

# **19<sup>th</sup> Avenue Landfill Superfund Site 2010 Five Year Review**

## **APPENDICES**

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## **Appendix A - Analysis of Groundwater Conditions, September 2010**

## **APPENDIX A**

### **ANALYSIS OF CURRENT GROUNDWATER CONDITIONS AT NINETEENTH AVENUE LANDFILL SUPERFUND SITE For 2010 Five-Year Review Report**

#### **Overview**

A review of the groundwater monitoring data for the Nineteenth Avenue Landfill Superfund Site during this Five-Year Review period of 2005 through June 2010 indicates that a few contaminants (arsenic, nitrate, 1,1-dichloroethene, and some metals) have been detected in nearby wells at concentrations above maximum contaminant limits (MCLs) or Site cleanup standards. Some of these chemicals appear to be naturally-occurring or from other sources, while others may be related to the compounds disposed of at the Nineteenth Avenue Landfill. The purpose of this analysis is to evaluate the site hydrogeology, monitoring well network, historical water levels and water quality data, groundwater regulatory requirements and other related information to determine whether additional sampling and analysis, investigation (additional monitor wells and/or remedial actions may be necessary to address these exceedances of groundwater cleanup standards. There is historical evidence that the intermittent or irregular detections could be a result of potential leakage from the landfill during periods when elevated groundwater levels re-mobilize site contaminants. However, there also is evidence that some exceedances of water quality standards are due to detections of contaminants from upgradient, off-site sources or other factors than potential contact of the groundwater table with the landfill refuse during periods of high flow in the adjacent Salt River.

#### **Site Location**

The 213 acre Nineteenth Avenue Landfill is located in an industrial area within the municipal boundaries of Phoenix and the property is owned by the City. (Attachment A, Figure 1, 2000 Five-Year Review (FYR) Report) The landfill is divided by the Salt River channel into two separate sections (known as Cell A and Cell A-1). Cell A is approximately 200 acres in size and is located north of the Salt River. Cell A-1 is approximately 13 acres and is located south of the Salt River. See Figure 1.2, 1989 RAP (Attachment B, Figure 2, 2000 FYR Report). The Salt River drains a large area in north-central and northeastern Arizona. The river channel is often dry in the vicinity of the landfill because river flows are controlled by a system of upstream water conservation dams. Water is released from the reservoirs when they become full. These controlled release results in river flows past the landfill. Flows in the Salt River also occur due to runoff from local rainfall or local discharge of groundwater pumped to dewater sand and gravel pits of construction projects. These nuisance flows are low volume flows. (p. 2-8, 1989 Remedial Action Plan (RAP)).

The 1989 ADEQ Remedial Action Plan (RAP) included a comprehensive summary of the groundwater hydrogeology, including the water quality, at the time the Remedial Investigation/ Feasibility Study (RI/FS) was completed in 1988. The RI findings are summarized in the RAP as follows.

### **Site Hydrogeology**

The Nineteenth Avenue Landfill is underlain by alluvial materials deposited within the West Basin of the Salt River Valley. (Attachment C, 1989 RAP, Figure 21.6, Hydrogeologic Conceptual Diagram). These materials can generally be divided into five different units which extend 350 feet below ground surface (bgs). There is a 15 foot surface layer composed of silty sand. Beneath this layer is approximately 100 feet of cobbles and coarse gravels. These next three units below this layer are divisions within the Upper Alluvial Unit. (Attachment D, Figure 2.10, 1989 RAP, Generalized Stratigraphic Column) (p. 2-28, RAP)

The alluvial materials beneath the site can transmit a relatively large amount of water because they are generally coarse grained. The transmissivity of the materials between a depth of approximately 100 and 150 feet is estimated to be 190,000 gallons per day per foot. The transmissivity of the cobble and gravel deposits above 100 feet is probably even greater. (p. 2-28, RAP)

#### Groundwater Flow Direction and Depth

The groundwater flow direction beneath the landfill generally flows from the southeast to the northwest at a rate of 1 to 8 feet per day. Measured water levels have varied between 20 and 80 feet bgs, with an average depth to groundwater of 50 to 60 feet. (Attachment E, Fourth Quarter 2007 Groundwater Monitoring Report, City of Phoenix, Figure 1, Groundwater Elevations) The depth to water and the groundwater flow rates at the landfill are influenced by irrigation and industrial wells that pump groundwater and by recharge from surface water. Groundwater flow gradients, and therefore flow rates, increase during the summer because of seasonal groundwater withdrawals. The use of agricultural irrigation wells northwest of the landfill is limited almost exclusively to the six-month summer growing season. The use creates drawdown in the aquifer and induces steeper flow gradients. Downward vertical gradients were also observed in the Upper Alluvial Unit in response to summer agricultural irrigation pumping from nearby production wells. (pp. 1-6, 1-7, 2-21, RAP)

Water levels have been observed to fluctuate 20 to 30 feet over a period of months. Most of the fluctuation is due to recharge from the Salt River caused by intermittent upstream release into the Salt River Bed. The high water tables resulting from the recharge of surface water are gradually reduced at a rate of about four feet of head per year by regional agricultural pumping. (p. 2-28, RAP)

When flow occurs in the Salt River, a groundwater mound develops beneath the river because of recharge, and groundwater appears to flow to the south and southeast on the south side of the

river based on data from shallow wells. The apparent local reversal of flow direction changes in water levels in the shallow wells due to the temporary recharge mound and does not affect regional flow. (p. 2-21, RAP)

### Groundwater Recharge

At the time of the 1988 RI, flows in the Salt River recharge the groundwater at an average rate of approximately one foot per day. The amount of recharge increased in relation to the amount of the Salt River channel that is covered with water. Therefore, the amount of water recharge is greatest when the river is in flood stage. (Attachment F, 1998 RAR, Figure 3-4, 100 Year Floodway). Water level increases of 20 to 30 feet were observed as a result of flood flows in the Salt River. The quality of water recharged by the Salt River flows was better than that of the groundwater in the area. (p.1-7, RAP)

Surface-water flow in the Salt River and 15<sup>th</sup> Avenue storm drain adjacent to the landfill have been observed to influence the groundwater levels in monitor wells at the site. Water percolates down from the Salt River bed and the bottom of the storm drain and enters the groundwater system. Flows lasting longer than two to three weeks in duration in the Salt River at the landfill may negate several years of water level decline. (p. 1-7, RAP)

### **Impact of Flooding and Rainfall at the Site**

Before the channelization of the Salt River was completed in March 1996, as a part of the final remedy, portions of the landfill were within the estimated 100-year flood plain of the Salt River. Rainfall and flooding impacted the Site during the 1960s through the 1980s, until the remedy was put into place. During one flood event in 1965 and intermittently during the 1970s, parts of the landfill were covered with water. In May 1978, flows in the Salt River washed refuse from the south-western portion of Cell A and the northern third of Cell A-1 into the river bed. These washed out areas were subsequently refilled. During one flood event in 1965 and intermittently during the 1970s, parts of the landfill were covered with water. Later in 1978, the washed out area of Cell A was refilled with refuse. In 1979, the damaged area of Cell A-1 was filled with construction debris. In the winter and spring of 1979, river flows again washed out refuse in the south-western part of Cell A; however, landfill operations were also ceased that year. During the next few years, following period of high river flows, the COP covered or repaired damaged areas with rubble, asphalt and dirt to function as rip rap.

Flows in the Salt River channel result from controlled releases at dams located more than thirty miles upstream as well as from rainfall and local sources of discharge into the riverbed.

In March 1996, the channelization of the Salt River was completed as a part of the final Site remedy. Flows in the Salt River at the landfill location result from controlled releases when dam storage capacity is exceeded at dams located more than thirty miles upstream, from rainfall and from local sources of discharge into the riverbed. During periods of flow in the adjacent Salt River, the groundwater table rises and may be in contact with the landfill refuse.

During the winter of 2009-2010, El Niño conditions brought record breaking rains to Arizona. From January through March 2010 an average of about seven inches of precipitation fell across the Salt River Watershed. The Salt River was flowing at an average rate of approximately 7,775 cubic feet per second (cfs) from March 9 through March 25, 2010 (the dates of the Five-Year Review site inspections). The last time the Salt River saw this much rain over the watershed was in 1993. However, the closed landfill showed no signs of damage from this rainfall or the continuous flows in the Salt River, with the exception of some small maintenance issues (minor erosion of the cap and erosion near perimeter drainage channels, shallow puddles on landfill roadways, and a rash of new vegetation). The engineering controls at the Site held up to periods of heavy rainfall and major flows in the Salt River. Spring 2010 brought drier conditions with only about four hundredths of an inch of rain being recorded.

#### Saturation of Bottom of Landfill Due to Rising Water Levels

A conceptual diagram of the hydrogeologic system at the landfill is shown on Figure 2.16 of the RAP (Attachment C). The diagram shows that when the water table is relatively high, groundwater rises into a portion of the refuse. The rising groundwater can saturate the refuse and provide a method for transporting materials away from the landfill. The water in the refuse will enhance the production of methane as well as dissolve components of the refuse (p. 2-29, RAP). Portions of the bottom of the landfill have probably been saturated by groundwater at various times since the mid-1970s, as also shown on a cross-section from the 1989 RAP. (Attachment G, 1989 RAP, Figure 2.17, Subsurface Cross-Section E-E') The saturation of the refuse in the landfill generated water that was relatively high in TDS (3000 to 10,000 mg/l) and contained low levels of VOCs (less than 10 part per billion or ppb) and metals. The RI then concluded that water flows out of the landfill and is diluted by groundwater with lower TDS (400-700 mg/l) flowing past the site, and migrates to the northwest along the direction of groundwater flow. (p. 1-7, RAP)

It was concluded during the 1988 RI that without additional flood protection, approximately 30 percent of the surface area of Cell A and 50 percent of the surface area of Cell A-1 could be subjected to inundation during a 100-year flow in the Salt River. (Attachment F)

In 2004, a Technical Memorandum prepared by ADEQ regarding arsenic detected in groundwater at the landfill also discussed extreme groundwater fluctuation and supported the similar conclusions in the 1989 RAP. ADEQ's Memorandum stated that "the observed fluctuations in groundwater levels (Figure 2) were due to heavy seasonal pumping from large irrigation wells of the Roosevelt Irrigation District (RID) northwest of the Site. The water table beneath the site is drawn down in spring and summer months to a relatively low stand in late summer or fall, then generally recovers to a relative high stand in January or February. The irrigation wells influence a large area and maintain a consistent northwesterly groundwater flow direction at the site. As determined in the RI, groundwater velocity has varied for 1 to 8 feet per day, and fluctuated between 20 to 80 feet below the ground surface. In recent years, drought in Arizona has produced a widespread decline in the water table upon which the seasonal

fluctuations are superposed.” Additional substantiating data, discussion and analysis are included in the Memorandum. (Attachment H, ADEQ Technical Memorandum, Arsenic Concentrations in Groundwater Monitor Wells at the Nineteenth Avenue Landfill, April 2004)

## **Groundwater Monitoring Network**

There are a total of nineteen wells in the current groundwater monitoring network, as shown on the attached map from the 1998 Operations and Maintenance (O&M) Manual. (Attachment I, Figure 4-1, Groundwater Monitoring Wells, O&M Program, Features Map). Table 8-2 from the 1998 Remedial Action Report (RAR) lists the 19 wells and their construction details. The table also identifies several monitor wells (I-2, I-5, and I-8) that have been abandoned. (Attachment J, 1989 RAR Report, Table 8-2, Summary of Well Construction Details, Groundwater Wells)

### Wells Installed After 1979 Landfill Closure and During 1987-1988 RI

After the landfill was closed, in 1979, monitor wells were installed around the boundary of the landfill for collecting groundwater levels and water quality data. This monitor well network consisted of 4 on-site wells (I-1, I-3, I-4, I-6), called the I-series wells. The I-series wells are located along the perimeters or boundaries of landfill cells A and A-1. These 4 wells at the boundary of the landfill have been sampled since 1980. (pp. 2-16, 2-17, RAP). The casing for these wells is 4” PVC, the well depth ranges from 100 to 102 feet bgs, and the screen intervals range from 59 feet to 70 feet in length. (Attachment J)

During the RI, additional monitoring wells were installed both on-site and off-site. In 1987, a total of 7 off-site wells DM-series wells were installed: a DM-3 cluster series (DM-3D, DM-3I, DM-3P) located northwest and downgradient of Cell A; DM4 (located due north and downgradient or cross-gradient of Cell A); DM-5D and DM5S (located southeast and upgradient of both landfill cells); and DM6 (located northwest and downgradient of Cell A). (pp. 2-16, 2-17, RAP). The well casing for these DM wells is 6” PVC, the well depth ranges from 164 to 370 feet, and the screen intervals are all 40 feet in length. (Attachment J). Three small diameter wells designated River North, River South and Jackrabbit area were also installed at this time and located along the banks of the Salt River. (pp. 2-16, 2-17, RAP) Subsequently, during construction of the final remedy, these wells were abandoned.

### Wells Installed in 1992 and 1996 Prior to 2000 Five-Year Review

In 1992, 4 additional off-site multi-depth wells were added to the DM-series: DM-7D and DM-7S (located just northwest and directly downgradient of Cell A); and DM-8D and DM-8S (located east of Cell A and northeast of Cell A-1, upgradient of the major portion of the landfill), for a total of 11 DM-series wells. The well casing for these additional DM wells is 6” PVC, the well depths range from 99 to 179 feet, and the screen intervals are 15 feet in the deeper (D) wells and 40 feet in the shallower (S) wells. (Attachment J)

In 1996, 3 additional I-series monitor wells (I-2R, I-5R, I-8R) were added along other border

areas in Cells A and A-1 for a total of seven I-series boundary wells. The well casing for these additional I-series wells is 4" PVC, the well depth ranges from 101 to 115 feet, and the screen intervals are 40 to 50 feet. And late in 1996, the 19<sup>th</sup> well, River North-R was also installed along the Salt River in the southeast corner of Cell A to a depth of 95 feet with a screen interval of 35 feet. (Attachment J)

The screen intervals of the monitor wells are generally long in length ranging from 40 to 70 feet. With the exception of two wells (DM-7D and DM-8D) installed in 1992 with screen intervals of 15 feet, the screen intervals are greater than 40 feet in length. In particular, groundwater monitor wells I-3 and I-4, the two wells that most often have exceedances of MCLs (see groundwater quality discussion that follows), have screen intervals of 54 feet and 69 feet, respectively. These two wells are boundary wells completed to a depth of 100 feet below ground surface (bgs) and 102 feet bgs, respectively.

### **Groundwater Contaminants of Concern (COCs) Identified in RI**

The 1988 RI conducted by the COP collected and performed a total of 1,794 analyses of groundwater for compounds with a Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL). Of this total 39 (approximately 2.2%) exceeded the respective MCL. Among the analytes found in groundwater in excess of their respective MCLs were:

- Arsenic
- Barium
- Carbon Tetrachloride
- Gross Alpha
- Gross Beta
- Mercury
- Nitrate
- Vinyl Chloride

### **Groundwater Cleanup Standards**

#### Standards in 1989 RAP, 1989 ROD and 1992 CD

The June 12, 1989 RAP identified the following Applicable and Relevant or Appropriate Requirements (ARARs) for the groundwater and surface water at the Site. These ARARs were also included in ADEQ's 1989 Letter of Determination (LOD) and EPA's 1989 Record of Decision (ROD). ADEQ's 1992 Consent Decree (CD) with the COP also established Threshold Levels (chemical-specific groundwater protection ARARs) for the Site that confirmed the ARARs identified in the 1989 RAP.

These Chemical-Specific Groundwater Protection ARARs are as follows:

- Safe Drinking Water Act Maximum Contaminant Levels (MCLs)
- Safe Drinking Water Act Proposed MCLs

- ADEQ Human Health-Based Guidance Levels (HBGLs) for Contaminants in Drinking Water and Soil (1990)
- ADEQ Laboratory Confidence Levels

Standards Current at Time of 2000 Five-Year Review

In 2000, the current groundwater protection standard was ADEQ’s Aquifer Water Quality Standards (AWQSs) addressed in Arizona Administrative Code (A.A.C.) Title 18, Chapter 11, Article 4. In the AWQSs, state-wide numeric values for protected use of drinking water (applicable for the Site) were established. Other numeric standards that were relevant or appropriate in 2000 included: the current MCLs and the national revised primary drinking water regulations (MCLs) in 40 CFR Part 141, Subparts B and G; ADEQ’s Health Based Guidance Levels (HBGLs) (June 1992); and/or EPA’s preliminary remediation goals (PRGs) for tap water.

In 2000, during the Five-Year Review, an analysis was conducted of the chemical-specific ARARs established for the site in the 1989 ADEQ LOD that approved the RAP, 1989 EPA ROD, and 1992 CD and then compared the groundwater standards to current year 2000 standards. The following 7 compounds were identified (Table 4, 2000 FYR) with lower concentrations than those originally established for the site.

| <u>Chemical</u>     | <u>Established<br/>LOD/ROD/CD</u> | <u>Current<br/>2003 ESD</u> |
|---------------------|-----------------------------------|-----------------------------|
| - Antimony          | 50 ug/l                           | 6 ug/l (MCL & AWQS)         |
| - Barium            | 5,000 ug/l                        | 2,000 ug/l (MCL & AWQS)     |
| - Beryllium         | 5 ug/l                            | 4 ug/l (MCL & AWQS)         |
| - Napthalene        | No standard                       | 28 ug/l (ADEQ HBGL)         |
| - Pentachlorophenol | No Standard                       | 1 ug/l (MCL)                |
| - Thallium          | 5 ug/l                            | 2 ug/l (MCL)                |
| - Toluene           | 2,000 ug/l                        | 1,000 ug/l (MCL & AWQS)     |

Updated Standards Established in 2003 ESD

After the 2000 Five Year Review identified a discrepancy between current groundwater standards considered protective of public health and the previously established standards in the 1989 LOD/ROD and 1992 CD standards, the Agencies proceeded to correct this deficiency. In September 2003, ADEQ and EPA signed an Explanation of Significant Difference (ESD) #2 for the Site that modified the cleanup standards. The ESD incorporated the chemical-specific ARARs and groundwater quality standards for those compounds that did not have established standards, or the applicable standards were changed since the CD. The ESD included two additional compounds, arsenic and nickel, that had not been included in the 2000 Five-Year Review analysis. The ESD made the following changes to the standards and identified them as new ARARs in Table 1 (2003 ESD), as follows:

| <u>Compound</u>     | <u>Established in<br/>LOD/ROD/CD</u> | <u>Current as of<br/>2003 ESD</u> |
|---------------------|--------------------------------------|-----------------------------------|
| - Arsenic           | 50 ug/L                              | 10 ug/L (MCL)                     |
| - Antimony          | 50 ug/l                              | 6 ug/l (MCL & AWQS)               |
| - Barium            | 5,000 ug/l                           | 2,000 ug/l (MCL & AWQS)           |
| - Beryllium         | 5 ug/l                               | 4 ug/l (MCL & AWQS)               |
| - Napthalene        | No standard established              | 28 ug/l (ADEQ HBGL)               |
| - Nickel            | 50 ug/L                              | 100 ug/L (Revised MCL)            |
| - Pentachlorophenol | No standard established              | 1 ug/l (MCL)                      |
| - Thallium          | 5 ug/l                               | 2 ug/l (Revised MCL)              |
| - Toluene           | 2,000 ug/l                           | 1,000 ug/l (MCL & AWQS)           |

#### Standards Current at Time of 2005 Five-Year Review

At the time of the 2005 Five Year Review, the September 2003 updating the groundwater MCLs had just been recently signed. No new groundwater ARARs or changes in the standards were identified during the September 2005 Review.

#### Standards Current at Time of 2010 Five-Year Review

During this 2010 Five Year Review, no new groundwater standards or changes to the groundwater ARARs were identified.

### **Groundwater Monitoring Requirements**

#### Monitoring Program Established in 1992 Consent Decree

The 1992 CD signed by ADEQ and the City of Phoenix (COP) established requirements for conducting a groundwater monitoring program at the Site, including groundwater monitoring Threshold Levels for triggering follow-up monitoring. The monitoring program is comprised of a network of upgradient and downgradient wells used to monitor the shallow and deeper aquifers within the boundary of the landfill cells. Groundwater monitoring and depth to groundwater measurements are required to be conducted on a quarterly basis by the COP. The data are compiled by the COP and the results are distributed in quarterly reports to ADEQ and EPA.

#### Groundwater Contingency Plan

In addition to the 1992 CD establishing Threshold Levels for the Site, the CD also required a Groundwater Contingency Plan (GCP). Under Section XII, Appendix A, the GCP was required to protect groundwater by identifying actions to be taken when the Threshold Levels are exceeded.

The following conditions trigger follow-up monitoring under the GCP in any downgradient well when:

- The average of three (3) consecutive quarterly samples of a constituent in a well exceeds the threshold level;
- A follow-up groundwater sample confirms that the exceedance condition has occurred.

The GCP requires submittal to ADEQ of a Groundwater Exceedance Report when specific constituents detected in a groundwater monitoring well exceeds the Threshold Levels established in the CD. To comply with this requirement, the COP evaluates the quarterly sample results and, if specific constituents are found to exceed the established Threshold Levels, the COP submits a Groundwater Exceedance Report to the Agencies. If a specific sample for a monitor well exceeds the Threshold Level, the COP conducts monthly groundwater sampling of that well until it no longer exceeds the Threshold Level, as required by the 1992 CD GCP, Section XII, Appendix A.

#### Groundwater Analytical Methods

Groundwater samples are submitted to an Arizona Department of Health Services (ADHS) certified laboratory for analysis using approved analytical methods. Appendix A of the 1992 CD specifies the use of EPA Method 601/602 for volatile organic compounds (VOCs) analysis, EPA Method 625 for semi-VOCs analysis, and EPA Method 608 for pesticides analysis. The laboratory currently contracted by the city of Phoenix for groundwater sample analysis uses EPA 624 for VOCs analysis, E300.0 for chloride, E350.1 for ammonia, SM5310C for total organic carbon, and SM4500P-E for total phosphorous. For metals analysis, the lab is currently using Methods 200.7 and 200.8, with the exception for mercury, method 245.1 is used.

### **Water Quality Sampling Results and Findings**

#### **Groundwater Data Review Results During 1987-1988 RI**

##### Overall Water Quality Findings During 1987-1988 RI

Water quality in wells on the boundary of the landfill sampled during the 1988 RI reflected the interaction of landfill materials and groundwater. Water quality in downgradient wells sampled during the RI showed little impact of the landfill and met drinking water standards. Downgradient off-site monitor wells range from 300 feet (DM-2) to 1,600 feet (DM-6) from the boundary of the landfill. During the 1988 RI/FS there were no significant floods. Therefore, the data collected during the RI does not necessarily reflect the groundwater quality conditions that may occur during large flood events.

The 1989 RAP concluded that a potential risk to public health and the environment could occur as a result of a rising water table that saturating a greater volume of refuse and releasing additional leachate. However, the RAP stated that such a risk could not be quantified and historical water quality data did not indicate a correlation between increasing water table

elevations and increasing groundwater VOC concentrations. The RAP concluded there was no current exposure risk to contaminated drinking water because the City of Phoenix provides drinking water to this area and will continue to in the future. The results of the RI are summarized below.

### Specific Water Quality Findings During 1987-1988 RI

#### *Metals*

Barium was detected at concentrations above the MCLs in Wells I-3, I-4 and I-8 that are located on the western boundary of the landfill, generally downgradient with respect to groundwater flow.

Mercury was also detected at concentrations above the MCLs in Wells I-3, I-4 and I-8

Arsenic was also detected in one sample from Well I-8. On-site, off-site, upgradient and downgradient wells displayed a similar pattern of infrequent detection at concentrations near, but above detection limits. (pp. 2-25, 2-26, RAP)

#### *Volatile Organic Compounds (VOCs)*

Vinyl chloride was detected in Wells I-1, I-2, and I-8 at concentrations exceeding the MCL of 2.0 ug/l. Carbon tetrachloride was detected once above the MCL in Well I-1. (p. 2-26, RAP) These historical exceedances of volatile organic compounds (VOCs) are believed to have resulted from historical releases from the tallow plant that was at one time located adjacent to the NE corner of Cell A at the landfill boundary.

#### *Pesticides and PCBs*

Pesticides and PCBs were also analyzed for in the groundwater during the RI. PCBs were below detection limits and pesticides were not detected above MCLs. (p. 2-26, RAP)

#### *Radionuclides*

Gross alpha and gross beta emissions measured on samples collected at each well were generally near detection limits. However, one sample from Well I-5 exceeded the gross alpha MCL. Three gross beta samples exceeded the MCL from Wells I-3 and I-6. (pp. 2-27, 2-28, RAP)

Table 2.14 of the RAP summarized the compounds that were detected above Maximum Contaminant Limits (MCLs), as follows:

- Nitrate - Upgradient (Wells DM-5S, DM-5D) (Max. Conc. 16 mg/L)
- Gross Beta - Boundary Cell A-1 (Well I-6) (Max. Conc. 92.8 pCi/L)
- Gross Beta – Boundary Cell A (Well I-3) (Max. Conc. 122 pCi/L)

- Gross Alpha - Boundary Cell A-1 (Well I-5) (Max. Conc. 17.9 pCi/L)
- Carbon Tetrachloride – Boundary Cell A (Well I-1) (Max. Con. 35.1 ug/L)
- Vinyl Chloride - Boundary Cell A (Wells I-1, I-2, I-8) (Max. Con. 2.6 ug/L)
- Barium – Boundary Cell A (Wells I-3, I-8) (Max. Con. 2.58 mg/L)
- Arsenic – Boundary Cell A (Well I-8) (Max. Con. 170 ug/L)
- Mercury – Boundary Cell A (Well I-4) (Max. Con. 11 ug/L)

### **Groundwater Data Review Results During 2000 Five-Year Review**

During the period leading up to the 2000 Five-Year Review, groundwater sampling and depth to groundwater measurements were conducted on a quarterly basis by the COP. The groundwater samples were submitted for analysis to an Arizona Department of Health Services (ADHS) certified laboratory that used State-approved analytical methods. The COP compiled the results into a quarterly report for submittal to ADEQ.

#### Overall Water Quality Findings During 2000 Review

During the 2000 Five-Year Review, Ron Serio, Landfill Manager for the City of Phoenix, concluded that there were no groundwater monitoring or water quality issues of concern at the Site. He noted that during 1999, the arsenic and nickel concentrations in Well I-4 exceeded the MCL. However, because the three quarter average arsenic concentration was below the MCL, the Groundwater Contingency Plan (GCP) was not implemented. In July 1999, the nickel concentration did exceed the GCP threshold of three times the MCL; however, a follow-up sample did not confirm this exceedance and the nickel concentration was less than the MCL. Regarding VOC concentrations, a few samples collected from downgradient wells detected 1,1-DCE above the MCL and the Threshold Level stated in the GCP. However, the City demonstrated that 1,1-DCE concentrations in the downgradient wells were coming from an upgradient source. Consequently, the GCP was not triggered. (p.17, 2000 FYR Report)

#### Specific Water Quality Findings During 2000 Review

A comparison analysis was conducted of the maximum concentrations of the major contaminants found in the groundwater sample results during pre and post implementation of the remedial action (RA) and in 1999. The results of this analysis were summarized in Table 11 of the 2000 Five Year Review Report. Some of the compounds initially detected prior to the issuance of the 1989 RAP (i.e., arsenic, mercury, carbon tetrachloride, vinyl chloride, gross alpha, gross beta) were either not detected or detected in concentrations lower than the MCL in the post remedial (1997) and 1999 sampling data. (p. 44, 2000 FYR Report)

#### *Metals*

Review of the groundwater data indicated that all appropriate metal compound concentrations were generally below the GCP Threshold Levels and current Arizona Water Quality Standards (AWQSs), except for thallium and nickel.

Nickel was detected in July 1999 in Well I-4 at a concentration greater than six times the current cleanup standard (0.1 mg/l). At the time of the 2000 Five-Year Review, there was no current MCL for nickel, because it was remanded by EPA on June 29, 1995. However, the Preliminary Remediation Goal (PRG) for nickel considered protective of human health and the environment (i.e., 0.73 mg/l) was higher than the GCP Threshold Level. During the same timeframe, nickel was also detected in Well I-3 at a concentration that just exceeded the Threshold Level. Because the average nickel concentration of the July 1999 sample and two additional consecutive rounds of sampling exceeded the Threshold Level in Well I-4, a confirmation sample was collected by City of Phoenix. The results of the confirmation sample did not confirm the exceedance of nickel in Well I-4, and the GCP was not implemented. No additional confirmation sampling for nickel was performed in Well I-3, because subsequent sampling rounds showed nickel below the Threshold Level. At the time of the 2000 Five Year Review, nickel concentrations in Wells I-3 and I-4, and all of the other wells were below the GCP Threshold Level. (p. 45, 2000 FYR Report)

Thallium was also detected in July 1999 in Well I-4 at a concentration greater than two times the Threshold Level (0.005 mg/l) that was established in the 1992 CD. However, because the average thallium concentration in Well I-4 did not exceed the GCP Threshold Level, no additional action was taken and the GCP was not triggered. No other wells exceeded the Threshold Level for thallium during the last two years. However, during the 2000 FYR, when comparing the groundwater data to the updated MCL for thallium (0.002 mg/l), the average concentration of three rounds of sampling of Well I-4 during the sample timeframe specified above, would have exceeded the MCL and could have potentially triggered the GCP. In July 1998, Well I-6 would have exceeded the updated MCL for thallium (0.002 mg/l). However, because the average thallium concentration for this and two consecutive rounds of sampling were below the current MCL, no follow-up action was required. The 4<sup>th</sup> quarter 1999 sampling results showed that thallium concentrations were below the MCL in all wells, including Wells I-4 and I-6. In addition, the results of the 1<sup>st</sup> and 2<sup>nd</sup> quarter 2000 sampling (not part of the original data review timeframe for the 2000 FYR) indicated that the thallium concentrations were below the current MCL in all of the wells, including Wells I-4 and I-6. (pp. 44-45, 2000 FYR Report)

### *VOCs*

1,1,-Dichloroethene (1,1,-DCE) consistently exceeded the GCP Threshold Level and AWQs (7 ug/l) in Wells DM-5S, DM-5D, DM-8S, DM-8D, DM-31, DM-6 and DM-7D. Normally the GCP would have been triggered; however, because 1,1-DCE was consistently detected in upgradient wells (i.e., DM-5S, DM-5D, DM-8S, and DM-8D). The COP demonstrated that the concentration of 1,1-DCE was coming from an off-site source, upgradient to the Site. This demonstration was accepted by both ADEQ and EPA. The last round of samples collected in October 1999, showed 1,1-DCE concentrations above the AWQS in Wells DM-8S (upgradient) and DM-31. This demonstrated that an off-site upgradient source was continuing to contribute to the elevated 1,1-DCE concentrations at the Site. No other VOC were detected in any of the wells that exceeded the GCP Threshold Levels or current AWQS. (p. 45, 2000 FYR)

Pentachlorophenol was detected in Well DM-8D (upgradient) and DM-3P in January 1998 at concentrations that exceeded the MCL (1.0 ug./l). In January 1999, pentachlorophenol was not detected when Well DM-8D was sampled; however that may be due to the laboratory using a higher detection limit (5.0 ug/L) than the MCL (1.0 ug/L). (p. 46, 2000 FYR)

#### *Radionuclides*

Gross alpha was detected in Well DM-5S (upgradient) and DM-6, on January 1998 and July 1998, respectively, at concentrations that exceeded the GCP Threshold Levels and AWQS (15 pCi/l) by a small order of magnitude. Subsequent samples of DM-5S and DM-6 were well below the AWQS, so no further action was necessary. Gross alpha was not detected in any other wells at concentrations exceeding the MCL. No radionuclides were detected in any other wells that exceeded their respective AWQSs or MCLs. (p. 46, 2000 FYR)

#### *Pesticides and PCBs*

Pesticides were not detected in any of the collected groundwater samples. (p. 46, 2000 FYR)

#### *Other Compounds*

Nitrate has exceeded the Threshold Level (10 mg/l) and AWQS (10 mg/l – the same) over the last two years in Well DM-5D, an upgradient well. Because Well DM-5D is upgradient, the nitrate concentration may be naturally occurring or influenced by an off-site upgradient source. Consequently, no additional action is necessary to address nitrate. The round of samples collected in October 1999, showed nitrate concentrations below the AWQS in all wells, except Well DM-5D.  
(pp. 45-46, 2000 FYR)

### **Groundwater Data Review Results During 2005 Five-Year Review**

During the period leading up to the 2005 Five-Year Review, the COP continued to conduct quarterly groundwater sampling and depth to groundwater measurements, and the samples were submitted for analysis to an Arizona Department of Health Services (ADHS) certified laboratory that used State-approved analytical methods. The COP continued to prepare and submit quarterly reports to the Agencies.

#### Overall Water Quality Findings During 2005 Review

The 2005 Five Year Review concluded that the groundwater for all compounds was in compliance with the current standards. It stated that the only MCL exceedances were for arsenic, nitrate, 1,1-dichloroethene (DCE) and vinyl chloride. In the case of arsenic, the exceedances were transient, occurred only beneath the landfill, and were thought to be the result

of a reducing environment that tends to precipitate naturally occurring arsenic from soil to groundwater.

The 2005 Five Year Review Report focused primarily on the arsenic sampling data collected during the review period. The review referred to Appendix F, a 2004 ADEQ Technical Memorandum that discusses and evaluates the arsenic findings at the Site (Attachment H). The Review also stated that the DCE exceedances were believed to be the result of upgradient, off-site releases, and the vinyl chloride exceedances were believed to be due to biodegradation of the DCE. It does not discuss the nitrate exceedances. (p. 26, 2005 Five Year Review Report)

#### Specific Water Quality Findings During 2005 Review

Unlike the analyses in the 1989 RAP and the 2000 Five Year Review, the 2005 Five-Year Review Report did not include a detailed analysis of the water quality data collected during the preceding five year period, nor did it include any summary table of exceedances in relation to the GCP. The only detailed analysis included in the Review was a discussion of ADEQ's Technical Memorandum on arsenic concentrations in groundwater monitor wells and the potential cause and source of the elevated levels of arsenic detected during the quarterly sampling events (Attachment H), as discussed below.

#### *Metals*

Arsenic concentrations were detected consistently near or below the cleanup standard of 10 ug/L (MCL) in 17 of the 19 site monitor wells, when reviewing historical arsenic sampling data. However, two monitor wells (Wells I-3 and I-4) located near the western edge of the landfill showed fluctuating and elevated levels (up to 92 ug/L) of arsenic, based upon the review of the eight preceding years of arsenic data. The 2004 ADEQ Memorandum states that the levels are:

- Are clearly above natural background concentrations for the area around the site;
- Fluctuate seasonally with water level drawdown to meet irrigation demand;
- Show no long-term trend or increase or decrease independent of water level trends; and
- Remain restricted to the immediate vicinity of the site (Boundary Wells 1-3 and 1-4).

The ADEQ 2004 Memorandum concluded that “the arsenic concentrations probably result from mobilization of arsenic and associated redox sensitive metals by reducing conditions in the vadose zone and capillary fringe beneath the landfill. Possible sources of the arsenic are: 1) the landfill trash, and 2) naturally occurring arsenic in sediments of the aquifer. The observed relationship between changes in groundwater elevation and arsenic and related metals (iron, manganese) concentrations strongly suggests that at least some, if not practically all of the arsenic, occurs naturally in the aquifer sediments. Regardless of the source of the arsenic, it is relatively immobile in the oxidizing groundwater conditions of the region and is not transported far beyond the site boundary before it is precipitated into low solubility compounds bound in the aquifer matrix. This is consistent with the lack of elevated arsenic in the monitor wells downgradient of boundary monitor wells I-3 and I-4. Except for long-term monitoring, no remedial action is recommended for the elevated arsenic.”

Additional substantiating data, discussion and analysis are included in the 2004 Memorandum. (Attachment H).

### **Groundwater Conclusions in 2006 Final Close-Out Report**

In 2006, the conclusions about the groundwater sampling data were similar to the prior conclusions reached in the 1989 RAP, the 1998 RAR, the 2000 FYR and the 2005 FYR. The July 2006 Final Close-Out Report (FCOR) concluded that the analytical results from the historical groundwater were inconclusive. The FCOR signed by EPA and ADEQ stated that:

*“Groundwater contaminants have generally not been detected or are detected inconsistently, with the exception of 1,1-DCE, vinyl chloride, and arsenic, which are not due to contaminants from the landfill. 1,1-DCE and vinyl chloride have been determined to be from an upgradient source. It has been determined that arsenic is being mobilized into the groundwater out of the soil due to reducing conditions at the landfill, and is not seen in the groundwater beyond the landfill boundaries, where oxidizing conditions resume. Since no trends can be established with ... the other the constituents that are detected, it has been determined that the landfill has not impacted groundwater.”*

The 2006 FCOR further states that if the landfill is found to be degrading the water quality, the City of Phoenix must evaluate alternatives for a groundwater remedy.

### **Groundwater Data Review Results During 2010 Five-Year Review**

During the period leading up to the 2010 Five-Year Review, the COP continued to conduct quarterly groundwater sampling and depth to groundwater measurements, and the samples were submitted for analysis to an Arizona Department of Health Services (ADHS) certified laboratory that used State-approved analytical methods. The COP continued to prepare and submit quarterly reports to the Agencies, although some recent 2009 and 2010 reports may summarize data collected over more than one quarter.

#### Overall Water Quality Findings During 2010 Review

During the period of this 2010 Five Year Review, the groundwater data displayed similar characteristics as observed previously at the time of the 1989 RAP, the 2000 and 2005 Five-Year Reviews, and the 2006 FCOR. There were irregular and intermittent exceedances of certain compounds. Arsenic, nitrate and 1,1-DCE were the primary contaminants identified that exceeded the updated cleanup standards established in the 2003 ESD. As shown on Table 1, Summary of Groundwater Exceedances by Well, Chemical and Quarter During 2010 Five-Year Review Period (Attachment K), there were a few exceedances of nickel and thallium, and just one exceedance each of chromium, tetrachlorethene (PCE) and gross alpha during the review period. The intermittent or irregular detections of certain compounds continue to appear to be a result of potential leakage from the landfill during periods when elevated groundwater levels remobilize site contaminants. And, other chemicals are believed to originate from upgradient, off-site sources, as discussed further below.

Over the period of 2005 to 2010, the number of exceedances per year declined for all detected chemicals with groundwater standards (Attachment L, Table 2, Total Number Groundwater Exceedances by Chemical and Year During 2010 Five-Year Review Period). Also, with the exception of one exceedance of PCE in downgradient well DM-7S in April 2008, no exceedances of groundwater standards were identified in the three shallow zone monitor wells located downgradient from the landfill boundary. This one detection of PCE is considered anomalous, in that PCE has not been previously associated with the Site. The three downgradient wells include DM-6 (completed to a depth of 170 feet bgs), DM-3P (completed to a depth of 170 feet bgs) and DM-7S (completed to a depth of 101 feet bgs), each with a screen interval of 40 feet in length. (Attachment J)

### Specific Water Quality Findings During 2010 Review

#### *Metals*

Arsenic routinely exceeded the MCL by a three to five-fold factor in two monitor wells (Well I-3 and I-4). The updated MCL for arsenic is 0.010 mg/l and the arsenic concentrations detected during the period of 2005 through June 2010 were often in the range of 0.050 to 0.060 mg/l in these two wells. These wells are completed to a depth of approximately 100 feet bgs and are located along the western boundary of Cell A of the landfill. A total of 91 exceedances of the cleanup standard for arsenic were identified during the review period. The highest number of exceedances were detected in 2005 (22), 2006 (28), and 2007 (23). The number of exceedances for arsenic have dropped significantly in more recent years: 2008 (8); 2009 (8); and January through June 2010 (2). The detections of arsenic continue to be localized in these two boundary wells, and the arsenic is not observed in any downgradient wells. As previously discussed during prior data reviews, the behavior of the arsenic has been predictable in the aquifer.

The 2005 Five Year Review concluded that a the majority of the elevated arsenic found in the area of monitor wells I-3 and I-4 most likely is caused by the chemical alteration of naturally-occurring arsenic in the local sediments by reducing conditions beneath the landfill. Fluctuations in the water table elevation periodically expose the sediments to the reducing conditions in the vadose zone, followed by re-saturation and mobilization of the altered arsenic. This may also account for other redox sensitive metals occasionally found at elevated concentrations in the area (Attachment H).

Chromium was detected once at a concentration exceeding the MCL (0.05 mg/l) during the October 2005 sampling in Well I-1 during this review period. Well I-1 is located in the middle of the northern boundary of Cell A. The concentration of chromium detected was 0.054 mg/l. This appears to be an anomaly, as chromium was not detected during historical sampling events at concentrations exceeding the MCL. It was not identified during the RI and no Threshold Level was established for chromium in the 1992 ADEQ CD or any other ADEQ/EPA decision documents.

Nickel was detected in 2005 during three sample events at concentrations exceeding the MCL (0.1 mg/l) in Well 1-4 and also in Well 1-3, and also in boundary well I-8R that is located just north Well I-4. Similar to wells I-3 and I-4, Well I-8R is also located along the western boundary of Cell A and is completed to shallow depth (115 feet bgs) and has a large screen interval (50 feet). The concentrations detected were in the range of 0.11 to 0.34 mg/l). Nickel has not been detected at concentrations above the MCL during any subsequent sample events.

Thallium was also detected during four sample events in 2005 and in two sample events in 2006 at concentrations exceeding its MCL (0.002 mg/l). Thallium was detected in the same boundary wells (Wells I-3, I-4 and I-8R) where nickel was detected. The concentrations of thallium detected ranged from 0.0024 mg/l to 0.015 mg/l). Thallium also has not been detected at concentrations above the MCL during any subsequent sample events.

### *VOCs*

1,1-DCE was detected at concentrations exceeding the MCL (7.0 ug/L) in 2005 (8 times) and then again once each in 2008, 2009 and 2010, for a total of 11 exceedances during the review period. Five exceedances were detected in Well DM-3I located to the northwest and downgradient of Cell A. Three exceedances were in Well DM-5S (located upgradient and southeast of Cell A-1) and the remaining three exceedances were detected in Well DM-8D located due north of DM-5S and east of Cell A-1. The exceedances in Wells DM-5S and DM-8D were all during the same three quarters in 2005. Downgradient Well DM-3I is completed to a depth of 232 feet, with a screen interval of 40 feet. Upgradient Well DM-5S is completed to a depth of 164 feet, with a screen interval of 40 feet. Side-gradient Well DM-8D is located east of Cell A-1, but downgradient from Well DM-5S, and is completed to a depth of 179 feet bgs, with a screen interval of 15 feet. In 2009, 1,1-DCE concentrations were slightly above the MCL in Well DM-3I only. The 1,1-DCE found in well DM-3I has long been attributed to an unidentified, up-gradient source (or sources). Because 1,1-DCE has been detected in upgradient monitor wells (DM-5S and DM-8D) at a depth of a 165-175 feet bgs), it is highly unlikely that the source of the 1,1-DCE is the landfill site.

Tetrachloroethene (PCE) was detected once during the five-year review period at a concentration exceeding the MCL (5.0 ug/l), and never detected again. In April 2008, PCE was detected at a concentration of 7.4 ug/l in Well DM-5S, located upgradient and southeast of Cell A-1. As previously discussed, Well DM-5S is completed to a depth of 179 feet bgs and has a screen interval of 15 feet. Similar to the detections of 1,1-DCE in upgradient wells, the source of the PCE appears to be an unidentified, upgradient source.

### *Radionuclides*

Gross Alpha was detected only once during the Five-Year Review period at a concentration exceeding the MCL (15 pCi/L). This exceedance was in January 2009 in Well I-6. This well is located in the southwest corner of Cell A-1, the smaller landfill cell located south of the Salt River. Well I-6 is completed to a depth of 102 feet, with a screen interval of 70 feet. The gross

alpha concentration at Well 1-6 was measured at 16 pCi/L +/- 3.8 pCi/L. At the same time, well DM-5D (completed to a depth of 300 feet, with a screen interval of 40 feet, located up-gradient and to the east of Cell A-1) was found with a gross alpha level of 14 pCi/L +/- 4.9 pCi/L. Also, Well DM-6 (completed to a depth of 170 feet, with a screen interval of 40 feet, and located to the west and down-gradient of Cell A) had a gross alpha level of 12 pCi/L +/- 3.4 pCi/L. These detections of gross alpha at varied depths and locations appear to indicate that the gross alpha is pervasive in groundwater in the area of the landfill. The detections do not show a migration pattern from the landfill site. Gross alpha is a common, naturally occurring contaminant in Arizona's alluvial aquifers composed of eroded granite. In 2009, a study completed by the University of Arizona, discusses this observation. (Attachment M, "Naturally Occurring Well Water Contaminants," University of Arizona, 2009)

### *Other Compounds*

Nitrate was detected during 19 sample events at concentrations exceeding the MCL (10 ug/l) during the five-year review period. These exceedance conditions were noted primarily in Wells I-3 and I-4 (14 of the 19 events). As previously discussed, both wells are boundary wells located on the western edge of Cell-A and completed at a depth of approximately 100 feet bgs. Nitrate exceedances were also detected in Well DM-5D that is located upgradient of the landfill and to the southeast of Cell A-1. This well is completed to a depth of 300 feet with a screen interval of 40 feet and had a detection of 12 ug/L nitrate in January 2005, 11 ug/L in April 2005, 10 ug/l in January 2007, and 11 ug/l in January 2008. Nitrate has been detected below or near the MCL in some upgradient wells. Very low concentrations of nitrate below the MCL are the norm in the down-gradient wells.

URS, a contractor for the COP, indicated in a September 12, 2008 report that "the incidence of elevated nitrate in groundwater at the Site recurs concomitantly with other parameters at Well 1-3 that are highly soluble and mobile in typical subsurface environments. Both historical sulfate and nitrate concentrations generally follow a similar pattern of oscillation between "normal" and "elevated" levels that appear strongly correlated with the flow in the Salt River, groundwater elevation and precipitation."  
(URS, 9/12/2008)

To further evaluate the extent of elevated nitrate concentrations at Well 1-3, URS compared nitrate data collected from Wells 1-3, 1-4 and I-5R. URS concluded that the results of this analysis suggest that the mechanism responsible for the elevated nitrate is localized and can be attenuated with distance from the Salt River. However, the river itself does not appear to directly supply the nitrate observed at Well 1-3; and nitrate concentrations at Well I-5R are negligible. URS states that the data suggest that the nitrate is the result of nitrification of ammonia which appears to occur when a recharge event raises the local groundwater table near Well 1-3. This mechanism also is likely applicable to Well 1-4, but the response is attenuated and delayed. URS closes by stating that ammonia has long been considered a relatively immobile contaminant associated with the landfill (Dames and Moore, 1988), but it is not considered a significant issue with respect to regional water quality. (URS, 9/12/2008).

## *Pesticides and PCBs*

Organochlorine pesticides and PCBs were also analyzed for in the groundwater (First Quarter 2009 Progress Report) during the review period and no exceedances were identified.

### **Groundwater Deficiencies and Recommendations for Follow-up**

- Groundwater Monitoring and Reporting: An evaluation needs to be conducted of all groundwater data currently being collected and analyzed to determine if potential efficiencies could be gained by reducing or changing the monitoring network, the analyte list, the reporting frequency or other aspects of the monitoring program. Based upon the results of this evaluation, modifications or amendments may be needed to the GCP, as defined in the 1992 CD, the O&M Report, the QAPP, or other related documents governing long-term O&M at the Site.
- Comparison of Data to 2003 ESD Cleanup Standards: The COP's Quarterly Groundwater Monitoring Reports still identify the Threshold Levels established in the 1992 ADEQ CD with the COP, not the updated groundwater standards established in the 2003 ESD #2 signed by ADEQ and EPA. Beginning in 2010, the groundwater standards in the COP quarterly reports need to be consistent with the 2003 ESD standards. The laboratory detection limits used for all chemicals that have updated or changed standards should also be checked. The 2010 data also needs to be compared to these updated standards to identify exceedances and file Exceedance Reports.
- Annual Summary Tables of Groundwater Exceedances: The compilation of groundwater exceedances during the Five-Year Review period of 2005 and 2010 was difficult because there were no annual summary tables included in the annual 4<sup>th</sup> Quarter Reports. For ease of tracking exceedances on an annual basis, as well as for the completing future Five-Year Reviews, annual summary tables of exceedances (by quantity compound, date, and concentration) need to be prepared and included in the 4<sup>th</sup> Quarter Report for each calendar year. Recommend a format similar to the tables in the 2010 Five Year Review Report, Table 4 (Attachment K) and Table 5 (Attachment L) attached to this summary analysis.
- Update Groundwater Contingency Plan (GCP): The GCP and the corresponding Threshold Levels established in the 1992 CD were not updated when the 2003 ESD was signed by ADEQ and EPA. All future sampling events, data analysis and compilation, and data reporting needs to be completed in a manner consistent with the 2003 ESD updated groundwater standards. The GCP plan needs to be updated to incorporate the current MCLs, as appropriate.
- Update Quality Assurance Project Plan (QAPP). The analytical methods specified in the GCP required under ADEQ'S 1992 CD with the COP have changed for certain

chemicals. The analytical methods in the GCP should be re-evaluated and updated, as necessary.

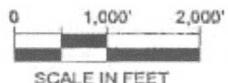
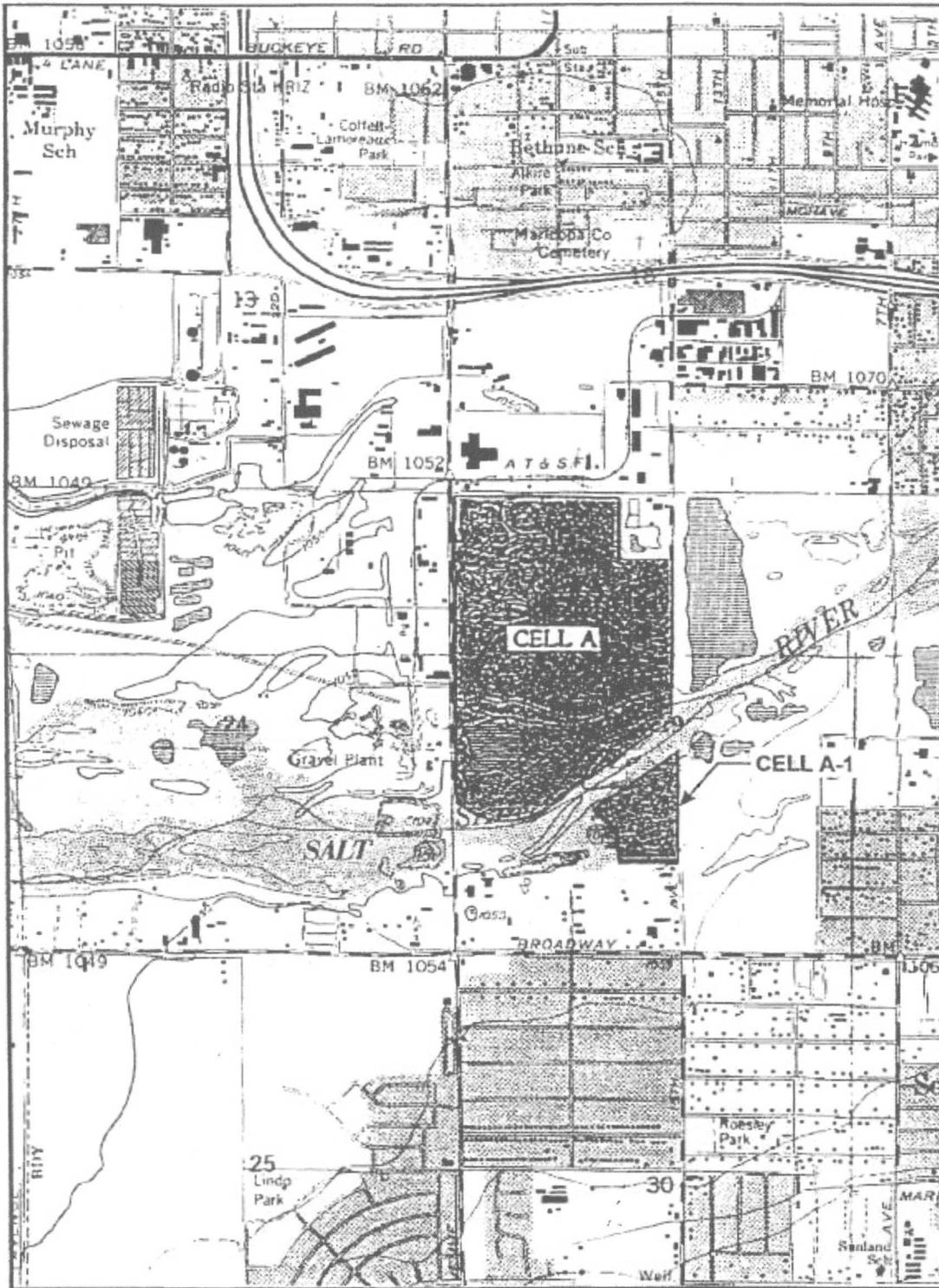
- Update Well Inventory and Monitor Well Map. The monitor well inventory used for this 2010 Five-Year Review was Table 8-2, attached to the 1998 RA Report. However, a current well inventory of all wells located within a mile radius or less of the landfill does not appear to be available for the Site. Although the exceedances of arsenic, nitrate and 1,1-DCE, as well as other more infrequent detections of other compounds, are intermittent and appear to be localized near the landfill, it is important to know where all nearby wells are located. A comprehensive well inventory, with a corresponding map, is needed that identifies all nearby agricultural wells, domestic supply wells or other types of production wells to document that no nearby wells could be inadvertently used for drinking water purposes.

### **Conclusions of This Groundwater Analysis**

This 2010 Review concludes that the intermittent and irregular exceedances of groundwater MCLs detected at or near the Nineteenth Avenue Landfill Superfund Site do not pose a threat to human health and the environment. While the groundwater needs to be continued to be regularly monitored for arsenic and other identified compounds, no additional action is required at the present time, other than the deficiencies and recommendations outlined in the preceding section of this analysis.

**Attachments to Analysis of Current Groundwater Conditions at Nineteenth Avenue Landfill Superfund Site for the 2010 Five Year Review**

|              |  |
|--------------|--|
| Attachment A | Map of 19 <sup>th</sup> Avenue Landfill and Vicinity<br>(Figure 1, 2000 Five Year Review Report)   |
| Attachment B | Map of General Site Layout, 19 <sup>th</sup> Avenue Landfill<br>(Figure 2, 2000 Five Year Review Report)   |
| Attachment C | Hydrogeologic Conceptual Diagram, 19 <sup>th</sup> Avenue Landfill<br>(Figure 2.16, 1989 Remedial Action Plan (RAP))                                 |
| Attachment D | Generalized Stratigraphic Column, 19 <sup>th</sup> Avenue Landfill<br>(Figure 2.10, 1989 RAP)  |
| Attachment E | Groundwater Elevations, 4 <sup>th</sup> Quarter 2007, 19 <sup>th</sup> Avenue Landfill (Figure 1, Fourth Quarter 2007 Groundwater Monitoring Report) |
| Attachment F | Map of 100 Year Floodway, 19 <sup>th</sup> Avenue Landfill<br>(Figure 3-4, 1998 Remedial Action Report (RAR))  |
| Attachment G | Subsurface Cross Section E-E', Showing Maximum Water Table Elevation in January 1986 (Figure 2.17, 1989 RAP)   |
| Attachment H | ADEQ Technical Memorandum, Arsenic Concentrations in Groundwater Monitor Wells at the Nineteenth Avenue Landfill Site, April 4, 2004.                |
| Attachment I | Groundwater Monitor Well Locations<br>(Figure 4-1, 1998 O&M Manual)  |
| Attachment J | Summary of Well Construction Details, 19 <sup>th</sup> Avenue Landfill<br>(Table 8-2, 2000 Five Year Review)   |
| Attachment K | Table 4, Groundwater Exceedances by Well, Chemical and Quarter During 2010 Five-Year Review Period   |
| Attachment L | Table 5, Total Number of Groundwater Exceedances by Chemical and Year for Entire 18 Well Monitor Network During Five-Year Review Period (2005-2010)  |
| Attachment M | University of Arizona, "Naturally Occurring Well Water Contaminants", 2009.  |



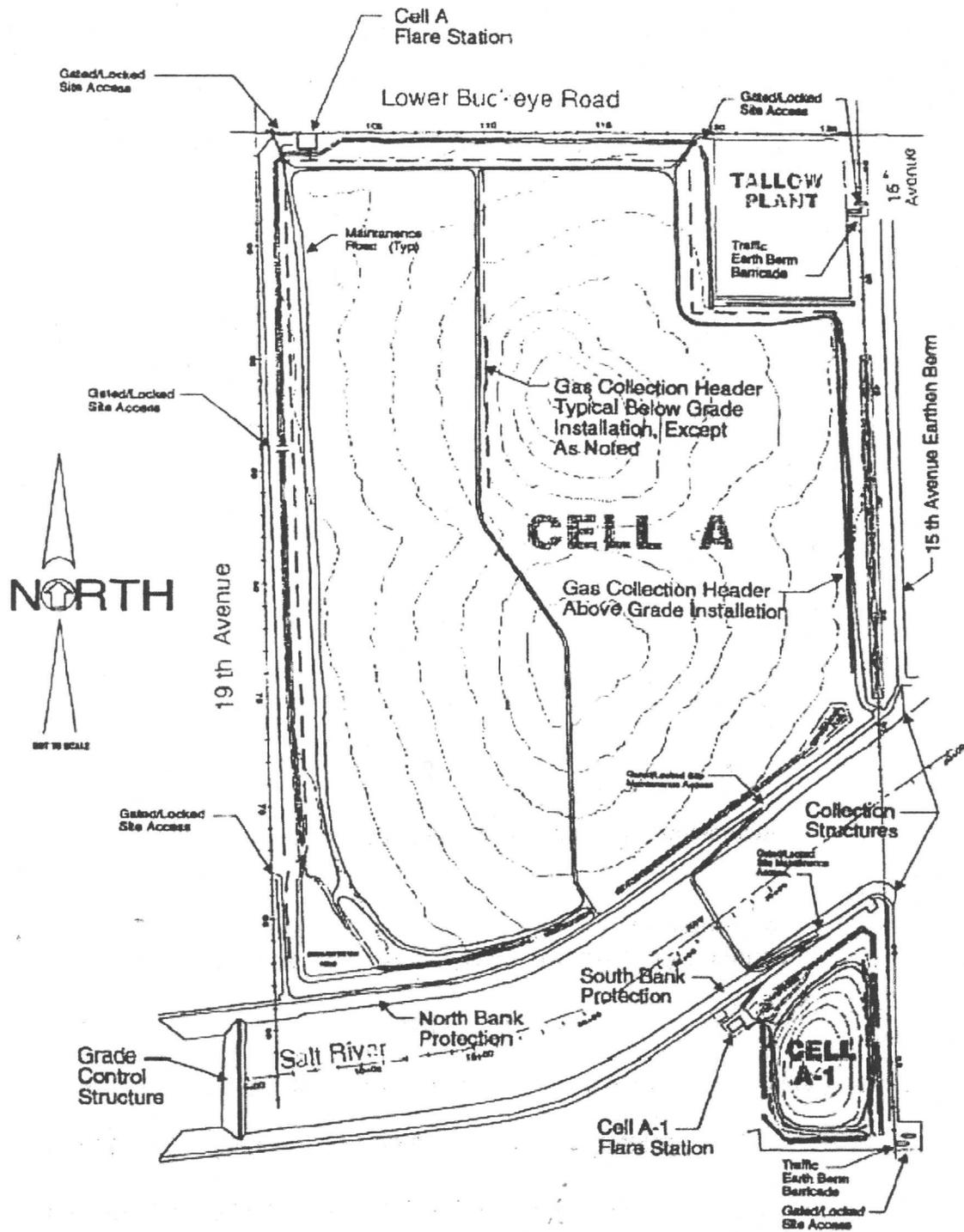
NOTE: MAP TAKEN FROM PHOENIX QUADRANGLE,  
ARIZONA - MARICOPA COUNTY, 7.5 MINUTE SERIES

**Environmental Science & Engineering, Inc.**  
A MACTEC COMPANY

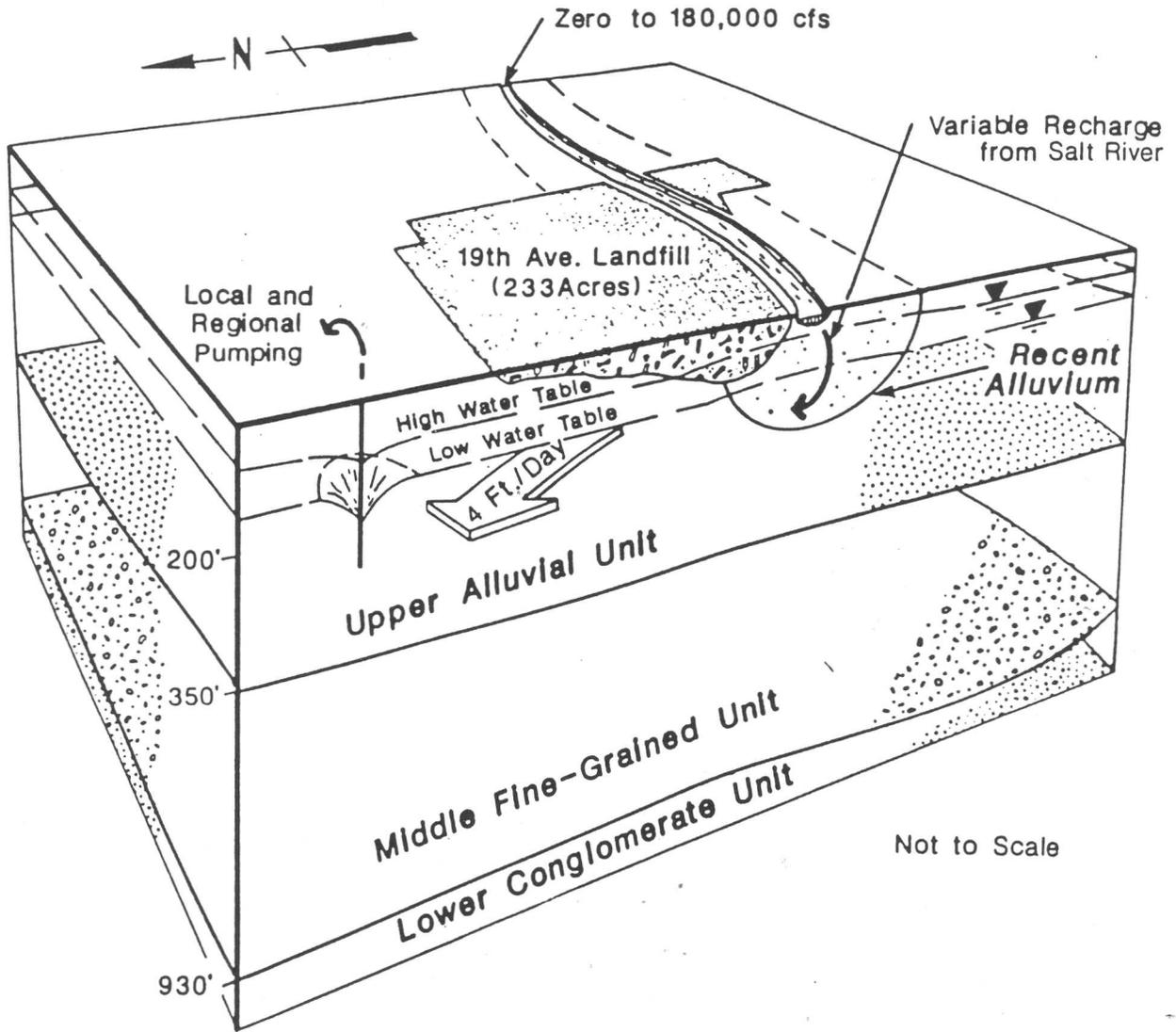
**19TH AVENUE LANDFILL  
SITE LOCATION MAP  
PHOENIX, ARIZONA**

Figure  
**1**

|                             |                           |                 |                |
|-----------------------------|---------------------------|-----------------|----------------|
| Drawn<br>Daniel L. Kudlicki | Project Number<br>6600001 | Approved<br>JSK | Date<br>3/3/00 |
|-----------------------------|---------------------------|-----------------|----------------|



NOTE: ORIGINAL SITE PLAN DEVELOPED BY SIMONS, LI & ASSOCIATES 9/15/98



**HYDROGEOLOGIC  
CONCEPTUAL  
DIAGRAM**

19th AVENUE LANDFILL

Figure 2.16

| DEPTH (FEET) | GRAPHIC LOG | USCS * | GEOLOGIC SUBSTRATUM | APPROXIMATE THICKNESS (FEET) | DESCRIPTION   |
|--------------|-------------|--------|---------------------|------------------------------|---|
| 0            |             | SM     | S                   | 15                           | SILTY SAND, BROWN TO LIGHT BROWN, 50-60% FINE TO MEDIUM SAND, 30-40% SILT WITH CLAY, <10% GRAVEL, TRACE CALICHE.  |
| 50           |             | GP     | A <sub>1</sub>      | 85                           | GRAVEL, 80-90% FINE TO COARSE GRAVEL AND COBBLES, 20-10% MEDIUM TO COARSE SAND, LITTLE TO NO FINES.   |
| 100          |             | GP-SP  | A <sub>2</sub>      | 90                           | SANDY GRAVEL, 60-70% FINE TO COARSE GRAVEL, 30-40% FINE TO COARSE SAND, MINOR SILT, INCREASING FINES (SAND & SILT) WITH DEPTH. INTERBEDDED SAND (SP) LENSES.  |
| 200          |             | SM-GM  | B                   | 50-30                        | SILTY SAND WITH GRAVEL, REDDISH BROWN, 40-50% FINE TO MEDIUM SAND, 40-50% SILT WITH CLAY, 10-15% FINE GRAVEL.   |
| 250          |             | GM     | C                   | 120                          | SANDY GRAVEL WITH SILT AND CLAY, BROWN, 40-50% FINE TO MEDIUM GRAVELS, 40-50% FINE TO COARSE SAND, 0-20% SILT WITH CLAY. INTERBEDDED SAND (SP) AND GRAVEL (GP) LENSES. DECREASING FINES (SILT & CLAY) WITH DEPTH. |
| 350          |             | SM-GM  | MFU                 | ~200                         | SILTY SAND WITH GRAVEL, CLAYEY SILTS, BROWN INTERBEDDED SANDY SILT, CLAYEY SILT AND SILTY SAND WITH MINOR FINE TO MEDIUM GRAVEL.  |
| 400          |             | SM-GM  |                     |                              |   |

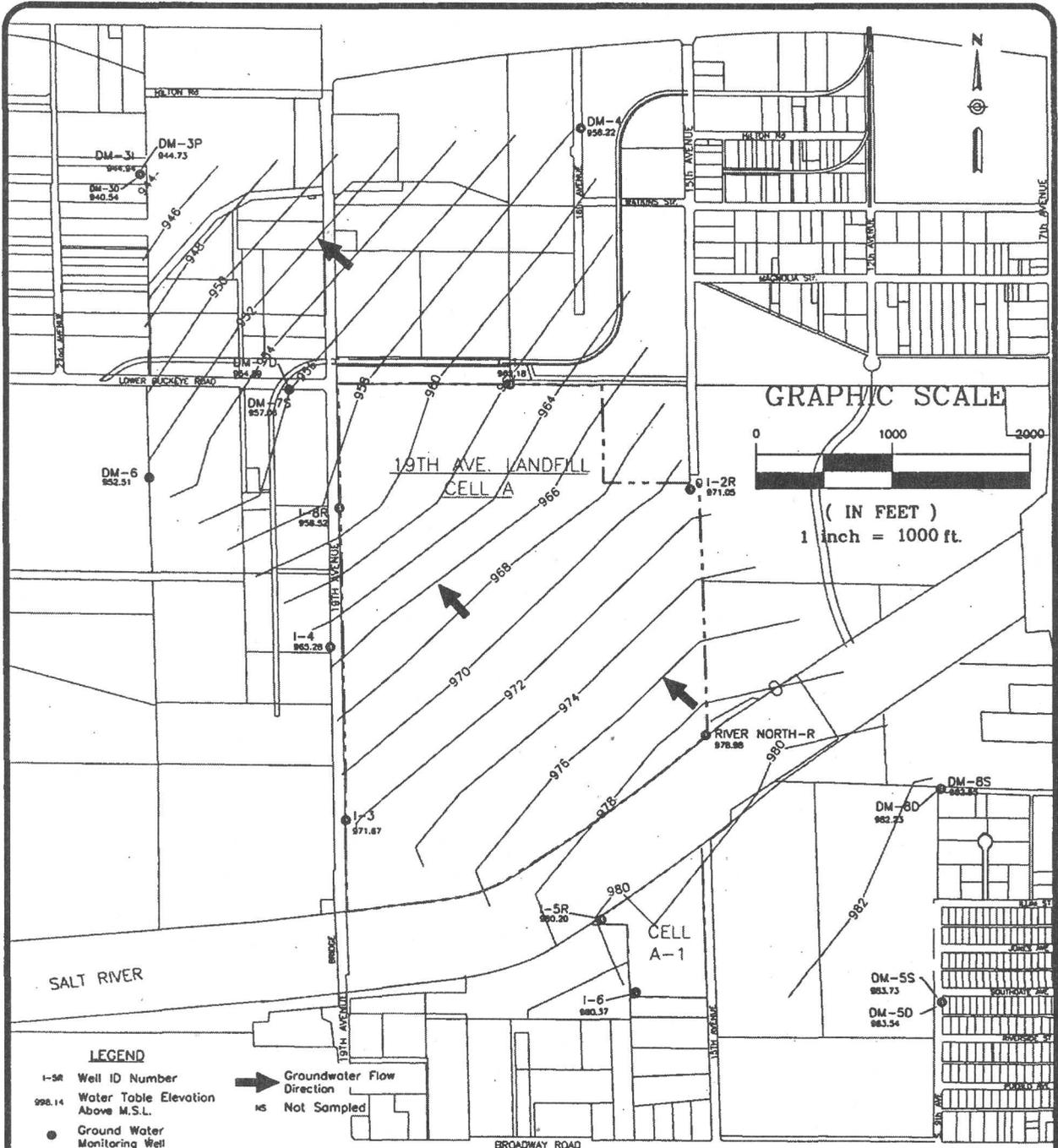
— CONTACT  
 - - - TRANSITIONAL CONTACT

## GENERALIZED STRATIGRAPHIC COLUMN

19th AVENUE LANDFILL  
 Figure 2.10

\* UNIFIED SOIL CLASSIFICATION SYSTEM

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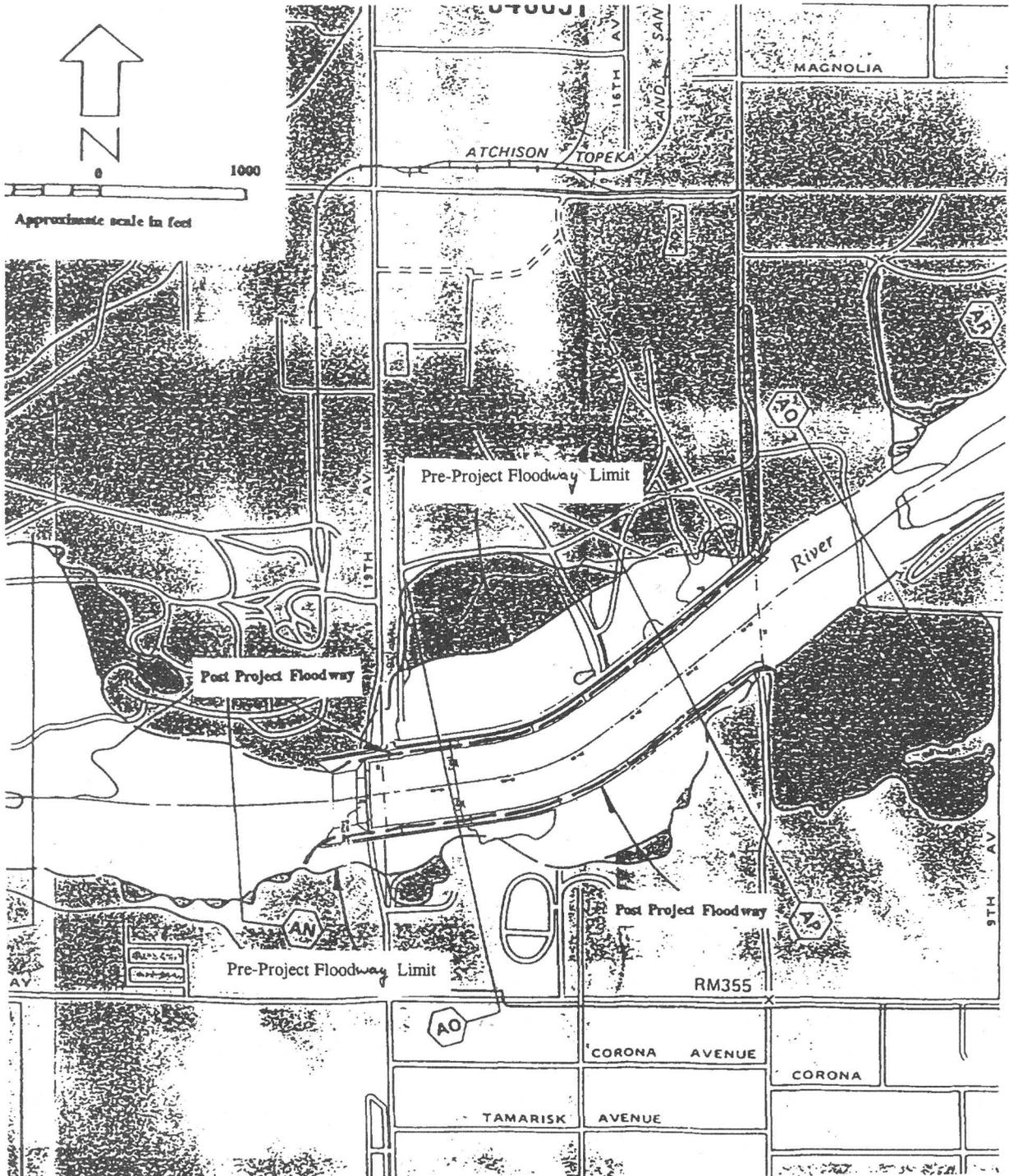

CITY OF PHOENIX  
SOLID WASTE MANAGEMENT  
3060 S. 27TH AVENUE  
PHOENIX, ARIZONA 85009

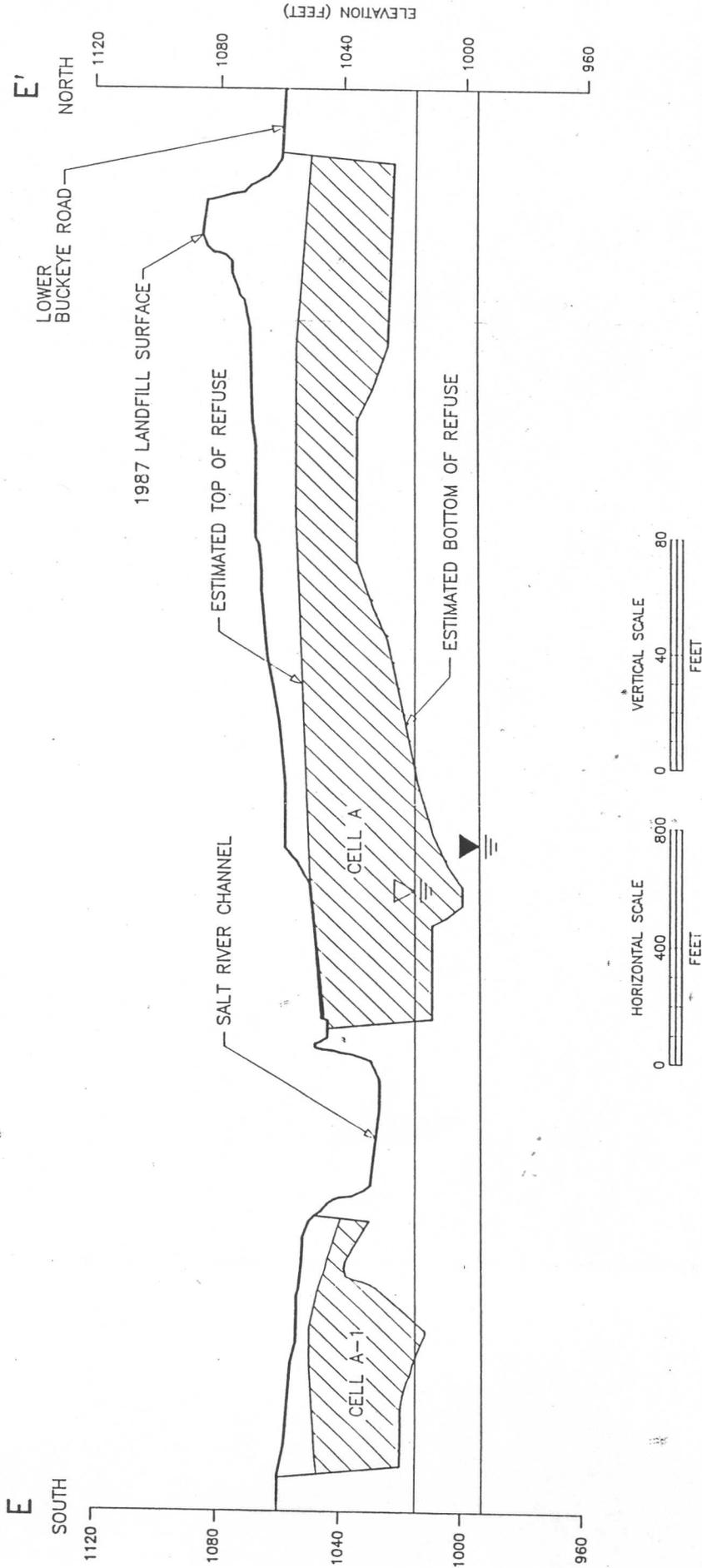
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**FIGURE 1**  
19TH AVENUE LANDFILL  
1701 W. LOWER BUCKEYE ROAD  
PHOENIX, ARIZONA  
**GROUNDWATER ELEVATIONS**  
**FOURTH QUARTER 2007**

# FIGURE 3-4

## 100 Year Floodway





NOTE: THE CROSS SECTION ALIGNMENT IS SHOWN ON FIGURE 2.3

- MAXIMUM WATER TABLE ELEVATION (1/10/86)
- MINIMUM WATER TABLE ELEVATION (9/25/87)
- REFUSE

**SUBSURFACE  
CROSS SECTION E-E'**  
19th AVENUE LANDFILL  
Figure 2.17



# Memorandum

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**Date:** April 14, 2004  
**To:** 19<sup>th</sup> Avenue Landfill Superfund Site  
Facility File  
**Thru:** Bill DePaul, Project Manager  
Federal Projects Unit  
**From:** Hugh Rieck, Hydrologist  
Remedial Investigations Hydrology Unit  
**Subject:** Technical memorandum on arsenic concentrations in groundwater monitor wells at the 19<sup>th</sup> Avenue Landfill Superfund Site

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## Summary

Of the nineteen monitor wells located around the 19th Avenue Landfill, seventeen consistently show arsenic concentrations near or below 10 µg/L, while two (I-3 and I-4) located near the western edge of the landfill have shown elevated and fluctuating levels of arsenic (6 – 92 µg/L). Analysis of the last eight years of historical groundwater elevation and water quality data shows that the elevated levels of arsenic and related elements at I-3 and I-4:

- § are clearly above natural background concentrations for the area around the site
- § fluctuate seasonally with water level drawdown to meet irrigation demand
- § show no long-term trend of increase or decrease independent of water level trends
- § remain restricted to the immediate vicinity of the site (boundary wells I-3 and I-4)

The locally elevated arsenic concentrations probably result from mobilization of arsenic and associated redox sensitive metals by the reducing conditions in the vadose zone and capillary fringe beneath the landfill. Possible sources of the arsenic are 1) the landfill trash, and 2) naturally occurring arsenic in sediments of the aquifer. The observed relationship between changes in groundwater elevation and arsenic and related metals (iron, manganese) concentrations strongly suggests that at least some, if not practically all of the arsenic, occurs naturally in the aquifer sediments. Regardless of the source of the arsenic, it is relatively immobile in the oxidizing groundwater conditions of the region and is not transported far beyond the site boundary before it is precipitated into low solubility compounds bound in the aquifer matrix. This is consistent with the lack of elevated arsenic in the monitor wells downgradient of I-3 and I-4. Except for long-term monitoring, no remedial action is recommended for the elevated arsenic.

## **Introduction**

The Arizona Department of Environmental Quality (ADEQ) has completed a review and evaluation of the last eight years of arsenic and related metals concentration data for groundwater monitor wells at the 19<sup>th</sup> Avenue Landfill National Priorities List (NPL) Site. The main objective of the review is to explain the elevated levels of arsenic in groundwater monitor wells I-3 and I-4, which are immediately adjacent to the western (obliquely down-gradient) boundary of the site. Fluctuating concentrations of arsenic in these wells have averaged near the previous regulatory threshold level of 50 micrograms/liter ( $\mu\text{g/L}$ ) specified in the ROD. However, the lowering of the drinking water standard (on which the ROD was based) to an MCL of 10  $\mu\text{g/L}$  has brought into question the significance of the arsenic concentration in these wells. If applied, the new standard would cause these two monitor wells to be consistently in an exceedance condition or out of compliance.

## **Background**

Quarterly groundwater monitoring data from all monitor wells of the 19<sup>th</sup> Avenue Landfill network (Figure 1), including upgradient, cross-gradient, and downgradient wells, show that, with the exception of wells I-3 and I-4, arsenic concentrations generally range between 1 and 20  $\mu\text{g/L}$  (Figures 2 and 3). Most wells, including those downgradient from I-3 and I-4 are consistently below 10  $\mu\text{g/L}$ .

During the last eight years, arsenic concentrations in samples from wells I-3 and I-4 have been highly variable, ranging from 6 to 99  $\mu\text{g/L}$ . However, concentrations in the higher end of this range (*i.e.* > 50  $\mu\text{g/L}$ ) have been transient, and until recently not triggered action beyond follow-up resampling at the end of the quarter, as specified in the contingency plan of the Consent Decree.

The frequency of fluctuations in arsenic concentrations at I-3 and I-4 suggests that they are related to observed fluctuations in groundwater levels (Figure 2) due to heavy seasonal pumping from large irrigation wells of the Roosevelt Irrigation District northwest of the site. The water table beneath the site is drawn down during spring and summer months to a relative low stand in late summer or fall, then generally recovers to a relative high stand in January or February. The irrigation district wells influence a large area and maintain a consistent northwesterly groundwater flow direction at the site. As determined in the RI, groundwater velocity has varied from 1 to 8 feet per day, and fluctuated between 20 and 80 feet below the ground surface. In recent years, drought in Arizona has produced a widespread decline in the water table upon which the seasonal fluctuations are superposed.

## **Discussion**

Arsenic can occur as a semi metallic element ( $\text{As}^0$ ), arsenate ( $\text{As}^{5+}$ ), arsenite ( $\text{As}^{3+}$ ), or arsine ( $\text{As}^{-3}$ ). Naturally, arsenic occurs almost exclusively as arsenite or arsenate. Anthropogenic arsenic may have any form including the organic arsine species (Vance, 2002). Elemental arsenic or arsine are unlikely to be present under conditions at wells I-3 and I-4, and the difficulties and expense of testing for these species are unwarranted under the present circumstances. Arsenic can readily change oxidation state between arsenite and arsenate species through chemical or biological reactions that are common in the environment.

The solubility and mobility of arsenic compounds in groundwater depend on the oxidation state, chemical composition of the groundwater, and adsorption/desorption reactions (Welch and others, 1988). These in turn are controlled by the oxidation-reduction potential (ORP/Eh), pH conditions, and possible biological activity. Arsenite compounds are 4 to 10 times more soluble in water than arsenate compounds (Robins, 1985).

Field measurements of pH reported for the site-related wells are within a typical range between 6.8 and 7.8. No site data have been reported for ORP (convertible to Eh). Nonetheless, from other studies, natural background values for Eh in the regional aquifer system can safely be assumed to be at least a slightly oxidizing (Eh greater than +100 to +200 mV). Eh/pH diagrams of arsenic oxidation state (Figure 4) show that, within the typical range of site pH values, the oxidation state of arsenic is probably above the arsenate/arsenite transition threshold. Thus, a reduction in Eh may tend to make arsenite the stable form.

The geochemical behavior of iron (and manganese) is similar to that of arsenic. At typical site pH values, iron will readily precipitate from solution under oxidizing conditions (Eh > +100 to 200 mV), forming ferric oxy-hydroxide minerals of low solubility (Hem, 1961; Krause and Ettl, 1985) (Figure 5). Arsenate is strongly adsorbed and incorporated into these low solubility complexes (Frank and Dennis, 1986). This co-precipitation of arsenic and iron can be used to effectively remove arsenic in drinking water treatment systems (US EPA, 2002). Under reducing (anaerobic) conditions, both elements are stable in their more soluble forms (arsenite and ferrous iron). Historical dissolved (ferrous) iron concentrations from site wells are generally below laboratory reporting limits (0.10 mg/L). Iron concentrations significantly above the laboratory reporting limit are reported only from wells I-3 and I-4, where they fluctuate with arsenic in response to changes in water table elevation.

Reducing conditions clearly exist in the vadose zone beneath the landfill cap, as evidenced by the large amount of methane gas being collected and burned by the methane extraction system in operation at the site. Seasonal lowering of the water table causes an influx of methane gas and associated reducing conditions downward into the expanding vadose zone and relatively thick capillary fringe (due to the fine-grained nature of the aquifer sediments) to the water table. The water table is only a few tens of feet below the base of the lowest trash layers.

## **Observations**

1. Arsenic (and iron) concentrations increase when the vadose zone expands downward and water table moves farther from base of landfill trash deposits due to a declining water table. This suggests mobilization of naturally occurring arsenic (and iron) in the sediments upon exposure to reducing conditions in the vadose zone, rather than increased contribution from a hypothetical landfill source.
2. The largest increases in arsenic concentration are generally seen after aquifer sediments which have previously always been fully saturated are first exposed to the reducing vadose zone conditions (*i.e.* the water table drops below any previous low stand). Arsenic concentrations (*i.e.* mobility) are seen to equilibrate and then diminish when the water table remains within or rises above a depth that has been previously dewatered (Figure 2). This suggests depletion of a finite amount of potentially mobile arsenic in the aquifer sediments.
3. The slight, long-term increasing trend in arsenic concentration at I-4 mirrors the overall long-term drop in water table elevation (Figure 2) and the continued downward expansion of the vadose zone. This also suggests that the primary source of arsenic is mobilization of naturally occurring arsenic in the aquifer sediment.
4. Sulfate concentrations are observed to be relatively low and consistent in all site wells except I-3 and I-4. Typical sulfate concentrations for site wells range between 80 and 160 mg/L with little variation at a single well. Sulfate concentrations for I-3 and I-4 are generally lower, normally ranging between about 10 and 90 mg/L, and are notably variable with water level. Increases in sulfate concentration indicate more oxidizing conditions. At wells I-3 and I-4 increases in sulfate correspond to increases in water level elevation. Sulfate spiked as high as 158 mg/L (comparable to other wells) in I-3 during the second quarter of 2003, concurrent with an abrupt increase in water level and drop in arsenic concentration to 6 µg/L (Figure 3).

### **Alternative Hypotheses**

URS Corporation, as consultant to the City of Phoenix, prepared a report to explain the arsenic exceedance at the 19th Avenue Landfill wells (URS, 2003). URS proposed seven hypotheses as possible explanations for the arsenic behavior at I-3 and I-4. Two of these (5 and 7, below) in combination are consistent with all available site data. The other five are not supported by the data.

1. *Variation in natural arsenic concentrations associated with aquifer material (independent of the landfill).* This hypothesis suggests that heterogeneity in the distribution of naturally occurring arsenic in the aquifer may be responsible for the locally elevated concentrations, *i.e.* an arsenic rich patch of sediment just upgradient from I-3 and I-4. This is unlikely because 1) the I-3 and I-4 fluctuations in concentration of arsenic and related constituents correlate closely with the patterns of change in water table elevation across a 30-foot thick interval described above and, 2)

- other site wells, including wells downgradient from I-3 and I-4, show relatively low, homogeneous and consistent concentrations of arsenic, iron, sulfate, and other related constituents.
2. *Dissolution of arsenic from a source located within the landfill.* Arsenic could be present in the landfill debris; however there is no evidence to suspect any significant arsenic source discarded within the landfill. URS acknowledges that the Remedial Investigation (RI) indicated that no significant [identifiable, localized] sources of contamination were present. Local infiltration through the landfill cap and debris is negligible; there may be net upward migration of water at the site. The correlation of increased arsenic concentration with lowered water table elevation suggests mobilization from the aquifer sediments rather than a landfill source. A landfill source could be expected to cause increased arsenic concentrations with rising water level.
  3. *Dissolution of arsenic from an off-site source.* URS acknowledges that the locations of wells I-3 and I-4 along the western edge of the landfill are (and have always been) downgradient from the landfill and upgradient of any potential off-site source, making this a very unlikely hypothesis.
  4. *The introduction of dislodged sediment from the well casing into groundwater samples.* URS acknowledges that this is unlikely because comparisons of filtered and unfiltered samples collected on the same day showed no significant differences. RIHU has considered possible differences in well construction or materials; however other wells built to identical specifications do not produce the high arsenic, iron, and related constituent results.
  5. *Decreasing groundwater elevations contributing to changes in water quality.* URS notes that historic data suggest transient increases in arsenic [at I-3 and I-4] are concomitant with decreases in groundwater elevation. They also note that although comparable changes in groundwater elevation occur in all site wells, arsenic elevation is observed only in these two wells. In combination with hypothesis number 7 (below), this appears to be an important component of any explanation.
  6. *Recharge as a result of flow in the Salt River.* URS points out that recent activities associated with the Rio Salado restoration project have resulted in continuous [very] low flows in the Salt River bed that are expected to result in recharge likely to affect hydrogeology and geochemistry of ground]water in the area. RIHU points out that the relationship between concentrations of arsenic and related elements at I-3 and I-4, and water table elevation, are evident in site data from many years before the Rio Salado restoration activities began. Also, any recharge from the river bed should affect at least several other site wells in addition to I-3 and I-4. The behavior of arsenic and related constituents remains anomalous only at I-3 and I-4. Any recharge that may be occurring beneath the site thus far is immeasurably small; the most recent

water table elevations beneath the site are at all-time historic lows. This hypothesis is unlikely to factor in to any explanation.

7. *Mobilization of naturally occurring arsenic mediated by reducing conditions imposed by the landfill.* URS states that site data indicate reducing conditions beneath the landfill and that reducing conditions favor dissolution of arsenic compounds. They conclude that mobilization of naturally occurring arsenic appears likely at I-3 and I-4.

## **Conclusion**

Drops in the water table exposing aquifer sediment for the first time to reducing vadose zone conditions beneath the landfill appear to be related to increases in arsenic concentration at wells I-3 and I-4, both located at the downgradient edge of the landfill. Some arsenic may be coming from landfill debris, but there is no evidence to support this, and some evidence to suggest that this is not the case. Most, if not all of the arsenic appears to be mobilized from naturally occurring arsenic in the aquifer sediment. Similar mobilization of naturally occurring arsenic has been documented beneath other landfill sites (*e.g.* White and Sevee, 1999). Regardless of the source of the arsenic, it should not be of significant concern or a hindrance to delisting of the site because 1) it is not mobile or being transported in the oxidizing environment of the regional aquifer system, 2) it is not a threat to human health (*i.e.* drinking water supply) or the environment, 3) the slight increasing trend in concentrations at I-3 and I-4 can be expected to reverse if water levels rise, 4) no technically feasible or cost effective remedy is available, and 5) long-term stability and predictability of the situation is unlikely to change.

## **Recommendations**

Groundwater monitoring should continue indefinitely to insure that any significant change in conditions or future threat is recognized.

Because the arsenic in groundwater at the western edge of the landfill is from a naturally occurring source, predictable, relatively stable, and does not pose a threat to human health or the environment, no remedial action is warranted and it should not hinder delisting of the site.

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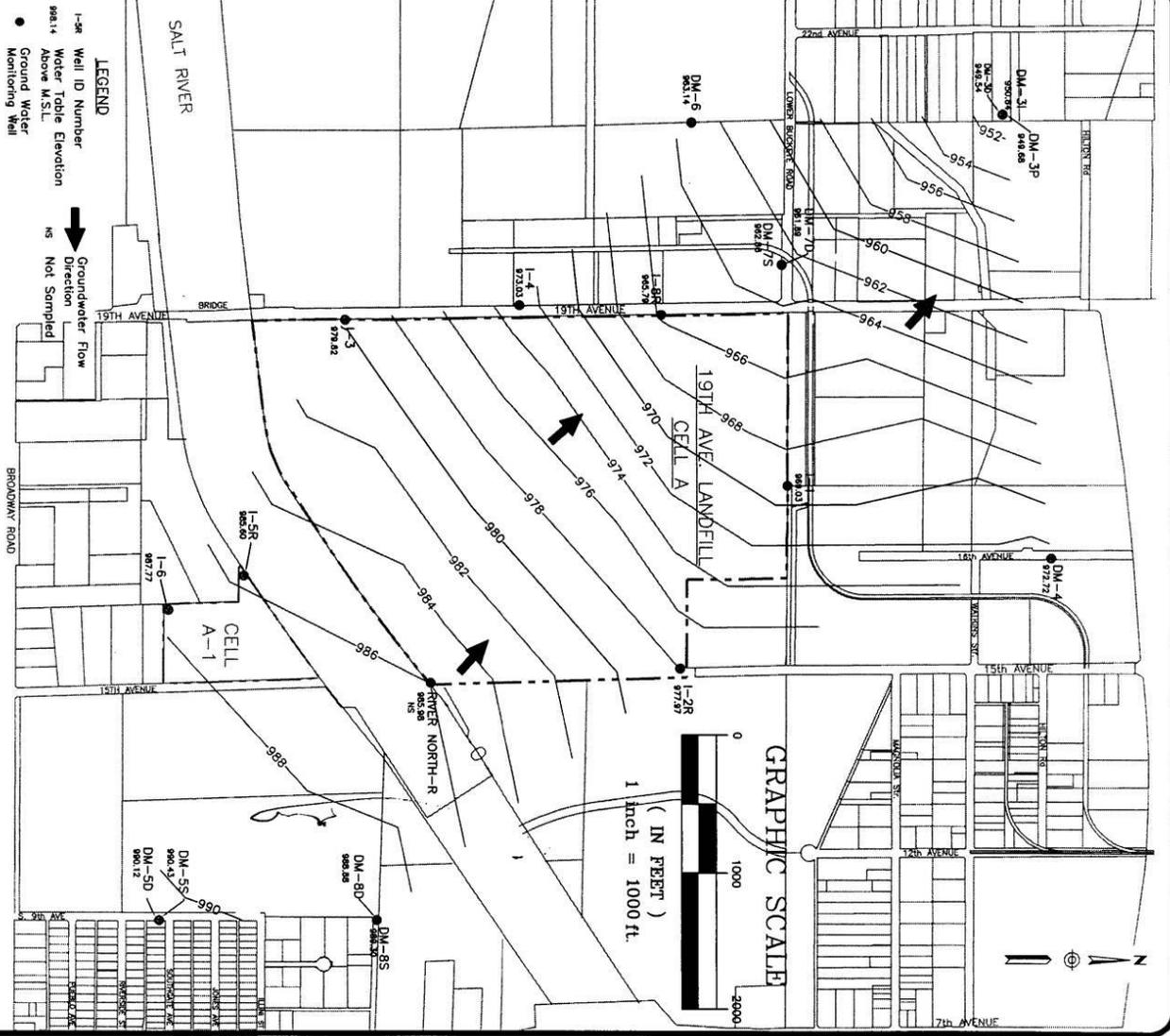
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CITY OF PHOENIX  
SOLID WASTE MANAGEMENT  
3060 S. 27TH AVENUE  
PHOENIX, ARIZONA 85009

DATE: 10/03  
DMN: SN  
REV: JW  
APP: BH

**FIGURE 1**  
19TH AVENUE LANDFILL  
1701 W. LOWER BUCKEYE ROAD  
PHOENIX, ARIZONA  
GROUNDWATER ELEVATIONS  
FOURTH QUARTER 2003



**LEGEND**  
I-SR Well ID Number  
Water Table Elevation  
Above M.S.L.  
● Ground Water  
Mentioning Well

Groundwater Flow  
Direction  
NS Not Sampled

**GRAPHIC SCALE**  
( IN FEET )  
1 inch = 1000 ft.

**Figure 2**

**19th Avenue Landfill  
Well I-4 Arsenic Concentrations and Groundwater Elevation**

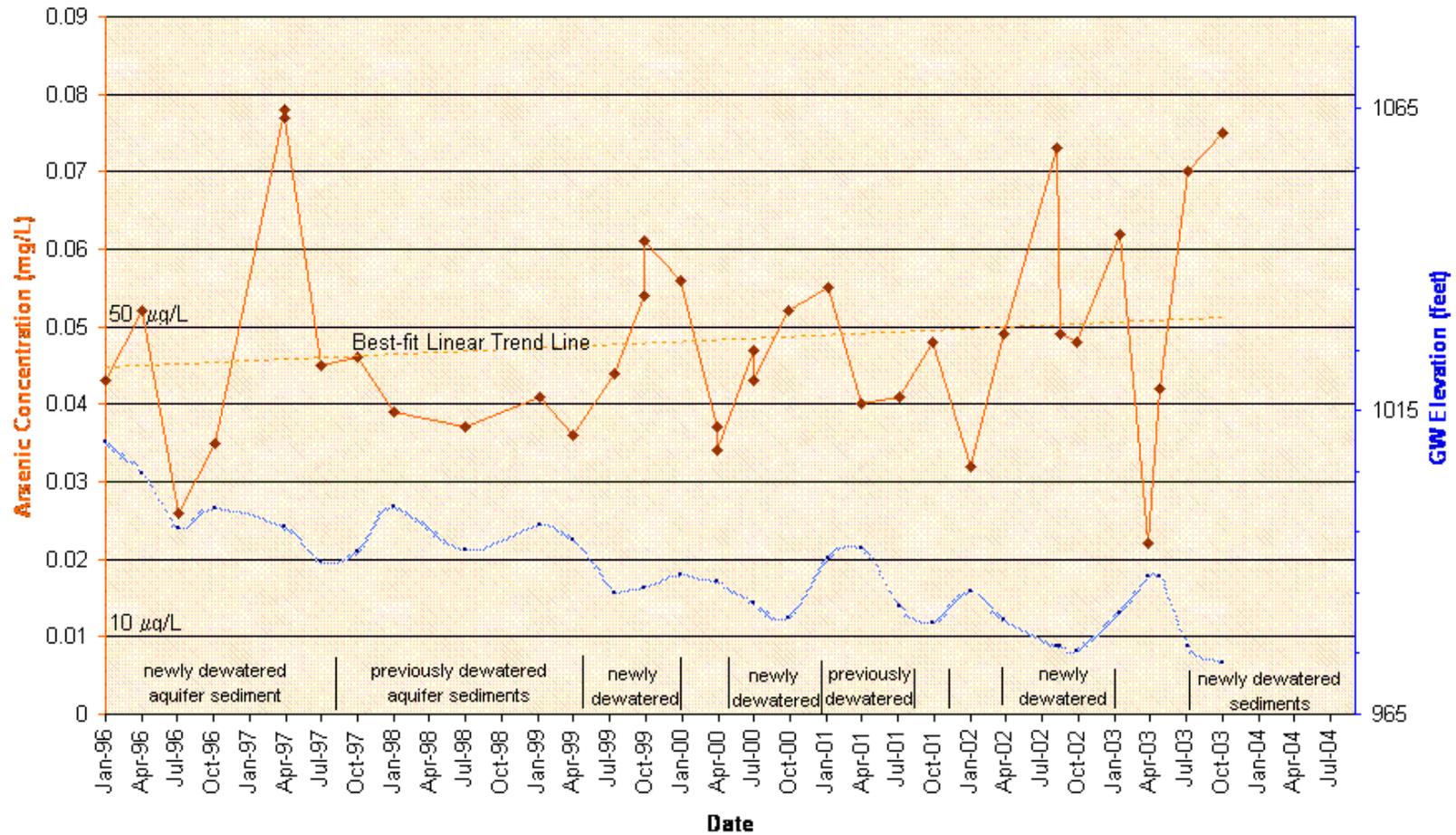


Figure 3

19th Avenue Landfill  
Arsenic Concentrations - All Wells

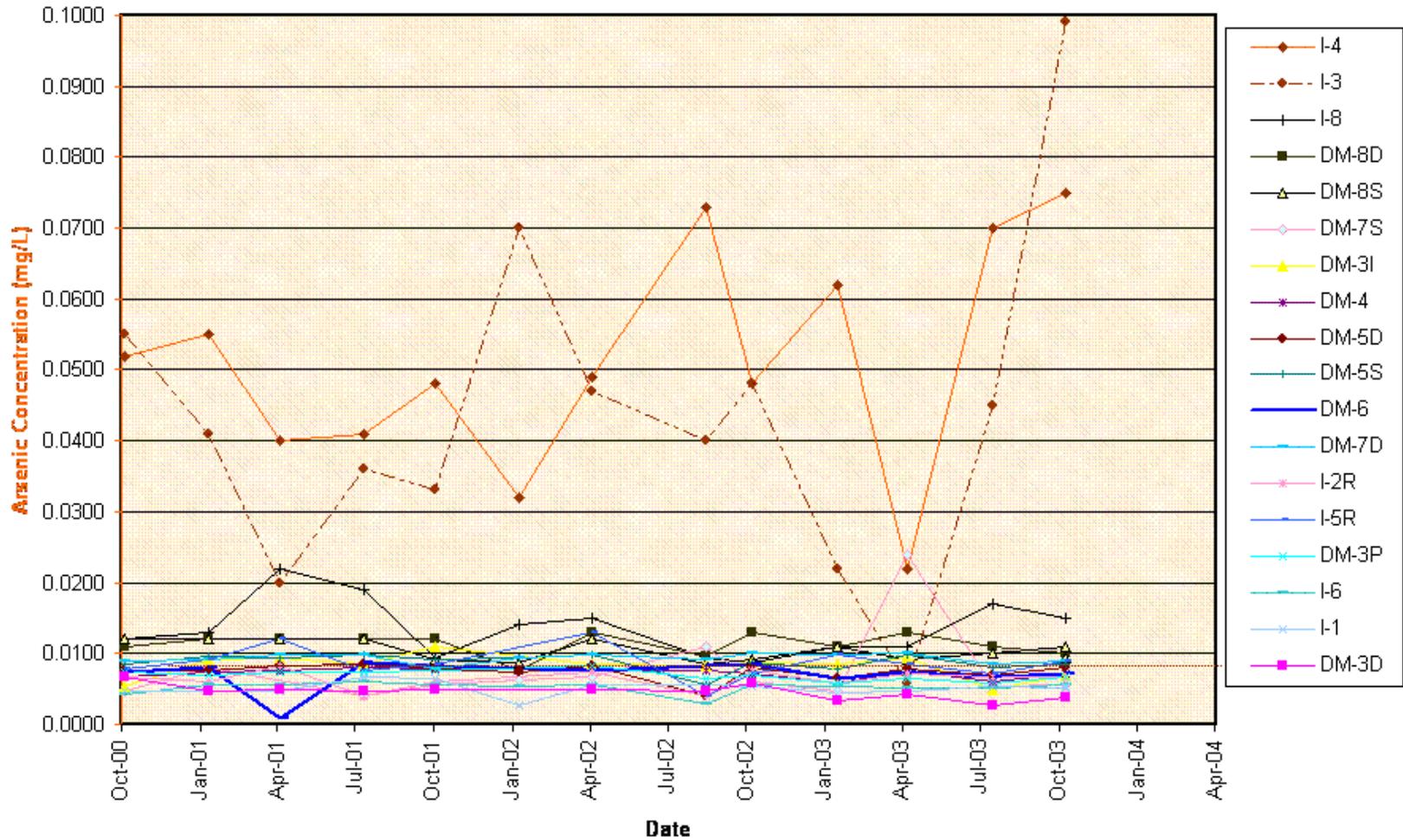
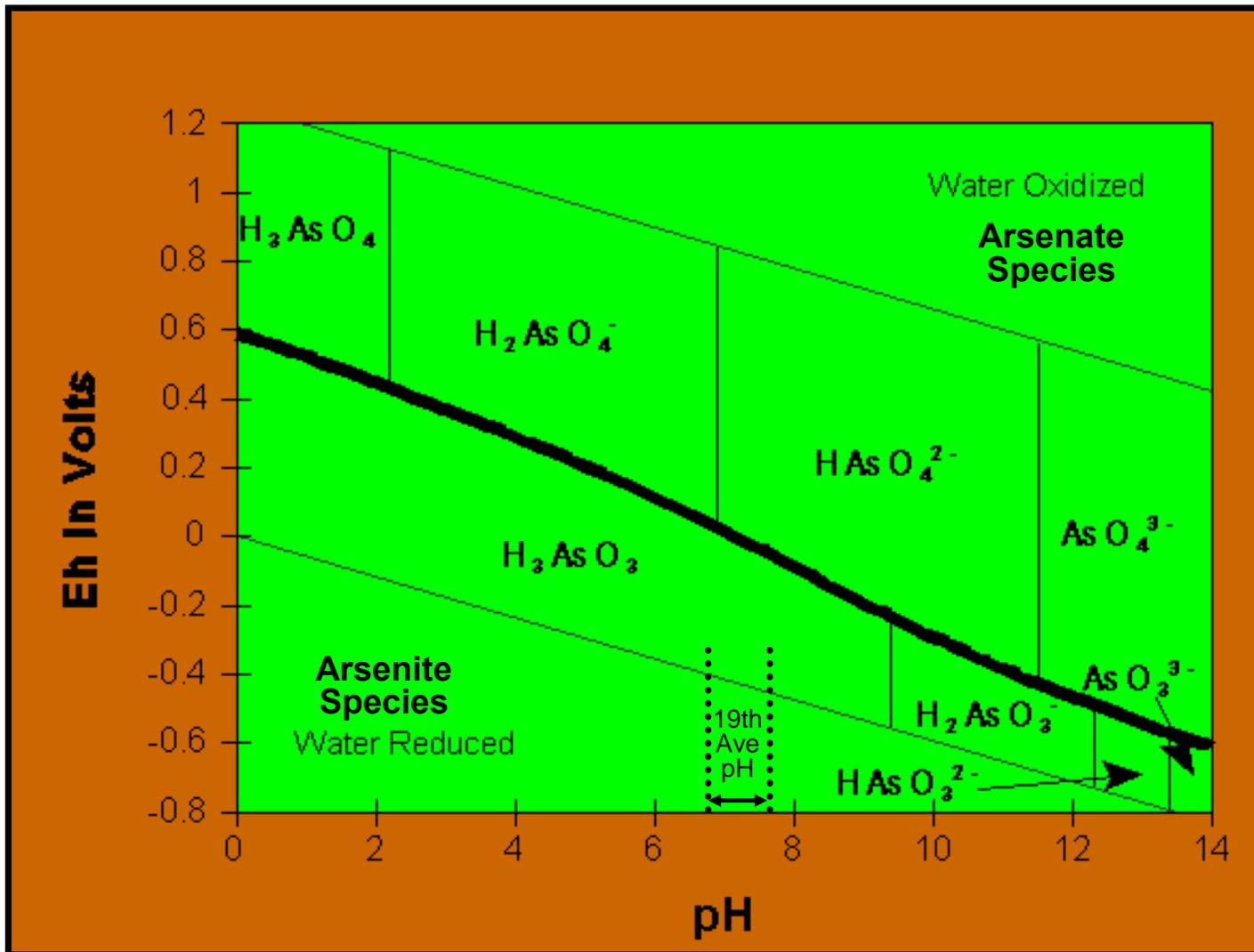


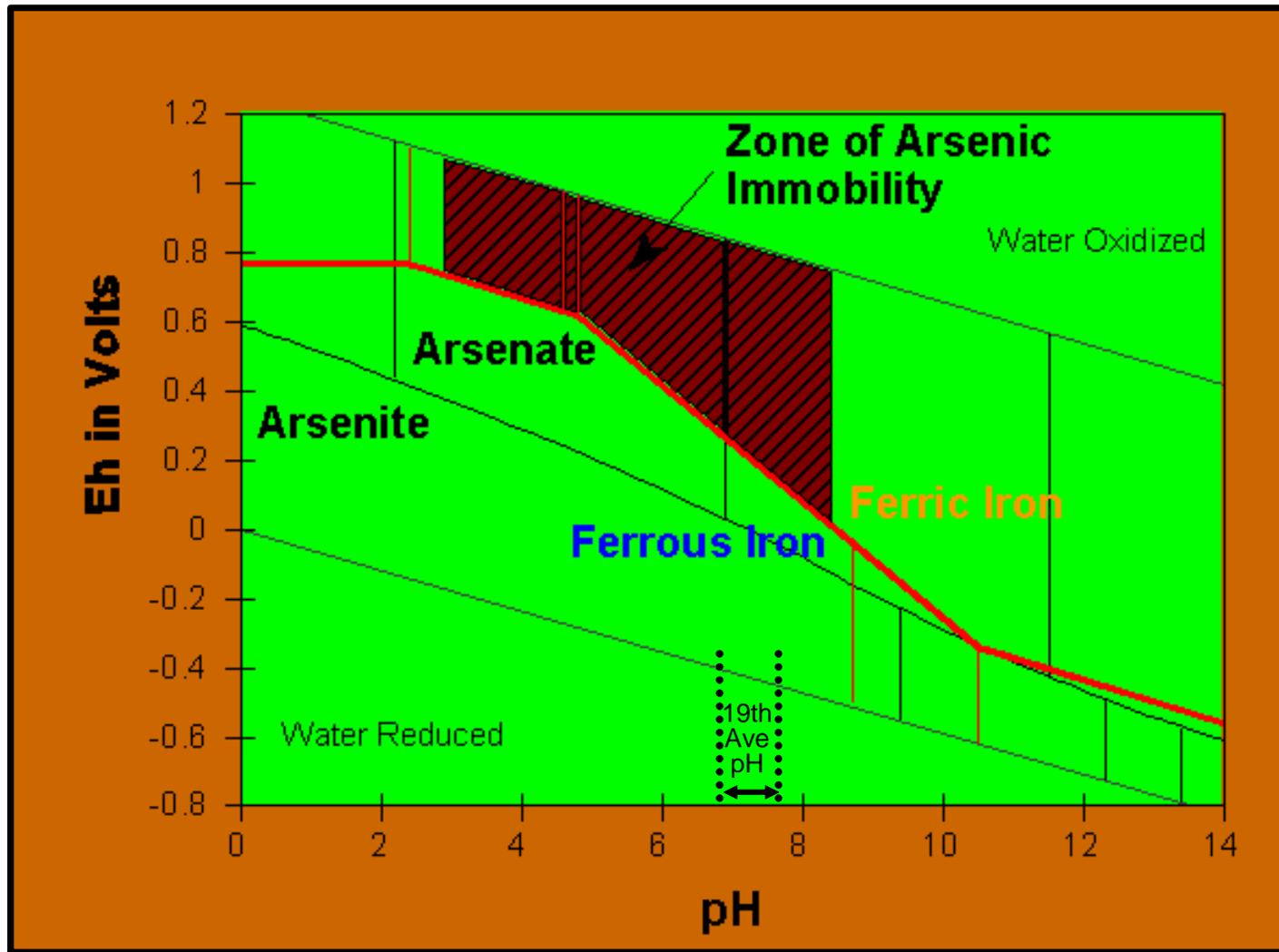
Figure 4 Eh/pH Conditions and Arsenic Speciation



after Vance, D. B., 2001

Figure 5

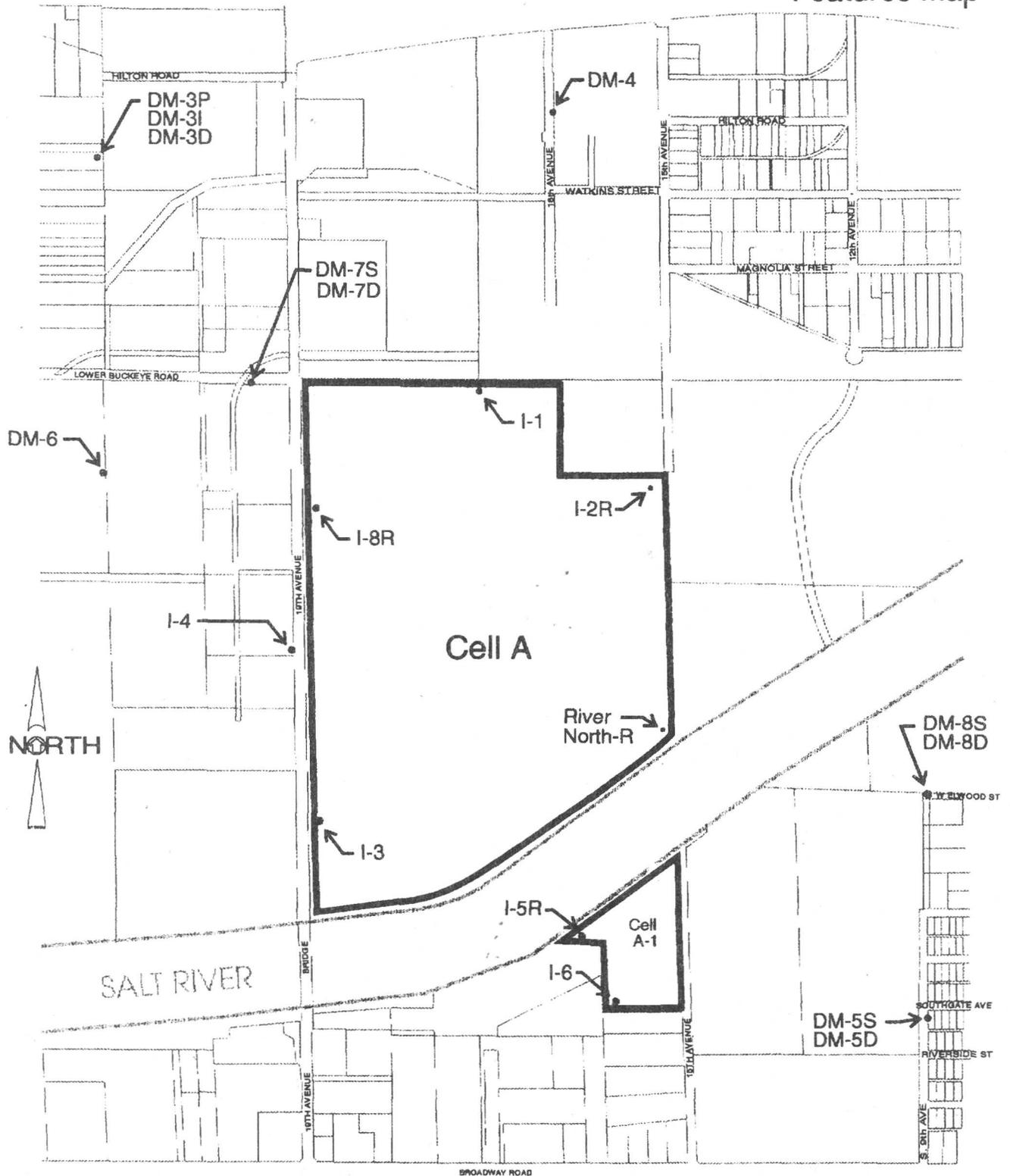
Eh/pH - Iron and Arsenic Speciation Overlay



after Vance, D. B., 2001

# FIGURE 4-1

## Groundwater Monitoring Wells O&M Program Features Map



**Table 8-2  
Summary of Well  
Construction**

| Well Name                             | Date Completed | Drilling Method   | Well Depth (in feet) | Casing Type | Screen Interval (in feet) |
|---------------------------------------|----------------|-------------------|----------------------|-------------|---------------------------|
| <b>Existing and Replacement Wells</b> |                |                   |                      |             |                           |
| DM-3D                                 | 6/15/87        | Mud Rotary        | 370                  | 6" PVC      | 280-320                   |
| DM-3I                                 | 6/26/87        | Mud Rotary        | 232                  | 6" PVC      | 185-225                   |
| DM-3P                                 | 6/20/87        | Mud Rotary        | 170                  | 10" PVC     | 110-150                   |
| DM-4                                  | 6/19/87        | Mud Rotary        | 170                  | 6" PVC      | 110-150                   |
| DM-5D                                 | 8/8/87         | Mud Rotary        | 300                  | 6" PVC      | 185-225                   |
| DM-5S                                 | 8/5/87         | Mud Rotary        | 164                  | 6" PVC      | 110-150                   |
| DM-6                                  | 6/11/87        | Mud Rotary        | 170                  | 6" PVC      | 110-150                   |
| DM-7D                                 | 5/13/92        | Casing Hammer     | 169                  | 6" PVC      | 153.4-168.4               |
| DM-7S                                 | 5/13/92        | Casing Hammer     | 101                  | 6" PVC      | 59-99                     |
| DM-8D                                 | 5/13/92        | Casing Hammer     | 179                  | 6" PVC      | 163.4-178.4               |
| DM-8S                                 | 5/13/92        | Casing Hammer     | 99                   | 6" PVC      | 58.9-98.9                 |
| I-1                                   | 10/27/79       | Casing Hammer     | 101                  | 4" PVC      | 32-101                    |
| I-2R                                  | 9/18/96        | Percussion        | 101                  | 4" PVC      | 60-100                    |
| I-3                                   | 12/6/79        | Casing Hammer     | 100                  | 4" PVC      | 46-100                    |
| I-4                                   | 11/3/79        | Casing Hammer     | 102                  | 4" PVC      | 33-102                    |
| I-5R                                  | 7/10/96        | Percussion Hammer | 115                  | 4" PVC      | 65-115                    |
| I-6                                   | 11/14/79       | Casing Hammer     | 102                  | 4" PVC      | 32-102                    |
| I-8R                                  | 7/11/96        | Percussion Hammer | 115                  | 4" PVC      | 65-115                    |
| River North-R                         | 10/30/96       | Percussion        | 95                   | 4" PVC      | 60-95                     |
| <b>Abandoned Wells</b>                |                |                   |                      |             |                           |
| I-2                                   | 11/7/79        | Casing Hammer     | 101                  | 4" PVC      | 32-101                    |
| I-5                                   | 11/16/79       | Casing Hammer     | 100                  | 4" PVC      | 41-100                    |
| I-8                                   | 2/2/82         | Drilled           | 100                  | 4" PVC      | 40-100                    |
| River North                           | unknown        | Casing Hammer     | 82                   | 3" PVC      | 47-82                     |

Attachment K

| Table 4. Groundwater Exceedances by Well, Chemical and Quarter (2005 thru 2006)<br>During 2010 Five-Year Review Period – Page 1 of 3 |   |  |                                   |  |  |  |   |   |
|--|---|--|-----------------------------------|--|--|--|---|---|
| Well #   | 1 <sup>st</sup> Qtr<br>2005   | 2nd Qtr<br>2005  | 3rd Qtr<br>2005                   | 4th Qtr<br>2005  | 1st Qtr<br>2006  | 2nd Qtr<br>2006  | 3rd Qtr<br>2006   | 4th Qtr<br>2006   |
| DM-3D  |   |  |                                   |  |  |  |   |   |
| DM-3I  | 1,1-Dichloro-ethene (DCE)<br>7.4 ug/l<br>1/5/05.  | 1,1-DCE<br>8.3 ug/l 4/4/05.  |                                   |  |  |  |   |   |
| DM-3P  |   |  |                                   |  |  |  |   |   |
| DM-4   |   |  |                                   |  |  |  |   |   |
| DM-5D  | Nitrate<br>12 mg/l,<br>1/6/05.  | Nitrate<br>11 mg/l, 4/5/05.  |                                   |  | Nitrate<br>11 mg/l,<br>1/9/06.   |  |   |   |
| DM-5S  | 1,1-DCE<br>7.1 ug/l,<br>1/6/05.   | 1,1-DCE<br>7.4 ug/l. 4/5/05.   |                                   | 1,1-DCE 7.1<br>ug/l, 10/4/05.  |  |  |   |   |
| DM-6   |   |  |                                   |  |  |  |   |   |
| DM-7D  |   |  |                                   |  |  |  |   |   |
| DM-7S  |   |  |                                   |  |  |  |   |   |
| DM-8S  |   |  |                                   | Arsenic<br>0.011 mg/l<br>10/4/05.  |  |  |   | Arsenic<br>0.010 mg/l<br>11/8/06.   |
| DM-8D  | 1,1-DCE<br>7.9 ug/l<br>1/6/05.  | Arsenic<br>0.010 mg/l 4/05.  | 1,1-DCE<br>7.1 ug/l<br>10/5/05.   | 1,1-DCE<br>7.1 ug/l  | Arsenic<br>0.010 mg/l<br>1/9/06.   | Arsenic<br>0.010 mg/l<br>4/27/06.  |   | Arsenic<br>0.011 mg/l<br>11/17/06.  |
| River<br>North-R   |   |  |                                   |  |  |  |   |   |
| I-1  |   |  |                                   | Chromium<br>0.054 mg/l<br>10/10/05.  |  |  |   |   |
| I-2R   |   |  |                                   |  |  |  |   |   |
| I-3  | Arsenic<br>0.033 mg/l,<br>1/18/05;<br>0.028 mg/l,<br>2/05;<br>0.021 mg/l,<br>3/05.        | Arsenic<br>0.014 mg/l,<br>4/7/05;<br>0.013 mg/l, 5/05;<br>0.033 mg/l, 6/05.<br>Nitrate<br>85 mg/l, 4/7/05.<br>Nickel<br>0.34 mg/l, 4/7/05. | Arsenic<br>0.029 mg/l<br>7/11/05. | Arsenic<br>0.041 mg/l<br>10/5/05; 0.033<br>mg/l 11/05;<br>0.033 mg/l<br>12/05. | Arsenic<br>0.030 mg/l<br>1/11/06;<br>0.028 mg/l<br>2/06;<br>0.034 mg/l<br>3/06.<br>Nitrate<br>14 mg/l,<br>1/11/06. | Arsenic<br>0.036 mg/l<br>4/13/06;<br>0.041 mg/l<br>5/06;<br>0.038 mg/l<br>6/06.          | Arsenic<br>0.073 mg/l<br>7/31/06;<br>0.062 mg/l<br>8/30/06;<br>0.040<br>9/06; 0.047<br>mg/l 9/11/06.<br>Nitrate 12<br>mg/l,<br>9/11/06. | Arsenic<br>0.048 mg/l<br>10/23/06;<br>0.048 mg/l<br>11/1/06;<br>0.055 mg/l<br>12/14/06.           |
| I-4  | Arsenic<br>0.051/<br>0.052 mg/l<br>1/18/05;<br>0.048 mg/l<br>2/05;<br>0.036 mg/l<br>3/05. | Arsenic<br>0.026 mg/l 4/7/05;<br>0.025 mg/l 5/05;<br>0.018 mg/l 6/05.<br>Thallium<br>0.015 mg/l 4/7/05.<br>Nickel<br>0.11 mg/l<br>4/7/05.  | Arsenic<br>0.048 mg/l<br>7/26/05. | Arsenic<br>0.062 mg/l<br>10/6/05; 0.057<br>mg/l 11/05;<br>0.065 mg/l<br>12/05. | Arsenic<br>0.062 mg/l,<br>1/18/06;<br>0.051 mg/l,<br>2/06;<br>0.063 mg/l<br>3/06.                                  | Arsenic<br>0.056/<br>0.057 mg/l<br>4/13/06;<br>0.065 mg/l<br>5/06;<br>0.050 mg/l<br>6/06 | Arsenic<br>0.065 mg/l<br>7/31/06;<br>0.073 mg/l<br>8/06; 0.053/<br>0.057 mg/l<br>9/11/06.   | Arsenic<br>0.064 mg/l<br>10/23/06;<br>0.064/<br>0.057 mg/l<br>11/1/06;<br>0.048 mg/l<br>12/14/06. |
| I-5R   |   |  |                                   |  |  |  |   |   |
| I-6  |   |  |                                   |  |  |  |   |   |
| I-8R   |   | Nickel<br>0.11 mg/l<br>4/11/05.<br>Thallium 0.0069<br>mg/l, 4/11/05.   |                                   |  |  |  |   |   |



Attachment K (cont.)

| Table 4. Groundwater Exceedances by Well, Chemical and Quarter (2009 thru June 2010)<br>During Five-Year Review Period – Page 3 of 3 |   |                                   |                                   |                                     |   |                 |                             |                             |
|--|---|-----------------------------------|-----------------------------------|-------------------------------------|---|-----------------|-----------------------------|-----------------------------|
| Well #   | 1 <sup>st</sup> Qtr<br>2009   | 2 <sup>nd</sup> Qtr<br>2009       | 3 <sup>rd</sup> Qtr<br>2009       | 4 <sup>th</sup> Qtr<br>2009         | 1 <sup>st</sup> Qtr<br>2010   | 2nd Qtr<br>2010 | 3 <sup>rd</sup> Qtr<br>2010 | 4 <sup>th</sup> Qtr<br>2010 |
| DM-3D  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-3I  |   |                                   |                                   | 1,1-DCE<br>8.2/8.4 ug/l<br>10/6/09. | 1,1-DCE<br>8.2/8.4 ug/l<br>1/12/10.                                 |                 |                             |                             |
| DM-3P  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-4   |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-5D  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-5S  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-6   |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-7D  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-7S  |   |                                   |                                   |                                     |   |                 |                             |                             |
| DM-8S  |   |                                   |                                   | Arsenic<br>0.010 mg/l<br>10/8/09.   |   |                 |                             |                             |
| DM-8D  |   |                                   |                                   | Arsenic<br>0.010 mg/l<br>10/8/09.   |   |                 |                             |                             |
| River<br>North-R   |   |                                   |                                   |                                     |   |                 |                             |                             |
| I-1  |   |                                   |                                   |                                     |   |                 |                             |                             |
| I-2R   |   |                                   |                                   |                                     |   |                 |                             |                             |
| I-3  | Arsenic<br>0.025 mg/l<br>1/13/09.<br>Nitrate<br>32 mg/l<br>1/13/09. | Arsenic<br>0.022 mg/l<br>4/15/09. | Arsenic<br>0.024 mg/l<br>7/21/09. | Arsenic<br>0.040 mg/l<br>10/5/09.   | Arsenic<br>0.046 mg/l<br>1/13/10.<br>Nitrate<br>20 mg/l<br>1/13/10. |                 |                             |                             |
| I-4  | Arsenic<br>0.054 mg/l<br>1/13/09.                                   | Arsenic<br>0.036 mg/l<br>4/14/09. | Arsenic<br>0.055 mg/l<br>7/21/09. | Arsenic<br>0.061 mg/l<br>10/5/09.   | Arsenic<br>0.050 mg/l<br>1/11/10.                                   |                 |                             |                             |
| I-5R   |   |                                   |                                   |                                     |   |                 |                             |                             |
| I-6  |   |                                   |                                   |                                     |   |                 |                             |                             |
| I-8R   | Gross Alpha<br>16 pCi/l<br>1/14/09.                                 |                                   |                                   |                                     |   |                 |                             |                             |

Attachment L

| <b>Table 5. Total Number of Groundwater Exceedances by Chemical and Year for Entire 19 Well Monitor Network During Five Year Review Period (2005 – 2010)</b> |  |             |             |             |             |             |                                |              |
|--|--|-------------|-------------|-------------|-------------|-------------|--------------------------------|--------------|
|  | <b>EPA<br/>Maximum<br/>Contaminant<br/>Levels (MCLs)</b> | <b>2005</b> | <b>2006</b> | <b>2007</b> | <b>2008</b> | <b>2009</b> | <b>2010<br/>(Jan-<br/>Mar)</b> | <b>Total</b> |
| <b>Arsenic</b>   | 0.010 mg/l   | 22          | 28          | 23          | 8           | 8           | 2                              | 91           |
| <b>Chromium</b>  | 0.10 mg/l  | 1           | 0           | 0           | 0           | 0           | 0                              | 1            |
| <b>1,1-DCE</b>   | 7 ug/l   | 8           | 0           | 0           | 1           | 1           | 1                              | 11           |
| <b>Nickel</b>  | 0.10 mg/l  | 3           | 0           | 0           | 0           | 0           | 0                              | 3            |
| <b>Nitrate</b>   | 10 mg/l  | 3           | 3           | 1           | 10          | 1           | 1                              | 19           |
| <b>Tetrachloro-<br/>ethene (PCE)</b>   | 5 ug/l   | 0           | 0           | 0           | 1           | 0           | 0                              | 1            |
| <b>Thallium</b>  | 0.002 mg/l   | 4           | 0           | 0           | 0           | 0           | 0                              | 6            |

## Attachment M



Home | Introduction | Aquifers in AZ | Water Facts | Well Water Quality | Domestic Private Wells | Water Problems | Related Websites | Sources

## Water Facts

Drinking Water Guidelines and Standards

Naturally Occurring Well Water Contaminants

Examples of Anthropogenic Contaminants

## Naturally Occurring Well Water Contaminants

An important consideration within the Basin and Range Province is how geologic forces have influenced the quality of water held within the aquifers. The Basin and Range could resemble an egg carton filled with sand, with many isolated basins and drainage systems that could not reach the sea, generating large inland seas—such as the Great Salt Lake in Utah—that concentrated the salts leached from the soils as water evaporated. Large **evaporite** deposits of salt are common within valley aquifers within the Basin and Range province, and elevated concentrations of chemical constituents such as boron, sodium chloride (salt) and calcium sulfate (gypsum) are often found in the deeper alluvium zones of the basin these aquifers.

In the Gila River Valley, for example, deep petroleum exploration boreholes have been drilled throughout the region. Although oil was not found, salt brines are now discharging to the land surface through improperly sealed abandoned boreholes, and the local water quality has been impacted. Thick layers of salt are found deep throughout the entire valley.

Today, the Wilcox Playa (near Wilcox) is an example of the formation of evaporite deposits. Because the basin is not drained, salts are accumulating on the land surface. However, the geologic barrier that stops the flow out of the Wilcox Basin is relatively recent in geologic time, and because of this only the shallow ground water is salty. Water quality in the deep aquifer of the Willcox Basin is excellent.

Figure 11 shows those portions of the state where ground water has been reported to be saline, either due to deep layers of salt originating from the depositional setting, **playa** formation, or in agricultural areas where evaporation of irrigation water concentrates naturally occurring salts.

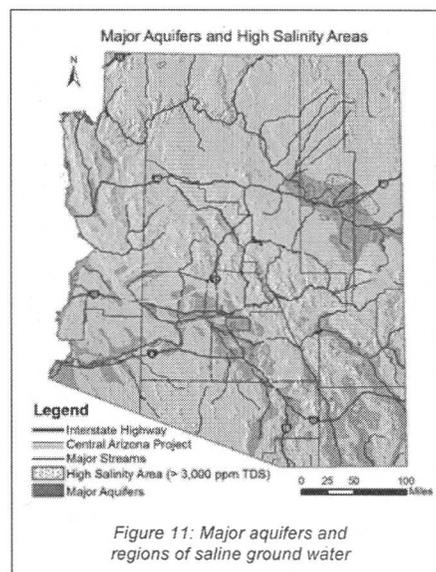
In addition to elevated total dissolved solids (see section 4), the most common constituents found in Arizona ground water in concentrations above drinking water standards are arsenic, fluoride, gross alpha radiation, and nitrate. Nitrate contamination, although it can be natural, is usually due to either agricultural practices (excessive fertilizer use and/or poor irrigation practices), or failing septic systems that allow contaminated waters to drain into the aquifer. Ammonium and phosphorus contamination, much less common in Arizona aquifers, are also linked to septic sewage water contamination. Naturally occurring ground water contaminants are dependent on aquifer geology, and are discussed below.

## Arsenic

Three significant geologic sources of arsenic are found in Arizona, and elevated concentrations of arsenic are found in each of the three geologic provinces. In geologically ancient Arizona, **magma** pushed upward into the host rock and hardened into granitic **plutons** and mineralized veins of ore containing copper, silver, gold, and arsenic. In Arizona, regions of granite bedrock with valuable gold ore often contain elevated concentrations of arsenic. Gold prospectors have found new mine sites by measuring the concentration of arsenic in rivers and streams, using arsenic as a pathfinder as they move upstream following greater and greater concentrations of arsenic until the source is found – and gold is discovered. In addition, Basin and Range aquifers consisting of alluvium eroded from granite bedrock will also contain arsenic.

The geology of northern Arizona and southern Utah consists of layers of ancient **sedimentary rock**, including the Redwall Limestone and the sandstone formations that can be seen in the exposed cliffs of the Grand Canyon, (see Figure 5). These sedimentary rocks are also found layered across the Colorado Plateau province of northeastern Arizona, and many water supply wells tap these formations. An extensive cave system was formed over 325 million years ago within the Redwall Limestone, similar to the limestone caves of Kartchner Caverns near Benson. Over geologic time, the weight of overlying rock layers that had accumulated on top of the caves in the Redwall Limestone collapsed, resulting in thousands of feet of vertical collapsed chimneys or drain pipes that filled with rock rubble. These pipes acted as drains, allowing ground water which contained dissolved chemicals from the adjacent sedimentary rock to concentrate. Arsenic, various metals, and uranium were deposited and concentrated within these pipes, which are found throughout the Supai Sandstone formation (Kenny, 2003). Wells constructed within the Supai Sandstone in the Colorado Plateau have elevated levels of dissolved arsenic in the ground water, as well as uranium and other radioactive elements, discussed below.

Arsenic is also found in the Central Highlands geologic province of Arizona. Within the past 2 to 5 million years, the Verde



## Attachment M (Cont.)

Valley of Yavapai County was formed as earth crust shifts produced faults that separated the Colorado Plateau from the Basin and Range. The arsenic rich Supai Sandstone formation was eroded and re-deposited in the Verde Alluvium Formation, which now forms the aquifer of the Big Chino and Verde Valley. The highest concentration of arsenic in ground water in Arizona was found near Pauldin in the Verde Valley, with a concentration of 2,900 parts per billion in a private, domestic (exempt) well. The EPA drinking water MCL for arsenic is 0.010 mg/L, or 10 parts-per-billion.

Because the solubility of arsenic in water is a function of its mineral form, water pH, and oxygen content, any change in the chemistry of an aquifer may increase or decrease arsenic concentrations. An example is with the introduction of oxygen as ground water elevations dropped due to drought in the Verde Valley. The change in geochemistry resulted in arsenic concentrations increasing, and consequently in arsenic poisoning of livestock (Foust et al., 2003)

[Click here](#) to access AZ Cooperative Extension's Arsenic in Arizona Ground Water.

### **Radioactive Elements**

Radioactivity is the release of energy from within atoms. Certain atom structures are inherently unstable and spontaneously break down (decay) to form more stable atoms. For example, the potassium-40 isotope decays very slowly (half-life of 1.25 billion years) but eventually becomes the element argon. Because potassium is a significant component of clay minerals, it is generally true that all clay, including clay soils, and bricks and pottery made from clay soils, and living organisms (animals and plants) that contain potassium, are all slightly radioactive.

In Arizona, the most common source of radioactivity is dissolved uranium and dissolved radon gas. Remember the collapsed chimneys or pipes above the Redwall Limestone Formation acted as drains, allowing ground water which contained dissolved chemicals from the adjacent sedimentary rock to concentrate. In addition to arsenic, uranium was deposited and concentrated within these pipes. Uranium mines are found throughout the Supai Sandstone Formation (Kenny, 2003). The water from wells within the Supai Sandstone in the Colorado Plateau show elevated concentrations of uranium, sometimes exceeding the MCL of 0.030 mg/L, or 30 parts-per-billion.

Radioactive minerals containing the elements uranium and thorium (760 million and 4.46 billion years half-life, respectively) are also found in some Arizona granites. These elements are unstable and decay, eventually becoming a new element called radium (half-life of 1,620 years), which then decays to the element radon (half-life of 3.8 days). Radon is strongly radioactive as it emits high energy alpha particles. Unfortunately, the radon element is an odorless, colorless, tasteless gas that dissolves in ground water and may migrate upward through the soil to eventually dissipate to the atmosphere. If radon gas is trapped within a structure, such as a basement, the concentration of radon gas within the closed structure may exceed health standards. The EPA estimates that 1 in 15 U.S. homes contain a high level of the gas and is considered to be the second leading cause of lung cancer in the country ([epa.gov/rado/radontest.html](http://epa.gov/rado/radontest.html)). The MCL for radon is 300 pCi/L.

'Gross alpha' is a measurement of the amount of radioactivity in water whether it is due to the decay of uranium, radium or radon, and is a gross measurement of overall radioactivity. 'Gross alpha' is a common naturally occurring "contaminant" in Arizona bedrock aquifers (such as the Supai Sandstone or granite) or in alluvial aquifers composed of eroded granite. The MCL for 'Gross alpha' is 15 pCi/L.

### **Fluoride**

Fluoride is a common mineral that is concentrated in volcanic materials, and mineral particles that contain fluoride are common in some sedimentary rocks. In Arizona, the highest fluoride concentrations are found in Cochise County (Hem, 1970); Mohave, Graham, and Greenlee counties (ADEQ, 2005); and, along the lower Gila River in Yuma county. Most of the elevated concentrations are associated with **confined** aquifers. Ground water from confined aquifers usually has not had the opportunity to mix with recently recharged water high in dissolved oxygen. Therefore, the low oxygen environment and long resident time in confined aquifers allows for fluoride naturally present in the aquifer geology to dissolve into the ground water. Although fluoride at high concentrations may be harmful, it is essential for strong teeth and bones; many municipal water supply systems add fluoride to the water in a process called fluoridation. Excessive concentrations in drinking water results in tooth mottling and discoloration. The MCL for fluoride is 4.0 mg/L.

Elevated levels of other naturally occurring constituents have been found in wells across Arizona. For example, naturally occurring hexavalent chromium (CrVI) has been found in Paradise Valley north of Phoenix and in the Detrital Valley near Kingman (Robertson, 1975). Hexavalent chromium is known to cause cancer. Lithium is found in the **brine** ground water of the Gila Valley near Safford. Selenium and boron are also found in geologic settings with evaporite deposits, and these elements have been detected in ground waters near Kingman. Each of these constituents have known health impacts and should be avoided in high concentrations. The mineral-rich geology of our state results in elevated levels of elements such as copper, silver, zinc, manganese, and sulfate minerals, occasionally being encountered in ground water near mining districts. Iron is found in nearly all ground water and is responsible for iron-bacterial fouling of some wells.