Appendix E
Data Review Memorandum

The purpose of this data review is to support an evaluation of whether the implemented groundwater remedies at the site remain protective of human health and the environment and to recommend future activities. This technical memorandum summarizes all the historical data at the AM1 site, including those of the last five years. Data since the third FYR in 2005 is discussed in Section 6.2.

This review also provides an evaluation of the trend and a statistical comparison of the last monitoring data to MCLs. Since there is no soil data collected in the last five years, the discussion is focused on groundwater only.

This summary is a synthesis of the following documents, with some sections obtained verbatim from these documents. Specific quotes will therefore not be provided.

- Five-Year Review Report for Applied Materials, Bowers Campus, Santa Clara, California (Weiss Associates, 2010)
- Applied Materials Five Year Review Memorandum (GSI Environmental, 2010)
- California Regional Water Quality Control Board, San Francisco Bay Region Orders (Regional Board, 1989, 1990, 1993)
- EPA Records of Decision (ROD, 1990, 1993)

Hydrogeology

Regional Hydrogeologic Setting

The AM1 site is located near the center of the Santa Clara Valley, which is a structural basin filled with unconsolidated, heterogeneous alluvial fill commonly interlayered with marine clay. The alluvial sediments were derived from flanking highlands and were deposited by streams on the valley floor over the past several hundred thousand years. The coarsest sediments correspond to well-sorted gravel and sand, and represent stream channel deposits with high to very high relative permeability. Progressively finer sediments reflect deposition at increased distances from the stream channels. These interchannel zones are characterized by silt and clay deposits originating from episodes of flooding and overbank deposition. The alluvial deposits are a heterogeneous mixture of sand and gravel channel deposits interbedded with silts and clays. These alluvial deposits exhibit abrupt changes in grain size both horizontally and vertically.

In most parts of the Santa Clara Valley, extensive sand and gravel beds are considered aquifers and interbedded silts and clays serve as confining beds. Most ground water extracted for drinking water in the vicinity of Applied Materials comes from aquifers 150 to 500 ft below ground surface (bgs). These aquifers are isolated from the shallower water-bearing layers by clay layers between 50 and 150 ft thick. Ground water flow in these deeper water-bearing layers is northerly towards San Francisco Bay.

AM1 Hydrogeologic Setting

Subsurface hydrogeology has been investigated extensively at the SBS due to the large number of industrial facilities in the area. The SBS and the AM1 site in particular, are underlain by heterogeneous marine and alluvial sediments with groundwater flow largely northward toward San Francisco Bay. The shallow groundwater (30 – 40 ft below ground surface [bgs]) is classified as a potential drinking water source, but most area municipal supply wells are screened much deeper (>200 ft bgs) in a lower groundwater zone separated from the upper zones by an aquitard. Because the shallow groundwater is classified as a potential drinking water supply, lower cleanup standards (federal and state Maximum Contaminant Levels [MCLs]) apply. The shallow subsurface is divided into several zones whose depth and thickness vary across the SBS. The strata consist of a mixture of low and higher permeability clays, silts and sands.

VOC transport in the subsurface at AM1 is mainly determined by ground water flow, which in turn is controlled by hydraulic gradients and the particular configuration of permeable alluvial deposits at the site. The subsurface materials at AM1 consist of alluvial deposits, as described above, which have been characterized by detailed logging of on-site boreholes drilled for well installation and soil sampling. Well details and depths are presented in Table E-1.

Table E-1: Well Details and Depths, Applied Materials Building 1 and Vicinity, Santa Clara, California

Well ID	Date Installed	Top of Casing Elevation (ft above msl)	Screened interval (ft)	Sand Pack Interval (ft)	Casing diameter (in)	Original Well Depth [1] (ft)	Date Destroyed
A-Zone Wells							
AM1-1	Nov-83	34.55	13.5-24.0	13.5-24.0	2	24.0	8-Dec-03
AM1-3	Apr-84	34.55	8.7-21.0	8.0-21.0	2	21.0	---
AM1-4	Apr-84	33.69	8.5-40.5	8-40.5	2	40.5	1-Jun-90
AM1-5	Jun-84	32.42	15.0-23.0	14.0-23.0	2	23.0	23-Jan-01
AM1-5E	Jan-85	31.90	14.0-24.0	13.0-24.0	4	24.0	---
AM1-6	Apr-85	33.21	11.7-21.5	10.0-21.5	2	21.5	---
AM1-7	Apr-85	33.78	17.5-27.0	15.5-27.5	2	27.5	---
AM1-8	Apr-85	32.06	8.0-23.0	6.0-23.0	2	23.0	1-Jun-90
AM1-9	Apr-85	34.36	14.0-24.0	9.54-24.0	2	24.0	8-Dec-03
AM1-11	Feb-91	32.30	13.0-23.0	11.5-23.0	2	23.0	---
AM1-12	Feb-91	33.17	13.0-23.0	10.5-23.0	2	23.0	23-Jan-01
AM1-EP	Jan-85	36.13	8.0-16.0	1.0-16.0	6	16.0	8-Dec-03
AM1-P1	Nov-84	33.82	15.0-20	14.0-20.0	2	20.0	23-Jan-01
AM1-P2	Nov-84	35.02	14.5-19.5	13.5-19.5	1	19.5	23-Jan-01
AM1-P3	Nov-84	34.94	14.0-19.0	13.0-19.0	1	19.0	23-Jan-01
HP-2	Aug-83	32.91	5.0-20.0	3.5-25.0	2	25.0	25-Oct-05
HP-5	Sep-83	32.00	9.0-29.0	7.0-31.5	2	31.5	24-Jun-05
HP-6	Sep-83	32.39	8.7-29.0	9.0-31.5	2	31.5	23-Jun-05
HP-8	Oct-88	31.23	5.0-20.0	3.0-20.0	2	20.0	23-Jun-05

A2-Zone Wells							
AM1-10	Mar-90	35.64	30.0-37.5	30.0-37.5	2	37.5	8-Dec-03
AM1-14	Sep-91	34.44	29.8-35.0	28.0-35.0	2	35.0	8-Dec-03
B-Zone Wells							
AM1-2	Jun-84	34.84	42.0-46.0	37.5-46.0	2	46.0	8-Dec-03
AM1-5B	Jan-85	32.18	37.5-47.0	36.5-47.5	4	47.0	24-Jun-05

Notes and Abbreviations:

1 = Original well depth determined during well installation from ground level. Subsequent depth measurements are typically from a different datum after grading.

--- = Well is still active, has not been destroyed

The AM1 subsurface is divided, in descending order, into the shallow A zone, the A/A2 aquitard, the A2 zone, the A2/B aquitard and the B zone. The A zone is defined from the ground surface to approximately 25 ft bgs. The A zone is composed of sandy clay and sand and is underlain by the low-permeability A/A2 aquitard. The A2 zone occurs at about 30 ft bgs with a thickness of approximately 6 to 12 feet at the AM1 site. The A2/B aquitard underlies the A2 zone and has variable thickness across the site. The AM1 B zone occurs below approximately 40 ft bgs.

Figures E-1 and E-2 depict the hydrogeologic setting of the AM1 site. Figure E-1 is an interpretive geologic cross-section depicting the subsurface stratigraphy and the water-bearing zones near the source area at AM1. Additionally, Figure E-2 correlates the hydrostratigraphic unit definitions between the AM1 site and its downgradient neighbor at 3175 Bowers Avenue, formerly Avantek and currently Hewlett-Packard (HP).

The northeastern end of section A-A' in Figure E-1 shows the geology of the neighboring HP site and illustrates the interrelationship between the hydrostratigraphic units as they are defined at each site. The conspicuous difference in definition of hydrostratigraphic units is that HP's B zone and A/B aquitard are equivalent to Applied Materials' A 2 zone and A/A2 aquitard. In the vicinity of the equipment pad, the A2 zone is composed of semi-continuous, silty sand and sand ranging from 6 to 12 ft thick. The top of the A2 zone ranges in depth from about 29 to 30 ft bgs at the AM1 treatment pad to about 31 ft bgs at off-site well AV-1B. Traversing to the northeast, the A2 zone is interpreted as the stratigraphic equivalent of the B zone defined at the 3175 Bowers Avenue site. At 3175 Bowers Avenue, the B water-bearing zone is characterized by thick and more laterally extensive, moderate to high-permeability channel deposits and coarse-grained debris flow deposits. These channel deposits are incised in fine-grained clayey silt and silty clays that are the stratigraphic equivalent to the A/B aquitard at AM1. Monitoring wells AM1-5B and AM1-2 (B-zone well) penetrated what was defined at AM1 as the B water-bearing zone (Figure E-2). No wells penetrated the hydrostratigraphic equivalent to this water-bearing layer at 3175 Bowers Avenue.

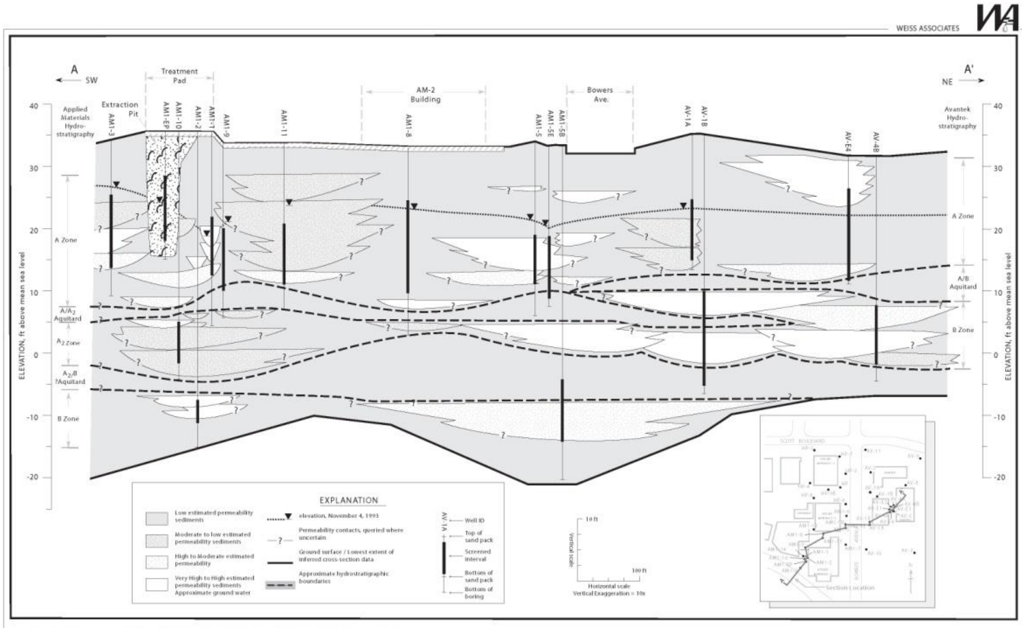

Figure E-1: Geologic Cross-section A-A'

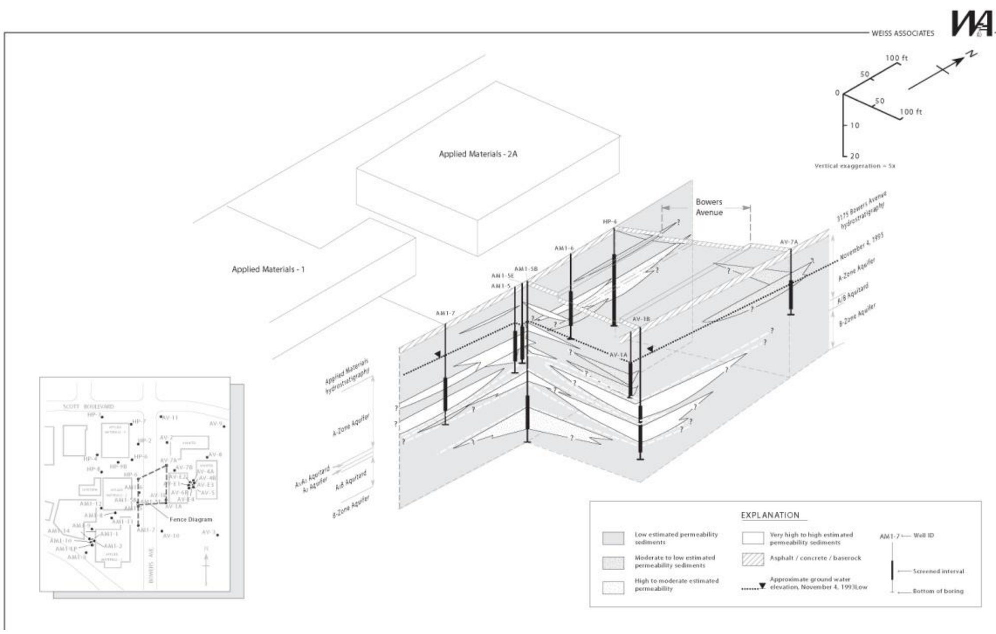

Figure E-2: Fence Diagram

Existing A2-zone data at AM1 and the neighboring site suggest that there was no direct stratigraphic connection between wells AM1-10 and AV-1B (Figures E-1 and E-2). The moderately permeable sediments screened in AM1-10 have limited downgradient extent. Well AV-1B was screened across two high to very high estimated permeability sands separated from each other by a very low permeability zone about 3-ft thick. Based on hydraulic test results (Weiss, 1989a), the permeable sediments identified at the top of the well AV-1B screened interval, interpreted as AM1 A zone equivalent, were in hydraulic communication with the AM1 A-zone sediments screened in wells AM1-5 and AM1-5E. Therefore, some of the VOCs detected in off-site well AV-1B were probably transported from the permeable A-zone sediments screened in AM1-5E, rather than through A2-zone sediments from the AM1 source area.

In contrast to well AV-1B, which was screened over both the AM1 A and A2 zones, well AV-1A was screened and completed only in the A zone. 1,1-DCA was the only VOC consistently detected in well AV-1A, and 1,1-DCA concentrations were below the 5 microgram per liter (μg/L) maximum contaminant level (MCL) for over five years (Table E-5) before the well was destroyed during Avantek site closure in 2006. VOC concentrations in well AV-1B also decreased over time, and all VOCs had been below their respective MCLs for more than a year when the well was destroyed in 2006.

AM1 Ground Water Flow

Shallow ground water flow beneath AM1 is generally to the northeast at a natural hydraulic gradient estimated to range from 0.002 to 0.007. Limited data from the A2 and B zones at AM1 also suggest a northeastern horizontal flow gradient. This flow gradient is consistent with northerly regional flow towards San Francisco Bay.

Pump tests established that there is also some hydraulic communication between the A-zone and A2-zone, and between the A2-zone and B-zone (Weiss, 1992). During ground water extraction, the lowering of the A-zone and A2-zone effectively increased the upward head of the B-zone. From July 1999 through January 2005 with A-zone extraction wells off, there was an upward gradient from the B zone to the A zone, as demonstrated in wells AM1-5E and AM1-5B, which discourages ground water and VOC movement from the A-zone to the B-zone. Prior to the wells being destroyed, an upward gradient from A2-zone well AM1-10 to A-zone well AM1-1 was also observed.

Using the median conductivity of 100 ft/day established by pump tests, the median ground water velocity in the A-zone at the AM1 site has been calculated at approximately 2 ft/day (Weiss, 1989a). This value compares favorably with velocities calculated for adjacent sites.

Summary of Historical Data

Operational data and monitoring data for the ground water remedy and monitoring are presented in the following Tables at the end of this Appendix:

- Table E-3: Total Ground Water Extracted and VOC Mass Removed for Individual Extraction Wells, June 1990 through January 2002, Applied Materials Building 1 and Vicinity, Santa Clara, California. Plots of data for the total mass removed, and mass removed for the three extraction wells AM1-1, AM1-5E, and AM1-10 are shown in Figures 7 through 10 in Section 4.3.2.
- Table E-4: Volatile Organic Compounds in Groundwater, Applied Materials Building 1 and Vicinity – January 2005 - January 2009

The Appendices of the 2010 Five-Year Review Report submitted by Weiss Associates includes the following Tables of data, which are not included here:

- Appendix A. VOCs in Ground Water, November 1983 through January 2010
- Appendix B. Ground Water Extraction and Treatment System Pumping Data, August 1985 through February 2002
- Appendix C. Ground Water Elevations, January 1987 through January 2010

Summary and Discussion on the last five years of data (2005-2010) for this FYR is presented below.

Ground water Elevations

As discussed above under Hydrology, historical water level measurements indicate shallow ground water flow beneath AM1 is generally to the northeast at a natural hydraulic gradient estimated to range from 0.002 to 0.007 ft/ft. This flow gradient is consistent with northerly regional flow towards San Francisco Bay. A composite set of A-zone potentiometric maps drawn from the January ground water elevation data from the years 2002 through 2010 is also shown on Figure E-3. The potentiometric surface maps show a consistent northeasterly ground water flow under non-pumping conditions.

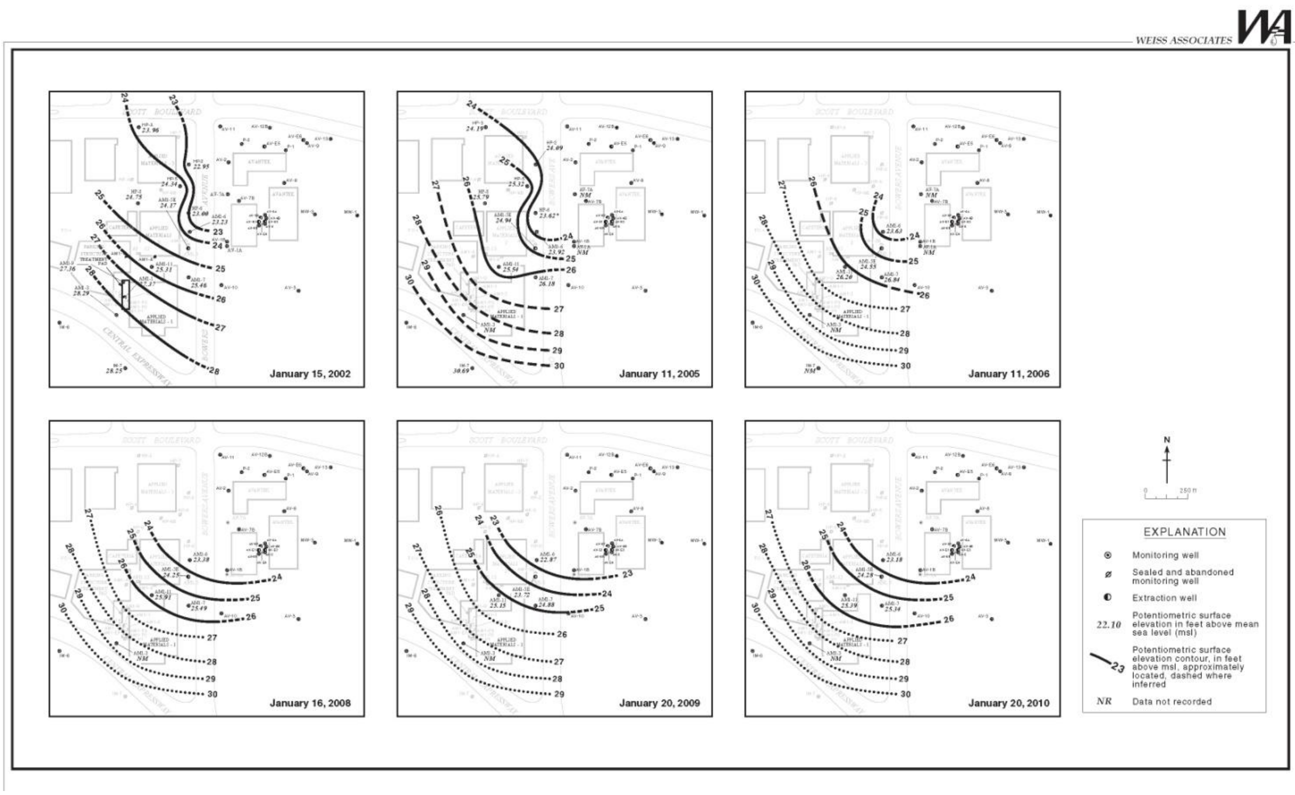

Figure E-3. Composite A zone Potentiometric Map, January 2002 through January 2010

A review of water level elevations in the key remaining AM1 wells, i.e., AM1-5E, AM1-6, AM1-7 and AM1-11, between September 1996 (when extraction well AM1-5E was shut off) and August 2000 (when water level measurement frequency was reduced from tri-annual to bi-annual) shows that there is no discernible seasonal pattern to water level elevations at AM1 (Figure E-4). In general, water levels at AM1 have increased slightly over time since the early 1990s, under both pumping and non-pumping conditions. Since the shutdown of AM1-10 in February 2002, there have been typical seasonal fluctuations, coupled with a slight increase in ground water elevations in wells located near extraction well AM1-10.

In addition, the ground water elevation versus time plots of the four individual wells AM1-5E, AM1-6, AM1-7 and AM1-11 (Figure E-4) indicate that a hydraulic steady state was reached over ten years ago. Ground water levels, flow direction and gradient have been consistent in the vicinity of these four wells since the ground water extraction was discontinued in 1996 (Figures E-3 and E-4).

Weiss Associates

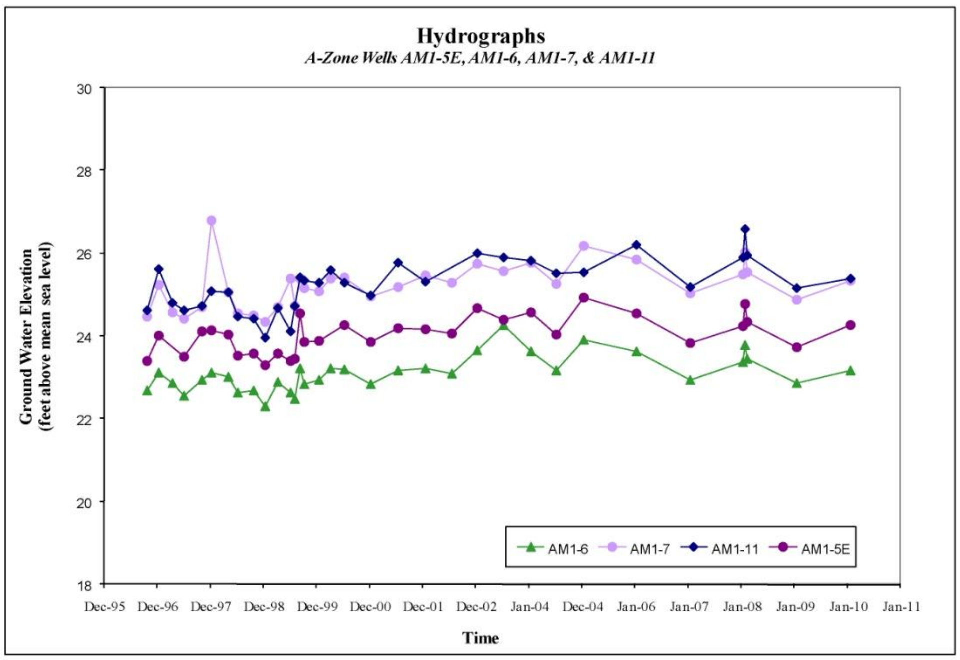

Figure E-4. Ground water Elevation vs. Time, Representative A-Zone Monitoring Wells

Volatile Organic Compounds Analysis

Since ground water extraction was initiated, VOC concentrations in ground water have dramatically decreased. The following figures discussed in this section are plotted using all historical data included in the Appendices of the Five Year Review Report by Weiss Associates (2010). Monitoring data from the last five years for the four remaining monitoring wells are summarized in Table E-1.

In extraction well AM1-EP, concentrations of 1,1,1-TCA decreased from an historical high of 370,000 µg/L in February 1985 to 27 µg/L in January 2003. Over the same time period, concentrations of 1,1-DCA in well AM1-EP decreased from 13,000 µg/L to 3.1 µg/L and 1,1-DCE concentrations decreased from 19,000 µg/L to less than the detection limit of 0.5 µg/L. Composite A-zone iso-concentration maps for 1,1,1-TCA, 1,1-DCA and 1,1-DCE, the three signature compounds found at AM1, are presented as Figures E-5 through E-7. These compound-specific iso-concentration maps are drawn from 1985, 2004, 2006, 2008, 2009, and 2010 data.

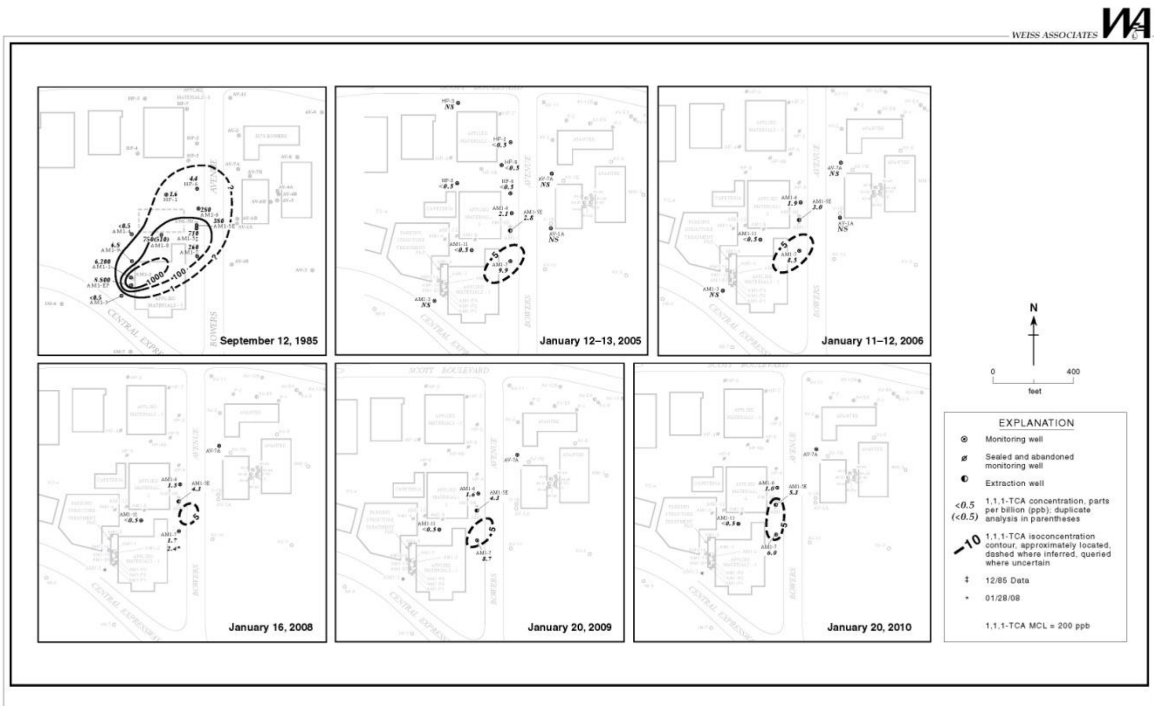

Figure E-5. 1,1,1-TCA in the A Water-Bearing Zone, 1985 through 2010

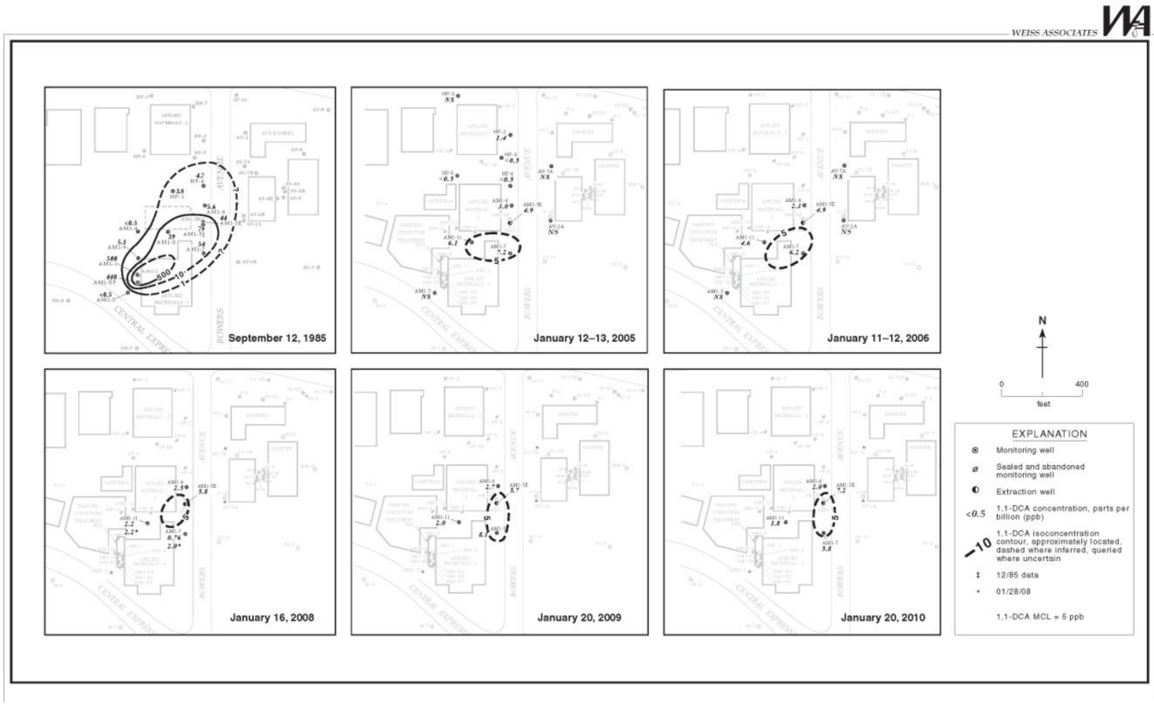

Figure E-6. 1,1-DCA in the A Water-Bearing Zone, 1985 through 2010

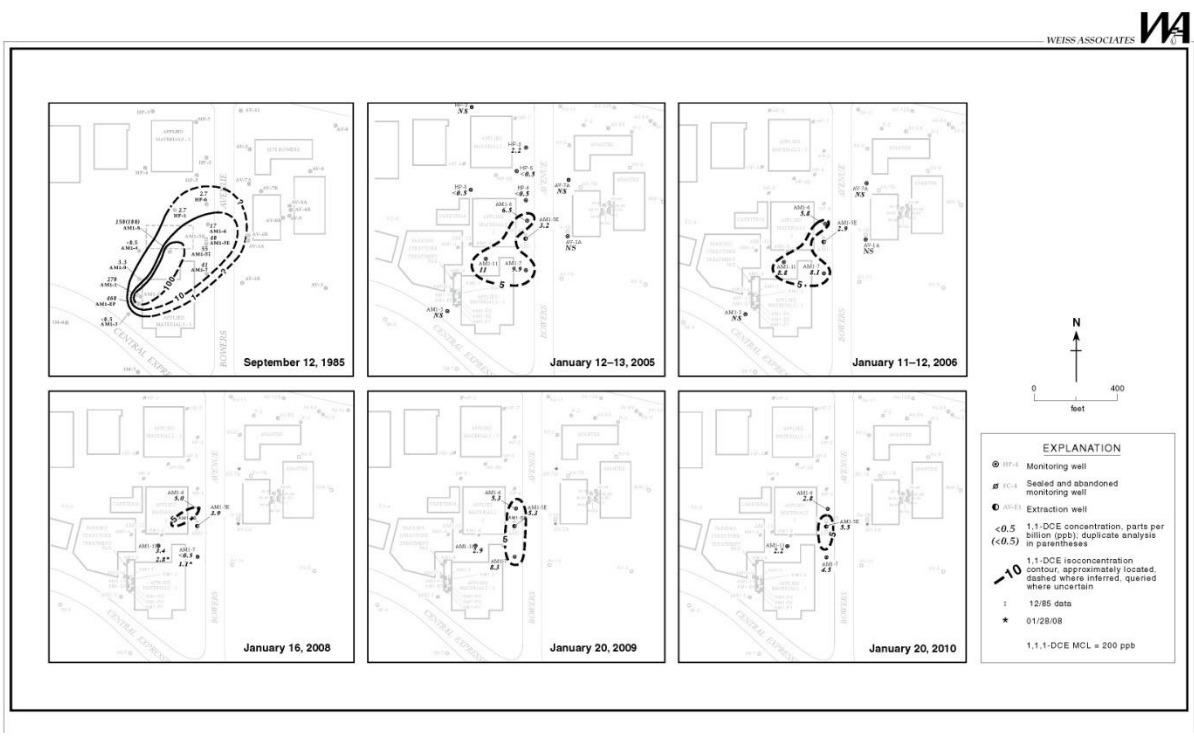

Figure E-7. 1,1-DCE in the A Water-Bearing Zone, 1985 through 2010

Concentration data for the last four monitoring wells are shown in Table E-1 for the five year period of this review. Additionally, plots of concentration data versus time for the three signature compounds 1,1,1-TCA, 1,1-DCE and 1,1-DCA are presented in Figures E-8 through E-10 for most of the wells on AM1. For the past ten years, 1,1,1-TCA has been well below the cleanup requirement of 200 µg/L in all AM1 wells. Based on the most recent sampling event in January 2010, the maximum concentrations for 1,1,1-TCA in A-zone wells is 6.0 µg/L in well AM1-7 (Figure E-9).

Since September 2004, only 1,1-DCE and/or 1,1-DCA in A-zone wells have been detected above their respective MCLs of 6 and 5 µg/L in A-zone ground water monitoring wells at AM1. As shown, wells AM1-5E, AM1-7 and AM1-11 have had 1,1-DCA concentrations slightly above the 5 µg/L MCL (Figures E-9 and E-10). The maximum concentration was 8.1 ug/L in AM1-7 in January 2009 (Figure E-9). 1,1-DCE concentrations above the 6 µg/L MCL were only slightly exceeded in wells AM1-6, AM1-7 and AM1-11 over the same time period (Figures E-9 and E-10). The maximum 1,1-DCE concentration was detected at 11 µg/L in well AM1-11 in January 2005 (Figure E-10). Based on the most recent sampling event in January 2010, the maximum concentration in A-zone wells for 1,1-DCA and 1,1-DCE is 7.2 µg/L and 5.5 µg/L, respectively, in well AM1-5E (Figure E-9). There are no existing A2-zone wells on the site, however, prior to well destructions in December 2003, the maximum concentrations of 1,1,1-TCA, 1,1-DCA, and 1,1-DCE were 1 µg/L, 2 µg/L, and 1 µg/L, respectively in well AM1-10 (Figure E-10).

Table E-1: VOCs in Ground Water, January 2005 through January 2010

Well ID	Sampling Date	Lab/ Analysis	Acetone	Chloro-form	1,1-DCA	1,2-DCA	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	1,2-DCP	Methylene Chloride	PCE	1,1,1-TCA	1,1,2-TCA	TCE	Vinyl Chloride	Freon 113	Freon 11	Freon 12
			<<						parts per billion (ppb)										>>
AM1- 5E	1/12/2005	STL/8260B	---	<0.5	4.9	<0.5	3.2	<0.5	<0.5	<0.5	<5	<0.5	2.8	<0.5	<0.5	<0.5	<0.5	<1	<1
	1/12/2006	STL/8260B	---	<1	4.9	<0.5	2.9	<0.5	<0.5	<0.5	<5	<0.5	3	<0.5	<0.5	<0.5	<0.5	<1	<0.5
	1/16/2007	STCL/8260B	---	<1	5.8	<0.5	4.5	<0.5	<0.5	<0.5	<5	<0.5	4	<0.5	<0.5	<0.5	0.89	<1	<0.5
	1/16/2008	STCL/8260B	---	<1	5.8	<0.5	3.9	<0.5	<0.5	<0.5	<5	<0.5	4.3	<0.5	<0.5	<0.5	0.86	<1	<0.5
	1/20/2009	TASF/8260B	---	<1	5.7	<0.5	5.3	<0.5	<0.5	<0.5	<5	<0.5	4.3	<0.5	<0.5	<0.5	1.3	<1	<0.5
	1/19/2010	TASF/8260B	---	<1	7.2	<0.5	5.5	<0.5	<0.5	<0.5	<5	<0.5	5.3	<0.5	<0.5	<0.5	0.98	<1	<0.5
AM1- 6	1/13/2005	STL/8260B	---	<0.5	3	<0.5	6.5	<0.5	<0.5	<0.5	<5	<0.5	2.1	<0.5	3	<0.5	16	<1	<1
	1/11/2006	STL/8260B	---	<1	2.3	<0.5	5.8	<0.5	<0.5	<0.5	<5	<0.5	1.9	<0.5	2.7	<0.5	17	<1	<0.5
	7/20/2006	STCL/8260B	---	<1	2.4	<0.5	6.1	<0.5	<0.5	<0.5	<5	<0.5	1.9	<0.5	2.6	<0.5	14	<1	<0.5
	1/16/2007	STCL/8260B	---	<1	2.5	<0.5	6.1	<0.5	<0.5	<0.5	<5	<0.5	1.9	<0.5	2.6	<0.5	17	<1	<0.5
	1/16/2008	STCL/8260B	---	<1	2.5	<0.5	5	<0.5	<0.5	<0.5	<5	<0.5	1.5	<0.5	2.4	<0.5	15	<1	<0.5
	1/20/2009	TASF/8260B	---	<1	2.7	<0.5	5.3	<0.5	<0.5	<0.5	<5	<0.5	1.6	<0.5	2.5	<0.5	14	<1	<0.5
	1/19/2010	TASF/8260B	---	<1	2	<0.5	2.8	<0.5	<0.5	<0.5	<5	<0.5	0.96	<0.5	1.5	<0.5	5.5	<1	<0.5
AM1- 7	1/12/2005	STL/8260B	---	<0.5	7.2	<0.5	9.9	<0.5	<0.5	<0.5	<5	<0.5	9.9	<0.5	<0.5	<0.5	2.3	<1	<1
	1/11/2006	STL/8260B	---	<1	6.2	<0.5	8.1	<0.5	<0.5	<0.5	<5	<0.5	8.5	<0.5	<0.5	<0.5	3	<1	<0.5
	1/16/2007	STCL/8260B	---	<1	6.3	<0.5	8.1	<0.5	<0.5	<0.5	<5	<0.5	8.4	<0.5	<0.5	<0.5	2.5	<1	<0.5
	1/16/2008	STCL/8260B	---	<1	0.76	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<0.5	1.7	<0.5	<0.5	<0.5	0.54	<1	<0.5
	1/28/2008	STCL/8260B	---	<1	2	<0.5	1.1	<0.5	<0.5	<0.5	<5	<0.5	2.4	<0.5	<0.5	<0.5	0.56	<1	<0.5
	1/20/2009	TASF/8260B	---	<1	8.1	<0.5	8.3	<0.5	<0.5	<0.5	<5	<0.5	8.7	<0.5	<0.5	<0.5	2.6	<1	<0.5
	1/19/2010	TASF/8260B	---	<1	5.8	<0.5	4.5	<0.5	<0.5	<0.5	<5	<0.5	6	<0.5	0.5	<0.5	1.4	<1	<0.5
AM1-11	1/12/2005	STL/8260B	---	<0.5	6.1	<0.5	11	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	3.5	<1	<1
	1/11/2006	STL/8260B	---	<1	4.6	<0.5	8.8	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	3.8	<1	<0.5
	7/20/2006	STCL/8260B	---	<1	4.6	<0.5	8.3	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	2.1	<1	<0.5
	1/16/2007	STCL/8260B	---	<1	4.2	<0.5	8.8	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	2.9	<1	<0.5
	1/16/2008	STCL/8260B	---	<1	2.2	<0.5	3.4	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	0.51	<1	<0.5
	1/28/2008	STCL/8260B	---	<1	2.2	<0.5	2.8	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1	<0.5
	1/20/2009	TASF/8260B	---	<1	2	<0.5	2.9	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1	<0.5
	1/19/2010	TASF/8260B	---	<1	1.8	<0.5	2.2	<0.5	<0.5	<0.5	<5	<0.5	<0.5	<0.5	0.52	<0.5	<0.5	<1	<0.5

1,1-DCA and 1,1-DCE Plume Mass

Dissolved plume mass concentrations were calculated for the A zone for 1,1-DCA and 1,1-DCE based on ground water monitoring data collected in January 2010. The plume mass was calculated by conservatively estimating the area within 1,1-DCA and 1,1-DCE contour intervals (area of approximately 91,000 square ft; Figures E-6 and E-7). The 2010 annual average 1,1-DCA and 1,1-DCE concentrations of 4.2 µg/L and 3.75 µg/L, respectively, for the four grouped wells were assigned to each area, and an aquifer thickness of 10 ft and a porosity of 0.3 was used in the calculations. Using this approach, the calculated mass currently remaining at AM1 for 1,1-DCA and 1,1-DCE is 28.9 grams (g) and 32.4 g, respectively, or approximately one ounce each.

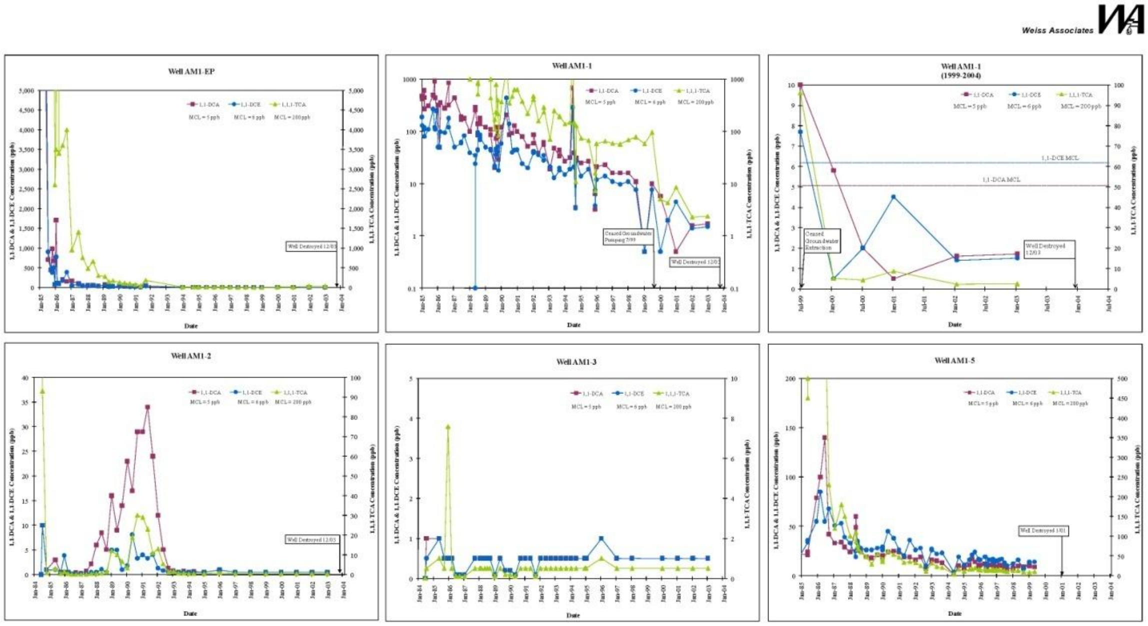

Figure E-8: Signature VOC Concentration History, Wells AM1-EP, AM1-1, AM1-2, and AM1-5

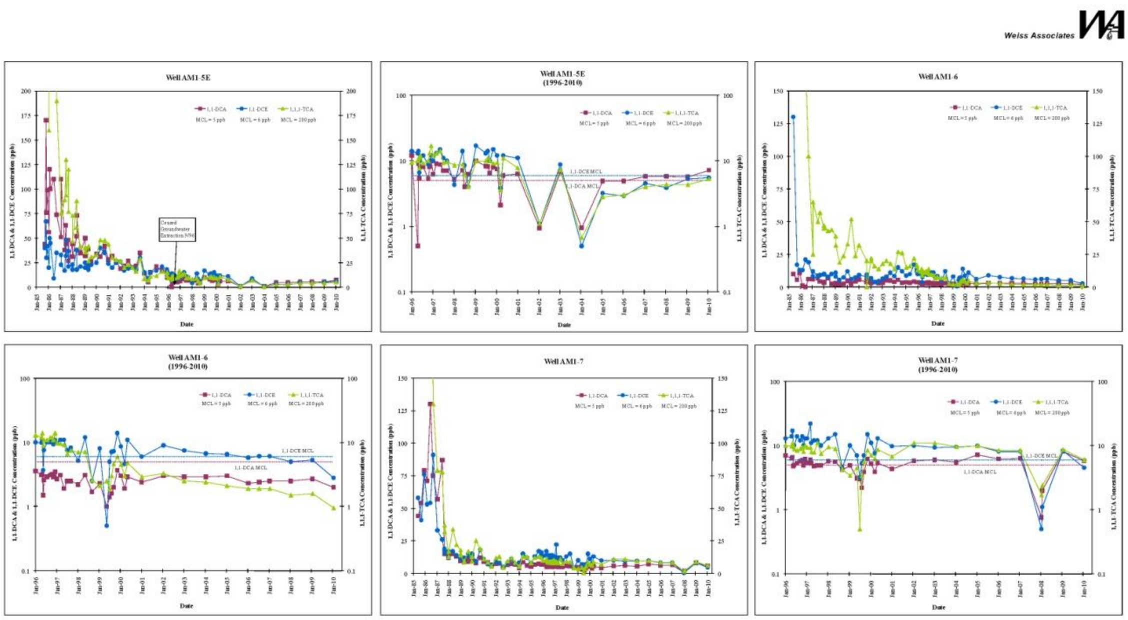

Figure E-9: Signature VOC Concentration History, Wells AM1-5E, AM1-6, and AM1-7

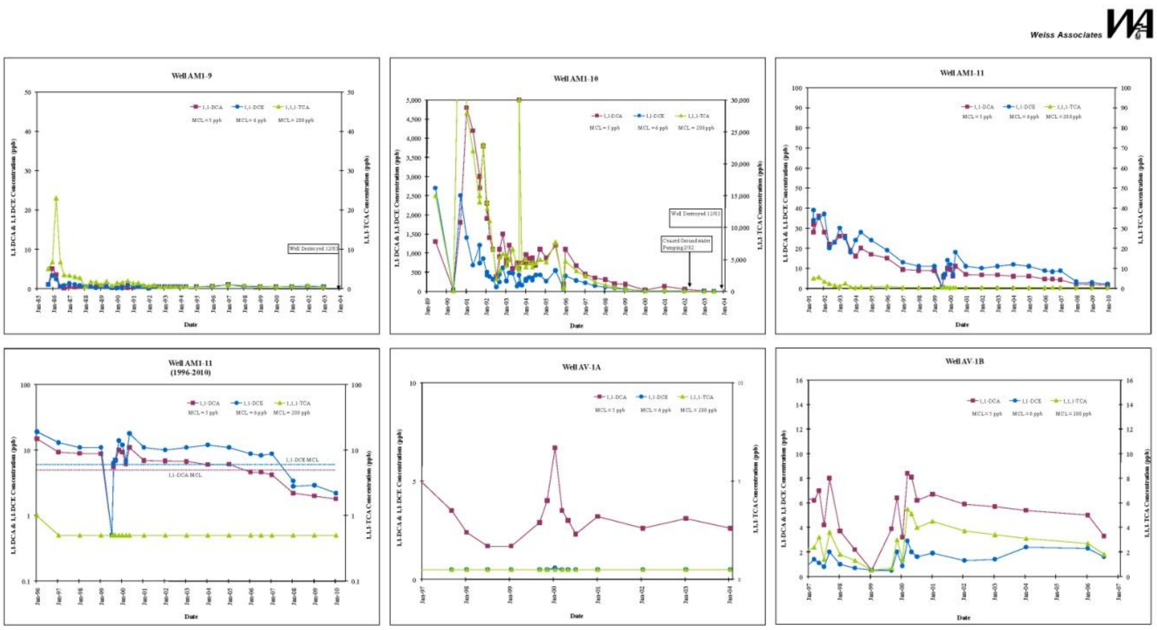

Figure E-10: Signature VOC Concentration History, Wells AM1-9, AM1-10, AM1-11, AV1-1A, and AV1-7A

Trend Analysis

The groundwater extraction and treatment system was operated between 1985 and 1999 in the A zone and in the A2 zone (well AM1-10) between 1990 and 2002. Monitoring data from 2002 resulted in a seven-year record of post-active remediation groundwater quality. This time frame is consistent with recommendations in the USEPA statistical attainment document (1992) recommending a sufficient sampling record since active remedy termination to assess groundwater at dynamic equilibrium with the surrounding environment. Since the shutdown of extraction wells in the vicinity of AM1, groundwater flow has returned to the original northeasterly direction. While shallow groundwater elevations can vary with seasonal recharge, groundwater flow direction does not diverge dramatically or change seasonally. Stability in flow direction is consistent with a reduced management effort at the site.

Trend data can be used to support site management decisions by demonstrating that groundwater has a stable or decreasing trend after active remediation efforts are completed. The USEPA statistical guidance (USEPA 1992) recommends collecting samples after the termination of active remediation to demonstrate that transient remediation-related effects have equilibrated. Trend analysis using the Monitoring and Remediation Optimization Software (MAROS) was performed to identify both stable and statistically decreasing trends. Decreasing trends after termination of the active remedy can indicate that attenuation mechanisms are still active.

Non-parametric Mann-Kendall concentration trends were evaluated for several wells for 1,1-DCA and 1,1-DCE between 1996 (the time of the initial Pumping Modification Program) and the most recent sampling event for each well (see Table E-2). 1,1,1-TCA was not evaluated as results have been below cleanup goals since the early 1990s. For the wells reviewed, most showed strongly decreasing (AM1-5B, AM1-5E, AM1-11, AM1-10, and AM1-1) or stable (AM1-6 and AM1-7 for 1,1-DCA) trends. "No trend" results for AV-1B, AV-7A and AM1-EP reflect higher data variance arising from very low concentrations interspersed with non-detect results. Several locations (AM1-9 and AM1-2) show all non-detect results. No increasing trends were found.

Trend results for the downgradient wells AM1-6, AM1-5E and AM1-7 show strongly decreasing trends for 1,1-DCE, and for AM1-5E for 1,1-DCA and stable trends for AM1-6 and AM1-7 for 1,1-DCA. These results indicate the plume is stable to shrinking, with many areas below cleanup levels, since termination of the active remedy. Decreasing trends through 2003 along with concentrations below cleanup levels in source area wells support the conclusion that the original source is exhausted. Decreasing to stable trends in the downgradient areas indicate that, even in the absence of active remediation, residual concentrations are still diminishing. Overall, trend data support the conclusion of a reduction in management effort.

Table E-2 includes the results of a sampling frequency evaluation for wells remaining in the monitoring program (AM1-5E, AM1-11, AM1-6 and AM1-7). The software-recommended sampling frequency for each location is annual, based on the rate of change of concentration for both 1,1-DCE and 1,1-DCA. The sampling frequency module considers the trend and the rate of change of concentrations relative to the screening level when determining the recommended sampling frequency. Other factors to consider in developing a final sampling frequency include the regulatory reporting frequency and whether additional data collection would achieve statistical significance for a particular analysis. In the case of AM1, the low rate of concentration change and the weight of evidence that supports reduced management effort may provide justification for biennial sampling, contingent upon stakeholder consensus.

Table E-2: Summary Results for Selected AM1 Wells (1996 – 2009)

Wells still currently monitored are AM1-5E, AM1-6, AM1-7, AM1-11

WellName	Number of Samples	Number of Detects	Percent Detection	Mann-Kendall Trend	Statistically Below Standard*?	Recommended Sampling Frequency
1,1-Dichloroethane						
AM1- 1	13	11	85%	D	NO	
AM1- 5B	14	5	36%	D	YES	
AM1-10	13	13	100%	D	NO	
AM1-11	21	20	95%	D	NO	Annual
AM1-2	8	0	ND	ND	YES	
AM1-5E	33	32	97%	D	NO	Annual
AM1-6	35	34	97%	S	YES	Annual
AM1-7	34	34	100%	S	NO	Annual
AM1-9	7	0	ND	ND	YES	
AM1-EP	11	10	91%	NT	YES	
AV- 1B	25	24	96%	D	NO	
AV- 7A	10	4	40%	D	YES	
1,1-Dichloroethene						
AM1- 1	13	11	85%	D	NO	
AM1- 5B	14	0	ND	ND	YES	
AM1-10	13	11	85%	D	NO	
AM1-11	21	20	95%	D	NO	Annual
AM1-2	8	0	ND	ND	YES	
AM1-5E	33	32	97%	D	NO	Annual
AM1-6	35	34	97%	D	NO	Annual
AM1-7	34	34	100%	D	NO	Annual
AM1-9	8	0	ND	ND	YES	
AM1-EP	11	0	ND	ND	YES	
AV- 1B	24	21	88%	NT	YES	
AV- 7A	11	1	9%	NT	YES	

Notes:

1. Data from Weiss Assoc. database 2009.
2. Trends are Mann-Kendall results from the 1996 to 2009 dataset.
3. D = Decreasing; S = Stable; NT = No Trend; ND = well has all non-detect results for COC.
4. Locations statistically below the cleanup standard by Sequential T-Test (USEPA, 1992).
5. Frequency recommendation from MAROS software based on rate of concentration change.

MCL Attainment

A more detailed discussion of an exit strategy is discussed in a Close out Memorandum, as Attachment 2 to the Letter on Close Out from the U.S EPA to Applied Materials, June 2010. A portion of that memorandum is presented here with regards to MCL attainment specifically.

In this FYR, one method of assessing if a dataset is reliably below a standard is a Sequential t-Test based on yearly concentration averages (Rogers 1992; USEPA 1992). *Methods for Evaluating the Attainment of Cleanup Standards* (USEPA 1992) states that "a well attains the cleanup standard if, based on statistical tests, it is unlikely that the average concentration (or the percentile) is greater than the cleanup goal". The test compares annual concentration averages to the screening standard over a period of years, and performs a hypothesis test that is sensitive to the statistical power of the dataset. The same calculation was performed for log normal data, with similar results.

The MAROS software Data Sufficiency module was used to identify locations that have sufficient data to statistically attain the cleanup goal using the Sequential t-Test. As illustrated by the results of the test in Table E-1 above, several wells are statistically below the screening level for both major constituents. Wells AM1-5B, AM1-2, AM1-9, AM1-EP and AV-7A have all attained cleanup using the Sequential t-Test method for both 1,1-DCE and 1,1-DCA. Data for AM1-9 define an area of clean groundwater to the north of the original source zone. Well AV-7A delineates the historical downgradient extent of the AM1 plume, and AM1-2 delimits the vertical extent of affected groundwater. Attainment status at these locations confirms that the plume has been successfully delineated. Statistical results for AM1-EP indicate that the source area has attained cleanup goals.

AM1-6 is statistically below the cleanup goal for 1,1-DCA but not 1,1-DCE, although individual sample results for 2008 and 2009 are below the goal. Well AV1-B has attained cleanup status for 1,1-DCE, but not for 1,1-DCA. Although the absolute concentrations fell below standards during the most recent sampling event, insufficient data have been collected to demonstrate that constituents at well AM1-10 are statistically below the screening levels.

Several locations within the historical AM1 plume appear to have attained cleanup goals using the Sequential t-Test. Other locations show concentrations that occasionally exceed goals for one or both remaining COCs. However, because there is little policy guidance on the number of samples necessary to show attainment, acceptable levels of variance in the data or the timeframe over which attainment data must be collected, it is difficult to recommend a sampling program that would provide sufficient data to make these demonstrations in the short-term.

A summary of all of the sampling locations in the Weiss database (Weiss, 2009) is provided in Table E-3. Each well with sampling results is listed with the earliest and the most recent sampling date from the database. Wells that are indicated as sealed and abandoned on site maps (Weiss, 2010) are indicated. Data were reviewed for each well, and wells where the concentrations of 1,1-DCA, 1,1-DCE, 1,1,1-TCA and TCE were below the cleanup level on the most recent sampling date are indicated. While this information is not as rigorous as the statistical tests described above, the data do show that the majority of locations were below the cleanup standards at the time they were decommissioned.

Table E-3: MCL comparison for 1,1-DCA, 1,1-DCE, 1,1,1-TCA and TCE

Wells still currently monitored are AM1-5E, AM1-6, AM1-7, AM1-11

Well Name	Earliest Sample Date	Latest Sample Date	Below MCLs on Most Recent Sample Date	Sealed and Abandoned
AM1- 1	11/27/1983	1/9/2003	Yes	X
AM1- 2	6/11/1984	1/8/2003	Yes	X
AM1- 3	6/11/1984	1/8/2003	Yes	
AM1- 4	6/11/1984	5/3/1990	Yes	X
AM1- 5	6/11/1984	5/12/1999	No	X
AM1- 5B	1/30/1985	1/8/2003	Yes	X
AM1- 5E	**9/12/1985**	**1/20/2009**	No (1,1-DCA)	
AM1- 6	**5/28/1985**	**1/20/2009**	Yes	
AM1- 7	**5/29/1985**	**1/20/2009**	No (1,1-DCA)	
AM1- 8	5/29/1985	5/3/1990	No	X
AM1- 9	5/28/1985	1/8/2003	No (TCE)	X
AM1-10	6/5/1989	7/11/2003	Yes	X
AM1-11	**5/2/1991**	**1/20/2009**	Yes	
AM1-12	5/2/1991	1/4/2001	Yes	X
AM1-14	10/3/1991	1/8/2003	Yes	X
AM1-EP	2/6/1985	1/8/2003	Yes	X
AV- 1A	5/23/1985	1/14/2004	Yes	X
AV- 1B	6/13/1996	7/20/2006	Yes	X
AV- 7A	5/28/1985	1/14/2004	Yes	X
HP- 1	9/7/1983	7/3/1990	Yes	X
HP- 2	11/15/1983	1/13/2005	No (TCE)	X
HP- 3	11/15/1983	7/20/1988	Yes	X
HP- 4	11/15/1983	7/21/1988	Yes	X
HP- 5	9/15/1983	1/12/2005	No (TCE)	X
HP- 6	9/15/1983	1/13/2005	Yes	X
HP- 7	11/15/1983	5/22/1985	Yes	X
HP- 8	10/28/1988	1/12/2005	No (TCE)	X
HP- 9B	10/28/1988	4/6/1990	Yes	X
MW-1	1/12/2005	1/16/2007	Yes	
MW-2	1/12/2005	1/16/2007	No	

Notes
1. Sample dates and well status are from Weiss Assoc. database 2009.
2. Wells in the current program are highlighed in **Bold**.
3. HP wells are located north of AM1 and AV wells are located to the north/northwest.
4. Recent sampling results for 1,1-DCE, 1,1-DCA, 1,1,1-TCA and TCE compared against site cleanup goals.
5. Values below MCLs indicated. Wells that exceed for only TCE indicated.

Conclusions

Extensive remediation efforts over the past 30 years have achieved groundwater concentrations very close to cleanup goals at the AM1 site. Trend analysis and MCL attainment evaluation indicate that many areas of the plume have achieved remediation goals, using a fairly conservative statistical test for attainment. The sampling frequency algorithm in MAROS recommends an annual sampling frequency for the wells remaining in the program. Lines of evidence developed from site data indicate that a reduced level of monitoring effort is appropriate for this site.

REFERENCES:

Rogers, J. (1992). "Assessing Attainment of Ground Water Cleanup Standards Using Modified Sequential t-Tests." Environmetrics **3**(3): 335-359.

USEPA (1992).*Methods for Evaluating the Attainment of Cleanup Standards: Volume 2 Ground Water.* 230-R-92-014. United States Environmental Protection Agency Office of Policy Planning and Evaluation. July 1992

USEPA (2000).*Close Out Procedures for National Priorities List Sites.* EPA 540-R-98-016

USEPA (2005).*Close Out Procedures for National Priorities List Sites: Addendum.* OSWER Directive 9320.2-13. US Environmental Protection Agency. December 2005

Weiss (2009). Database of groundwater sampling results. Weiss Associates, September, 2009.

Weiss (2010). Five-Year Review Report for Applied Materials Bowers Campus Santa Clara, California. Weiss Associates, 5 March, 2010.