701-20, September 1987.

(Az Pay Dirt, 1979) Arizona Pay Dirt, Tour Ends Newspaper Generated Flap Over Proposed Uranium Plant At Bisbee, *Arizona Pay Dirt*, August 1979.

(ARRA, 1987) Arizona Radiation Regulatory Agency, information obtained during telephone conversation between ARRA and USEPA contractor personnel, June 1987.

(ATIG, 1992) Arizona Toxic Information Group, comments from Michael Gregory to ADEQ on Aquifer Protection Permit Application submitted by Phelps Dodge s Copper Queen Branch Concentrator Tailing Storage Area, January 8, 1992.

(ASARCO 1997) ASARCO Santa Cruz, In-Situ Copper Mining Research Project, Aquifer Protection Permit No 101413, Quarterly Compliance Monitoring Report for 4th Quarter 1996, Jan 28, 1997.

(ASARCO 1994) ASARCO Santa Cruz, In-Situ Copper Mining Research Project, Aquifer Protection Permit No 101413, October 30, 1994.

(CRC, 1978) CRC Press, *CRC Handbook of Chemistry and Physics*, 59th Edition. Robert C. Weast, Ph.D., editor, 1978-1979.

(Cyprus, 11/1997b) Cyprus Sierrita Corp, Additional Characterization of Hydrogeologic Conditions Sierrita Operation Aquifer Protection Permit Application, Volume 1, November 13, 1997.

(Cyprus, 11/1997a) Cyprus Sierrita Corp, Twin Buttes mine, Characterization of Hydrogeologic Conditions in support of Aquifer Protection Permit Application Oxide Plant Area Twin Buttes mine, November 13, 1997.

(Cyprus, 1996) Cyprus Mineral Park Corp, Supplemental Aquifer Protection Permit Application Data Table: data collected during and after June 1995 and data collected prior to June 1995, 1996.

(Cyprus, 1994) Cyprus Mineral Park Corp, Aquifer Protection Permit Application Draft, containing radiochemistry data for Cyprus Mineral Park mine, analytical results: (Between 6/20 to 8/20, 1996) and (Report No.: 02788 April 26,1993), January 1994.

(Cyprus, 12/1993) Cyprus Bagdad Copper Corporation, Groundwater Investigation Hillside Loadout Property, Report 022, submitted to ADEQ as part of their APPA, December 7, 1993.

(Cyprus, 10/1993) Cyprus Bagdad Copper Corporation, APPA, Groundwater Investigation Hydrologic Area HA-7 Bagdad Mine, October 26,1993.

(Cyprus, 6/1993) Cyprus Bagdad Copper Corporation, APPA, Vol 2, Groundwater Investigation Hydrologic Areas HA-1, HA-2, HA-4, HA-5 of the Bagdad Mine. June 1, 1993.

(Cyprus, 1992) Cyprus Bagdad Copper Corporation, letter to ADEQ on compliance monitoring at Bagdad, submitted to ADEQ as part of their APPA, February 18, 1992.

(Duncan and Spencer, 1992) Duncan, John T., and Jon Spencer, USGS, and Pejman and Steve Emrick, ADEQ, A Reconnaissance Study of Radon and Other Radionuclides in Arizona Well Water, 1992.

(Hopkins and Lynch, 1977) Hopkins, W.R., and Lynch, Anamax Oxide Plant: A New U.S. Dimension in Solvent Extraction, in *Engineering and Mining Journal*, February 1977.

(Keith, 1970) Keith, S.B, Uranium in Arizona, in *Arizona Bureau of Mines Bulletin 182*, *Arizona Geological Survey*, 1970.

(Lorenz, 1982) Lorenz, W.R., Uranium Recovery from Copper Leach Solutions at Twin Buttes, in *Society of Mining Engineers of AIME*, 1982.

(Maest, 1991) Maest, Ann, comments on Aquifer Protection Permit Application submitted by Phelps Dodge s Copper Queen Branch Concentrator Tailing Storage Area, December 19, 1991.

(Magma 4/1996) Magma BHP Copper Pinto Valley, Supplemental Aquifer Protection Permit Application, April 04, 1996.

(Magma, 1/1996) Magma Florence: Aquifer Protection Permit Application, Volume IV, Modeling Report Section 3.7.4,5,6, January 15 1996.

(Magma, 1992) Magma Copper Corporation, letter to ADEQ, March 31, 1992.

(Magma, 1991) Magma Copper Corporation, letter to ADEQ, October 4, 1991.

(Margolla, 1992) Margolla, Judy, Two Groups Say: PD Impacts Threaten Groundwater, in *Arizona Daily Star*, January 19, 1992.

(NAS, 1999) National Academy of Sciences, National Research Council, Evaluation of Guidelines for the Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials, National Academy Press, January 1999.

(NCRP, 1987) National Council on Radiation Protection and Measurements, Exposure of the Population in the United States and Canada From Natural Background Radiation. Recommendations of NCRP Report No. 94, December 1987.

(Paschoa, 1998) Paschoa, Anselmo S., Naturally Occurring Radioactive Materials in the Environment: Potential Environmental and Regulatory Implications of Naturally Occurring Radioactive Materials (NORM), in *Applied Radiation and Isotopes*, Volume 49 Number 3, SO969-8043(97)00239-X, March 1998.

(Pewe, 1989) Pewe, Troy L., Environmental Geology of Arizona, in *Geologic Evolution of Arizona*, J.P. Jenney and S.J. Reynolds, editors, Arizona Geological Society Digest 17, 1989.

(PD, 1997) Phelps Dodge Morenci Inc, Evaluation of Radionuclide Sampling and Analyses, March 12, 1997.

(PD, 1996) Phelps Dodge, Copper Queen, Supplemental Aquifer Protection Permit Application, June 20, 1996.

(PD, 1995) Phelps Dodge Morenci District, Aquifer Protection Permit Application Vol II Sec 4-7, 6.4.3.2.5 Radionuclides and Table 6-29 Groundwater Characterization Analytical Laboratory

Results for Radionuclides, March 28,1995.

(PD, 1994) Phelps Dodge Corporation, Aquifer Protection Permit Application submitted by Copper Queen Branch Concentrator Tailing Storage Area, Site Characterization, June 16,1994.

(PD, 1993) Phelps Dodge New Cornelia Mine, Report of Radionuclide Analytic Results, submitted to ADEQ as part of their APPA, March 1993.

(PD, 1990) Phelps Dodge Corporation, Aquifer Protection Permit Application excerpts, Copper Queen Branch Concentrator Tailing Storage Area, 1990.

(3R, 1992) 3R Resources, report to ADEQ on analytical results submitted to ADEQ, September 9, 1992.

(Still, 1962) Still, A R.,Uranium at Copper Cities and Other Porphyry Copper Deposits, Miami District Arizona, unpublished thesis, Harvard University, 1962.

(USEPA, 1994) U.S. Environmental Protection Agency, Technical Background Document, Review of Radionuclide Concentrations in Rocks, Soils, Mining Materials, and Coal Ash, July 1994.

(USEPA, 1990) U.S. Environmental Protection Agency, Report to Congress on Special Wastes from Mineral Processing, EPA/530-SW-90-070C, July 17, 1990.

(USEPA, 12/1985) U.S. Environmental Protection Agency, Report to Congress: Waste from the Extraction and Beneficiation of Metallic Ores, Phosphate and Rock Asbestos. Overburden from Uranium Mining, and Oil Shale, EPA/5-SW-8S-033, December 1985.

(USEPA, 10/1985) U.S. Environmental Protection Agency, Natural Occurrence of Radon and Other Natural Radioactivity in Public Water Supplies, EPA 520/5-85-008, October 1985.

(USGS, 1987) U.S. Geological Survey, USGS Water Resources Investigations Report 87- 4103, Groundwater Resources of the Bisbee - Naco Area, Coshise County, Arizona, Report Findings: Bisbee-Naco Groundwater Quality Fact Sheet H-6500.08, 1987.

(USGS, 1963) U.S. Geological Survey, Mineralogy, Internal Structural and Textural Characteristics, and Paragenesis of Uranium-Bearing Veins in the Conterminous United States, in *Professional Paper 455*-D, 1963.

(USGS, 1955) U.S. Geological Survey, Geology and Ore Deposits of the Bagdad Area, Yavapai County, Arizona, in *Professional Paper 278*, 1955.

(Yozwiak, 1992) Yozwiak, Steve, Environmentalist Battle Plan for Mine Tailings in *The Arizona Republic*, January 1992.

APPENDIX A

Arizona State Bureau of Mines
Uranium Occurrences Associated with Copper Minerals
that are Verified with Sample Analyses or Assay Information

The Arizona Department of Mines and Mineral Resources maintains a computerized database called the Mineral Industry Location System (AZMILS) that lists all known mineral occurrences in Arizona. A section of the AZMILS database identifies 421 old miner records of primary uranium occurences and another 161 records of byproduct occurrences of uranium, for a total of 582 known occurrences of uranium in Arizona. About fourteen percent or 80 of the 582 records are associated with copper minerals. The majority of these records were taken from Keith s 1970 work on uranium in The Arizona Bureau of Mines Bulletin 182, entitled *Uranium in Arizona* (Keith, 1970). References cited below may be found in Keith (Ibid.); and the site identification numbers are those used from the same source. This Appendix lists all of the old miner records of uranium that are associated with copper and that have sample analyses or assay information. When scintillation or GEIGER counters were used, an entry is denoted by eU. The data are arranged by site identification number (Figure A shows the location of each site), mine name, location (township and range), physical description, mineralogy, and the Arizona State Bureau of Mine file references for each site. Copper minerals associated with the uranium are shown in bold.

Site Identification #, Mine Name, Location, Physical Description, Mineralogy, and References

V4. Cerbat Mountain Range mines.
V4A. Detroit group. W. Central Sec,. 31. T. 23 N., R. 17 W.
V4B. Summit mine. Central Sec. 32. T. 23 N., R. 17 W.
V4C. Bobtail mine. SW. 1/4 Sec. 31, T. 23 N., R. 17 W.
V4D. Jim Kane (Monitor group) NE. 1/4 Sec. 8, T. 22 N., R. 17 W.
V4E. Prosperity et alia. N. Central Sec. 6, T. 22 N., R. 17 W.
V4F. J. C. and Fort Lee. SE. 1/4 Sec. 12, T. 22 N., R. 18 W. and others in Mohave County area. Finely disseminated uranium mineralization associated with base metal sulfides and quartz gangue in fault fissures and shear zones in granite. Samples range from less than 0.01 to about 0.50 percent uranium, but overall average is too low to recover economically. Old base-metal and precious metal mines. (Misc. AEC PRR reports, Hart, 1955, Hart and Hetland, 1953).

V10. Hillside mine, Seven Star claim. NW. 1/4 Sec. 21, T. 15 N., R. 9 W. Yavapai County. Pitchblende and secondary uranium carbonates (andersonite, bayleyite, swartzite) locally present in gold-silver-base sulfide-fluorite fissure vein cutting Precambrian Yavapai Schist. Samples showed trace to 0.11 percent uranium. Mined extensively for gold, silver and base sulfides. A few tons of uranium ore shipped. (Wright, 1950; Anderson, Scholz and Strobell, 1955).

V15. Buckhorn, Cuba, Lucky Day, Independence mines. SE. 1/4 Sec. 8, SW. 1/4 Sec. 9, T. 11 N., R. 5 W. (Unsurveyed) Yavapai County. Sparse torbernite along a quartz vein and thin coating of uranophane on surface of granite. Average sample less than 0.01 percent uranium, but radioactivity of granite is locally abnormal. Tungsten and beryllium mineralization present. Old copper, tungsten and gold mines. (Granger and Raup, 1962).

V16. Little Surprise. SE. 1/4 Sec. 33, T. 11 N., R. 1 E. Yavapai County. Torbernite in small quartz-barite vein with copper staining cutting Precambrian rocks. Grab sample ran 0.701 percent eU. Old silver prospect. (Barrett and Robison, 1954, AEC PRR A-P-245).

V17. Ford claim (Gazelle mine). NE. 1/4 Sec. 33, T. 10 N., R. 1 W. Yavapai County. Torbernite and uranophane in small quartz stringers in fault carrying base metal sulfides and gold and silver values. Select sample assayed 0.18 percent eU. Old gold mine. (Robison, 1955, AEC PRR A-16).

V18. Abe Lincoln mine. SE. 1/4 Sec. 11, T. 8 N., R. 3 W. Yavapai County. Uraninite and schoepite associated with copper and iron minerals and quartz, calcite and fluorite gangue in gouge veins cutting Precambrian complex of gneiss and schist intruded by granite and dikes. Select samples from dumps ran up to 0.46 percent uranium. Old copper mine. (Granger and Raup, 1962).

Vl9. Denver group. Approx. NW. 1/4 T. 8 N., R. 3 W. Yavapai County. Radioactivity associated with copper mineralization, fluorite, quartz, calcite, pyrite and siderite along fault-fissure vein cutting Precambrian complex. Select sample ran up to 0.61 percent uranium. Old copper working. (Ashwill, 1955, AEC PRR A-54).

V25. Copper Kid group. Sec. 10, T. 6 N., R. 4 E. Maricopa County. Uraninite, copper carbonates, galena and barite in red jasper zone in precambrian schist intruded by dikes. Select sample ran 0.77 percent uranium. Old lead-silver prospect. (Reyner and Ashwill, 1954, AEC PRR A-P-280).

V27. Golondrina claims. Approx. SE. 1/4 Sec. 13, T. 11 S., R, 25 E. (Unsurveyed) Graham County. Radioactive pyromorphite, quartz and limonite in cavities and fractures in layer of agglomerate or flow breccia and porphyritic volcanics. Trace of copper minerals. Generally low grade but some samples ran as high as 0.26 percent eU. Prospect pits and adit. (Granger and Raup, 1962).

V33. Wooley No. 1. Sec. 33, T. 4 S., R. 13 E. Pinal County. Unidentified uranium mineral associated with iron and weak copper oxides or staining in veins cutting granite. Selected sample ran 0.017 percent uranium. Prospected. (Granger and Raup, 1962).

V34. Name Unknown. Secs. 26 and 35, T. 4 S., R. 11 E. Pinal County. Radioactivity associated with zones of small stringers of iron and copper oxides and carbonates in granite. Select assay ran 0.012 to 0.124 percent eU. Old adits and shaft. (Ashwill, 1954, AEC PRR A-P-291).

V38. Sure Fire No. 1. Sec. 15, T. 13 S., R. 18 E. Pima County. Radioactive minerals (uranophane and autunite) associated with quartz-fluorite and minor copper in leached, crushed and altered precambrian schist. Samples indicate 0.002 to 0.008 percent uranium. Prospect pits. (Granger and Raup, 1962).

V40. Copper Squaw. Sec. 19, T. 14 S., R. 2 E. Pima County. Unidentified uranium mineralization associated with oxidized copper and iron in vein in altered andesite. Selected samples ran 0.76 and 1.4 percent eU, but may have other radioactive elements besides uranium. Old copper property. (Wells and Putluck, 1953, AEC PRR A-P-102).

V42. Black Dike. Secs. 23, 24, 25 and 26, T. 17 S., R. 10 E. Pima County. Pitchblende and manganese oxide along fractures and in contact metamorphized granite along basaltic dike. Associated copper mineralization and fluorite. Assays showed 0.011 to 0.16 percent uranium. Shaft. (Granger and Raup, 1962).

V44. Diamond Head group. Sec. 34, T. 17 S., R. 11 E. Pima County. Uraninite associated with iron and copper sulfides and hematite, in fault vein structure cutting intrusive. Assays of 0.22 and 0.74 percent uranium reported but average much lower. Adits and pits. (Miller and Miller, 1956, AEC PRR A-94).

V45. Escondida. Sec. 34, T. 17 S., R. 11 E. Pima County. Uraninite with iron and copper sulfides in contact zone along basic dike intruding granitic rock. Select samples ran 0.03 to 0.06 percent eU. Pits. (Miller, 1955, AEC PRR A-35).

V49. Esperanza mine. Secs. 8, 9, 16 and 17, T. 18 S., R. l2 E. Pima County. Uraninite and secondary uranium minerals associated with molybdenite and copper minerals in New Year s Eve mine and in veinlets in porphyry copper deposit. Assays of old ore stockpile ran 0.111 to 0.182 percent eU. Shaft and open pit. (Robison, 1954, AEC PRR A-P-255; Lynch, 1968).

V50. King mine. E. Central Sec. 24, T. 18 S., R. 15 E. Pima County. Pitchblende with iron and copper sulfides and quartz-calcite gangue in pockets along limestone quartz monzonite contact. Samples assayed 0.14 to 0.93 percent eU. Old silver-copper mine. (Miller, 1955, AEC

PRR A-37).

V51. Gismo group. Sec. 5 T. 21 S., R. 10 E. Pima County. Sooty uraninite, kasolite and schroeckingerite identified with copper and iron mineralization in fault-fissure vein in granite. Samples assayed 0.12 to 0.30 percent eU. Old gold-silver mining area. (Magleby, 1957, AEC PRR A-114).

V54. Alto group (Gold Tree, El Plomo). SE. 1/4 Sec. 12, N. _ Sec. 13, T. 21 S., R. 14 E. Santa Cruz County. Very fine uraninite crystals on cross-fractures in quartz-latite agglomerate. Assay showed 0.07 percent eU. Old silver-base metal mine. (Miller and Robison, 1955, AEC PRR A-P-360).

V56. Cracker Jack group. Sec. 29, T., 21 S,., R. 15 E, Santa Cruz County. Pitchblende associated with base sulfide mineralization in fissure veins cutting quartz latite. Assays up to 0.07 percent eU. Prospect pits. (Miller, 1955, AEC PRR A-39).

V57. Grandview group. N. Center Sec. 20, T. 22 S., R, 10 E. Santa Cruz County. Kasolite with iron and copper oxides in vein cutting silicified volcanics. Samples assayed up to 0.076 percent eU. Shaft and open cut. (Reyner and Robison, 1955, AEC PRR A-P-319).

V58. Little Doe. Sec. 20, T. 22 S., R. 10 E. Santa Cruz County. Gummite and kasolite with iron and copper oxides in fracture zones in volcanics. Samples assayed 0.036 to 0.125 percent uranium. Old workings. (Webb and Coryell, 1952, AEC PRR A-SL-3; Miller and Weathers, 1953, AEC PRR A-SL-3 Suppl.).

V61. Annie Laurie. SE. 1/4 Sec. 1, T. 23 S., R. 11 E. Santa Cruz County. Pitchblende and secondary uranium minerals associated with base sulfide and oxides in shear fractures in altered granite and porphyry. Selected samples may be relatively high but average is close to 0.01 percent uranium. Prospect pits. (Granger and Raup, 1962).

V62. White Oaks mine (Clark mine). NE. l/4 Sec. 2, T. 24 S., R. 12 E. Santa Cruz County. Kasolite, uranophane, dumontite, autunite, and uranium-bearing pyromorphite with oxidized lead and copper minerals in fissures and gouge of shear zone in rhyolite volcanics. Selected samples assayed up to 0.02 percent uranium, but average much lower. Adits and pits. (Granger and Raup, 1962).

V78. Mickey Dolan mine. SE. 1/4 Sec. 5, T. 6 N., R. 13 W. Yuma County. Unidentified uranium mineral associated with secondary copper and iron minerals in fault cutting granite and schist. Samples assayed 0.018 to 0.185 percent uranium. Pits, shaft and drifts. (Williams and Walthier, 1953, AEC PRR A-SL-4).

V79. Bonanza mine. NW. 1/4 Sec. 26, T. 7 N., R. 13 W. Yuma County. Unidentified uranium mineral associated with iron and copper secondary minerals in fissure cutting granite and schist. Sample assayed 0.07 percent uranium. Incline shaft and drifts. (Ashwill, 1954-1955, AEC PRR A-P-301).

V80. Rayvern group. NW. 1/4 Sec. 13, T. 6 N., R. 18 W. Yuma County. Uranophane and meta-autunite associated with iron and copper staining in fissures and limestone beds overlying granite. Select samples ran O.03 to 0.08 percent eU. Small pits and shaft. (Ashwill, 1955, AEC PRR A-P-148).

V84. McMillan prospect. NE. Corner Sec. 16, T. 16 S., R, 16 W. (Unsurveyed) Yuma County. Unidentified uranium mineral associated with secondary iron and copper minerals in fracture zone in granite. Sample of stockpiled copper ore ran 0.034 percent uranium. (Granger and Raup, 1962).

127. Rainbow (Last Chance). NW. 1/4 Sec. 25, T. 40 N., R. 6 W. Mohave County. Copper-uranium mineralization occurs in coarse grained, poorly sorted sandstone with pebble conglomerate lenses. Iron oxides, manganese oxides and carbonaceous trash. Probably sandy strata of Petrified Forest Member. Shallow mineralization. Old copper prospect. Uranium assays 0.012 to 0.24 percent uranium. Copper assays 0.025 percent. (Holen and Twitchell, 1955, AEC PRR R-Rs-106).

128. Radon claims. SE. 1/4 Sec. 23, T. 40 N., R. 6 W. Mohave County. Probably continuation of occurrence at Rainbow (No. 127). Copper-uranium mineralization occurs in coarse grained, poorly sorted sandstone with pebble conglomerate lenses. Iron oxides, manganese oxides and carbonaceous trash. Probably sandy strata of Petrified Forest Member. Shallow mineralization. Old copper prospect. Uranium assays 0.012 to 0.24 percent uranium. Copper assays 0.025 percent. Few loads reported shipped. (Scott and Twitchell, 1954, AEC PRR R-R-204).

S7. Katy J. claims. Approx. SW. 1/4 Sec. 14, T. 39 N., R. 4 W, Mohave County. Uranium mineralization (0.016 to 0.224 eU percent), possibly torbernite, occurs with copper carbonate and carbonaceous trash in eight inch friable, white to tan, medium-grained sandstone between red sandy shale. Prospected. (Holen and Twitchell, 1955, AEC PRR R-R-286).

S31. Red Hills (Tate). West Central Sec. 7, T. 11 N., R. 13 W. Mohave County. Secondary yellow and orange uranium minerals associated with some copper oxides coating fractures in shattered and brecciated chalcedonic quartz, barite, fluorite and copper oxide vein in fault or sedimentary breccia at base of Artillery Formation (Eocene). Breccia consists of fragments of schist, felsite, conglomerate and limestone cemented by silica, carbonate and manganese oxide; part of thrust sheet. Radioactivity strongest at intersections of crosscutting shear zones and vein. Channel samples in shaft averaged 0.06 percent uranium over 10 foot wide. Select samples ran up to 0.314 percent uranium. Origin believed to be due to groundwater deposition. Shallow shaft and surface cuts. (Hart, 1955., Granger and Raup, 1962).

P4. Copper House Colition Nos. 1 and 2. Approx. Secs. 1 and 2, T. 32 N., R. 11 W. Mohave County. Unidentified uranium mineralization associated with copper mineralization in curving or circular brecciated zones in bleached and fractured, coarse sediments of the Supai Formation. Assay results showed 0.006 to 0.165 percent uranium. Prospected for copper and uranium but no production noted. (Meehan, 1953, AEC PRR R-R135, 136, Finch, 1967).

P5. Orphan mine. SW. 1/4 Sec. 14, T. 31 N., R. 2 E. Coconino County. Uraninite and secondary uranium minerals in a nearly vertical, circular, pipe-like body of collapse breccia. The breccia consists mostly of highly fractured Coconino Sandstone and Hermit Shale dropped into the collapse structure. Strong bleaching and alteration. Mineralization, strongest around the periphery, consisting of disseminations and vein-like stringers of uraninite in association with sulfides of iron, copper, lead, zinc, cobalt and molybdenite. Pipe increases somewhat in size downward from 175 to 450 feet in diameter. Ore is high grade, average samples running up to over 1.0 percent uranium. A major producer in Arizona, supplying close to 500,000 tons of ore averaging 0.30 to 0.60 percent uranium. Probably contains at least 100,000 tons of additional ore of about 0.30 percent uranium. (Granger and Raup, 1962, AEC Guidebook, 1959, Finch, 1967).

P6. Ridenour mine. NE. 1/4 Sec. 6, T. 31 N., R. 8 W. Coconino County. Carnotite-type mineralization associated with copper carbonates, silicates and sulfides along with pyrite and iron oxides in an inferred pipe like body of fractured and bleached, collapsed Supai Formation sediments. Mineralization is both disseminated and in vein-like structures, strongest along the periphery. Samples ran from trace to almost 0.5 percent uranium. Vanadium to uranium ratio greater than 10:1 and vanadium minerals widely distributed. Traces of cobalt also detected. Originally mined for copper. Some production shipped and a small resource may remain. (Miller, 1954, AEC RME-2014.; Finch, 1967).

P8. Copper Mountain mine. SW. l/4 Sec. 14, T. 32 N., R. l0 W. Mohave County. Probably uraninite and secondary uranium minerals associated with copper, zinc and lead minerals in brecciated fine-grained sandstone of Supai Formation on periphyry of pipe-like body of collapse structure. Samples ran from 0.013 to 0.75 percent eU. Worked originally for copper. No uranium production reported. (King and Henderson, 1953, AEC PRR A-P-99; Finch, 1967).

2. Alta Vista group (Little Sis No. 1 et alia, Irish Barco). Secs. 4, 5, 8 and 9, T. 4 N., R. 14 E. (Protracted). In short, deep, SW. trending canyons draining mesas to N. and E. Probably in flat-lying black facies overlying barren quartzite. No apparent nearby diabase but faulting to E. Anomalous radioactivity related to limonite-stained fractures with copper carbonates. No uranium minerals recognized. Radioactivity moderately high and selected Cu stained sample ran 0.056 percent eU. Worked originally for copper. No uranium production reported. (Schwartz, 1954, AEC PRR A-P250; Granger and Raup, 1969b, p. 6).

6. Black Brush group (10 claims). SE. 1/4 Sec. 4, T. 6 N., R. 14 E. On S. slope of ridge between NE. trending canyons tributary to Cherry Creek, at about 5,600 foot elevation. At intersection of fracture zone with black facies immediately overlying barren quartzite. Sierra Ancha diabase sheet 80 feet below. Close to Cherry Creek, monocline. Irregular radioactivity. Primary uraninite associated with minor pyrrhotite, chalcopyrite, marcasite, galena and pyrite. More sulfides in barren quartzite. Torbernite near surface. Select samples ran greater than 1.5 percent uranium, but average over one foot width was less than 0.1 percent uranium. Two shipments: -7.94 tons of 0.11 percent uranium (Late 1955) -11.23 tons of 0.07 percent uranium (mid 1956). There may be a few hundred tons of very low-grade material. (Schwartz, 1955, AEC PRR A-P-310; Granger and Raup, 1969a, Fig. 40; Granger and Raup, 1969b, p. 12).

8. Blevins Canyon deposit (36+claims). NE. 1/4 Sec. 1, T. 6 N., R.12 E. (Protracted). On N. wall of Dupont (Blevins) Canyon at about 5,500 foot elevation. Bedded deposit in fine-grained arkosic sandstone of upper member in paleochannel cut in middle member. Probably discordant diabase body eroded away above. Copper-bearing quartz veins to N. Abnormal radioactivity over 15 foot of strata for 200 feet along canyon wall but only metatorbernite recognized. Abundant copper and limonite staining. Selected sample ran 0.351 percent eU. Three foot vertical cut sample ran 0.032 percent eU. (Schwartz, 1954, AEC PRR A-P-257; Granger and Raup, 1969b, p.16).

12. Cataract deposit (7 claims). SW. 1/4 Sec. 19, T. 7 N., R. 13 E. (Protracted). On southward projecting nose of Middle Mountain on N. slope of Cataract Canyon at about 5,600 foot elevation. Apparently a bedded deposit in lower part of upper member in shallow channel cut in middle member. No diabase close-by. Weakly disseminated pyrite and chalcopyrite with fracture coatings of limonite, clay, metatorbernite, malachite and chrysocolla.

Irregular radioactivity. Selected samples ran 0.18 to 0.21 percent eU. No production known. May be a few tons of low-grade material. (Schwartz, 1955, AEC PRR A-P-353; Granger and Raup, 1969b, p, 24).

13. Conway deposit. South Central Sec.34, T. 7 N., R. 12 E. (Protracted). On bench between Malicious Gap and Mud Springs Canyon on SW. slope of Copper Mountain. In upper member. Diabase may underlie deposit. Cut by copper-bearing quartz vein. Autunite, metatorbernite, and disseminated sulfides. Radioactivity about 26X background. Chip samples ran 0.30 and 0.66 percent eU. No production known. No resources estimated. (Schwartz and Kinneson, 1956, AEC PRR A-92).

15. Donna Lee deposits (15 claims). SE. 1/4 Sec. 13, T. 5 N., R. 14 E. On W. wall of Deer Creek Canyon at about 4,800 foot elevation. In strongly weathered and oxidized black facies 10-15 feet above barren quartzite. Major fault to W. Diabase sills in Pioneer Formation below and dike in fault. Irregular vein-type mineralization-pyrite, limonite, secondary copper minerals, gypsum and sulfate. Metatorbernite only uranium mineral noted. Relatively strong radioactivity. Chip and grab samples ran 0.24-0.29 percent eU. No production reported. Possibly about 100 tons of low to moderate grade material. (Schwartz 1954, AEC PRR A-P-262; Schwartz, 1955, AEC PRR A-6; Granger and Raup, 1969b, p. 27, Fig. 2).

16. Easy deposit (12 claims). SE. 1/4 Sec. 35, T. 7 N., R. 13 E. (Protracted). On SW slope of McFadden Peak about 1 1/4 mile WSW of Lookout Tower at 6,100 feet elevation. Bedded-type deposit in lower part of upper member immediately above contact with middle member. No nearby diabase known. Sparse and irregular abnormal radioactivity. Finely disseminated pyrite and chalcopyrite, metatorbernite, uraniferous opal, saleeite, bassetite, metazeunerite, covellite and limonite. Select samples ran 0.42 percent eU. Cut and grab samples ran 0.02-0.08 percent eU. No production reported. No resources estimated. (Granger and Raup, 1969b, p. 30).

18. First Chance deposits (11 claims). SE. 1/4 Sec. 1, T. 5 N., R. 13 E. about 0.4 miles N. of Parker Creek experimental Station at about 5,600 foot elevation. Vein-type deposits along fractures in black facies about 10-13 feet above barren quartzite complex structure. Sierra Ancha diabase sheet originally close-by. Disseminated pyrite, chalcopyrite and chalcocite, metatorbernite, malachite, azurite, bassetite, uraniferous hyalite on fractures. Abundant limonite, chalcanthite and sulfate. Radioactivity weak to moderate. Channel samples ran 0.02 to 0.12 percent U. One shipment: 35.53 tons of 0.08 percent U (2nd Quat. 1957). Possibly 100 tons of low-grade material. (Granger and Raup, 1969a, Fig. 26; Granger and Raup, 1969b, p. 35).

24. Hope deposit (16 claims). NE. 1/4 Sec. 30, T. 6 N., R. 14 E. On steep NE. wall of Workman Creek about 1.5 miles upstream from Globe-Young road. Vein-type in hornfels of black facies 10-25 feet above barren quartzite. Sierra Ancha diabase sheet cuts host rocks discordantly with associated irregular aplite dikes and sill-like syenite. Contains black deuteric veinlets. Abundant disseminated and veinlets of pyrite and marcasite, pyrrhotite, molybdenite, galena, sphalerite, chalcopyrite, calcite, chlorite, nontronitc and disseminated and stringers of uraninite. Oxidized portion shows B-uranophane, metatorbernite, limonite and gypsum. Some fluorite noted. Most productive deposit. Shipments: 1,380 tons 0.18 percent uranium; 188 tons 0.13 percent uranium; 4,743 tons 0.26 percent uranium; 2,000 tons 0.38 percent uranium. Probably a few thousand tons of low to moderate grade still present. (Schwartz, 1954, AEC PRR A-P-289; Granger and Raup, 1969a, Pl. 3; Granger

and Raup, 1969b, p. 44).

25. Horse Shoe deposit (Crying Jew et alia). SW. Corner Sec. 11, T.6 N., R. 14E. On side of Gold Creek about 0.7 miles from Cherry Creek at about 4,300 foot elevation. Bedded-type in shattered gray facies. Two to eight feet thick. Sierra Ancha diabase sheet above and to W. About 30 feet above contact with middle member Ample sulfides but no uranium minerals recognized; pyrite, marcasite, chalcopyrite, sphalerite and galena disseminated or in veinlets. Radioactivity about l00X background. Probably disseminated uraninite. Two shipments: 6.55 tons 0.17 percent uranium; 7.34 tons 0.02 percent uranium. No resources estimated. (Schwartz, 1956, AEC PRR A-102; Granger and Raup, 1969a, Fig. 48; Granger and Raup, 1969b, p. 54).

29. Jackie deposits (Lucky chance, Uranium). Approx. East Center Sec. 9 T. 4 N., R. 14 E. On steep upper to SE. of Alta Vista (No. 2) group. In upper member. No nearby diabase noted. Disseminated copper oxides along fractures but no uranium minerals noted. Maximum radioactivity about 15X background. Samples ran 0.10 to 0.21 percent eU and 8.48 percent Cu. No resources estimated. (Wells, 1954, AEC PRR A-P-180; Schwartz, 1956, AEC PRR A-109).

34. Lost Dog deposits. North Central Sec. 30, T. 6 N., R. 14 E. On S. side of Workman Creek about 1 mile up stream from the Globe Young road and 5,900-6,000 feet elevation. Vein-type with some bedded mineralization in fractured and partly recrystallized black facies just above barren quartzite and overlying Sierra Ancha diabase sheet. Disseminated pyrite and sparse chalcopyrite and graphite. Abundant metatorbernite on fractures and bedding planes. Uraniferous hyalite, rare galena. Radioactivity irregular but locally strong. About 1,400 tons shipped ranging from less than 0.01 to 0.20 percent uranium. (Barrett, 1954, AEC PRR A-P-232; Granger and Raup, 1969a, Pl. 2, Figs. 18, 28; Granger and Raup, 1969b, p.74).

35. Lucky Boy deposit (50 claims). North Central Border Secs. 31-32, T. 2 S., R. 15 E. 1/4 mile W. of old Pioneer Stage Station road. In shear zone in dipping bedding planes of black facies about 40-45 feet above barren quartzite and 170 feet below Mescal Limestone. Diabase sheet 70 feet below. Abundant fracturing probably very finely disseminated uraninite, especially in association with mica and chloite mafic alteration. Pyrite, pyrrhotite, chalcopyrite, metatorbernite, bassetite, fluorescent opal, uranophane, limonite, jarosite, gypsum. Some 2,430 tons shipped ranging from 0.1-0.2 percent uranium and averaging 0.18 percent uranium. Some resources remain. (Granger and Raup, 1969, Fig. 38; Granger and Raup, 1969b, p.78).

37. Lucky Stop deposits (17 claims). NW. 1/4 Sec., 30, T. N. 6 N., R. 14 E. On SW. side of Workman Creek about 0.6 miles upstream from Globe-Young road at 5,800 foot elevation. Vein-type with some disseminated mineralization in lower 20 feet of black facies just above barren quartzite and diabase intrusion. Minor recrystallization. Uraninite, pyrite, galena, pyrrhotite, chalcopyrite, sphalerite, marcasite, sphene, diopside, chlorite, albite, calcite. 2,383 tons shipped ran 0.15-0.20 percent uranium averaged 0.16 percent uranium. 95 tons ran 0.22 percent uranium. Some resources remain. (Weathers, 1954, AEC PRR A-P-222; Granger and Raup 1969a, Figs. 18, 20; Granger and Raup, 1969b, p. 82)

44. Quartzite deposit. NW. 1/4 Sec. 12, T. 6 N., R. 14 E. In steep re-entrant on E. wall of Cherry Creek Canyon about 1 mile N. of junction with Horse Camp Creek. Elevation 4,600 feet. Weathered mineralization on bedding planes and jointing in black facies two

to three feet above barren quartzite. No diabase noted. Iron oxides, malachite staining, kaolinite, sulfate, minor pyrite, metatorbernite. Weak radioactivity. Chip samples ran 0.06-0.11 percent eU. No production known. No resources estimated. (Schartz, 1956, AEC PRR A-87; Granger and Raup, 1969b, p. 97).

46. Red Bluff deposits. SE. 1/4 Sec., 31, T. 5 N., R. 14 E. About 750 feet E. of Globe-Young road on E. and W. walls of Warm Creek Canyon. Vein-type and some bedded-type in gray unit from lower black facies, and 35 feet of gray sandstone facies divided by barren quartzite. Partly recrystallized to hornfels. Thick diabase dike divides the deposit; aplite dikes and deuteric veinlets in diabase; disseminated uraninite, pyrite, chalcopyrite, galena, metatorbernite, bassetite, meta-autunite, beta-uranophane, saleeite, kasolite, uraniferous opal, gypson, limonite, malachite, chlorite, kaolinite, illite. Spotty ore and radioactivity. Samples ran 0.04-0.07 eU. Over 2,000 tons of greater than 0.1 percent uranium shipped and several hundred tons stockpiled. Could be potential low-grade resources. (Granger and Raup, 1969a, P1. 4, Figs. 16, 17; Granger and Raup, 1969b, p. 102).

51. Shepp No. 2 (5 claims). Central Border Sec. 31, T. 8 N., R. 15E, and Sec. 36, T. 8 N., R. 14 E. In Wilson Creek about 1.4 miles ENE. of Junction with Cherry Creek. Both vein- and bedded-type. Irregular mineralization in black facies about 40 feet above barren quartzite. Diabase above and to N. Disseminated pyrite and chalcopyrite. Calcite and clay in fractures. Metatorbernite, limonite, gypsum, malachite, azurite. Weak to moderate radioactivity. 1.7 foot wide chip sample ran 0.11, 0.17 percent eU. Composite sample ran 0.12 percent eU. Few tons stockpiled but none shipped. Minor resources probably low-grade. (Raup, Shride and Haines, 1953, AEC PRR D-718; Wells and Mead, 1953, AEC PRR A-P-43; Granger and Raup, 1969a, Fig. 24; Granger and Raup,1969b, p. 115).

53. Snakebit deposit (9 claims - Sunset, Mono, et alia). SE. 1/4 Sec. 32, T. 5 N., R. 17 E. (Protracted). On N. wall of deep tributary canyon to Ash Creek at 4,450 foot elevation. Bedded-type along fracture in black facies about two feet above barren quartzite. Thick diabase sill below to W. limonite with metatorbernite, disseminated pyrite, chalcopyrite, galena, and sparse sphalerite. Irregular radioactivity. No production known. No resources estimated. Samples ran 0.05 to 0.16 percent uranium. (Ashwill and Schwartz, 1954, AEC PRR A-P-234; Granger and Raup, 1969b, p.120).

54. Sorrel Horse deposits (Citation, Lobo, T-Bone, and Maybe). South Central Sec. 4, T. 6 N., R. 14 E. On walls of NE. trending tributary to Cherry Creek at 5,440 foot elevation. Weak vein-type and disseminations at various stratigraphic horizons in grey facies below barren quartzite. Sierra Ancha diabase sheet intrudes beds 60 to 70 feet below barren quartzite; irregular syenite type segregations, black deuteric veinlets, local aplite dikes. Mica, pyrite, sparse chalcopyrite, limonite, quartz, siderite, fluorite, sphalerite, galena, clay. Moderate radioactivity but no uranium minerals noted. Sample ran 0.57 percent eU. No production known. No resources estimated. (Schwartz, 1955, AEC PRR A- 62; Schwartz, 1956, AEC PRR A-100; Granger and Raup, 1969b, p.122).

56. Suckerite deposit (16 claims - Definitely et alia). South Center Sec.24, T. 6 N., R. 13 E. (Protracted). 300 feet S. of Workman Creek and 0.3 miles W. of Globe-Young road on W. flank of ridge. In narrow, mineralized, bedding-plane fracture zone in xenolith enclosed in diabase along Sierra Ancha monocline. Mineralized zone about 10-15 feet above diabase and 45 feet below Buff unit. Rock mildly recrystallized, abundant limonite and sulfides

uraninite, pyrite, pyrrhotite, molybdenite, chalcopyrite, and galena in short veinlets and disseminated grains. Some 2,453 tons shipped averaging 0.234 percent uranium. Probably additional resources present. (Schwartz, 1954, AEC PRR A-P-252; Granger and Raup, 1969a, Pl. 2, Fig. 37; Gramger and Raup, 1969b, p. 125).

58 Tomato Juice deposit (24 claims — Grandview, King, Snake et alia). SE. 1/4 Sec. 14, T. 5 N., R. 16 E. (Protracted). In Regal Canyon about 900 feet SE. of Salt River at 3,200 foot elevation. Vein-type associated with ankerite-filled fissure in black facies. Partly recrystallized. Strong faulting with nearby diabase intrusion. Spotty pyrite, chalcopyrite and fluorite. Disseminated uraninite and minor uranophane, gypsum. Strong radioactivity in fracture. 140 tons of 0.16 percent uranium shipped and a few hundred tons remain. (Schwartz and Fink, 1955, AEC PRR A-P-364; Granger and Raup, 1969a, Fig. 19; Granger and Raup, 1969b, p. 136).

APPENDIX B

Arizona State Bureau of Mines
Unverified Occurrences of Uranium Associated with Copper Minerals:
No Sample Analyses or Assays Conducted

This Appendix lists all of the old miner records of uranium that are associated with copper minerals without sample analyses or assay information. The data are arranged by site identification number (Figure 1 shows the location of each site), mine name, location (township and range), physical description, mineralogy, and the Arizona State Bureau of Mines file references for each site. Copper minerals associated with the uranium are shown in bold.

Site Identification #, Mine Name, Location, Physical Description Mineralogy, and References

S3. Cibecue area. Approx. NW. 1/4 Sec. 11, T 8 N., R. 17 E. (Protracted). Navajo County. Unidentified uranium mineral and copper oxides in gray limy mudstone overlain by six feet of resistant thin-bedded calcareous silty sandstone. Field reconnaissance indicated limestone-pebble conglomerate and carbonized plant material. (Weathers, 1954, AEC PRR A-P-175; ABM reconnaissance, 1969).

S4. Anita Copper deposit. Approx. SE. 1/4, T. 29 N., R. 1 E, Coconino County. Very weak radioactivity noted with copper carbonate mineralization disseminated in sandstone and limestone and concentrated on joints in Kaibab Limestone. Old copper workings. (Gibson, 1951, AEC PRR RG-34).

S5. Copper # l and Willaha group. Secs. 34, 35, T. 28 N., R., 1 E, Coconino County. Radioactivity up to l0 times background in two foot zone in and below copper oxide mineralization embedded in Kaibab Limestone. Old copper workings. (Rambosek and Weathers, 1953, AEC PRR A-P-41).

S8. Little Three # 1. Reportedly Sec. 6, T. 39 N., R. 3 W. Mohave Co. Radioactivity 50-l00 times background found associated with stringers and pockets of carbonaceous trash and fair copper showing in brown medium to fine grained sandstone and shale in lower part of Moenkopi. Prospected. (Scott and Twitchell, 1954, AEC PRR R-R-205).

S9. White Mesa Copper (Arizona claim). Approx. S, Center Sec. 5, T. 37 N., R. 9 E. (Protracted). Coconino County. Generally weak uranium mineralization (torbernite) associated with oxidized copper mineralization in white to gray, cross bedded sandstone. Old copper mines. (Gibson, 1951, AEC PRR RG-35-51).

P3. Grandview mine. NE. 1/4 Sec. 5, T. 30 N., R. 4 E. (Protracted). Coconino County. Undetermined uranium mineral associated with limonite; copper carbonates, silicates and sulfides; and pyrite in brecciated, bleached and partially marmorized Redwall Limestone in pipe like body. Weak to moderate radioactivity. Last worked in early 1900. (Marvin, 1951, AEC PRR RG-33).

P7. Hack Canyon mine. NE. 1/ 4 Sec. 26, T. 31 N., R. 5 W. Mohave County. Uraninite and secondary uranium minerals associated with primary and secondary copper minerals in brecciated Hermit Shale in throat of apparent pipe like body of collapse breccia. Uranium values probably average 0.1 to 0.2 percent uranium. Originally mined for copper and some minor uranium ore production. There are possibilities of some additional ore. (Granger and Raup, 1962; Finch, 1967).

52. Sky deposit (20 claims - Fran et alia). East Central Sec. 3, T. 3 S., R. 15 E. On nose between creeks feeding into El Capitan Canyon, about 0.6 miles E. of State Highway 77. Bedded-type, probably lowest strata in upper member in paleochannel in quartzite. Discordant diabase to S. Appears to be limited secondary enrichment with metatorbernite coating and fracture filling. Pyrite, malachite, limonite, gypsum, and barite. Spotty radioactivity. No production known. No resources estimated. (Mead, 1954, AEC PRR A-P-229; Schwartz, 1955, AEC PRR A-P-229; Granger and Raup, 1969b, p. 118).

Vl. Chapel claim. NE. 1/4 Sec. 25, T. 33 N., R. 10 W. Mohave County. Uranophane and possibly other uranium minerals in leached zone in sandy facie of Hermit Shale with copper oxides. May be indication of pipelike breccia body. Indicated grade probably below 0.02 percent uranium. Prospected and possibly a few tons shipped out. (Nelson and Ranbosek, 1952, AEC PRR RA-ll).

V3. De La Fontaine mine. SE. 1/4 Sec. 5, T. 22 N., R. 17 W. Mohave County. Uranium mineralization, probably uraninite, finely disseminated locally in quartz-base metal sulfide filled fracture zones and shear breccias in granite and schist. Local high radioactivity. An old base-metal mine. (King and Rambosek, 1952, AEC PRR-35; Hart, 1955, Hart and Hetland, 1953).

V29. Morenci area. S. _ T, 3 S., R.29 E. N. _ T. 4 S., R. 29 E. Greenlee County. Traces of scattered uranium mineralization (torbernite) associated with copper mineralization. Large open pit mine. (ABM files).

V48. Abe Lincoln. Secs. 34 and 35, T.17 S., R. 11 E. Pima Co. Metatorbernite, secondary copper minerals, molybdenite, quartz and chlorite in fault fissure in granite. Old drift. (Miller, 1956, AEC PRR A-90).

V52. Iris and Natalie claims. SW. 1/4 Sec. 26, T. 21 S., R. 11 E. Kasolite reportedly found in specimen from copper-bearing shear zones in rhyolite cut by iron stained quartz veins. Probably spotty, local occurrences. Old property. (Granger and Raup, 1962).

V74. Walnut mine. Sec. 17, T. 23 S., R. 20 E. Cochise County. Uraninite with copper and iron sulfides in irregular lenses and quartz veins along faults and fractures in granite. Old lead-scheelite property. (Miller, 1956, AEC PRR A-95).

V77. Bisbee area. Sec. 16, T. 23 S., R. 24 E. Cochise County. Very fine-grained uraninite occurs in slip planes or as crusts in zones through base-metal sulfide ore-bodies. Average grade would be low. Major base-metal mine. (Bain, 1952).

4. Hunts Mesa: (Koley No. 2 and Sam Charlie No. 1) Approx. N. central Sec. 10 and NW. 1/4 Sec. 11, T. 40 N., R. 21 E. (Protracted) Navajo County. Shinarump, mostly concealed under sand dunes, caps mesa and lies in at least two or more paleochannels trending E-W cut into Moenkopi; one wide and relatively shallow, the other narrow and deeper. Moenkopi deeply cracked with Shinarump filling cracks. Paleochannels show conglomeratic sandstone with clay and siltstone pebbles at bottom grading upward into course-to medium-grained sandstone. Minute specks of azurite, malachite and tyuyamunite impregnates paleochannel fill and mineralization partially replaces clay pebbles. Sediments are cross-bedded and contain silicified and carbonized wood. A few hundred tons produced but grade erratic. (Chester, 1951; Witkind and Thaden, 1963).

7. Harvey Black: Approx. SW. 1/4 Sec. 1, T. 41 N., R. 19 E. (Protracted) Navajo County. No detail information available. Massive medium grained Shinarump sandstone in paleochannel some 200 feet wide and 50 feet-deep cut in Moenkopi. Silicified wood and carbonized debris. Secondary copper minerals. Character of uranium mineralization not reported. Unknown production or resources. (Witkind and Thaden, 1963; AEC Guidebook, 1959).

8. Monument No. 1 Annex and Mitton No.2: Approx. NE. 1/4 Sec. 24 to S. central Sec. 13, T. 41 N., R. 19 E. and W. central Sec. 19, T. 41 N., R. 20 E. (Protracted) Navajo County.

Trashy conglomerate, silica-cemented sandstone and calcite-cemented sandstone with silicified wood, carbonaceous matter and clay pebbles occur in basal remnant of paleochannel of Shinarump cut into Moenkopi. Two 2,000 foot long segments trend N to NW. Ore zone varies from ten to 95 feet wide and 1-18 feet thick, consisting of uranium-vanadium and copper minerals impregnating trashy conglomerate and silica-cemented sandstone. Calcite-cemented sandstone lenses unmineralized. Unoxidized core surrounded by oxidized mineralization. Roughly concentric mineralization with tyuyamunlte, metatyuyamunite, metatorbernite, corvusite, hewettite, volborthite, pyrite, azurite, chrysocolla, malachite and limonite. V:U ratio averaged 2.5:1 but varied greatly throughout. Produced a few hundred tons of vanadium ore in 1942-1944 period. Reopened in 1952 and until 1956 produced several thousand tons. Resources now depleted. (Witkind,1961; Witkind and Thaden, 1963).

16. Todechere(Azansoso): Approx. SE. corner Sec. 8, T. 40 N., R. l8 E. (Protracted) Navajo County. Little detail information available. Paleochannel of coarse-grained massive sandstone with carbonized and silicified wood showing carnotite, vanadium minerals, malachite and limonite. Little if any production. Mineralization generally low grade. (Witkind and Thaden, 1963; Finch, 1967).

17. Lehneer Prospect: NW. 1/4 Sec. 34, T.41 N., R. 7 E. In Paria Canyon on N. side of Paria River. Coconino County. Small, tabular occurrence of metatorbernite, torbernite, zippeite and secondary copper minerals associated with sparse black carbonaceous material in thicker sandstone in upper and lower sandstone strata of Chinle above Shinarump. Short drift on mineralization but no production. Mineralization limited and low grade. (Phoenix, 1963).

20. El Pequito mine: NW. corner Sec 14, T. 40 N., R., E. About 2 mi. WNW of Lees Ferry. Coconino County. Small spoon-shaped channel of Shinarump containing conglomeratic sandstone and carbonized wood. Uraninite with pyrite and chalcopyrite occurs in calcite veinlets and oxidized uranium and copper minerals cost pebbles and sand grains as well as impregnating carbonized wood. Some production reported but resources limited and low grade. (Phoenix, 1963).

24. Vermilion No. 1 mine: NE. 1/4 Sec. 20, T. 38 N., R. 5 E. On Emmett Hill S. of U.S. 89. Coconino County. Metatorbernite and possibly other uranium and copper minerals occur in a small 300 foot long, 30-50 foot wide, 10-20 foot deep channel filled with poorly sorted clay, sand and gravel of Shinarump. Minerallzation in Shinarump and Moenkopi at or near contact. Produced a few tons of low-grade mineralization. Resources of low grade very limited. Open pit. (Peterson, 1957).

S1. Promontory Butte area: Approx. central Sec. 24, T. 11 N., R. 12 E. Gila County. Uraninite-type and possibly other uranium minerals in limestone-pebble conglomerate and overlying carbonaceous shale. Minor sulfides of iron, copper and lead. Bedded type of deposit essentially horizontal and 1-4 feet thick. Abundant carbonized wood and plant remains. Prospected by an adit in 1950 and recently drilled and benched. Extent and grade unknown. (Finch, 1967; ABM reconnaissance, 1969).

APPENDIX C

Results of Radiochemical Analyses:
Groundwater, Sediment and Soil, Surface Water, Process Solution, and Process Waste Data

Note: For each facility and each media, the maximum and minimum values are shown in italics.

Results of Radiochemical Analyses

All Groundwater Data (pCi/L)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Cyprus Bagdad Copper Creek	GW	MW-1	*58.00*						*10.80*	*31.00*			
Cyprus Bagdad Copper Creek	GW	MW-2	*8.00*						*12.90*	*2.00*			
CB-CC	**STotal = 2**	**Average**	**33.00**						**11.85**	**16.50**			
		STD	**35.36**						**1.05**	**14.50**			
Cyprus Bagdad Lawler Peak	GW	MW 1	18.30	*72.70*	*6.00*	*6.80*	0.40		1.40	*2.00*	*12.60*		
Cyprus Bagdad Lawler Peak	GW	MW 2	*13.20*		6.80	8.00	*0.30*		*0.70*	*0.10*	14.00		
Cyprus Bagdad Lawler Peak	GW	MW 3	*52.80*	19.90	*15.30*	14.40	*1.20*		*4.20*	1.90	26.60		
Cyprus Bagdad Lawler Peak	GW	MW 4	33.00	*4.00*	15.10	*16.60*	0.70		1.20	1.50	*30.10*		
CB-LP	**STotal = 4**	**Average**	**29.33**	**32.20**	**10.80**	**11.45**	**0.65**		**1.88**	**1.38**	**20.83**		
		STD	**17.76**	**35.96**	**5.09**	**4.79**	**0.40**		**1.58**	**0.88**	**8.82**		
Cyprus Bagdad Hillside Loadout	GW	MW-1	5.50	*3.60*	*2.30*	*8.20*	*0.10*		*1.60*	*6.20*	*3.50*	3540.00	
Cyprus Bagdad Hillside Loadout	GW	MW-2	*100.00*	136.00	*0.40*	1.80	*0.10*		1.40		*0.70*	*3680.00*	
Cyprus Bagdad Hillside Loadout	GW	MW-2A	*0.80*	*215.00*	0.50	*1.30*			*0.50*	*0.50*	*0.70*	*2690.00*	
Cyprus Bagdad Hillside Loadout	GW	MW-3	3.10	7.50	0.60	2.50	*0.10*		*0.50*		*0.70*	2910.00	
Cyprus Bagdad Hillside Loadout	GW	MW-3 Dup	2.50	8.00	*0.40*	1.90	*0.10*		0.80	2.20	*0.70*	3180.00	
CB-HL	**STotal = 5**	**Average**	**22.38**	**74.02**	**0.84**	**3.14**	**0.10**		**0.96**	**2.97**	**1.26**	**3200.00**	
		STD	**43.42**	**96.77**	**0.82**	**2.86**	**0.00**		**0.51**	**2.93**	**1.25**	**415.51**	
Phelps Dodge New Cornelia	GW	MW 2-1	9.00	8.00	2.60	5.30	0.10		0.70	1.30	4.90		
Phelps Dodge New Cornelia	GW	MW 2-2	6.00	6.00	2.80	5.50	0.30		0.80	1.00	5.60		
Phelps Dodge New Cornelia	GW	MW 3-1	28.00	22.00	5.60	11.00	0.40		0.70	2.00	9.80		
Phelps Dodge New Cornelia	GW	MW 3-2	10.00	5.00	5.00	12.00	0.70		0.60	0.60	9.80		
Phelps Dodge New Cornelia	GW	MW 3-3	14.00	9.00	7.00	11.00	0.60		0.80	1.90	11.90		
Phelps Dodge New Cornelia	GW	MW 4-2	8.00	5.00	*1.10*	5.30	0.10		0.60	0.90	*3.50*		
Phelps Dodge New Cornelia	GW	MW 4-3	6.00	5.00	1.40	6.10	0.10		0.40	0.90	*3.50*		
Phelps Dodge New Cornelia	GW	MW 5-2	17.00	14.00	2.10	4.20	0.20		3.00	*7.30*	4.20		
Phelps Dodge New Cornelia	GW	MW 5-3	13.00	31.00	2.00	4.00	*0.00*		*3.50*	6.70	4.20		
Phelps Dodge New Cornelia	GW	MW 6-5	5.00	13.00	1.30	5.30	0.40		0.20	0.50	*3.50*		
Phelps Dodge New Cornelia	GW	MW 7-2	6.00	6.00	2.10	5.80	0.30		0.20	0.70	4.20		
Phelps Dodge New Cornelia	GW	MW 7-3	9.00	5.00	2.50	6.50	*0.00*		0.10	0.10	4.20		
Phelps Dodge New Cornelia	GW	MW 8-B5	6.00	8.00	2.40	9.00	0.80		*0.00*	0.20	5.60		
Phelps Dodge New Cornelia	GW	MW 8-B Dup	8.00	11.00	3.40	8.00	0.10		0.20	0.40	5.60		
Phelps Dodge New Cornelia	GW	MW 9B5	12.00	10.00	8.50	10.00	0.80		0.20	*0.00*	15.40		
Phelps Dodge New Cornelia	GW	MW 10-5	3.00	5.00	2.30	2.40	0.10		*0.00*	*0.00*	4.20		
Phelps Dodge New Cornelia	GW	MW 12-2	4.00	4.00	3.00	5.90	0.10		0.10	0.20	4.90		
Phelps Dodge New Cornelia	GW	MW 12-3	5.00	3.00	2.50	5.10	0.20		0.20	*0.00*	4.90		

STD = Standard Deviation
AVG = Average

Maximum and minimum values are shown in italics
Bold text (STD and AVG) also appear in summary tables (1-5)

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelps Dodge New Cornelia	GW	MW 13-1	33.00	*66.00*	2.00	3.10	*0.00*		1.20	2.30	*3.50*		
Phelps Dodge New Cornelia	GW	MW 13-2	15.00	27.00	1.60	3.60	*0.00*		0.60	1.80	*3.50*		
Phelps Dodge New Cornelia	GW	MW 13-3	*0.00*	11.00	1.70	3.10	0.20		0.60	1.00	*3.50*		
Phelps Dodge New Cornelia	GW	MW 14-1	33.00	25.00	10.00	9.20	0.10		3.10	6.80	15.40		
Phelps Dodge New Cornelia	GW	MW 14-2	37.00	17.00	*21.00*	*24.00*	*1.10*		0.20	4.60	37.10		
Phelps Dodge New Cornelia	GW	MW 14-3	*43.00*	15.00	*21.00*	*24.00*	*1.10*		0.40	0.30	*38.60*		
Phelps Dodge New Cornelia	GW	MW 15-1	3.00	38.00	2.00	*1.80*	0.10		0.20	0.20	4.20		
Phelps Dodge New Cornelia	GW	MW 15-2	6.00	8.00	2.50	2.20	0.30		0.10	0.80	4.20		
Phelps Dodge New Cornelia	GW	MW 15-3	2.00	*2.00*	2.10	2.20	0.10		*0.00*	*0.00*	4.20		
Phelps Dodge New Cornelia	GW	MW 16-1	7.00	31.00	2.30	4.20	0.30		0.80	1.80	4.20		
Phelps Dodge New Cornelia	GW	MW 16-2	35.00	50.00	2.90	4.60	0.30		1.80	1.00	5.60		
Phelps Dodge New Cornelia	GW	MW 16-3	*0.00*	4.00	1.60	3.00	0.10		1.20	2.90	*3.50*		
Phelps Dodge New Cornelia	GW	MW 17-1	10.00	12.00	6.00	14.00	0.30		0.30	0.70	9.10		
Phelps Dodge New Cornelia	GW	MW 17-2	18.00	25.00	4.70	10.00	0.30		0.70	6.00	8.40		
Phelps Dodge New Cornelia	GW	MW 17-3	6.00	5.00	5.70	13.00	0.20		0.30	0.10	9.10		
Phelps Dodge New Cornelia	GW	MW 18-1	5.00	18.00	3.10	5.50	0.40		0.40	0.60	6.30		
Phelps Dodge New Cornelia	GW	MW 18-2	31.00	35.00	7.70	13.00	0.50		2.50	*0.00*	12.60		
Phelps Dodge New Cornelia	GW	MW 18-3	7.00	17.00	7.80	13.00	0.40		0.50	0.70	11.20		
PD-NC	**STotal = 36**	**Average**	**12.78**	**16.00**	**4.54**	**7.66**	**0.31**		**0.76**	**1.56**	**8.17**		
		STD	**11.65**	**14.35**	**4.65**	**5.36**	**0.29**		**0.91**	**2.08**	**8.06**		
Cyprus Sierrita Twin Buttes	GW	MW-15 7/10/97	*30.00*	42.00					*0.00*	1.20	*0.27*		
Cyprus Sierrita Twin Buttes	GW	MW-15 8/26/97	42.00	*28.00*					*0.00*	*0.00*	0.30		
Cyprus Sierrita Twin Buttes	GW	MW-16 7/11/97	62.00	29.00					0.10	0.50	0.56		
Cyprus Sierrita Twin Buttes	GW	MW-16 8/21/97	53.00	35.00					0.30	*1.70*	0.65		
Cyprus Sierrita Twin Buttes	GW	MW-17 7/31/97	*268.00*	*234.00*					*0.00*	1.30	*3.64*		
Cyprus Sierrita Twin Buttes	GW	MW-17 8/25/97	144.00	123.00					0.30	0.10	3.43		
Cyprus Sierrita Twin Buttes	GW	MW-18 7/24/97	163.00	131.00					*4.60*	*0.00*	1.51		
Cyprus Sierrita Twin Buttes	GW	MW-18 8/25/97	157.00	113.00					*0.00*	0.80	3.30		
CS-TB	**STotal = 8**	**Average of Samples**	**114.88**	**91.88**					**0.66**	**0.70**	**1.71**		
		STD	**82.40**	**72.61**					**1.60**	**0.65**	**1.50**		
Cyprus Sierrita	GW	MW-17 6/26/97	85.00	56.00					9.30	15.00	0.82		
Cyprus Sierrita	GW	MW-17 8/15/97	85.00	57.00					*130.00*	19.00	0.07		
Cyprus Sierrita	GW	MW-18 6/19/97	14.00	13.00					0.90	*0.00*	0.13		
Cyprus Sierrita	GW	MW-18 8/14/97	12.00	4.70					*0.00*	0.90	0.12		
Cyprus Sierrita	GW	MW-19 7/31/97	23.00	*0.20*					0.10	0.60	0.14		

STD = Standard Deviation
AVG = Average

Maximum and minimum values are shown in italics
Bold text (STD and AVG) also appear in summary tables (1-5)

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Cyprus Sierrita	GW	MW-19 8/25/97	23.00	21.00					1.50	1.20	0.16		
Cyprus Sierrita	GW	MW-21 7/16/97	*557.00*	*334.00*					7.30	9.10	*7.55*		
Cyprus Sierrita	GW	MW-21 8/15/97	406.00	299.00					15.00	6.20	5.01		
Cyprus Sierrita	GW	MW-22 6/24/97	262.00	122.00					*0.00*	1.70	3.43		
Cyprus Sierrita	GW	MW-22 8/19/97	117.00	132.00					0.40	1.10	2.61		
Cyprus Sierrita	GW	MW-23 7/02/97	70.00	71.00					0.40	5.60	0.37		
Cyprus Sierrita	GW	MW-23 8/21/97	17.00	8.00					0.50	1.00	0.51		
Cyprus Sierrita	GW	PZ-1 6/18/97	*7.50*	8.20					*0.00*	0.10	0.03		
Cyprus Sierrita	GW	PZ-1 8/21/97	9.70	9.50					*0.00*	*0.00*	*0.02*		
Cyprus Sierrita	GW	PZ-2 6/27/97	48.00	40.00					1.20	10.00	0.12		
Cyprus Sierrita	GW	PZ-2 8/13/97	14.00	59.00					2.20	10.00	0.14		
Cyprus Sierrita	GW	PZ-3 6/26/97	61.00	49.00					2.00	1.70	0.51		
Cyprus Sierrita	GW	PZ-3 8/13/97	32.00	50.00					4.50	13.00	0.49		
Cyprus Sierrita	GW	PZ-4 6/23/97	63.00	49.00					0.60	0.80	0.82		
Cyprus Sierrita	GW	PZ-4 8/20/97	56.00	70.00					0.50	1.60	0.82		
Cyprus Sierrita	GW	PZ-5 6/26/97	232.00	150.00					1.40	5.80	3.84		
Cyprus Sierrita	GW	PZ-5 8/19/97	245.00	129.00					3.10	7.10	2.40		
Cyprus Sierrita	GW	PZ-6 7/02/97	26.00	27.00					2.70	*30.00*	0.12		
Cyprus Sierrita	GW	PZ-6 8/20/97	19.00	44.00					3.20	8.30	0.14		
Cyprus Sierrita	GW	PZ-9 7/11/97	137.00	50.00					*0.00*	1.50	1.44		
Cyprus Sierrita	GW	PZ-9 8/26/97	186.00	37.00					0.20	*0.00*	1.17		
Cyprus Sierrita	GW	PZ-13 8/06/97	15.00	47.00					*0.00*	2.10	0.21		
Cyprus Sierrita	GW	PZ-13 8/25/97	29.00	1.00					*0.00*	0.90	0.23		
Cyprus Sierrita	GW	PZ-14 8/01/97	53.00	14.00					0.10	*0.00*	0.14		
Cyprus Sierrita	GW	PZ-14 8/22/97	14.00	4.00					0.10	1.10	0.16		
CS Average	**STotal = 30**	**Average**	**97.27**	**65.19**					**6.24**	**5.18**	**1.12**		
		STD	**128.84**	**79.53**					**23.61**	**6.89**	**1.76**		
Phelp Dodge Copper Queen	GW	TM 2 6/20/96			13.00	51.00	2.00				66.00		
Phelp Dodge Copper Queen	GW	TM 19 6/20/96			3.90	19.00	0.30				23.20		
Phelp Dodge Copper Queen	GW	BF 2 8/8/96									17.50		
Phelp Dodge Copper Queen	GW	TM 2 8/8/96									18.40		
Phelp Dodge Copper Queen	GW	TM 19 8/8/96									6.60		
Phelp Dodge Copper Queen	GW	TM 16 8/8/96									2.50		
Phelp Dodge Copper Queen	GW	TM 7 8/8/96									4.30		
Phelp Dodge Copper Queen	GW	(D-24-24)05acc 8/8/96									5.70		

STD = Standard Deviation
AVG = Average

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All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Copper Queen	GW	(D-24-24)17bbb 8/8/96									4.10		
Phelp Dodge Copper Queen	GW	(D-23-24) 29bcb 8/8/96									*1.20*		
Phelp Dodge Copper Queen	GW	BF 1 10/93	13.15		10.19	32.84	0.45		0.30	0.83	46.56	*60.00*	
Phelp Dodge Copper Queen	GW	BF 1 11/93	14.48		9.98	33.76	0.67		0.27	0.92	49.73		
Phelp Dodge Copper Queen	GW	BF 2 10/93	44.27		1.88	39.80	0.50		0.37	*0.65*	46.83	240.00	
Phelp Dodge Copper Queen	GW	BF 2 11/93	54.04		11.86	38.65	0.47		0.27	0.80	60.99		
Phelp Dodge Copper Queen	GW	TM 2 11/93	59.48		24.56	*60.37*	*2.54*		*0.38*	0.72	*72.78*		
Phelp Dodge Copper Queen	GW	TM 19 11/93	4.97		0.78	4.72	*0.01*		0.34	0.76	4.21		
Phelp Dodge Copper Queen	GW	TM-2A 11/93	22.18		3.58	15.40	*0.01*		0.35	0.98	19.99		
Phelp Dodge Copper Queen	GW	19 A 11/93	*2.45*		1.10	2.80	*0.01*		0.28	0.74	6.16		
Phelp Dodge Copper Queen	GW	GL 1 11/93	17.48		3.44	17.55	*0.01*		0.27	0.70	23.77		
Phelp Dodge Copper Queen	GW	GL 3 11/93	3.35		0.47	1.98			0.29	*1.50*	2.36		
Phelp Dodge Copper Queen	GW	8S 7/91	5.10	7.50	*0.06*	16.00			0.14			521.00	
Phelp Dodge Copper Queen	GW	8D 7/91	*72.00*	5.00	0.40	4.30			0.27			332.00	
Phelp Dodge Copper Queen	GW	4S 7/91	34.00	*35.00*	*35.00*	58.00			0.13			542.00	
Phelp Dodge Copper Queen	GW	4Dup 7/91	3.90	33.00	*35.00*	60.00			*0.10*			586.00	
Phelp Dodge Copper Queen	GW	4D 7/91	3.00	*4.90*	0.52	*1.90*			0.16			*1330.00*	
CQ Average	**STotal = 25**	**Average**	**23.59**	**17.08**	**9.16**	**26.95**	**0.63**		**0.26**	**0.86**	**24.14**	**515.86**	
		STD	**23.43**	**15.50**	**11.69**	**21.48**	**0.85**		**0.09**	**0.25**	**23.93**	**405.41**	
BHP Copper Inc Pinto Valley	GW	W14B	11.60	*5.60*				1.20	0.70	*0.50*	12.20	530.00	
BHP Copper Inc Pinto Valley	GW	W12	*179.00*	68.00				1.60	1.20	1.60	*209.00*	150.00	
BHP Copper Inc Pinto Valley	GW	W11	67.40	22.00				2.20	0.60	2.20	84.00	300.00	
BHP Copper Inc Pinto Valley	GW	W17	48.00	33.00				5.23	2.80	5.20	*0.00*	2680.00	
BHP Copper Inc Pinto Valley	GW	W15B	19.00	11.80				*0.80*	0.30	0.80	22.00	190.00	
BHP Copper Inc Pinto Valley	GW	W19	*7.00*	5.80				1.10	0.60	1.10	6.00	120.00	
BHP Copper Inc Pinto Valley	GW	NW24	25.30	*164.00*				*122.00*	*61.00*	*122.00*	2.20	2000.00	
BHP Copper Inc Pinto Valley	GW	NE26	35.00	39.00				29.70	14.90	29.70	5.10	*3980.00*	
BHP Copper Inc Pinto Valley	GW	APP-1A	17.00	14.00				1.30	0.30	1.00	1.30	300.00	
BHP Copper Inc Pinto Valley	GW	APP-2	15.00	12.00				1.10	0.30	0.80	1.10	427.00	
BHP Copper Inc Pinto Valley	GW	APP-3A	85.00	14.00				0.90	*0.20*	0.70	80.00	520.00	
BHP Copper Inc Pinto Valley	GW	APP-3B	38.00	7.60				1.60	0.40	1.20	50.00	140.00	
BHP Copper Inc Pinto Valley	GW	APP-4	24.00	17.00				1.10	0.30	0.80	0.84	940.00	
BHP Copper Inc Pinto Valley	GW	APP-5A	14.00	12.00				1.20	0.30	0.90	7.20	150.00	
BHP Copper Inc Pinto Valley	GW	APP-5B	8.00	7.00				0.90	*0.20*	0.70	4.60	*16.00*	

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All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
BHP Copper Inc Pinto Valley	GW	APP-6	10.40	6.30				0.90	*0.20*	0.70	25.00	2000.00	
PV Average	**STotal = 16**	**Average**	**37.73**	**27.44**				**10.80**	**5.27**	**10.62**	**31.91**	**902.69**	
		STD	**43.70**	**39.90**				**30.49**	**15.30**	**30.56**	**54.62**	**1151.75**	
Cyprus Mineral Park	GW	MW-2A 8/20/95	*0.00*	*0.00*									
Cyprus Mineral Park	GW	MW-6 8/1/95	220.00	170.00									
Cyprus Mineral Park	GW	MW-7 8/1/95	140.00	*0.00*									
Cyprus Mineral Park	GW	MW-8 8/2/95	50.00	40.00									
Cyprus Mineral Park	GW	MW-9 8/2/95	*1500.00*	*500.00*									
Cyprus Mineral Park	GW	MW-10 8/2/95	19.00	42.00									
Cyprus Mineral Park	GW	MW-12 8/4/95	*0.00*	60.00									
Cyprus Mineral Park	GW	MW-14 8/1/95	*0.00*	*0.00*									
Cyprus Mineral Park	GW	MW-15 8/1/95	*0.00*	*0.00*									
Cyprus Mineral Park	GW	MW-16 8/1/95	80.00	*0.00*									
Cyprus Mineral Park	GW	MW-17 8/19/95	80.00	29.00									
Cyprus Mineral Park	GW	MW-18 8/19/95	73.00	*0.00*									
MP Average	**STotal =12**	**Average**	**180.17**	**70.08**									
		STD	**420.98**	**143.90**									
All GW	**Total = 138**	**PureAvg**	**60.25**	**44.34**	**5.91**	**12.83**	**0.38**	**10.80**	**2.96**	**4.07**	**11.97**	**1216.21**	
		PureSTD	**150.82**	**72.63**	**7.57**	**14.77**	**0.47**	**30.49**	**13.40**	**12.72**	**24.93**	**1308.91**	
Morenci > Fed & AZ Standards													
Phelp Dodge Morenci	GW	Chase Creek -42 11/1/95	4.50	74.30									
Phelp Dodge Morenci	GW	Chase Creek -43 11/1/95	30.00	47.80									
Phelp Dodge Morenci	GW	Chase Creek -31 6/26/95	1.50	*347.00*									
Phelp Dodge Morenci	GW	Gold Gulch -04 3/7/96	9.00	57.00									
Phelp Dodge Morenci	GW	Morenci Pit -07 2/14/96	5.60	56.10									
Phelp Dodge Morenci	GW	Morenci Pit -8 11/14/95	81.00	40.00									
Phelp Dodge Morenci	GW	Rock Gulch -01 9/26/95	117.00	149.00									
Phelp Dodge Morenci	GW	WestTailingDam-23 2/15/96	16.00	5.40									
Phelp Dodge Morenci	GW	South West -44 2/21/96	136.00	254.00									
Phelp Dodge Morenci	GW	South West -58 8/9/95	*1.40*	237.00									
Phelp Dodge Morenci	GW	South West -50 7/31/95	15.30	8.60									
Phelp Dodge Morenci	GW	South West -65 10/30/95	17.00	7.00									
Phelp Dodge Morenci	GW	South West -66 10/30/95	15.20	5.00									
Phelp Dodge Morenci	GW	South West -68 1/25/95	15.00	2.00									

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Results of Radiochemical Analyses

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	DW-3 11/2/96 Upgradient	10.00	59.00	0.10	4.70	1.70	2.60	0.90	1.70	6.90		
Phelp Dodge Morenci	GW	DW-3 12/16/96 "	17.00	50.00	0.50	23.00	8.70	2.90	1.30	1.60	33.50		
Phelp Dodge Morenci	GW	DW-14 11/30/96 "	9.00	5.00	0.40	10.00	3.70	14.20	13.00	1.20	12.60		
Phelp Dodge Morenci	GW	DW -01 11/22/96 "	28.00	66.00	1.20	2.80	*0.00*	11.60	4.90	6.70	5.00		
Phelp Dodge Morenci	GW	DW-19 12/12/96 "	12.00	5.00	1.80	11.00	0.30	*0.00*	*0.00*	*0.00*	13.10		
Phelp Dodge Morenci	GW	Gold Gulch -4 10/31/96	27.00	56.00	4.00	6.30	0.30	9.70	2.60	7.10	10.60		
Phelp Dodge Morenci	GW	Gold Gulch -4 12/11/9	13.00	47.00	7.00	18.00	2.60	8.30	3.70	4.60	27.60		
Phelp Dodge Morenci	GW	Lower Chase Creek-10 12/14/96	12.00	10.00	1.00	8.20	*0.00*	0.50	*0.00*	0.50	9.20		
Phelp Dodge Morenci	GW	Chase Creek -42 1/2/96	7.00	60.00	2.50	2.40	*0.00*	4.90	1.00	3.90	4.90		
Phelp Dodge Morenci	GW	Chase Creek -43 11/2/96	21.00	61.00	*0.00*	0.10	*0.00*	34.00	13.00	21.00	0.10		
Phelp Dodge Morenci	GW	Chase Creek -43 11/30/96	28.00	52.00	0.20	0.20	*0.00*	19.30	0.30	19.00	0.40		
Phelp Dodge Morenci	GW	Chase Creek -50 12/19/96	23.00	39.00	1.40	6.70	*0.00*	3.80	17.00	14.00	8.10		
Phelp Dodge Morenci	GW	Morenci Pit -1 11/5/96	150.00	140.00	*110.00*	130.00	*10.00*	42.00	*28.00*	14.00	*250.00*		
Phelp Dodge Morenci	GW	Morenci Pit -1 11/21/96	*240.00*	160.00	100.00	*150.00*	*-0.10*	37.60	*28.00*	9.60	249.90		
Phelp Dodge Morenci	GW	Morenci Pit -2 11/21/96	7.00	30.00	0.30	1.00	0.10	6.60	3.20	3.40	1.40		
Phelp Dodge Morenci	GW	Morenci Pit -5 11/5/96	79.00	100.00	61.00	61.00	1.10	2.00	0.70	1.30	123.10		
Phelp Dodge Morenci	GW	Morenci Pit -5 11/22/96	96.00	68.00	62.00	67.00	0.50	1.40	0.60	0.80	129.50		
Phelp Dodge Morenci	GW	Morenci Pit -7 11/6/96	4.00	27.00	0.10	1.50	0.10	7.80	1.60	6.20	1.70		
Phelp Dodge Morenci	GW	Metcalf Pit DC Sump -7 11/22/9	3.00	31.00	*0.00*	*0.00*	0.10	6.70	1.50	5.20	0.10		
Phelp Dodge Morenci	GW	Metcalf Pit DC Sump -8 11/6/96	51.00	51.00	12.00	21.00	0.40	18.00	8.50	9.50	42.00		
Phelp Dodge Morenci	GW	Metcalf Pit DC Sump -8 11/22/96	40.00	38.00	10.00	18.00	1.60	16.30	8.50	7.80	29.60		
Phelp Dodge Morenci	GW	South West SX Plant -50 10/15/96	19.00	6.00	2.90	18.00	1.00	1.50	*0.00*	1.50	21.90		
Phelp Dodge Morenci	GW	South West SX Plant -50 11/19/96	18.00	7.00	2.30	19.00	0.60	0.20	0.20	*-0.10*	21.90		
Phelp Dodge Morenci	GW	South West Stockpile -58 10/9/96	2.00	170.00	*0.00*	*0.00*	*0.00*	1.60	0.80	0.80	*0.00*		
Phelp Dodge Morenci	GW	South West Stockpile -58 11/13/96	2.00	110.00	*0.00*	*0.00*	*0.00*	0.30	0.20	0.10	*0.00*		
Phelp Dodge Morenci	GW	South West-61 10/10/96	8.00	6.00	0.80	8.50	0.10	2.50	1.80	0.70	10.00		
Phelp Dodge Morenci	GW	South West-61 11/20/96	10.00	7.00	1.10	8.80	0.50	1.60	1.00	0.60	0.40		
Phelp Dodge Morenci	GW	South West SX Plant -65 10/1/96	35.00	*0.00*	10.00	54.00	2.20	0.30	*0.00*	0.30	66.20		
Phelp Dodge Morenci	GW	South West SX Plant -65 11/13/96	66.00	11.00	14.00	77.00	2.40	0.50	0.20	0.30	93.40		
Phelp Dodge Morenci	GW	South West SX Plant -66 10/11/96	20.00	8.00	3.70	17.00	0.20	0.30	0.20	0.10	20.90		
Phelp Dodge Morenci	GW	South West SX Plant -66 11/13/96	19.00	4.00	3.00	20.00	0.20	0.50	0.30	0.20	23.20		
Phelp Dodge Morenci	GW	Rocky Gulch Dam -1 12/4/96	190.00	190.00	38.00	64.00	*0.00*	*117.70*	7.70	*110.00*	102.00		
Phelp Dodge Morenci	GW	LSB-2 10/11/96 Lower silver Basin	17.00	41.00	0.50	1.40	*0.00*	2.30	0.80	1.50	1.90		
Phelp Dodge Morenci	GW	South West -44 11/15/96	27.00	53.00	1.00	2.30	*0.00*	4.40	0.70	3.70	3.30		
Phelp Dodge Morenci	GW	SW-48 10/16/96	6.00	10.00	1.90	5.60	0.10	1.20	0.10	1.10	7.60		

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All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	SW-48 11/14/96	8.00	8.00	1.70	6.70	0.30	0.60	0.10	0.50	8.70		
Phelp Dodge Morenci	GW	South West -53 10/8/96	18.00	25.00	2.00	3.20	*0.00*	1.70	0.90	0.80	5.20		
PD MM Average	**STotal = 51**	**Average**	**35.42**	**60.81**	**12.39**	**22.93**	**1.05**	**10.47**	**4.14**	**7.06**	**36.38**		
		STD	**50.17**	**73.11**	**26.93**	**35.25**	**2.21**	**20.98**	**7.14**	**18.21**	**62.11**		
All GW + MM>	**Total = 189**	**Pure avg**	**53.18**	**49.40**	**8.33**	**16.60**	**0.65**	**10.57**	**3.25**	**4.82**	**17.76**	**1216.21**	
		PureSTD	**130.62**	**72.95**	**17.66**	**24.83**	**1.47**	**23.94**	**12.17**	**14.30**	**38.44**	**1308.91**	
Morenci <Fed & AZ Standards — These wells are not located on map (Figure Q) or Table 33													
Phelp Dodge Morenci	GW	Chase Creek -04 7/6/95	0.90	10.20									
Phelp Dodge Morenci	GW	Chase Creek -05 7/10/95	2.80	6.70									
Phelp Dodge Morenci	GW	Chase Creek -07 6/21/95	8.60	13.30									
Phelp Dodge Morenci	GW	Chase Creek -08 6/21/95	1.90	18.70									
Phelp Dodge Morenci	GW	Chase Creek -10 8/7/95	7.40	2.00									
Phelp Dodge Morenci	GW	Chase Creek -14 6/21/95	5.10	23.00									
Phelp Dodge Morenci	GW	Chase Creek -28 12/6/95	9.40	9.90									
Phelp Dodge Morenci	GW	Chase Creek -29 6/28/95	2.70	9.30									
Phelp Dodge Morenci	GW	Chase Creek -33 6/29/95	2.70	14.40									
Phelp Dodge Morenci	GW	Chase Creek -40 12/6/95	1.70	8.10									
Phelp Dodge Morenci	GW	Chase Creek -44 6/26/95	2.40	10.10									
Phelp Dodge Morenci	GW	Chase Creek -45 12/7/95	1.90	13.20									
Phelp Dodge Morenci	GW	Chase Creek -46 12/13/95	1.50	8.70									
Phelp Dodge Morenci	GW	Chase Creek -50 2/26/95	1.10	5.20									
Phelp Dodge Morenci	GW	DW -01 2/25/95 Upgradient	5.60	25.20									
Phelp Dodge Morenci	GW	DW -02 9/19/95	6.30	17.50									
Phelp Dodge Morenci	GW	DW -03 2/21/95	13.40	42.30									
Phelp Dodge Morenci	GW	DW -04 2/22/95	7.00	8.40									
Phelp Dodge Morenci	GW	DW -14 10/17/95	0.40	3.90									
Phelp Dodge Morenci	GW	DW -14 2/12/95	5.60	4.00									
Phelp Dodge Morenci	GW	GG -02 9/18/95 Gold Gulch	2.90	7.90									
Phelp Dodge Morenci	GW	GG -07 8/31/95	0.90	10.00									
Phelp Dodge Morenci	GW	GG -08 8/30/95	2.30	5.20									
Phelp Dodge Morenci	GW	GG -09 2/13/95	4.10	9.00									
Phelp Dodge Morenci	GW	GG -10 2/12/95	8.00	38.00									
Phelp Dodge Morenci	GW	GG -11 9/11/95	0.75	3.85									
Phelp Dodge Morenci	GW	GG -14 2/8/95	3.00	7.00									
Phelp Dodge Morenci	GW	GG -18 2/26/95	7.10	12.90									

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Results of Radiochemical Analyses

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	LSB -02 1/23/95 Lower Silver Basin	6.90	22.50									
Phelp Dodge Morenci	GW	LSB -03 8/17/95	0.70	6.40									
Phelp Dodge Morenci	GW	LSB -05 1/29/95	2.50	4.40									
Phelp Dodge Morenci	GW	MP -01 12/12 Morenci Pit	6.00	44.00									
Phelp Dodge Morenci	GW	MP -02 11/9/95	5.40	34.80									
Phelp Dodge Morenci	GW	MP -03 8/22/95	0.90	20.60									
Phelp Dodge Morenci	GW	MP -05 2/20/95	*16.00*	33.00									
Phelp Dodge Morenci	GW	MP -06 11/8/95	6.20	29.00									
Phelp Dodge Morenci	GW	MP -09 2/7/95	2.80	20.10									
Phelp Dodge Morenci	GW	RG -02 10/4/95 Rocky Gulch	*0.00*	9.20									
Phelp Dodge Morenci	GW	RG -03 10/3/95	2.30	24.80									
Phelp Dodge Morenci	GW	RG -05 10/31/95	0.29	2.70									
Phelp Dodge Morenci	GW	SW -26A 7/26/95 South West	1.10	7.10									
Phelp Dodge Morenci	GW	SW -27A 7/26/95	3.80	4.00									
Phelp Dodge Morenci	GW	SW -28B 1/23/96	3.30	9.10									
Phelp Dodge Morenci	GW	SW -30B 1/24/96	*0.00*	7.50									
Phelp Dodge Morenci	GW	SW -33 7/13/95	0.13	3.20									
Phelp Dodge Morenci	GW	SW -34 7/18/95	0.70	6.20									
Phelp Dodge Morenci	GW	SW -35 1/9/96	*0.00*	6.90									
Phelp Dodge Morenci	GW	SW -36 1/15/96	1.20	6.60									
Phelp Dodge Morenci	GW	SW -37 7/27/95	0.70	16.00									
Phelp Dodge Morenci	GW	SW -38 7/27/95	1.60	8.90									
Phelp Dodge Morenci	GW	SW -39 1/10/96	0.30	5.80									
Phelp Dodge Morenci	GW	SW -40 8/16/95	3.00	7.00									
Phelp Dodge Morenci	GW	SW -41 7/13/95	3.30	10.10									
Phelp Dodge Morenci	GW	SW -42 1/11/96	0.20	8.30									
Phelp Dodge Morenci	GW	SW -43 1/11/96	11.70	14.80									
Phelp Dodge Morenci	GW	SW -45 2/12/96	1.60	6.50									
Phelp Dodge Morenci	GW	SW -46 7/20/95	9.30	23.00									
Phelp Dodge Morenci	GW	SW -47 8/3/95	7.10	9.70									
Phelp Dodge Morenci	GW	SW -48 2/14/96	11.50	16.80									
Phelp Dodge Morenci	GW	SW -49 8/2/95	8.50	9.00									
Phelp Dodge Morenci	GW	SW -52 7/12/95	6.70	12.80									
Phelp Dodge Morenci	GW	SW -53 7/12/95	3.40	7.60									
Phelp Dodge Morenci	GW	SW -54 2/14/95	14.00	32.00									

STD = Standard Deviation
AVG = Average

Maximum and minimum values are shown in italics
Bold text (STD and AVG) also appear in summary tables (1-5)

Results of Radiochemical Analyses

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	SW -55 8/1/95	1.20	4.00									
Phelp Dodge Morenci	GW	SW -56 7/31/95	1.50	4.30									
Phelp Dodge Morenci	GW	SW -57 8/8/95	0.30	7.10									
Phelp Dodge Morenci	GW	SW -59 8/14/95	0.40	3.90									
Phelp Dodge Morenci	GW	SW -60A 12/14/95	3.70	3.10									
Phelp Dodge Morenci	GW	SW -61 8/15/95	10.50	3.80									
Phelp Dodge Morenci	GW	SW -64 1/24/96	9.10	9.00									
Phelp Dodge Morenci	GW	SW -67 11/29/95	2.50	7.30									
Phelp Dodge Morenci	GW	DW-04 12/03/96 Upgradient	4.00	8.00	1.00	1.40	*0.00*	1.80	0.40	1.40	2.40		
Phelp Dodge Morenci	GW	DW-04 12/12/96	5.00	9.00	1.00	3.30	0.10	0.70	0.40	0.30	4.40		
Phelp Dodge Morenci	GW	DW-05 12/3/96	4.00	7.00	0.40	2.00	*0.00*	1.20	0.20	1.00	2.40		
Phelp Dodge Morenci	GW	DW-05 12/12/96	4.00	7.00	0.50	3.00	*0.00*	0.50	0.10	0.40	3.50		
Phelp Dodge Morenci	GW	DW-14 10/26/96	9.00	5.00	*1.80*	*6.50*	*0.00*	1.30	0.40	0.90	8.30		
Phelp Dodge Morenci	GW	GG-2 12/6/96 Gold Gulch	2.00	6.00	*0.00*	*0.00*	*0.00*	1.00	0.60	0.40	*0.00*		
Phelp Dodge Morenci	GW	GG-8 4/24/96	1.60	2.70				0.70	0.25	1.10			
Phelp Dodge Morenci	GW	GG-8 10/18/96	3.00	7.00	*0.00*	0.80	*0.00*	*0.00*	*0.00*	0.10	0.60		
Phelp Dodge Morenci	GW	GG-8 12/6/96	2.00	9.00	0.30	1.20	*0.00*	0.30	0.30	*0.00*	1.50		
Phelp Dodge Morenci	GW	GG-9 12/6/96	2.00	8.00	0.10	0.40	*0.00*	0.20	0.20	0.20	0.50		
Phelp Dodge Morenci	GW	GG-10 4/24/96	2.30	5.40									
Phelp Dodge Morenci	GW	GG-10 10/18/96	6.00	14.00	1.50	2.70	*0.00*	0.60	0.40	0.20	4.20		
Phelp Dodge Morenci	GW	GG-10 12/7 96	9.00	17.00	*1.80*	3.30	*0.00*	1.40	0.80	0.60	5.10		
Phelp Dodge Morenci	GW	GG-13 12/12/96	2.00	3.00	0.30	1.10	*0.00*	0.40	0.20	0.20	1.40		
Phelp Dodge Morenci	GW	GG-13 12/11/96	*0.00*	3.00	0.20	1.00	*0.00*	0.30	0.20	0.10	1.20		
Phelp Dodge Morenci	GW	GG-14 12/7/96	14.00	17.00	1.70	4.90	*0.00*	0.90	0.30	0.60	6.60		
Phelp Dodge Morenci	GW	GG-18 12/6/96	6.00	23.00	1.70	2.60	*0.00*	2.30	*0.00*	1.70	4.30		
Phelp Dodge Morenci	GW	CC-4 4/24/96 Lower Chase Creek	1.60	3.90				0.60	*0.00*	0.90			
Phelp Dodge Morenci	GW	CC-4 10/30/96	10.00	4.00	0.80	6.00	*0.00*	0.30	*0.00*	0.30	6.80		
Phelp Dodge Morenci	GW	CC-4 10/17/96	11.00	25.00	0.40	2.20	*0.20*	0.10	*0.00*	0.10	2.80		
Phelp Dodge Morenci	GW	CC-4 12/14/96	7.00	18.00	0.50	2.50	*0.00*	*0.00*	*0.00*	*0.00*	3.00		
Phelp Dodge Morenci	GW	CC-5 10/19/96	3.00	10.00	0.90	3.60	0.10	0.50	*0.00*	0.50	4.60		
Phelp Dodge Morenci	GW	CC-5 12/16/96	2.00	8.00	0.40	3.10	*0.00*	*0.00*	*0.00*	*0.00*	3.60		
Phelp Dodge Morenci	GW	CC-7 9/18/96	2.00	8.00	0.80	1.90	*0.00*	*0.00*	*0.00*	*0.00*	2.70		
Phelp Dodge Morenci	GW	CC-7 11/13/96	5.00	12.00	0.70	1.20	*0.00*	0.10	0.10	*0.00*	1.90		
Phelp Dodge Morenci	GW	CC-8 9/18/96	1.00	33.00	0.20	2.10	*0.00*	0.50	0.10	0.40	2.30		
Phelp Dodge Morenci	GW	CC-8 11/13/96	4.00	16.00	0.10	1.50	*0.00*	0.10	0.10	*0.00*	1.60		

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All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	CC-14 9/18/96	1.00	7.00	0.40	1.30	*0.00*	*0.00*	*0.00*	*0.00*	1.70		
Phelp Dodge Morenci	GW	CC-14 11/13/96	3.00	11.00	0.40	1.60	0.10	0.50	*0.00*	0.50	2.10		
Phelp Dodge Morenci	GW	CC-31 9/19/96	3.00	16.00	0.80	1.30	*0.00*	0.70	0.10	0.60	2.10		
Phelp Dodge Morenci	GW	CC-31 11/13/96	6.00	15.00	0.70	0.80	*0.00*	*0.00*	*0.00*	*0.00*	1.50		
Phelp Dodge Morenci	GW	CC-44 9/19/96	2.00	10.00	0.20	0.40	*0.00*	0.50	0.10	0.40	0.60		
Phelp Dodge Morenci	GW	CC-44 11/15/96	2.00	6.00	0.10	0.30	*0.00*	0.20	*0.00*	0.20	0.40		
Phelp Dodge Morenci	GW	CC-44 11/30/96	1.00	8.00	0.30	0.60	0.10	0.20	*0.00*	0.20	1.00		
Phelp Dodge Morenci	GW	CC-45 10/22/96	2.00	12.00	0.60	2.00	0.10	0.60	*0.00*	0.60	2.70		
Phelp Dodge Morenci	GW	CC-45 11/29/96	2.00	10.00	0.50	1.70	*0.00*	0.30	0.20	0.10	2.20		
Phelp Dodge Morenci	GW	CC-46 10/22/96	*0.00*	8.00	0.50	2.00	0.10	0.10	*0.00*	0.10	2.60		
Phelp Dodge Morenci	GW	CC-46 11/29/96	3.00	11.00	0.60	2.00	0.10	0.50	0.10	0.40	2.70		
Phelp Dodge Morenci	GW	CC-51 10/19/96	7.00	8.00	0.30	1.30	*0.00*	0.20	*0.00*	0.30	1.60		
Phelp Dodge Morenci	GW	CC-51 11/29/96	4.00	10.00	1.10	3.30	0.10	0.50	0.10	0.40	4.50		
Phelp Dodge Morenci	GW	CC-42 11/29/96 Mining Area	6.00	*46.00*	1.30	2.90	*0.00*	3.60	1.20	2.40	4.20		
Phelp Dodge Morenci	GW	DW-2 10/31/96	5.00	13.00	1.40	1.30	*0.00*	1.20	0.60	0.80	2.70		
Phelp Dodge Morenci	GW	DW-2 11/30/96	4.00	22.00	1.10	0.20	*0.00*	0.40	0.20	0.20	1.20		
Phelp Dodge Morenci	GW	MP-2 12/11/96	7.00	23.00	0.30	1.10	*0.00*	3.80	1.60	2.20	1.40		
Phelp Dodge Morenci	GW	MP-9 11/04/96	4.00	15.00	0.20	0.30	*0.00*	*4.50*	*2.70*	1.80	0.50		
Phelp Dodge Morenci	GW	MP-9 11/22/96	8.00	28.00	0.70	1.10	*0.00*	3.60	2.30	1.30	1.80		
Phelp Dodge Morenci	GW	SW-4510/12/96	3.00	5.00	0.40	1.70	*0.00*	0.30	0.10	0.20	2.10		
Phelp Dodge Morenci	GW	SW-45 11/19/96	1.00	6.00	0.50	2.20	*0.00*	*0.00*	*0.00*	*0.00*	2.70		
Phelp Dodge Morenci	GW	SW-47 10/15/96	4.00	8.00	0.40	1.70	0.10	0.60	0.10	0.50	2.20		
Phelp Dodge Morenci	GW	SW-47 11/15/96	3.00	*1.00*	0.50	1.20	*0.00*	0.10	*0.00*	0.10	1.70		
Phelp Dodge Morenci	GW	SW-55 10/7/96	1.00	4.00	0.20	0.50	*0.00*	0.80	0.10	*7.00*	0.70		
Phelp Dodge Morenci	GW	SW-55 11/14/96	2.00	4.00	0.10	1.30	*0.00*	0.20	0.10	0.10	1.40		
Phelp Dodge Morenci	GW	SW-56 11/11/96	3.00	4.00	0.30	1.30	*0.00*	0.50	*0.00*	0.50	1.60		
Phelp Dodge Morenci	GW	SW-56 12/12/96	3.00	4.00	0.20	1.10	*0.00*	0.10	0.10	0.20	1.30		
Phelp Dodge Morenci	GW	SW-59 10/10/96	1.00	3.00	*0.00*	0.80	*0.00*	0.70	*0.00*	0.70	1.00		
Phelp Dodge Morenci	GW	SW-59 11/13.96	4.00	6.00	*0.00*	1.00	*0.00*	0.10	0.10	*0.00*	1.00		
Phelp Dodge Morenci	GW	SW-60A 10/10/96	4.00	3.00	0.40	4.40	*0.00*	1.50	0.70	0.80	4.80		
Phelp Dodge Morenci	GW	SW-60A 11/14/96	3.00	2.00	0.30	3.80	*0.00*	0.70	0.30	0.40	4.10		
Phelp Dodge Morenci	GW	SW-67 10/12/96	8.00	8.00	1.10	3.70	*0.00*	0.20	0.10	0.10	4.80		
Phelp Dodge Morenci	GW	SW-67 11/19/96	7.00	10.00	0.80	3.60	0.10	0.10	0.10	*0.00*	4.50		
Phelp Dodge Morenci	GW	RG-2 12/4/96	1.00	11.00	0.20	0.40	*0.00*	0.90	0.20	0.70	0.60		
Phelp Dodge Morenci	GW	RG-2 12/12/96	2.00	11.00	0.20	0.80	*0.00*	0.50	0.10	0.40	1.00		

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Results of Radiochemical Analyses

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	RG-3 12/4/96	2.00	13.00	0.40	0.80	*0.00*	1.00	0.30	0.70	1.20		
Phelp Dodge Morenci	GW	RG-5 11/2/96	1.00	3.00	*0.00*	*0.00*	*0.00*	0.10	0.10	*0.00*	*0.00*		
Phelp Dodge Morenci	GW	RG-5 12/5/96	1.00	2.00	*0.00*	0.40	*0.00*	0.30	*0.00*	0.30	0.40		
Phelp Dodge Morenci	GW	LSB-2 11/13/96 Downgrdt of Tail. Dams	9.00	22.00	0.70	1.50	*0.00*	0.80	0.20	0.50	2.20		
Phelp Dodge Morenci	GW	SW-26A 10/2/96	2.00	9.00	0.30	0.90	*0.00*	2.60	2.30	0.30	1.20		
Phelp Dodge Morenci	GW	SW-26A 11/19/96	2.00	10.00	0.40	1.30	*0.00*	0.50	*0.00*	0.50	1.70		
Phelp Dodge Morenci	GW	SW-30B 9/2/96	1.00	12.00	0.30	0.70	*0.00*	*0.00*	*0.00*	*0.00*	1.00		
Phelp Dodge Morenci	GW	SW-30B 12/14/96	4.00	13.00	0.40	0.90	*0.00*	*0.00*	*0.00*	*0.00*	1.30		
Phelp Dodge Morenci	GW	SW-33 10/7/96	*0.00*	3.00	0.10	0.20	*0.00*	0.60	*0.00*	0.67	0.30		
Phelp Dodge Morenci	GW	SW-33 11/16/96	1.00	3.00	0.10	0.20	*0.00*	*0.00*	*0.00*	*0.00*	0.30		
Phelp Dodge Morenci	GW	SW-34 10/7/96	3.00	6.00	0.10	0.80	0.10	1.10	*0.00*	1.10	1.00		
Phelp Dodge Morenci	GW	SW-34 11/23/96	2.00	6.00	0.40	0.90	0.10	0.20	*0.00*	0.20	1.40		
Phelp Dodge Morenci	GW	SW-35 10/3/96	2.00	10.00	0.10	1.10	*0.00*	0.60	*0.00*	0.60	1.20		
Phelp Dodge Morenci	GW	SW-35 11/23/96	2.00	7.00	0.40	0.90	0.10	0.50	*0.00*	0.40	1.40		
Phelp Dodge Morenci	GW	SW-36 10/2/96	1.00	7.00	0.40	0.80	*0.00*	0.60	*0.00*	0.60	1.20		
Phelp Dodge Morenci	GW	SW-36 1126/96	1.00	8.00	0.10	0.30	*0.00*	0.20	0.10	0.10	0.40		
Phelp Dodge Morenci	GW	SW-37 10/3/96	1.00	10.00	0.30	1.00	*0.00*	1.20	*0.00*	1.20	1.30		
Phelp Dodge Morenci	GW	SW-37 11/19/96	1.00	45.00	0.20	1.00	*0.00*	0.20	0.20	*0.00*	1.20		
Phelp Dodge Morenci	GW	SW-38 9/20/96	1.00	8.00	0.40	1.00	*0.00*	*0.00*	*0.00*	*0.00*	1.40		
Phelp Dodge Morenci	GW	SW-38 11/21/96	2.00	28.00	*0.00*	0.60	0.10	0.10	0.10	*0.00*	0.70		
Phelp Dodge Morenci	GW	SW-39 9/20/96	1.00	10.00	0.40	0.90	*0.00*	*0.00*	*0.00*	*0.00*	1.30		
Phelp Dodge Morenci	GW	SW-39 11/21/96	2.00	10.00	0.20	1.50	*0.00*	*0.00*	*0.00*	*0.00*	1.70		
Phelp Dodge Morenci	GW	SW-40 11/8/96	7.00	23.00	0.60	2.70	*0.00*	0.20	0.10	0.10	3.30		
Phelp Dodge Morenci	GW	SW-40 11/20/96	1.00	24.00	0.50	1.80	*0.00*	0.20	*0.00*	0.20	2.30		
Phelp Dodge Morenci	GW	SW-41 10/11/96	3.00	9.00	0.30	1.30	*0.00*	0.10	*0.00*	0.10	1.60		
Phelp Dodge Morenci	GW	SW-41 11/16/96	2.00	9.00	0.20	1.00	*0.00*	0.10	*0.00*	0.10	1.20		
Phelp Dodge Morenci	GW	SW-42 4/26/96	1.60	3.40				1.30	0.24	1.20			
Phelp Dodge Morenci	GW	SW-42 11/16/96	3.00	10.00	0.30	1.30	0.10	0.20	*0.00*	0.20	1.70		
Phelp Dodge Morenci	GW	SW-42 10/17/96	*0.00*	8.00	0.20	0.80	*0.00*	0.10	0.10	*0.00*	1.00		
Phelp Dodge Morenci	GW	SW-43 10/14/96	3.00	10.00	0.20	1.50	*0.00*	1.30	0.10	1.20	1.70		
Phelp Dodge Morenci	GW	SW-44 11/15/96	5.00	13.00	0.40	1.80	*0.00*	1.60	0.70	0.90	2.20		
Phelp Dodge Morenci	GW	SW-46 10/15/96	2.00	7.00	0.10	0.90	*0.00*	1.30	*0.00*	1.40	1.00		
Phelp Dodge Morenci	GW	SW-46 11/17/96	2.00	8.00	0.20	1.20	*0.00*	0.10	0.10	*0.00*	1.40		
Phelp Dodge Morenci	GW	SW-52 10/8/96	2.00	8.00	0.20	1.10	*0.00*	0.80	0.20	0.60	1.30		
Phelp Dodge Morenci	GW	SW-52 11/14/96	2.00	8.00	0.10	0.90	0.10	0.10	0.10	*0.00*	1.10		

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Results of Radiochemical Analyses

All Groundwater Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	GW	SW-53 11/19/96	6.00	11.00	0.60	2.60	*0.00*	0.60	0.30	0.30	3.30		
Phelp Dodge Morenci	GW	SW-54 10/10/96	10.00	16.00	0.10	0.50	*0.00*	0.60	0.10	0.50	1.60		
Phelp Dodge Morenci	GW	SW-54 11/13/96	4.00	11.00	0.10	0.90	*0.00*	0.20	0.10	0.10	1.00		
Phelp Dodge Morenci	GW	SW-57 10/11/96	3.00	6.00	0.10	1.60	*0.00*	0.90	0.40	0.50	1.70		
Phelp Dodge Morenci	GW	SW-57 11/13/96	1.00	7.00	0.50	1.40	*0.00*	0.60	0.20	0.40	2.00		
Phelp Dodge Morenci	GW	SW-64 10/9/96	2.00	8.00	0.90	3.30	0.10	0.30	*0.00*	0.30	4.20		
Phelp Dodge Morenci	GW	SW-64 11/19/96	4.00	7.00	0.90	2.90	*0.00*	0.10	0.10	*0.00*	3.80		
Phelp Dodge Morenci	GW	SW-68 10/8/96	6.00	9.00	0.90	2.20	0.10	0.60	0.20	0.40	3.20		
Phelp Dodge Morenci	GW	SW-68 11/19/96	2.00	2.00	0.40	1.70	0.10	0.60	0.10	0.50	2.20		
Phelp Dodge Morenci	GW	SW-70B 10/30/96	2.00	13.00	0.40	1.40	*0.00*	0.20	*0.00*	0.20	1.80		
Phelp Dodge Morenci	GW	SW-70B 11/19/96	3.00	4.00	0.30	1.90	0.10	*0.00*	*0.00*	0.40	*23.00*		
PD MM < Average	**STotal=179**	**Average**	**3.64**	**11.28**	**0.47**	**1.61**	**0.02**	**0.63**	**0.21**	**0.49**	**2.31**		
		STD	**3.16**	**8.71**	**0.41**	**1.20**	**0.04**	**0.81**	**0.45**	**0.80**	**2.54**		
All MM only Average	**STotal =230**	**Average**	**10.68**	**22.26**	**3.59**	**7.21**	**0.29**	**3.16**	**1.22**	**2.18**	**11.25**		
		STD	**27.06**	**40.64**	**14.64**	**20.23**	**1.21**	**11.40**	**3.99**	**9.60**	**34.97**		
All GW Average	**Total=368**	**P.ure Average**	**28.41**	**29.62**	**4.30**	**8.92**	**0.32**	**3.92**	**2.00**	**2.99**	**11.58**	**1216.21**	
		PureSTD	**95.54**	**54.37**	**12.92**	**18.88**	**1.05**	**14.49**	**9.45**	**11.07**	**30.73**	**1308.91**	

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AVG = Average

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Results of Radiochemical Analyses

All Soil - Sediments Data (pCi/g)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Cerbat Mt. American Legion	SS	S6	*62.30*	*93.40*	*4.20*	*22.80*			*7.40*				
Cerbat Mt. American Legion	SS	S7	*15.10*	*23.40*	*6.80*	*7.00*			*0.94*				
AL Average	**STotal = 2**	**Average**	**38.70**	**58.40**	**5.50**	**14.90**			**4.17**				
		STD	**33.38**	**49.50**	**1.84**	**11.17**			**4.57**				
Cerbat Mt. De la Fontaine	SS	S1	44.30	52.50	4.90	4.80			5.30				
Cerbat Mt. De la Fontaine	SS	S2	95.80	*134.00*	*9.90*	*10.80*			12.80				
Cerbat Mt. De la Fontaine	SS	S3	*8.20*	*30.80*	*0.99*	*0.87*			*0.71*				
Cerbat Mt. De la Fontaine	SS	S4	73.00	94.20	6.90	7.80			*18.40*				
CONFLUENCE AL/DF	SS	S5	*171.00*	57.20	6.60	6.70			7.20				
DF Average	**STotal = 5**	**Average**	**78.46**	**73.74**	**5.86**	**6.19**			**8.88**				
		STD	**61.23**	**40.68**	**3.26**	**3.69**			**6.86**				
Cerbat MT Avg	**Total = 7**	**PureAverage**	**67.10**	**69.36**	**5.76**	**8.68**			**7.54**				
		STD	**55.33**	**39.59**	**2.77**	**6.92**			**6.34**				
Hillside Boulder Creek	SS	AA No. 1	57.40	54.30	5.90	2.90			5.50				
Hillside Boulder Creek	SS	A O.p. Bank	*9.60*	33.20	*0.70*	*0.88*			*0.69*				
Hillside Boulder Creek	SS	A Terrace	20.10	31.50	2.50	2.70			1.90				
Hillside Boulder Creek	SS	A Channel	21.10	53.00	0.97	1.08			0.94				
Hillside Boulder Creek	SS	A Upland	19.40	34.50	1.23	1.23			2.00				
Hillside Boulder Creek	SS	B Terrace	60.10	68.40	5.90	6.10			9.40				
Hillside Boulder Creek	SS	B Upland	35.90	46.90	3.90	4.10			4.30				
Hillside Boulder Creek	SS	BC 100 Upper Tails	17.30	*22.00*	1.79	1.82			0.89				
Hillside Boulder Creek	SS	D Lower Tails	20.90	45.40	1.49	1.90			1.74				
Hillside Boulder Creek	SS	E Middle Tails	26.70	48.10	2.30	2.20			1.40				
Hillside Boulder Creek	SS	F Middle Tails	16.00	45.30	1.70	2.46			0.77				
Hillside Boulder Creek	SS	G Middle Tails	261.00	185.00	25.60	51.30			44.00				
Hillside Boulder Creek	SS	H Middle Tails	*395.00*	*248.00*	*63.30*	*60.80*			*82.60*				
HS Average	**STotal = 13**	**Average**	**73.88**	**70.43**	**9.02**	**10.73**			**12.01**				
		STD	**117.05**	**67.13**	**17.59**	**20.25**			**24.21**				
Phelp Dodge Morenci	SS	PD M ine Leval 2016-X 9/2/95	*0.50*	82.00									
Phelp Dodge Morenci	SS	Lone Star Stockpile 9/23/95	*86.00*	*100.00*									
Phelp Dodge Morenci	SS	GRA- SV-X Soil 2/15/96	18.70	49.50									
Phelp Dodge Morenci	SS	GARFIELD Oxide-X Soil 2/15/96	24.40	57.30									
Phelp Dodge Morenci	SS	GARFIELD DV-X Soil 2/15/96	16.80	*45.40*									
MM Average	**STotal = 5**	**Average**	**29.28**	**66.84**									
		STD	**32.93**	**23.35**									
All SS Average	**Total = 25**	**Pure Average**	**63.06**	**69.41**	**7.88**	**10.01**			**10.44**				
		STD	**90.01**	**52.32**	**14.15**	**16.59**			**19.69**				

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Results of Radiochemical Analyses

Surface Water (pCi/L)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Cyprus Mineral Park	SW	Golden Egale Spring 8/04/95	16.00	18.00									
Cyprus Mineral Park	SW	Jamison Wash Adit 8/04/95	68.00	35.00									
Cyprus Mineral Park	SW	Bismark Wash Adit 8/04/95	11.00	20.00									
Cyprus Mineral Park	SW	Keystone Wash Adit 8/03/95	20.00	10.00									
Cyprus Mineral Park	SW	Keystone Wash Adit 8/04/95	43.00	22.00									
Cyprus Mineral Park	SW	Keystone Wash Adit 8/04/95	*0.00*	6.00									
Cyprus Mineral Park	SW	Long Wash Adit 8/04/95	36.00	26.00									
Cyprus Mineral Park	SW	Long Wash 4/5/95	62.00	*0.00*					*0.80*	*1.40*	*0.10*	*120.00*	
Cyprus Mineral Park	SW	Jamison Wash 4/5/95	47.00	*0.00*					0.50	*1.80*	0.05	46.00	
Cyprus Mineral Park	SW	Jamison Wash 8/04/95	37.00	24.00									
Cyprus Mineral Park	SW	Mineral Park Wash 8/03/95	140.00	*0.00*									
Cyprus Mineral Park	SW	No Name Wash 8/04/95	*150.00*	*90.00*									
Cyprus Mineral Park	SW	Turquoise Wash 8/04/95	37.00	43.00									
Cyprus Mineral Park	SW	Turquoise Wash 8/05/95	27.00	*0.00*					*0.40*	*1.60*	*0.01*	*39.00*	
MP Average	**STotal = 14**	**Average**	**49.57**	**21.00**					**0.57**	**1.60**	**0.05**	**68.33**	
		STD	**44.52**	**24.17**									
Phelp Dodge Morenci	SW	Gold Gulch Spring 8/28/95	*36.00*	*17.00*									
Phelp Dodge Morenci	SW	Central Chase Creek Wash	1.70	*5.70*									
Phelp Dodge Morenci	SW	Producer Creek Seep	*1.60*	8.80									
MM Average	**STotal = 3**	**Average**	**13.10**	**10.50**									
		STD	**19.83**	**5.84**									
Cyprus Bagdad Copper Creek	SW	BC-2 Up gradient	19.00						*0.00*	*0.00*			
Cyprus Bagdad Copper Creek	SW	BC-1 Down gradient	*84.00*						*0.00*	2.00			
Cyprus Bagdad Copper Creek	SW	BC-0 Down gradient	20.00						*0.00*	*0.00*			
Cyprus Bagdad Copper Creek	SW	S-4	18.00						*0.00*	*0.00*			
Cyprus Bagdad Copper Creek	SW	S-3	*2.00*						*8.00*	*0.00*			
Cyprus Bagdad Copper Creek	SW	S-2	27.00						*0.00*	*7.00*			
Cyprus Bagdad Copper Creek	SW	S-1	10.00						0.60	2.00			
CB-CC	**STotal = 7**	**Average**	**25.71**						**1.23**	**1.57**			
		STD	**26.91**						**2.99**	**2.57**			
Cyprus Bagdad Lawler Peak	SW	SW-1 Spring	23.50	6.70	12.00	*33.90*	0.80		0.40	1.90	18.90		
Cyprus Bagdad Lawler Peak	SW	SW-2 Adit	13.70	*3.10*	9.10	16.20	1.20		*0.20*	*0.20*	19.60		
Cyprus Bagdad Lawler Peak	SW	SW-3 Spring	*57.10*	*59.80*	*18.70*	21.90	*2.90*		*19.30*	*17.80*	*32.90*		
Cyprus Bagdad Lawler Peak	SW	SW-4 Adit	1.10	6.60	*0.80*	*1.10*			0.30	4.40	*0.70*		
Cyprus Bagdad Lawler Peak	SW	SW-5 Spring	3.30		1.30	2.10	*0.10*		*0.20*	3.10	2.10		

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Results of Radiochemical Analyses

Surface Water (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Cyprus Bagdad Lawler Peak	SW	SW-6 Lake	3.00	11.40							*0.70*		
Cyprus Bagdad Lawler Peak	SW	SW-7 Lake	1.50	8.70							1.40		
Cyprus Bagdad Lawler Peak	SW	SW-8 Lake	*0.60*	7.70							1.40		
Cyprus Bagdad Lawler Peak	SW	SW-9 Lake	2.80	5.70							*0.70*		
CB-LP	**STotal = 9**	**Average**	**11.84**	**13.71**	**8.38**	**15.04**	**1.25**		**4.08**	**5.48**	**8.71**		
		STD	**18.61**	**18.77**	**7.54**	**13.84**	**1.19**		**8.51**	**7.06**	**11.99**		
Three R	SW	2 6/92	*139.00*	*128.00*									
Three R	SW	3 6/92	35.00	37.00									
Three R	SW	4 7/93	53.70	54.33	*30.98*	*52.13*	1.36		0.67	1.70			
Three R	SW	5 7/93	131.60	126.74	23.02	34.10	*1.42*		*10.38*	*0.00*			
Three R	SW	6 7/93	*0.00*	*10.24*	22.60	32.74	0.98		*0.00*	*55.45*			
Three R	SW	MT 7/93	5.61	49.91	*0.12*	*0.19*	*0.04*		0.10				
TR Average	**STotal = 6**	**Average**	**60.82**	**67.70**	**19.18**	**29.79**	**0.95**		**3.68**	**19.05**			
		STD	**60.97**	**48.71**	**13.28**	**21.62**	**0.64**		**5.07**	**31.53**			
Cerbat Mt American Legion	SW	2A	*53.30*		23.50	26.60			1.10				
Cerbat Mt American Legion	SW	2B	54.80		25.30	27.10			0.80				
Cerbat Mt American Legion	SW	3A	55.90		*22.30*	*23.80*			*20.30*				
Cerbat Mt American Legion	SW	3B	67.40						16.70				
Cerbat Mt American Legion	SW	4A	154.00		112.00	110.00			16.80				
Cerbat Mt American Legion	SW	4B	*297.00*		*115.00*	*117.00*			12.80				
Cerbat Mt American Legion	SW	5A	158.00						*0.50*				
Cerbat Mt American Legion	SW	5B	159.00		73.70	77.10			0.60				
Cerbat Mt American Legion	SW	6A	66.80										
Cerbat Mt American Legion	SW	6B	68.30		30.00	33.60			*0.50*				
AL Average	**STotal = 10**	**Average**	**113.45**		**57.40**	**59.31**			**7.79**				
		STD	**78.95**		**42.28**	**41.32**			**8.62**				
Cherbat Mt De la Fontaine	SW	1A	*55.70*						*3.40*				
Cherbat Mt De la Fontaine	SW	1B	*43.60*										
DF Average	**STotal = 2**	**Average**	**49.65**						**3.40**				
		STD	**8.56**										
Hillside Boulder Creek	SW	2.1 Up gradient	*6.90*		*11.60*	*3.80*			*0.10*				
Hillside Boulder Creek	SW	5	*1240.00*		*678.00*	*577.00*			*71.80*				
Hillside Boulder Creek	SW	6	644.00		383.00	330.00			18.50				
HS Average	**STotal = 3**	**Average**	**630.30**		**357.53**	**303.60**			**30.13**				
		STD	**616.66**		**333.93**	**287.51**			**37.24**				
All SW Average	**Total = 54**	**Pure Average**	**83.51**	**27.14**	**83.84**	**80.02**	**1.10**		**6.43**	**5.58**	**6.55**	**68.33**	
		STD	**188.38**	**33.99**	**168.21**	**141.80**	**0.90**		**13.76**	**13.13**	**10.95**	**44.88**	

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Results of Radiochemical Analyses

All Process Solution Data (pCi/L)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	PS	King Placer Diversion Reservoir	*3450.00*	*2390.00*									
Phelp Dodge Morenci	PS	Dam BC5 8/8/95	1530.00	840.00									
Phelp Dodge Morenci	PS	Treat/Stor. Res. Dam 2B 8/21/95	160.00	140.00									
Phelp Dodge Morenci	PS	Treat/Stor. Res. Dam 6 8/22/95	46.00	10.00									
Phelp Dodge Morenci	PS	Treat/Stor. Res. Dam 7B 8/22/95	313.00	169.00									
Phelp Dodge Morenci	PS	Treat/Stor. Res. Dam 4B 8/21/95	1210.00	610.00									
Phelp Dodge Morenci	PS/PW?	Treatment Storage Res. DAM 11	*1.30*	4.90									
Phelp Dodge Morenci	PS/PW?	Treatment Storage Res. DAM5B	5.00	*3.00*									
MM TSR Average	**STotal = 8**	**Average**	**839.41**	**520.86**									
		STD	**1206.90**	**816.59**									
Cyprus Mineral Park	PS	Bismark Sump 7/31/95	*1200.00*	600.00									
Cyprus Mineral Park	PS	Central Sump 8/2/95	730.00	590.00									
Cyprus Mineral Park	PS	Gross Sump 1 8/2/95	780.00	480.00									
Cyprus Mineral Park	PS	Gross Sump 3 8/2/95	1700.00	*880.00*									
Cyprus Mineral Park	PS	Hardy Sump 7/31/95	1100.00	370.00									
Cyprus Mineral Park	PS	Ithaca Sump 1 7/31/95	260.00	190.00									
Cyprus Mineral Park	PS	Ithaca Sump 2 7/31/95	410.00	290.00									
Cyprus Mineral Park	PS	Ithaca Sump 3 7/31/95	820.00	430.00									
Cyprus Mineral Park	PS	Sump 27 8/4/95	*28.00*	*56.00*									
MP Sumps Average	**STotal = 9**	**Average**	**780.89**	**431.78**									
		STD	**512.60**	**244.99**									
Phelp Dodge Morenci	PS	4250 Sump 8/8/95	*3970.00*	1930.00									
Phelp Dodge Morenci	PS	4500 Sump 8/9/95	1030.00	600.00									
Phelp Dodge Morenci	PS	HORSESHOE Sump8/9/95	3800.00	*3060.00*									
Phelp Dodge Morenci	PS	Queen Hill Sump 8/17/95	202.00	162.00									
Phelp Dodge Morenci	PS	Copper Mountain Sump 8/17/95	2080.00	1290.00									
Phelp Dodge Morenci	PS	Stargo Sump 8/24/95	1760.00	1040.00									
Phelp Dodge Morenci	PS	Morenci Pit Sump 8/21/ 95	*21.00*	*76.00*									
Phelp Dodge Morenci	PS	23/25 Morenci Mine Sump 8/23/95	1590.00	1100.00									
Phelp Dodge Morenci	PS	27Morenci Mine Sump 8/23/95	720.00	280.00									
Phelp Dodge Morenci	PS	Medler Sump 8/17/85	1050.00	710.00									
Phelp Dodge Morenci	PS	Metcalf Sump 8/17/95	3060.00	1630.00									
Phelp Dodge Morenci	PS	5X Sump 8/25/95	1930.00	930.00									
Phelp Dodge Morenci	PS	Pond-29 8/6/95	1060.00	1150.00									
MM Sumps Average	**STotal = 13**	**Average**	**1713.31**	**1073.69**									

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Results of Radiochemical Analyses

All Process Solution Data (pCi/L) (continued)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
		STD	**1255.91**	**810.17**									
All PS Sumps = 22		**Pure Average**	**1331.86**	**811.09**									
		STD	**1105.26**	**708.72**									
PLS													
Phelp Dodge Morenci	PS	Modoc SX PLS 8/16/95	2990.00	1910.00									
Phelp Dodge Morenci	PS	Metcalf Cent. Fac. SX PLS 8/16/95	3600.00	2140.00									
Phelp Dodge Morenci	PS	Central SX PLS 8/95	*3700.00*	*2390.00*									
Phelp Dodge Morenci	PS	South West SX PLS Tank 4 8/9/95	*1250.00*	*1110.00*									
MM PLS Average	**STotal = 4**	**Average**	**2885.00**	**1887.50**									
		STD	**1134.27**	**554.16**									
Magma Florance ISL	PS	ISL leach test Quartz Monznite	*8649.00*	*3683.00*	*1611.00*	*1745.00*	*598.00*		33.60	*2.00*	*4362.00*	810.00	
Magma Florance ISL	PS	ISL Leach test Granodorite	*897.00*	*612.00*	*248.00*	*254.00*	*11.60*		*19.50*	*2.00*	*0.84*	*243.00*	
ASARCO Santa Cruz ISL	PS	ISL PLS	4410.00						*99.00*	*8.30*	1823.00	*3760.00*	
Cyprus Sierrita Twin Butts	PS	Oxide Tailing liquid									1020.00		*1500.00*
Cyprus Sierrita Twin Butts	PS	Oxide Tailing liquid									1300.00		*2500.00*
All PLS Average	**STotal = 9**	**Average**	**3642.29**	**1974.17**	**929.50**	**999.50**	**304.80**		**50.70**	**4.10**	**1701.17**	**1604.33**	**2000.00**
		STD	**2560.82**	**1070.23**	**963.79**	**1054.30**	**414.65**		**42.42**	**3.64**	**1628.72**	**1888.27**	**707.11**
Raffinate													
Phelp Dodge Morenci	PS	Modoc SX Raffinate 8/16/95	*3550.00*	*2010.00*									
Phelp Dodge Morenci	PS	Metcalf Cent. Fac. SX Raff. 8/14/95	3480.00	1810.00									
Phelp Dodge Morenci	PS	South West SX Raff. Tank 8/9/95	*670.00*	*660.00*									
Phelp Dodge Morenci	PS	Central SX Raffinate 8/16/95	2060.00	910.00									
MM Raff Average	**STotal = 4**	**Average**	**2440.00**	**1347.50**									
		STD	**1365.16**	**662.54**									
Cyprus Mineral Park	PS	Raffinate Pond 8/2/95	*1100.00*	*750.00*									
ASARCO Santa Cruz ISL	PS	ISL Raffinate	*6800.00*						*193.00*	*19.00*	*2870.00*	*2410.00*	
MM Average	**Total = 27**	**Pure Average**	**1862.30**	**1150.26**									
		STD	**1366.37**	**848.87**									
All Raff Average	**STotal = 6**	**Average**	**2943.33**	**1228.00**					**193.00**	**19.00**	**2870.00**	**2410.00**	
		STD	**2230.52**	**632.95**									
All PS	**Total = 45**	**Pure Average**	**1841.22**	**975.51**	**929.50**	**999.50**	**304.80**		**86.28**	**7.83**	**1895.97**	**1805.75**	**2000.00**
		STD	**1850.38**	**881.70**	**963.79**	**1054.30**	**414.65**		**79.13**	**8.02**	**1532.93**	**1593.52**	**707.11**

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Results of Radiochemical Analyses

All Process Waste Data (pCi/L)

Site Name	Type	Monitoring Well-Sample ID	Alpha	Beta	U-238	U-234	U-235	Total Ra	Ra-226	Ra-228	Total U	Rn-222	Th-230
Phelp Dodge Morenci	PW	Metcalf Conc. Thickener 1 8/8/95	*0.00*	80.00									
Phelp Dodge Morenci	PW	Morinci Tail.Thickener 1 8/10/95	*0.00*	86.00									
Phelp Dodge Morenci	PW	Metcalf Tail.Thickener 4 8/10/95	1.50	93.00									
Phelp Dodge Morenci	PW	Morenci Concentrator Thickener 1	1.60	21.40									
Phelp Dodge Morenci	PW	Morenci Concentrator Thickener 2	5.70	15.60									
Phelp Dodge Morenci	PW	Morenci Concentrator Thickener 6	2.40	36.50									
Phelp Dodge Morenci	PW	1 West Tailings Pond 8/24/95	81.00	80.00									
Phelp Dodge Morenci	PW	3 West Tailings Pond 8/25/95	*102.00*	*214.00*									
Phelp Dodge Morenci	PW	4 West Tailings Pond 8/24/95	3.40	121.00									
Phelp Dodge Morenci	PW	Silver Basin I Tailings Pond 8/23/95	*0.00*	66.00									
Phelp Dodge Morenci	PW	South West I Tailing Pond 8/23/95	0.30	68.00									
Phelp Dodge Morenci	PW	West Tailings Dam-07 8/15/96	1.80	6.40									
Phelp Dodge Morenci	PW	West Tailing Dam-23 2/15/96	16.00	*5.40*									
Phelp Dodge Morenci	PW	Columbine Reservoir 8/8/95	0.60	81.00									
Phelp Dodge Morenci	PW	West Tails Seep	1.60	18.00									
Phelp Dodge Morenci	PW	INDRAINOUTL	3.00	12.70									
MM Average	**STotal = 16**	**Average**	**13.81**	**62.81**									
		STD	**30.81**	**54.34**									
BHP Copper Inc Pinto Valley	PW	Tailings	*53.00*	150.00				*2.20*	0.40	2.20	*0.17*	*10.00*	
Cyprus Mineral Park	PW	Tailings Pond -1 8/3/95	660.00	370.00									
Phelps Dodge Copper Queen	PW	North Tailing Water-1	75.60		*156.76*	*131.53*	*6.87*		*0.28*	*0.70*	*0.70*	*57.00*	
Magma San Manual	PW	CuS04 Solution	75.00	*104.00*					1.00	2.00			
Magma San Manual	PW	Smelter Flue Dust	*4100.00*	*4400.00*					*20.00*	*7.10*			
All Others	**STotal = 5**	**Average**	**992.72**	**1256.00**	**156.76**	**131.53**	**6.87**	**2.20**	**5.42**	**3.00**	**0.44**	**33.50**	
		STD	**1755.87**	**2099.21**									
All PW Average	**Total = 21**	**Pure Average**	**246.88**	**301.45**	**156.76**	**131.53**	**6.87**	**2.20**	**5.42**	**3.00**	**0.44**	**33.50**	
		STD	**894.35**	**968.45**					**9.73**	**2.81**	**0.37**	**33.23**	

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