SUMMARY OF ROUBIDOUX WATER QUALITY TESTS
FOR PHASE II AFTER ACTION MONITORING
AT THE TAR CREEK SUPERFUND SITE
OTTAWA COUNTY, OKLAHOMA

EPA Cooperative Agreement #V-006449-01-N

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SUMMARY OF ROUBIDOUX WATER QUALITY TESTS FOR PHASE II OF THE TAR CREEK AFTER ACTION MONITORING PROJECT (9/02)

Background

After Action Monitoring (AAM) is being conducted at the Tar Creek Superfund Site by the Oklahoma Department of Environmental Quality (DEQ) under a cooperative agreement with the EPA (V-006449-01-N). The Tar Creek Superfund Site is located in northern Ottawa County, Oklahoma where shallow ground water within the Boone aquifer became contaminated by past underground lead and zinc mining operations conducted during the early 1900s through 1960s. This resulted in the formation of a huge mine pool at shallow depths (between 100 and 300 feet below ground level) that eventually filled the mines and began discharging at the surface in 1979 near Commerce. The discharges of acid mine water caused the contamination of Tar Creek and led to the listing of the site on the NPL in 1980. The presence of the mine pool over deep groundwater posses a threat of contamination to the Roubidoux aquifer (at approximately 900 feet below ground level) that is the main source of public drinking water supplies for the area. The 1984 Record of Decision (ROD) for Operable Unit 1 of the Tar Creek Superfund Site identified two possible pathways for migration of acid water from the Boone Formation into the Roubidoux: natural flow though the intervening strata; and, flow through abandoned Roubidoux wells. The first pathway was considered improbable for various reasons, mostly due to the low permeability of the 300 to 400 feet of rock separating the Boone and the Roubidoux. Consequently, remedial actions concerned with protection of the Roubidoux focused on plugging abandoned deep wells that were suspected conduits for the transport of contaminants within the Boone, down to the Roubidoux and into active drinking water supply wells. Eighty-three (83) abandoned wells were identified for well plugging during remedial actions of the mid 1980s. The ROD also indicated that if more abandoned wells were discovered in the future, additional funds would have to be requested in order to plug them.

The ROD indicated that the State would undertake a long-term ground water monitoring program of the Roubidoux to assure its safety as a source of drinking water. The Roubidoux was not contaminated at the time the ROD was written except for a few localized areas around Quapaw and all the water distributed by the public water supplies and rural water districts of the Tar Creek area were reported to be safe to drink. Alternate raw water supplies (Neosho River, Spring River and Grand Lake) were identified in the event of wide spread contamination of the Roubidoux was detected by the AAM program and indicated that future remedial actions may be required if the selected alternatives do not adequately mitigate the risk to human health.

The ROD required that After Action Monitoring (AAM) be conducted to assess the effectiveness of well plugging in preventing pollutants within the Boone from contaminating the Roubidoux aquifer. A Roubidoux monitoring plan was included in the ROD that identified locations for monitoring, the frequency of monitoring, and the parameters to monitor, but no “trigger” was identified as a basis for conclusions/decisions. Phase I AAM activities, known as well–head sampling, occurred during 1992 and 1993 and included USGS sampling of 11 municipal drinking water supply wells within the mining area once a month for 6 months and sampling an additional 11 wells outside the mining area once. During Phase II AAM, the Oklahoma

Department of Environmental Quality (DEQ) took discrete water samples of the Roubidoux Aquifer periodically from ten wells (Figure 1) over the course of 6 years between 1996 through 2002. The wells sampled included five new monitor wells, installed by DEQ, and five existing municipal wells identified in Phase I AAM as impacted by mine water from the Boone.

The five impacted municipal wells produced water with elevated iron, zinc and sulfate concentrations. It was unknown whether the Roubidoux was contaminated or whether mine water was entering the wells directly from the Boone through inadequate or deteriorated well casing seals. Phase II AAM was designed and implemented to determine if the Roubidoux Aquifer has been contaminated by mine water. Modifications were made to the impacted wells to obtain discrete samples of Roubidoux water for analysis. These modifications were designed to isolate the Roubidoux and limit water production from the Roubidoux aquifer only. Inflatable packers were installed in four wells (Figure 2) and a PVC liner was installed in the fifth one. Discrete Roubidoux samples were also acquired by DEQ for analyses through the installation of five new monitor wells, one in 1997 and four in 2000. The monitor wells were constructed similar to municipal water supply wells of the area (Figure 3) using state-of-the-art techniques including installation of additional casing through the Boone zone and using acid-resistant cement to seal all the well casing above the Roubidoux.

Results

The analytical results of discrete sampling of the Roubidoux during Phase II AAM are shown in the accompanying table in Appendix A. No exceedances of primary drinking water standards, Maximum Contaminant Levels (MCLs), were detected in the discrete Roubidoux water samples from any of the wells tested during Phase II AAM. The primary MCLs are standards established for those chemicals that may adversely affect public health. All of these contaminants, specifically lead, cadmium, arsenic, and mercury, tested below, or very near, analytical detection limits. The data also show that the Roubidoux is impacted by mine water locally around two Phase II monitor wells (Picher #6-MW and Quapaw #5-MW). All five Phase I wells plus two of the Phase II monitor wells (Picher #5-MW and Picher #7-MW) show indications of possible Roubidoux contamination. The 'MW' designates a new monitor well installed by DEQ under Phase II AAM.

The absence of criteria in the ROD as a "trigger" for action / decision concerning the effectiveness of well plugging led to the establishment of background concentrations (Roubidoux water outside the mining area) and parameters indicative of mine water contamination were determined in Phase I AAM (December 1993, DEQ Technical Memo: "Sampling Results of Public Water Supply Wells, August 1992 through January 1993, Tar Creek Superfund Site"). Three parameters that showed the greatest concentration difference between mine water and Roubidoux water were identified in Phase I AAM as indicators - iron, zinc and sulfate. Tolerance limits were established for each indicator parameter. Tolerance limits are statistically determined values for each parameter representing the upper limit of background concentrations in the Roubidoux (basically two standard deviations above the mean). A measured value for a discrete Roubidoux water sample above the tolerance limit for one of the parameters is considered outside the range of background values and represents a probable indicator of contamination of the Roubidoux by mine water.

Tables in Appendix B1 show the differences in water quality characteristics of mine water compared to background Roubidoux water. The figure in Appendix B shows the graphical depiction on a Piper diagram of the differences in composition of the two waters. This figure does not show any concentration differences, only percent difference in the major ionic components of the two waters. Piper diagrams are useful in identifying the source of groundwater sample through its chemical character – 'fingerprinting'.

The mean concentrations of the indicator parameters (zinc, iron and sulfate) from AAM testing are summarized in the following two tables. The tables also provide the background concentrations representing Roubidoux, Secondary Maximum Contaminant Levels (SMCLs), and tolerance limits for three indicator parameters. SMCLs are standards for some water quality parameters that are related to aesthetic quality of water. The values in bold type represent exceedances of the tolerance limits while italicized type indicates values above background but below tolerance limits. A well producing water with concentrations in excess of the tolerance limits for all three of the indicator parameters is considered impacted by mine water.

The first table enables comparison of the data between well-head sampling and discrete sampling of the Roubidoux, as well as comparison of Phase I and Phase II sample results with background, SMCLs and Tolerance Limits. All five of the wells in Table 1 under Phase I are above tolerance limits for all three indicator parameters and are impacted by mine water.

Table 1: Mean Concentrations of Indicator Parameters in Existing Wells (1996 –1997).

WELL	Zinc (ug/l)		Iron (ug/l)		Sulfate (mg/l)	
Background Conc.	8.8		61.5		25	
Tolerance Limit	43		207		82	
Secondary MCL	5,000		300		250	
AAM Category	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Picher #2	**150**	13	**441**	**403**	**122**	**134**
Picher #3	**65**	*32*	**407**	**772**	**202**	**225**
Picher #4	**129**	12	**894**	**907**	**289**	**212**
Quapaw #2	**45**	**55**	**932**	**1,597**	**187**	**242**
Commerce #3	**51**	*29*	**397**	**413**	**122**	**157**

* Note: Phase I heading represents summary data from well-head samples.
Phase II heading is summary data of Roubidoux water from Discrete samples.
Bold type indicates value greater than tolerance limit.
Italicized values are above background but below tolerance limits.
Where analyses are below detection limits, the detection limit value was used in calculation of means.
Total and dissolved metals concentrations were used in calculation of means.

Table 1 also shows that mean iron and sulfate concentrations for the Phase II (discrete) samples are nearly the same or greater than the Phase I (well-head) samples for all the wells, indicating possible contamination of the Roubidoux aquifer near these wells. In contrast, for all but one of the wells, the mean zinc concentrations were lower for the discrete samples (Phase II samples). In general, the first sample taken after placement of the discrete sampling devices showed a decrease in concentration of the indicator parameters compared to the well-head sample taken just prior to placement of the sampling devices (See Table of Analytical Results in Appendix A).

Over time these concentrations tended to increase to, or exceed, the initial well-head concentrations. These results suggest 1) failure to isolate and produce Roubidoux water, or 2) contamination is from the Roubidoux. These uncertainties about the degree of isolation of the Roubidoux in discrete sampling led DEQ to do more work. Specifically, DEQ installed the five monitor wells to obtain more reliable and representative water quality data from the Roubidoux. The analytical results of discrete samples obtained from the new monitor wells are summarized in Table 2.

Table 2 shows that two monitor wells, the Quapaw #5-MW, and the Picher #6-MW, exceed background and tolerance limits for all three parameters and SMCLs for iron, indicating that the Roubidoux aquifer is impacted locally near these wells by mine water. The Quapaw #2 municipal well meets these criteria also, as seen in Table 1. The Commerce #5-MW monitor well produces the best quality water with sulfate and zinc concentrations representative of background values. Even though the iron concentrations are above background levels and below tolerance levels, the Roubidoux is not considered impacted by mine water at this site. The elevated iron concentrations may be from corrosion of the well casing due to H_2S gas present naturally in the Roubidoux and detected by odors during sampling.

Discrete samples from other wells are above background levels and exceed tolerance limits for two of the three parameters, indicating the Roubidoux is **probably** impacted by mine water near these wells. They are the Picher #2, Picher #3, Picher #4, and the Commerce #3 municipal wells. Some of the new monitor wells have parameters above background for two of the three parameters and above tolerance limits for one of the parameters indicating **possible** impacts to the Roubidoux by mine water. These are the Picher #5-MW and Picher #7-MW (aka: Picher-Cardin).

Table 2: Mean Concentration of Indicator Parameters in Monitor Wells (1997 – 2002)

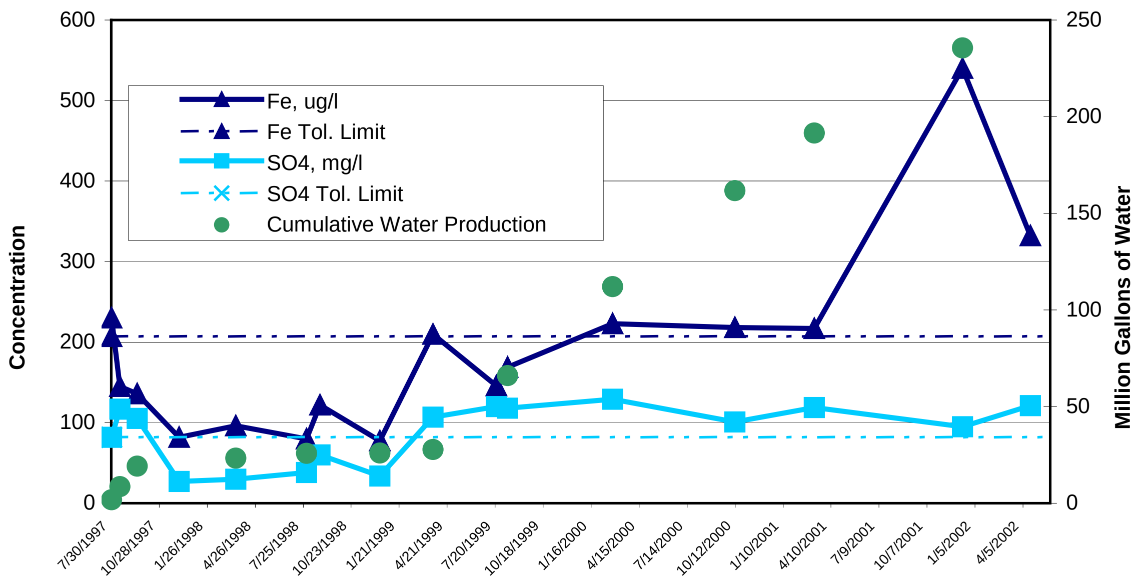
Well	Zinc (ug/l)	Iron (ug/l)	Sulfate (mg/l)
Background Conc.	8.8	61.5	25
Tolerance Limit	43	207	82
Secondary MCL	5,000	300	250
Picher #5-MW	<10	*151*	**83**
Picher #6-MW	**60**	**1,412**	**239**
Picher #7-MW	<10	*129*	**92**
Commerce #5-MW	<10	*157*	17
Quapaw #5-MW	**114**	**2,677**	**309**

* Note: Italicized values are above background but below tolerance limits.
Bold type indicates value greater than tolerance limit.
Where analyses are below detection limits, the detection limit value was used in calculation of means.
Total and dissolved metals concentrations were used in calculation of means.

Tests of water quality indicate the Picher #5-MW, Picher #7-MW and Commerce #5-MW monitor wells produce water of good quality for use as drinking water sources, with the Commerce well having the best water. The Picher #5-MW and Picher #7-MW have been connected to the public water supply systems of Picher and Cardin, with the Picher #7-MW being used as a backup well for both cities. Picher abandoned its other three wells that were impacted by mine water and uses the Picher #5-MW as their primary source of drinking water supply. The City of Commerce is working to incorporate the Commerce #5-MW well into its public water supply system. Commerce also has abandoned one of its wells (Commerce #3) due to impacts from mine water. These four abandoned wells will be plugged soon by DEQ, with EPA's approval, as part of the continued remedial action for Operable Unit #1 of the Tar Creek Superfund Site.

Water quality at the Picher #5-MW well appears to have degraded over time from near background levels initially to levels above the 95% tolerance limits for iron and sulfate around April 1999 (Figure 4). The increase in concentrations coincides with a sharp increase in water production from the well when Picher started using it as their main source of drinking water supply. The greater water production would cause a larger area of head differential between the Roubidoux and the Boone such that more Boone water could flow into the Roubidoux, and then into the well, if there were nearby conduits connecting the two aquifers. However, concentrations of the other indicator parameter, zinc, have remained below detection limits. This clouds the interpretation that the Roubidoux aquifer has been impacted by mine water at this well site due to the large amounts of water pumped. The trend of increasing mine water impacts to the Roubidoux could result in exceedances of MCLs in the future. Long term monitoring of these trends must continue to protect human health and to gain better understanding of the Boone - Roubidoux interactions.

Figure 4: WATER QUALITY DATA FOR PICHER #5 WELL
Iron and Sulfate Concentrations and 95% Tolerance Limits
plus Cumulative Water Production from the Well



The Picher #6-MW and Quapaw #5-MW monitor wells produce water of poor quality (high iron, sulfate and total dissolved solids concentrations). The two wells are not hooked into any public water supply system and probably never will be used for drinking water supply wells. The Picher #6-MW appears to be improving while the Quapaw #5-MW water remains the worst, both in terms of its water quality and quantity (low well yield). The Roubidoux Sandstone is encountered at more shallow depths near Quapaw than in wells to the west but is thin and water yields are low. Wells near Quapaw are thus drilled to greater depths to tap deeper formations (e.g., the Gunter Sandstone) to obtain more water.

The Town of Quapaw was counting on the Quapaw #5-MW well to be a good water producer so it could be used to replace the #2 well, which produces Roubidoux water of poor quality. The Quapaw #2 well is impacted by mine water but is currently being used by the town as a backup well. Two other wells near Quapaw were reported in the ROD as abandoned because of mine water influx. They were not mentioned by name but are thought to be the Quapaw #1-A and Quapaw #3 wells. DEQ plugged the Quapaw #1-A in 2000 and Eagle-Picher had previously plugged the Quapaw #3. The town needs another source of good water, but determining a location to place a new well is problematic due to the poorly defined extent of contamination in the Roubidoux near Quapaw. One possible option for the town would be to treat the well water for iron, zinc, sulfate, and dissolved solids removal.

Another cause for concern to the Town of Quapaw is that its main water supply, the Quapaw #4, is located a little over ½ mile south, in the direction of flow for the contaminated groundwater detected at the Quapaw #5-MW monitor well. It seems to be just a matter of time before the contaminants reach the producing well. However, based on simple calculations, the groundwater is estimated to be traveling at a rate of about 30 feet per year. If the withdrawal rates from the Quapaw #4 well remain constant, then it would take approximately 100 years for the contaminants to travel the distance between the two wells. Flowing groundwater travel rates may be faster where the formation is fractured, or if withdrawal rates increase.

After mine impacts in the Roubidoux were encountered at the Quapaw #5-MW monitor well, it became desirable to immediately plug the nearby abandoned municipal well, the Quapaw #1-A deep well. This would eliminate it as a possible contaminant source and the #5-MW well could be monitored for improved water quality. This would provide a means to directly evaluate the effectiveness of well plugging on water quality within the Roubidoux. Prior to plugging the Quapaw #1-A, a flow meter test was conducted in the well but did not show any appreciable downward flow of mine water from the Boone into the Roubidoux. Subsequent water quality tests at the Quapaw #5-MW monitor well have not shown any improvements. Another contaminant source may be indicated by these results and records show that there is an abandoned municipal well located nearby that may not be plugged. It will be investigated further and plugged if found.

Conclusions:

All Phase II AAM water quality data are below primary MCLs and all of the primary pollutants tested below, or very near, analytical detection limits. Currently, the Roubidoux aquifer still represents a useable source of drinking water and the produced water has been safe to drink. Furthermore, it has been demonstrated that a well can be constructed in the main part of the mine field and produce ample supply of good quality drinking water. Also, overall degradation of the Roubidoux water quality due to mine water impacts may be occurring at the Tar Creek Superfund site as indicated by increases in the levels of indicator parameters above background concentrations for the Roubidoux.

No definitive statement can be made about the effectiveness of well plugging in protecting the Roubidoux from acid mine water impacts since some contamination of the Roubidoux has been detected locally near several of the monitor wells that displayed indicator parameter concentrations above tolerance limits. However, the source of contamination of the Roubidoux near these wells cannot be conclusively determined (whether it is a nearby leaking abandoned well or naturally occurring conduit such as a fracture). The occurrence of contamination within the Roubidoux by mine water coupled with the difficulty in identifying specific contaminant sources, are reason enough to continue plugging of abandoned Roubidoux wells.

Some of the municipal wells have been impacted by mine water and have tested water quality parameters (iron, sulfate, and TDS) that are greater than SMCLs. In general, it is thought that a well which has become impacted by mine water will show elevated concentrations of the three indicator parameters and concentrations exceeding secondary MCLs for some parameters and would be removed from use as a drinking water supply source prior to any contaminants with primary MCLs reaching dangerous levels.

Recommendations:

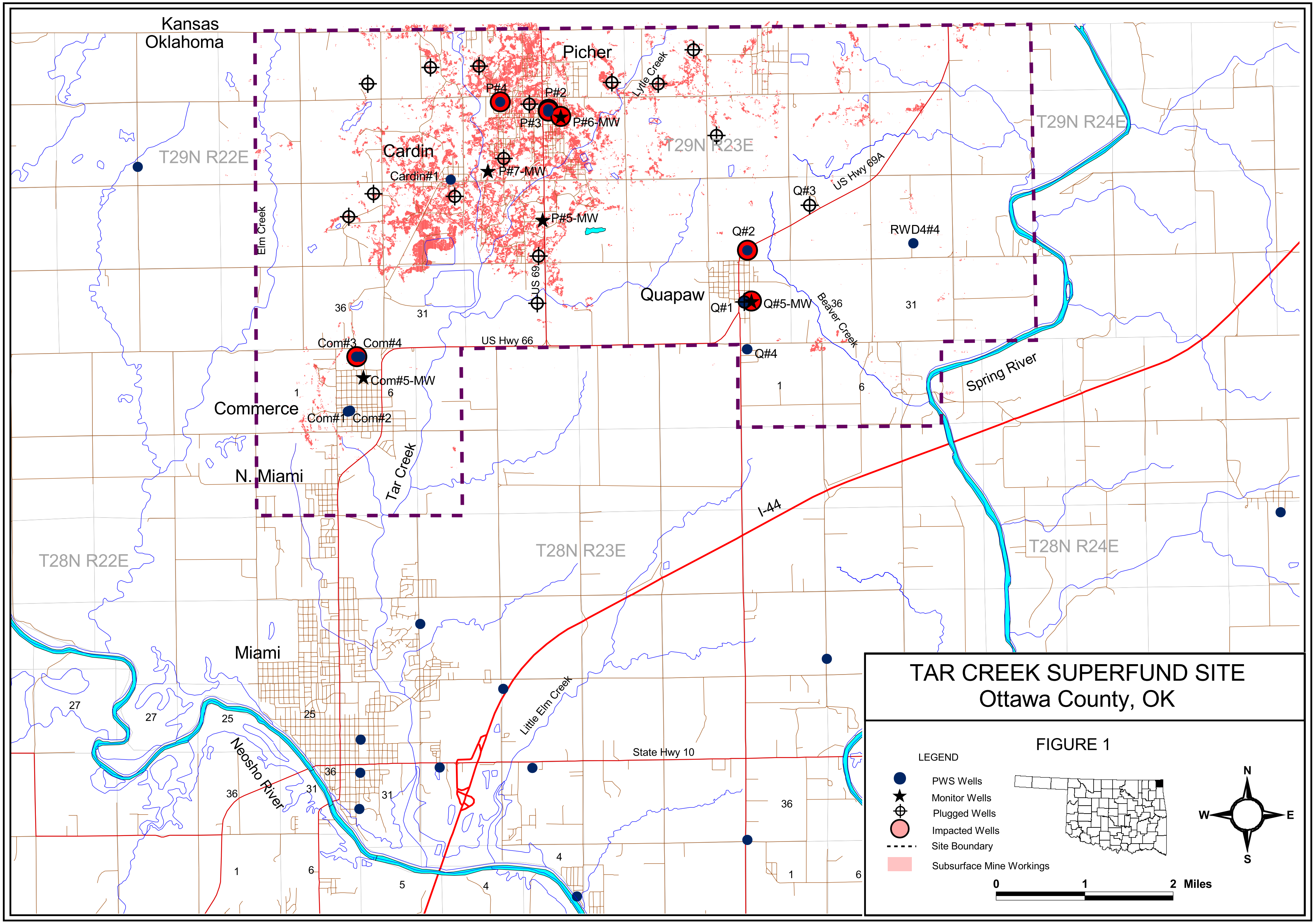
1) Since the concentrations of contaminants tested greater than Roubidoux background and increasing trends were observed at the Picher #5-MW, that could reach MCLs at some future date if trends persist, the long term effects of pumping Roubidoux water from below the mine pool needs to be assessed through continued monitoring. A long-term monitoring network composed of approximately ten wells should be sampled twice a year for five years.

2) A trend analyses should be performed on the well data to identify the existence of any significant trends. If established the trends could be used as a predictive tool for future management decisions.

3) All abandoned deep Roubidoux wells that are discovered in the future should be plugged as stated in the ROD.

4) Tolerance limits for the indicator parameters should be reevaluated based on new data. This data would be acquired through a sampling program composed of approximately ten wells located immediately outside the mining area similar to the program used in the Phase I AAM project.

FIGURES


TAR CREEK SUPERFUND SITE
Ottawa County, OK
FIGURE 1
LEGEND
PWS Wells
Monitor Wells
Plugged Wells
Impacted Wells
Site Boundary
Subsurface Mine Workings
0
1
2 Miles
N
S
E
W
Kansas
Oklahoma
Picher
Cardin
Quapaw
Commerce
N. Miami
Miami
T29N R22E
T29N R23E
T29N R24E
T28N R22E
T28N R23E
T28N R24E
P#4
P#2
P#3
P#6-MW
P#7-MW
P#5-MW
Cardin#1
Q#2
Q#3
Q#1
Q#5-MW
Q#4
RWD4#4
Com#3
Com#4
Com#5-MW
Com#1
Com#2
Elm Creek
Lytle Creek
Tar Creek
Beaver Creek
Spring River
Neosho River
Little Elm Creek
US Hwy 69A
US 69
US Hwy 66
I-44
State Hwy 10

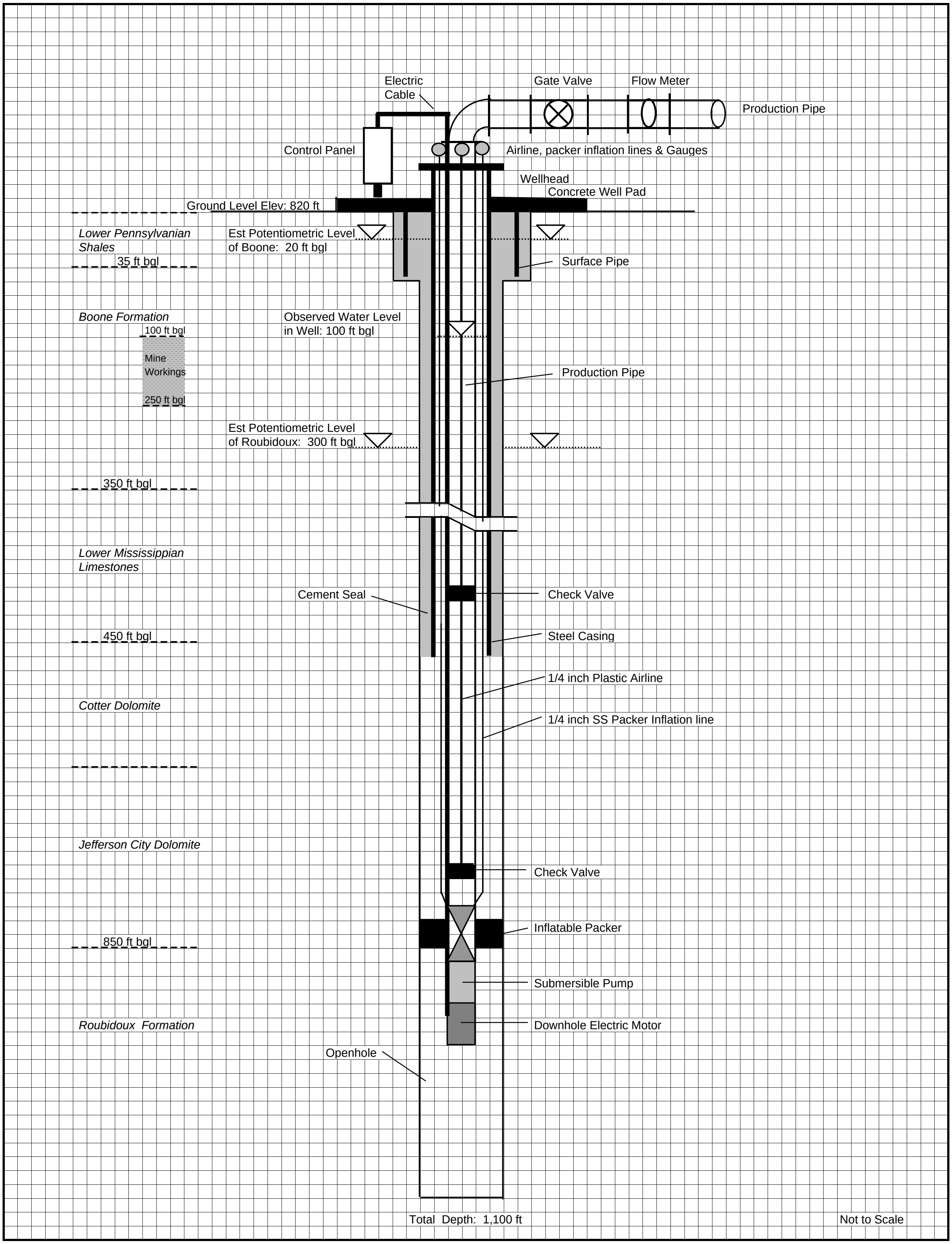


Figure 2: Typical Well Diagram with Packer Installed in Openhole

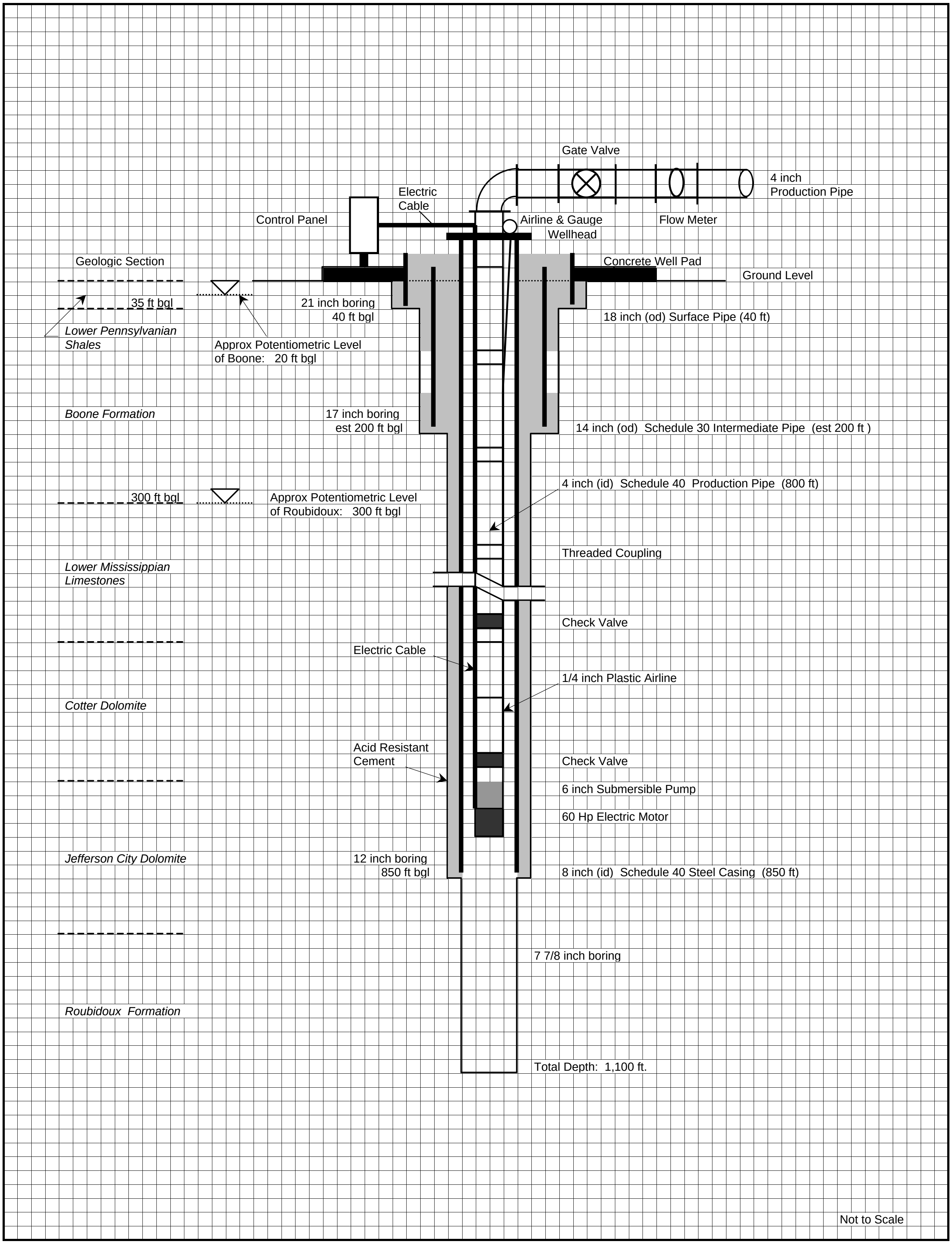


Figure 3: Well Design with 14 inch (od) Intermediate Casing

APPENDIX A

Analytical Data for Tar Creek After Action Monitoring - Phase II (Discrete Samples from Roubidoux Wells)

WELL	DATE		Spec Cond (Field) uS/cm	Temp (Field) ^oC	pH (Field)	Alkalinity $CaCO_3$ mg/l	Chloride Cl mg/l	Sulfate SO_4 mg/l	Tot Dis Sol TDS mg/l	Hardness $CaCO_3$ mg/l	Calcium Ca mg/l	Magnesium Mg mg/l	Sodium Na mg/l	Potassium K mg/l
		MCL/(SMCL)					**(250)**	**(250)**	**(500)**					
Commerce #3:		**SE NE NW NW 6-T28N-R23E; N 36 56 33.89, W 94 52 24.26, EL 812**												
	10/14/96	Totals	840	21	7.55	147.46	115.56	90.7	527	328.35	75	29	65	6
		Dissolved	-	-	-	na	na	na	na	na	75	29	66	6
	12/11/96	Totals	800	19.5	7.04	165.17	75.62	221.8	665	400	109	39	47	6
		Dissolved	-	-	-	na	na	na	na	na	109	38	48	6
	1/10/97	Totals	700	15	6.71	146	62.43	139.5	510	336	84	32	41	5
		Dissolved	-	-	-	na	na	na	na	na	83	32	40	5
	4/17/97	Totals	675	19	6.89	177	59.4	182.3	486	298	81	30	36	3
		Dissolved	-	-	-	na	na	na	na	na	80	30	37	3
	* 4/17/97	Totals	-	-	-	175	63.4	182.9	490	308	76	28	34	3
		Dissolved	-	-	-	na	na	na	na	na	80	30	37	3
	7/23/97	Totals	700	22	6.98	157	62	153.1	466	232	73	27	32	< 2
		Dissolved	-	-	-	na	na	na	na	na	73	27	32	< 2
	11/6/97	Totals	600	18	7.14	154	47.8	126.3	480	118	71	26	31	3
		Dissolved	-	-	-	na	na	na	na	na	72	26	32	4
		Averages	**719**	**19.1**	**7.05**	**160.23**	**69.46**	**156.7**	**518**	**289**	**82**	**30**	**41**	**4**
Commerce #5 MW:		**NW SE NW 6-T28N-R23E; N 36 56 19.66, W 94 52 17.90, EL 810**												
	10/13/00	Totals	333	20.5	7.68	113	16.1	11	179	129	na	na	11	na
		Dissolved	-	-	-	na	na	na	na	na	na	na	na	na
	10/13/00	Totals	333	20.5	7.68	112	15.7	10.3	174	129	28	14	12	2
		Dissolved	-	-	-	na	na	na	na	na	27	14	11	2
	3/9/01	Totals	296	15.6	7.75	118	13	12.4	165	125	28	14	10	2
		Dissolved	-	-	-	na	na	na	na	na	28	14	10	2
	12/13/01	Totals	282	17.7	7.48	119	9.2	40.9	123	126	27	13	10	2
		Dissolved	-	-	-	na	na	na	na	na	27	13	10	2
	4/18/02	Totals	294	20.6	7.5	109	15	11.6	149	128	28	14	11	2
		Dissolved	-	-	-	na	na	na	na	na	27	14	10	2
		Averages	**301**	**18.6**	**7.62**	**114.20**	**13.80**	**17.2**	**158**	**127**	**28**	**14**	**11**	**2**
Picher #2:		**NE SW NW NW 21-T29N-R23E; N 36 59 7.16, W 94 49 48.10, EL 820**												
	10/1/96	*Totals*	*490*	*20*	*6.87*	*145*	*13.93*	*151*	*369*	*266.66*	*61*	*27*	*14*	*4*
		Dissolved	-	-	-	*na*	*na*	*na*	*na*	*na*	*59*	*26*	*14*	*4*
	10/25/96	Totals	500	19.5	7.38	127.76	19.91	121	366	278.6	62	27	14	4
		Dissolved	-	-	-	na	na	na	na	na	63	27	13	3
	4/9/97	Totals	625	18	7.08	145	25	200.4	490	188	88	35	17	3
		Dissolved	-	-	-	na	na	na	na	na	86	35	17	3
	7/15/97	Totals	455	23	6.95	125	23.2	121	300	240	53	22	13	< 2
		Dissolved	-	-	-	na	na	na	na	na	53	22	12	< 2
	11/6/97	Totals	305	16	7.31	128	12.6	44.3	252	177	40	17	11	2
		Dissolved	-	-	-	na	na	na	na	na	39	17	11	2
	8/12/99	Totals	620	23.7	7.2	191	8.5	182	100	322	79	33	17	2
		Dissolved	-	-	-	na	na	na	na	na	78	33	18	2
		Averages	**501**	**20.0**	**7.18**	**143.35**	**17.84**	**133.7**	**302**	**241**	**64**	**27**	**14**	**3**

WELL	DATE	Antimony Sb mg/l	Arsenic As mg/l	Cadmium Cd mg/l	Chromium Cr mg/l	Iron Fe mg/l	Lead Pb mg/l	Manganese Mn mg/l	Mercury Hg mg/l	Nickel Ni mg/l	Selenium Se mg/l	Thallium Tl mg/l	Zinc Zn mg/l	CAT / AN BALANCE % Error
		0.006	**0.05**	**0.005**	**0.1**	**(0.3)**	**0.015**	**0.05**	**0.002**	**0.1**	**0.05**	**0.002**	**(5)**	
Commerce #3:														
	10/14/96	< 0.002	< 0.002	< 0.002	0.013	0.307	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.038	5.90
		< 0.002	< 0.002	< 0.002	0.012	0.281	< 0.005	na	< 0.0005	< 0.010	0.010	< 0.001	< 0.010	
	12/11/96	< 0.002	< 0.002	< 0.002	< 0.010	0.269	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.052	3.81
		< 0.002	< 0.002	< 0.002	< 0.010	0.264	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.018	
	1/10/97	< 0.002	< 0.002	< 0.002	< 0.010	0.210	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.036	7.07
		< 0.002	< 0.002	< 0.002	< 0.010	0.197	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.065	
	4/17/97	< 0.002	< 0.002	< 0.002	0.012	0.354	< 0.005	na	< 0.0008	< 0.010	< 0.010	< 0.001	0.040	-4.98
		< 0.002	< 0.002	< 0.002	0.011	0.352	< 0.005	na	< 0.0008	< 0.010	< 0.010	< 0.001	0.015	
	* 4/17/97	< 0.002	< 0.002	< 0.002	0.011	0.338	< 0.005	na	< 0.0008	< 0.010	< 0.010	< 0.001	0.039	-8.60
		< 0.002	< 0.002	< 0.002	0.011	0.346	< 0.005	na	< 0.0008	< 0.010	< 0.010	< 0.001	< 0.010	
	7/23/97	< 0.002	< 0.002	< 0.002	< 0.010	0.862	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.030	-5.33
		< 0.002	< 0.002	< 0.002	< 0.010	0.859	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	11/6/97	< 0.002	< 0.002	< 0.002	< 0.010	0.575	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.030	-0.17
		< 0.002	< 0.002	< 0.002	< 0.010	0.568	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.011**	**0.413**	**0.005**	**-**	**0.0006**	**0.010**	**0.010**	**0.001**	**0.029**	**0.18**
Commerce #5 MW:														
	10/13/00	< 0.002	< 0.002	< 0.002	< 0.010	0.208	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		na	na	na	na	na	na	na	na	na	na	na	na	
	10/13/00	< 0.002	< 0.002	< 0.002	< 0.010	0.220	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	3.78
		< 0.002	< 0.002	< 0.002	< 0.010	0.178	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	3/9/01	< 0.002	< 0.002	< 0.002	< 0.010	0.197	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	0.88
		< 0.002	< 0.002	< 0.002	< 0.010	0.137	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/13/01	< 0.002	< 0.002	< 0.002	< 0.010	0.159	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-9.16
		< 0.002	< 0.002	< 0.002	< 0.010	0.120	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	4/18/02	< 0.002	< 0.002	< 0.002	< 0.010	0.116	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	3.99
		< 0.002	< 0.002	< 0.002	< 0.010	0.082	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.010**	**0.157**	**0.005**	**0.010**	**0.0005**	**0.010**	**0.010**	**0.001**	**0.010**	**-0.26**
Picher #2:														
	10/1/96	*< 0.002*	*< 0.002*	*< 0.002*	*< 0.010*	*0.440*	*< 0.005*	*na*	*< 0.0005*	*0.010*	*< 0.010*	*< 0.001*	*0.270*	*-3.68*
		< 0.002	*< 0.002*	*< 0.002*	*< 0.010*	*0.376*	*< 0.005*	*na*	*< 0.0005*	*< 0.010*	*< 0.010*	*< 0.001*	*0.172*	
	10/25/96	< 0.002	< 0.002	< 0.002	< 0.010	0.181	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	3.37
		< 0.002	< 0.002	< 0.002	< 0.010	0.171	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	4/9/97	< 0.002	< 0.002	< 0.002	0.010	0.745	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.028	1.97
		< 0.002	< 0.002	< 0.002	< 0.010	0.719	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.027	
	7/15/97	< 0.002	< 0.002	< 0.002	< 0.010	0.277	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-6.09
		< 0.002	< 0.002	< 0.002	< 0.010	0.267	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	11/6/97	< 0.002	< 0.002	< 0.002	< 0.010	0.225	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.014	0.50
		< 0.002	< 0.002	< 0.002	< 0.010	0.138	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	8/12/99	< 0.002	< 0.002	< 0.002	< 0.010	0.674	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-2.94
		< 0.002	< 0.002	< 0.002	< 0.010	0.639	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.010**	**0.404**	**0.005**		**0.0005**	**0.010**	**0.010**	**0.001**	**0.014**	**-0.51**

WELL	DATE		Spec Cond (Field) uS/cm	Temp (Field) ^oC	pH (Field)	Alkalinity $CaCO_3$ mg/l	Chloride Cl mg/l	Sulfate SO_4 mg/l	Tot Dis Sol TDS mg/l	Hardness $CaCO_3$ mg/l	Calcium Ca mg/l	Magnesium Mg mg/l	Sodium Na mg/l	Potassium K mg/l
		MCL/(SMCL)					**(250)**	**(250)**	**(500)**					
Picher #3:		**NE SW NW NW 21-T29N-R23E; N 36 59 6.55 W 94 49 48.51; EL 820**												
	9/23/96	*Totals*	*800*	*21*	*6.7*	*174.44*	*19.9*	*245.5*	*646*	*457.7*	*115*	*46*	*21*	*5*
		Dissolved	*-*	*-*	*-*	*na*	*na*	*na*	*na*	*na*	*110*	*44*	*20*	*5*
	6/6/97	Totals	975	23	6.92	193	18	245.5	739	482	133	49	21	4
		Dissolved	-	-	-	na	na	na	na	na	131	48	21	4
	7/15/97	Totals	850	22	6.89	173	25.1	291.8	630	242	117	42	19	< 2
		Dissolved	-	-	-	na	na	na	na	na	114	41	19	< 2
	11/6/97	Totals	600	17	7.01	156	15.8	139	493	382	83	32	16	3
		Dissolved	-	-	-	na	na	na	na	na	82	31	16	2
		Averages	**808**	**20.7**	**6.94**	**174.00**	**19.63**	**225.4**	**621**	**369**	**110**	**41**	**19**	**3**
Picher #4:		**NE NE NE NW 20-T29N-R23E; N 36 59 13.34, W 94 50 26.10; 830**												
	9/16/96	*Totals*	*1120*	*20*	*7.03*	*223*	*24.83*	*410*	*920.88*	*660*	*163*	*53*	*27*	*6*
		Dissolved	*-*	*-*	*-*	*na*	*na*	*na*	*na*	*na*	*171*	*53*	*25*	*5*
	10/8/96	Totals	725	22	6.88	152.25	27.89	197.6	545	358.2	90	35	15	4
		Dissolved	-	-	-	na	na	na	na	na	90	35	15	4
	4/9/97	Totals	700	19	6.82	147	32	223	543	222	98	38	18	3
		Dissolved	-	-	-	na	na	na	na	na	99	38	17	3
	8/28/97	Totals	715	23	6.9	181	30.9	248.4	510	394	95	36	18	3
		Dissolved	-	-	-	na	na	na	na	na	96	36	18	3
	9/16/97	Totals	700	22	6.89	158	24.5	211.6	211	367	81	32	15	3
		Dissolved	-	-	-	na	na	na	na	na	81	32	15	3
	12/11/97	Totals	630	17.5	6.92	145	33.2	181.6	508	339	85	35	18	3
		Dissolved	-	-	-	na	na	na	na	na	81	34	17	2
		Averages	**694**	**20.7**	**6.88**	**156.65**	**29.70**	**212.4**	**463**	**336**	**90**	**35**	**17**	**3**
Picher #5-MW:		**SE SE NE 29-T29N-R23E; N 36 57 55.6, W 94 49 54.7; GL(topo) 812.**												
	7/30/97	Totals	470	22	7.04	137	52	82	310	248	na	na	17	na
		Dissolved	-	-	-	na	na	na	na	na	na	na	na	na
	8/15/97	Totals	550	22	7.3	131	44	117	375	248	60	27	17	3
		Dissolved	-	-	-	na	na	na	na	na	59	26	17	3
	9/16/97	Totals	550	22	6.94	130	31.7	105.3	371	283	57	26	17	3
		Dissolved	-	-	-	na	na	na	na	na	55	25	16	3
	12/4/97	Totals	400	18	7.17	124	34.5	41.1	271	220	49	21	18	3
		Dissolved	-	-	-	na	na	na	na	na	48	21	17	3
	* 12/4/97	Totals	-	-	-	128	34.7	13.1	269	214	48	21	18	3
		Dissolved	-	-	-	na	na	na	na	na	49	22	18	3
	3/20/98	Totals	325	15	7.06	109	59.7	29.9	42	180	39	18	19	3
		Dissolved	-	-	-	na	na	na	na	na	38	17	18	3
	7/31/98	Totals	485	21.5	6.85	185	31.7	38	352	260	57	27	19	3
		Dissolved	-	-	-	na	na	na	na	na	57	27	17	3
	8/25/98	Totals	480	21	7.06	108	37.1	60	345	236	55	25	19	3
		Dissolved	-	-	-	na	na	na	na	na	55	25	19	3
	12/15/98	Totals	380	20	7.18	117	36.5	34	273	191.7	40	19	19	1.3
		Dissolved	-	-	-	na	na	na	na	na	40	19	19	2
	* 12/15/98	Totals	-	-	-	123	34.9	33.8	245	182.2	40	19	20	2.7
		Dissolved	-	-	-	na	na	na	na	na	40	18	19	1.2

WELL	DATE	Antimony Sb mg/l	Arsenic As mg/l	Cadmium Cd mg/l	Chromium Cr mg/l	Iron Fe mg/l	Lead Pb mg/l	Manganese Mn mg/l	Mercury Hg mg/l	Nickel Ni mg/l	Selenium Se mg/l	Thallium Tl mg/l	Zinc Zn mg/l	CAT / AN BALANCE % Error
		0.006	**0.05**	**0.005**	**0.1**	**(0.3)**	**0.015**	**0.05**	**0.002**	**0.1**	**0.05**	**0.002**	**(5)**	
Picher #3:														
	9/23/96	*< 0.002*	*< 0.002*	*< 0.002*	*< 0.010*	*0.377*	*< 0.005*	*na*	*< 0.0008*	*0.013*	*< 0.010*	*< 0.001*	*0.093*	*7.13*
		< 0.002	*< 0.002*	*< 0.002*	*< 0.010*	*0.264*	*< 0.005*	*na*	*< 0.0008*	*0.012*	*< 0.010*	*< 0.001*	*0.089*	
	6/6/97	< 0.002	0.002	< 0.002	< 0.010	0.468	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.052	10.44
		< 0.002	0.002	< 0.002	< 0.010	0.444	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.063	
	7/15/97	< 0.002	0.002	< 0.002	0.014	0.803	< 0.005	na	< 0.0005	0.014	< 0.010	< 0.001	0.025	-0.58
		< 0.002	0.002	< 0.002	0.012	0.778	< 0.005	na	< 0.0005	0.014	< 0.010	< 0.001	0.025	
	11/6/97	< 0.002	< 0.002	< 0.002	< 0.010	1.116	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.016	7.79
		< 0.002	< 0.002	< 0.002	< 0.010	1.024	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.011**	**0.772**	**0.005**		**0.0005**	**0.011**	**0.010**	**0.001**	**0.032**	**5.33**
Picher #4:														
	9/16/96	*< 0.002*	*0.003*	*< 0.002*	*0.017*	*7.174*	*< 0.005*	*na*	*< 0.0008*	*0.067*	*0.095*	*< 0.001*	*2.430*	*0.48*
		< 0.002	*< 0.002*	*< 0.002*	*0.016*	*3.212*	*< 0.005*	*na*	*< 0.0008*	*0.041*	*0.024*	*< 0.001*	*0.104*	
	10/8/96	< 0.002	< 0.002	< 0.002	0.013	0.279	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	1.14
		< 0.002	< 0.002	< 0.002	0.012	0.247	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	4/9/97	< 0.002	< 0.002	< 0.002	0.010	2.566	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.011	2.27
		< 0.002	< 0.002	< 0.002	< 0.010	2.539	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	8/28/97	< 0.002	< 0.002	< 0.002	< 0.010	0.709	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.015	-6.02
		< 0.002	< 0.002	< 0.002	< 0.010	0.659	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	9/16/97	< 0.002	< 0.002	< 0.002	< 0.010	0.404	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-5.42
		< 0.002	< 0.002	< 0.002	< 0.010	0.380	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/11/97	< 0.002	< 0.002	< 0.002	< 0.010	0.716	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.022	2.35
		< 0.002	< 0.002	< 0.002	< 0.010	0.568	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.011**	**0.907**	**0.005**		**0.0005**	**0.010**	**0.010**	**0.001**	**0.012**	**-1.39**
Picher #5-MW:														
	7/30/97	< 0.002	< 0.002	< 0.002	< 0.010	0.230	< 0.005	<0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
			na	na	na	na	na	na	na	na	na	na	na	
	8/15/97	< 0.002	< 0.002	< 0.002	< 0.010	0.145	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-2.13
		< 0.002	< 0.002	< 0.002	< 0.010	0.069	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	9/16/97	< 0.002	< 0.002	< 0.002	< 0.010	0.136	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	1.01
		< 0.002	< 0.002	< 0.002	< 0.010	0.133	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/4/97	< 0.002	< 0.002	< 0.002	< 0.010	0.080	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	7.78
		< 0.002	< 0.002	< 0.002	< 0.010	0.075	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 12/4/97	< 0.002	< 0.002	< 0.002	< 0.010	0.084	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	13.35
		< 0.002	< 0.002	< 0.002	< 0.010	0.063	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	3/20/98	< 0.002	< 0.002	< 0.002	< 0.010	0.096	< 0.005	na	< 0.0005	< 0.025	< 0.010	< 0.001	< 0.005	-1.75
		< 0.002	< 0.002	< 0.002	< 0.010	0.058	< 0.005	na	< 0.0005	< 0.025	< 0.010	< 0.001	< 0.005	
	7/31/98	< 0.002	< 0.002	< 0.002	< 0.010	0.080	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	5.18
		< 0.002	< 0.002	< 0.002	< 0.010	0.064	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	8/25/98	< 0.002	< 0.002	< 0.002	< 0.010	0.122	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	12.32
		< 0.002	< 0.002	< 0.002	< 0.010	0.069	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/15/98	< 0.002	< 0.002	< 0.002	< 0.010	0.068	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	4.05
		< 0.002	< 0.002	< 0.002	< 0.010	0.044	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 12/15/98	< 0.002	< 0.002	< 0.002	< 0.010	0.087	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	4.08
		< 0.002	< 0.002	< 0.002	< 0.010	0.034	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	

WELL	DATE		Spec Cond (Field) uS/cm	Temp (Field) °C	pH (Field)	Alkalinity $CaCO_3$ mg/l	Chloride Cl mg/l	Sulfate SO_4 mg/l	Tot Dis Sol TDS mg/l	Hardness $CaCO_3$ mg/l	Calcium Ca mg/l	Magnesium Mg mg/l	Sodium Na mg/l	Potassium K mg/l
		MCL/(SMCL)					**(250)**	**(250)**	**(500)**					
	3/25/99	Totals	440	15	7.04	125	30.4	107	342	292	55	26	19	2.7
		Dissolved	-	-	-	na	na	na	na	na	55	25	18	2.7
	7/22/99	Totals	490	19.5	7.05	135	24.5	120	370	262	64	29	22	3
		Dissolved	-	-	-	na	na	na	na	na	64	29	21	3
	* 7/22/99	Totals	-	-	-	129	23.1	119	371	262	64	29	18	3
		Dissolved	-	-	-	na	na	na	na	na	63	29	19	3
	8/12/99	Totals	550	23	7.45	178	23.9	118	106	268	62	28	19	2
		Dissolved	-	-	-	na	na	na	na	na	na	na	na	na
	2/25/00	Totals	621	20.2	7.07	153	30	129	379	284	60	28	19	2
		Dissolved	-	-	-	na	na	na	na	na	59	28	18	3
	10/11/00	Totals	571	20.2	7.15	134	24.3	101	366	280	55	27	17	3
		Dissolved	-	-	-	na	na	na	na	na	56	27	17	3
	3/9/01	Totals	580	19.1	7.22	151	24.3	119	375	266	58	28	17	3
		Dissolved	-	-	-	na	na	na	na	na	57	28	17	3
	12/13/01	Totals	527	15.4	7.21	134	35.6	94.8	429	216	49	24	23	3
		Dissolved	-	-	-	na	na	na	na	na	49	24	23	3
	4/18/02	Totals	591	19.9	7.11	136	25	121	377	271	62	29	17	3
		Dissolved	-	-	-	na	na	na	na	na	62	29	17	3
		Averages	**490**	**19.6**	**7.12**	**135.11**	**33.57**	**83.3**	**314**	**245**	**54**	**25**	**18**	**3**
Picher #6 MW:		**SE NW NW 21-T29N-R23E; N 36 59 00.8, W 94 49 38.8, EL 821 Topo**												
	10/12/00	Totals	980	23	7.05	220	6.8	294	842	973	na	na	19	na
		Dissolved	-	-	-	na	na	na	na	na	na	na	na	na
	10/17/00	Totals	900	20.5	6.94	207	6.7	307	836	874	153	57	17	3
		Dissolved	-	-	-	na	na	na	na	na	152	57	17	3
	2/26/01	Totals	863	19.1	7.08	191	8.8	358	623	483	111	42	16	3
		Dissolved	-	-	-	na	na	na	na	na	111	42	16	3
	12/13/01	Totals	569	18.9	7.13	149	6.7	152	370	276	65	27	13	2
		Dissolved	-	-	-	na	na	na	na	na	65	27	13	2
	4/18/02	Totals	565	20.3	7.24	142	7.1	86	364	280	63	27	13	2
		Dissolved	-	-	-	na	na	na	na	na	65	27	12	2
		Averages	**775**	**20.4**	**7.09**	**181.80**	**7.22**	**239.4**	**607**	**577**	**98**	**38**	**15**	**3**
Picher #7 MW:		**aka: PICHER - CARDIN MW; NW SE SW 20-T29N-R23E; N 36 58 28.2, W 94 50 38.0, EL 810**												
	10/13/00	Totals	495	21.7	7.59	124	14.3	89.1	313	244	na	na	14	na
		Dissolved	-	-		na	na	na	na	na	na	na	na	na
	10/17/00	Totals	453	16.9	7.25	120	15.7	71.1	282	215	45	22	13	2
		Dissolved	-	-	-	na	na	na	na	na	45	22	13	2
	* 10/17/00	Totals	-	-	-	117	15.6	68.4	277	216	46	23	13	2
		Dissolved	-	-	-	na	na	na	na	na	45	23	12	2
	3/9/01	Totals	546	17.7	7.48	174	14.6	121	351	257	55	28	13	2
		Dissolved	-	-	-	na	na	na	na	na	54	28	13	2
	12/13/01	Totals	455	16.9	7.6	131	18	93.3	241	211	45	23	14	3
		Dissolved	-	-	-	na	na	na	na	na	45	23	13	3
	* 12/13/01	Totals	-	-	-	131	15.8	93.7	253	203	47	23	14	3
		Dissolved	-	-	-	na	na	na	na	na	46	23	14	3
	4/19/02	Totals	525	20.2	7.38	132	14.1	112	332	255	54	27	13	3
		Dissolved	-	-	-	na	na	na	na	na	53	27	13	2
	* 4/19/02	Totals	-	-	-	132	14.2	91	338	255	54	28	13	3
		Dissolved	-	-	-	na	na	na	na	na	55	28	13	3
		Averages	**495**	**18.7**	**7.46**	**132.63**	**15.29**	**92.5**	**298**	**232**	**49**	**25**	**13**	**3**

WELL	DATE	Antimony Sb mg/l	Arsenic As mg/l	Cadmium Cd mg/l	Chromium Cr mg/l	Iron Fe mg/l	Lead Pb mg/l	Manganese Mn mg/l	Mercury Hg mg/l	Nickel Ni mg/l	Selenium Se mg/l	Thallium Tl mg/l	Zinc Zn mg/l	CAT / AN BALANCE % Error
		0.006	**0.05**	**0.005**	**0.1**	**(0.3)**	**0.015**	**0.05**	**0.002**	**0.1**	**0.05**	**0.002**	**(5)**	
	3/25/99	< 0.002	< 0.002	< 0.002	< 0.010	0.210	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	1.73
		< 0.002	< 0.002	< 0.002	< 0.010	< 0.010	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	7/22/99	< 0.002	< 0.002	< 0.002	< 0.010	0.146	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	5.81
		< 0.002	< 0.002	< 0.002	< 0.010	0.116	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 7/22/99	< 0.002	< 0.002	< 0.002	< 0.010	0.155	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	6.04
		< 0.002	< 0.002	< 0.002	< 0.010	0.129	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	8/12/99	< 0.002	< 0.002	< 0.002	< 0.010	0.169	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-3.18
		na	na	na	na	na	na	na	na	na	na	na	na	
	2/25/00	< 0.002	< 0.002	< 0.002	< 0.010	0.223	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-3.24
		< 0.002	< 0.002	< 0.002	< 0.010	0.216	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	10/11/00	< 0.002	< 0.002	< 0.002	< 0.010	0.218	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	2.82
		< 0.002	< 0.002	< 0.002	< 0.010	0.206	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	3/9/01	< 0.002	< 0.002	< 0.002	< 0.010	0.173	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-1.36
		< 0.002	< 0.002	< 0.002	< 0.010	0.156	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/13/01	< 0.002	< 0.002	< 0.002	< 0.010	0.540	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-1.42
		< 0.002	< 0.002	< 0.002	< 0.010	0.393	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	0.014	
	4/18/02	< 0.002	< 0.002	< 0.002	< 0.010	0.332	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	2.90
		< 0.002	< 0.002	< 0.002	< 0.010	0.323	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.010**	**0.151**	**0.005**	**0.010**	**0.0005**	**0.011**	**0.010**	**0.001**	**0.010**	**1.99**
Picher #6 MW:														
	10/12/00	< 0.002	0.004	< 0.002	< 0.010	2.288	< 0.005	0.032	< 0.0005	0.026	< 0.010	< 0.001	0.098	
		na	na	na	na	na	na	na	na	na	na	na	na	
	10/17/00	< 0.002	0.004	< 0.002	< 0.010	2.304	< 0.005	0.027	< 0.0005	0.030	< 0.010	< 0.001	0.110	10.16
		< 0.002	0.004	< 0.002	< 0.010	2.295	< 0.005	0.028	< 0.0005	0.033	< 0.010	< 0.001	0.112	
	2/26/01	< 0.002	0.004	< 0.002	< 0.010	1.669	< 0.005	0.024	< 0.0005	0.032	< 0.010	< 0.001	0.079	-8.22
		< 0.002	0.004	< 0.002	< 0.010	1.659	< 0.005	0.025	< 0.0005	0.032	< 0.010	< 0.001	0.078	
	12/13/01	< 0.002	0.003	< 0.002	< 0.010	0.677	< 0.005	0.012	< 0.0005	0.010	< 0.010	< 0.001	0.016	-2.00
		< 0.002	0.003	< 0.002	< 0.010	0.653	< 0.005	0.012	< 0.0005	< 0.010	< 0.010	< 0.001	0.016	
	4/18/02	< 0.002	< 0.002	< 0.002	< 0.010	0.600	< 0.005	0.011	< 0.0005	< 0.010	< 0.010	< 0.001	0.015	10.68
		< 0.002	< 0.002	< 0.002	< 0.010	0.563	< 0.005	0.011	< 0.0005	< 0.010	< 0.010	< 0.001	0.017	
		0.002	**0.003**	**0.002**	**0.010**	**1.412**	**0.005**	**0.020**	**0.0005**	**0.021**	**0.010**	**0.001**	**0.060**	**-0.31**
Picher #7 MW:														
	10/13/00	< 0.002	< 0.002	< 0.002	< 0.010	0.348	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		na	na	na	na	na	na	na	na	na	na	na	na	
	10/17/00	< 0.002	< 0.002	< 0.002	< 0.010	0.163	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	3.91
		< 0.002	< 0.002	< 0.002	< 0.010	0.159	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 10/17/00	< 0.002	< 0.002	< 0.002	< 0.010	0.180	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	6.69
		< 0.002	< 0.002	< 0.002	< 0.010	0.164	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	3/9/01	< 0.002	< 0.002	< 0.002	< 0.010	0.173	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-6.15
		< 0.002	< 0.002	< 0.002	< 0.010	0.160	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	12/13/01	< 0.002	< 0.002	< 0.002	< 0.010	0.063	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-2.46
		< 0.002	< 0.002	< 0.002	< 0.010	0.049	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 12/13/01	< 0.002	< 0.002	< 0.002	< 0.010	0.074	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	-0.91
		< 0.002	< 0.002	< 0.002	< 0.010	0.048	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	4/19/02	< 0.002	< 0.002	< 0.002	< 0.010	0.092	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	1.75
		< 0.002	< 0.002	< 0.002	< 0.010	0.073	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
	* 4/19/02	< 0.002	< 0.002	< 0.002	< 0.010	0.111	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	6.70
		< 0.002	< 0.002	< 0.002	< 0.010	0.079	< 0.005	< 0.010	< 0.0005	< 0.010	< 0.010	< 0.001	< 0.010	
		0.002	**0.002**	**0.002**	**0.010**	**0.129**	**0.005**	**0.010**	**0.0005**	**0.010**	**0.010**	**0.001**	**0.010**	**1.32**

WELL	DATE		Spec Cond (Field) uS/cm	Temp (Field) ^{o}C	pH (Field)	Alkalinity $CaCO_3$ mg/l	Chloride Cl mg/l	Sulfate SO_4 mg/l	Tot Dis Sol TDS mg/l	Hardness $CaCO_3$ mg/l	Calcium Ca mg/l	Magnesium Mg mg/l	Sodium Na mg/l	Potassium K mg/l
		MCL/(SMCL)					**(250)**	**(250)**	**(500)**					
Quapaw #2:		**NE SE SE SW 26-T29N-R23E; N 36 57 37.36, W 94 47 9.75, EL 840 Topo**												
	10/14/96	*Totals*	*600*	*18.5*	*7.22*	*151.5*	*31.87*	*121.9*	*452*	*228.85*	*74*	*31*	*22*	*5*
		Dissolved	*-*	*-*	*-*	*na*	*na*	*na*	*na*	*na*	*74*	*31*	*21*	*5*
	2/4/97	Totals	700	16	7.13	193.8	44.63	212.1	607	322	86	39	25	5
		Dissolved	-	-	-	na	na	na	na	na	88	40	25	< 1
	7/17/97	Totals	950	23.5	6.85	205	65.6	269	713	457	114	46	33	3
		Dissolved	-	-	-	na	na	na	na	na	115	46	33	3
	11/6/97	Totals	875	17	6.91	210	59.4	243.6	774	410	114	47	33	5
		Dissolved	-	-	-	na	na	na	na	na	113	47	33	4
		Averages	**842**	**18.8**	**6.96**	**202.93**	**56.54**	**241.6**	**698**	**396**	**105**	**44**	**30**	**4**
Quapaw #5 MW:		**SW SW NE 35-T29N-R23E; N 36 57 04.80, W 94 47 07.12, EL 850 Topo**												
	10/13/00	Totals	1166	21.5	7.02	221	71.3	279	825	907	na	na	42	na
		Dissolved	-	-	-	na	na	na	na	na	na	na	na	na
	3/9/01	Totals	1144	20.2	7	224	69.2	293	814	558	124	57	41	6
		Dissolved	-	-	-	na	na	na	na	na	148	74	33	3
	* 3/9/01	Totals	-	-	-	226	68.3	290	809	555	149	74	33	3
		Dissolved	-	-	-	na	na	na	na	na	125	57	40	6
	12/14/01	Totals	1237	15.3	6.96	234	80.3	376	828	610	133	61	49	7
		Dissolved	-	-	-	na	na	na	na	na	126	59	48	7
	4/18/02	Totals	1231	21	6.77	224	86.6	305	890	665	135	63	47	7
		Dissolved	-	-	-	na	na	na	na	na	130	61	46	7
		Averages	**1195**	**19.5**	**6.94**	**225.80**	**75.14**	**308.6**	**833**	**659**	**134**	**63**	**42**	**6**

NOTE: Detection limits used in calculation of means; total and dissolved metals concentrations used in calculation of means; means are in bold type; well head samples are in italics type; Duplicate samples are highlighted with asterisk near date of sample.

WELL	DATE	Antimony Sb mg/l	Arsenic As mg/l	Cadmium Cd mg/l	Chromium Cr mg/l	Iron Fe mg/l	Lead Pb mg/l	Manganese Mn mg/l	Mercury Hg mg/l	Nickel Ni mg/l	Selenium Se mg/l	Thallium Tl mg/l	Zinc Zn mg/l	CAT / AN BALANCE % Error
		0.006	**0.05**	**0.005**	**0.1**	**(0.3)**	**0.015**	**0.05**	**0.002**	**0.1**	**0.05**	**0.002**	**(5)**	
Quapaw #2:														
	10/14/96	*< 0.002*	*0.003*	*< 0.002*	*0.015*	*1.707*	*< 0.005*	*na*	*0.0007*	*< 0.010*	*< 0.010*	*< 0.001*	*0.146*	*6.27*
		< 0.002	*0.002*	*< 0.002*	*0.013*	*1.566*	*< 0.005*	*na*	*< 0.0005*	*< 0.010*	*< 0.010*	*< 0.001*	*0.029*	
	2/4/97	< 0.002	< 0.002	< 0.002	0.014	1.335	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.044	-4.55
		< 0.002	< 0.002	< 0.002	0.013	1.336	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.043	
	7/17/97	< 0.002	0.002	< 0.002	0.015	1.807	< 0.005	na	< 0.0005	0.010	< 0.010	< 0.001	0.063	-2.84
		< 0.002	0.002	< 0.002	0.015	1.765	< 0.005	na	< 0.0005	0.010	< 0.010	< 0.001	0.060	
	11/6/97	< 0.002	< 0.002	< 0.002	< 0.010	1.688	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.061	0.22
		< 0.002	< 0.002	< 0.002	< 0.010	1.653	< 0.005	na	< 0.0005	< 0.010	< 0.010	< 0.001	0.059	
		0.002	**0.002**	**0.002**	**0.013**	**1.597**	**0.005**		**0.0005**	**0.010**	**0.010**	**0.001**	**0.055**	**-1.89**
Quapaw #5 MW:														
	10/13/00	< 0.002	0.003	< 0.002	< 0.010	2.832	< 0.005	0.036	< 0.0005	< 0.010	< 0.010	< 0.001	0.132	
		na	na	na	na	na	na	na	na	na	na	na	na	
	3/9/01	< 0.002	0.003	< 0.002	< 0.010	2.325	< 0.005	0.036	< 0.0005	< 0.010	< 0.010	< 0.001	0.118	1.13
		< 0.002	0.003	< 0.002	< 0.010	2.599	< 0.005	0.036	< 0.0005	< 0.010	< 0.010	< 0.001	0.115	
	* 3/9/01	< 0.002	0.003	< 0.002	< 0.010	2.855	< 0.005	0.036	< 0.0005	< 0.010	< 0.010	< 0.001	0.113	9.29
		< 0.002	0.003	< 0.002	< 0.010	2.082	< 0.005	0.035	< 0.0005	< 0.010	< 0.010	< 0.001	0.109	
	12/14/01	< 0.002	0.003	< 0.002	< 0.010	2.762	0.012	0.037	< 0.0005	< 0.010	< 0.010	< 0.001	0.135	-2.79
		< 0.002	0.004	< 0.002	< 0.010	2.619	< 0.005	0.037	< 0.0005	< 0.010	< 0.010	< 0.001	0.141	
	4/18/02	< 0.002	0.003	< 0.002	< 0.010	3.072	< 0.005	0.037	< 0.0005	< 0.010	< 0.010	< 0.001	0.080	3.19
		< 0.002	0.003	< 0.002	< 0.010	2.943	< 0.005	0.037	< 0.0005	< 0.010	< 0.010	< 0.001	0.080	
		0.002	**0.003**	**0.002**	**0.010**	**2.677**	**0.006**	**0.036**	**0.0005**	**0.010**	**0.010**	**0.001**	**0.114**	**2.98**

NOTE: Detection limits used in calculation of means; total and dissolved metals concentrations used in calculation of means; means are in bold type; well head samples are in italics type; Duplicate samples are highlighted with asterisk near date of sample.

APPENDIX B

Comparison of Roubidoux Water and Mine Water Quality

Parameter	Roubidoux water*	Mine Water**	MCLs
Total Zinc (ug/l)	8.8	108,000	(5,000)
Total Iron (ug/l)	61.5	110,000	(300)
Sulfate (mg/l)	25	1,950	(250)
Aluminum (ug/l)	51.7	9,040	(500 – 200)
Total Manganese (ug/l)	4.3	3,370	(50)
Total Nickel (ug/l)	6.7	1,800	100
Total Lead (ug/l)	4.8	220	15
Total Cadmium (ug/l)	2	310	5
Total Copper (ug/l)	---	45	(1,000)
Total Arsenic (ug/l)	---	2.8	50
Dissolved Solids (mg/l)	*290*	*3,410*	(500)
Specific Conductance (uS/cm)	*566*	*2,680*	---
Hardness (mg/l $CaCO_3$)	*142*	*1,800*	---
Alkalinity (mg/l $CaCO_3$)	*143*	*23*	---
pH	*7.9*	*6.4*	(6.5 – 8.5)

* Means of sample results from 10 wells outside mining area, AAM: 1993 data. (Note: Detection Limits used in calculating averages).

** Mean concentrations of mine water (Playton, Davis and McClaflin, 1980).

Italicized values: a) 50th percentile values from Roubidoux wells in NE Oklahoma (Christenson, 1995).
b) 50th percentile values of mine water (Playton, Davis, and McClaflin, 1980).

Parentheses indicate Secondary MCLs

PIPER PLOT: MINE WATER IN BOONE (MW) & ROUBIDOUX WATER

Parameter	MIne Water	Roubidoux
Ca	395	31.9
Mg	133	23
Na	54	15.4
K	4	2.5
HCO3	61	138
SO4	1950	86.7
Cl	11.8	19.4
Fe	88	0.31
Al	4.9	---
Zn	175	0.017

Note: All values in mg/l