

ALTERNATE SOURCE DEMONSTRATION FOR LANDFILL GAS-RELATED IMPACTS TO GROUNDWATER: A CASE STUDY

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INTRODUCTION

An Alternate Source Demonstration (ASD) was performed at a municipal landfill in the southeastern United States to address volatile organic compound (VOC) and cobalt concentrations detected in one of their detection monitoring wells (MW-7). The landfill is a municipal solid waste facility the State Agency which adopted Federal solid waste permitting regulations. The purpose of the ASD was to evaluate the source of the VOC and cobalt detections in groundwater from MW-7. Specifically, the ASD sought to demonstrate that the source was not leachate migration from the landfill. The ASD was performed in accordance with State regulations, as they apply to alternate source demonstrations.

BACKGROUND

In March 2003, cis-1,2-dichloroethene (cis-1,2 DCE), acetone, ethylbenzene, xylene, and vinyl chloride (Table 1) were detected and verified in well MW-7 at concentrations exceeding the laboratory reporting limits. The results were reported to the State in May 2003 and verified during the 2nd Semi-Annual Groundwater Monitoring Event performed in September 2003, including toluene and benzene, which were not detected in the previous monitoring event. The semi-annual monitoring results also indicated an exceedance of the initial control limit value (10 ug/L) for cobalt at MW-7. Due to the cobalt exceedance, MW-7 was resampled on October 22, 2003 and analyzed for total cobalt. The results verified an exceedance of the nonparametric prediction, and statistical limit for cobalt.

The ASD was initiated to investigate the possible cause of the VOC and cobalt detections in groundwater at MW-7. The ASD included an investigation of potential landfill gas impacts by collecting headspace samples from MW-7 to measure methane, carbon dioxide and VOC concentrations.

Additionally, soil samples were collected from borings near MW-7 to evaluate the presence of cobalt, whether or not the cobalt (if detected) could mobilize under simulated vadose zone conditions, and if cobalt (if present) is preferentially dissolving into groundwater due to the presence of landfill gas. Results of our investigation provided strong evidence that landfill gas was the source of VOC detections in groundwater. At first, VOCs detections in groundwater at MW-7 were nondetect, followed by intermittent detections in 2002.. Consistent VOC detections in groundwater were observed at approximately the same time that landfill gas was reported in the headspace of MW-7 (Figure 1).

Landfill gas is generally 45-50% methane (CH₄) and 45-50% carbon dioxide (CO₂). The remaining residual gas is typically nitrogen (N₂) and other VOCs. The investigation was focused on evaluating whether or not landfill gas was present at MW-7; therefore, we collected methane measurements from the headspace in MW-7.

Methane concentrations were measured in MW-7 on three different occasions; April 17, 2003 (30% methane), October 16, 2003 (65% methane) and October 22, 2003 (58% methane). The April 17, 2003 results included constituent-specific, analytical results to support that VOC vapors in the landfill gas was the source of VOC detections measured at MW-7, not mixing from landfill leachate. From our experiences with similar landfills and subsurface conditions, we were confident that the landfill gas VOC analytical data would support the distinct contrast between groundwater impacts from a leachate source versus a landfill gas source.

While the impact of landfill gas on VOC's in groundwater is not a new concept, the impact of landfill gas on the presence of metals in groundwater

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generally is. We were confident that if we had empirical evidence that cobalt was a naturally-occurring element near MW-7, the combination of the landfill gas and the naturally-occurring cobalt could account for recent detections in groundwater. We implemented a soil quality investigation to evaluate whether or not cobalt was detectable in soil near MW-7 and if the metal cobalt (if present) was capable of mobilizing into groundwater. Soil sampling and leachability results verified that cobalt is present (at detectable concentrations) in soil near MW-7, and that the cobalt is capable of leaching to groundwater under acidic solution conditions.

Results of the ASD provided strong evidence that landfill gas was the source affecting the cobalt detections in groundwater at MW-7. Cobalt detections in groundwater at MW-7 were sporadic in the past until landfill gas was observed at MW-7. Consistent cobalt detections in groundwater were observed approximately the same time that landfill gas problems were reported (Figure 2).

The soil sampling results near MW-7 confirmed that cobalt is a naturally occurring element in the saturated, Miocene sediments near MW-7. Dissolution of cobalt in the saturated zone may be expected due to acidic conditions posed when landfill gas (45-50% CO₂) geochemically reacts with the saturated zone sediment.

Site Description and Background

The topography of the site is gently rolling, with slopes toward the southeast and northwest ranging in elevation from 60 to approximately 160 feet above mean sea level (msl). A northeast trending topographic drainage bisects the northwest corner of the site.

The landfill consists of a closed, unlined pre-Subtitle D disposal cell, located along the west side of the site, a lined Subtitle D cell to the south of the unlined (Expansion Area 1), and a lined Subtitle D disposal cell in the southwest corner of the site (Expansion Area 2). Landfill operations are currently being performed in Expansion Area 2. Capping of the unlined portion of the landfill with compacted clay was completed in late 1998 and was certified closed in March 1999. A leachate collection system collects and removes liquids from the two Subtitle D landfill cells.

Summary of Site Geologic and Hydrogeologic Setting

The landfill is located in a plain developed on Miocene estuarine deposits. The Miocene series sediments are undifferentiated, discontinuous laminated to thinly bedded clays, sands, and sandy clays. The sands range from fine to coarse-grained. In outcrop, the sands and silty sands weather to a variety of colors (gray, brown, tan, orange, and red) and can be mottled. The sediments range from 100 to greater than 3400 feet in thickness and dip gently to the southwest.

Groundwater ranges in depth from less than 5 to 65 feet below ground surface, depending on the topographic location and the screened interval. Groundwater flows generally toward the north and appears to be topographically controlled. Groundwater flow may be influenced by discharge via a northeast trending drainage.

Detection and Assessment Monitoring Programs

Detection monitoring at the landfill is performed in accordance with the Site Permit and under the Ground Water Monitoring Plan. The groundwater detection monitoring system for the site consists of ten groundwater monitoring wells located around the landfill footprint. Two wells (MW-5 and MW-11) are considered background and are located southeast and northwest of the landfill, respectively. Under the detection monitoring program, the wells are sampled and analyzed semi-annually for the Appendix I parameters in 40 CFR 258.

SOURCE EVALUATION

Numerous studies have established that VOCs present in landfill gas partition into groundwater. VOCs detected in groundwater samples collected from wells near solid waste landfills often are falsely attributed to landfill leachate without consideration of other potential sources such as landfill gas. Transfer of VOCs from gas to groundwater can occur both within the monitor well only (intra-well) and/or outside the monitor well. Intra-well gas to water transfer of VOCs occurs commonly in monitoring wells that have screen lengths that extend above the water table (i.e., screen is only partially saturated) exposing pathways for landfill gas migration into the well screen. Faulty well construction can also allow migration of landfill gas into the well headspace.

In situations where monitoring well screens extend above the water table or where breaches occur in the well casing, free (landfill gas) vapors within the vadose zone can flow toward exposed monitor well

pathways when atmospheric pressures are less than subsurface gas pressures. The pressure gradients cause the monitor well to act as a vent allowing landfill gas in the vadose zone to flow into the well, ultimately partitioning to groundwater. Partitioning of VOCs in the (landfill gas) vapor phase to the water phase in the well can occur within the well headspace, impacting the water quality measured in the well. This intra-well transfer of VOCs to groundwater is enhanced due to the following conditions: 1) mixing during sampling increases the diffusion gradient creating more efficient transfer; 2) the large surface area available for transfer (versus the comparatively small porosity limited surface area) outside the well and; 3) preferential pathway migration (into the well) which inhibits transfer outside the well.

In our experience with newly detected inorganic metals measured in groundwater, the first place to look for a potential source of impacts is leachate. Without supporting evidence that leachate may be the source we look for naturally-occurring conditions, or new facility activities. In the case of this landfill, there was no supporting evidence to suggest a leachate source, and there were no new activities to suggest why cobalt had recently been detected groundwater from MW-7.

In situations where naturally-occurring metals are suspected as a possible source, we confirm the presence of the metal, and evaluate whether or not the metal is capable of leaching to groundwater under simulated vadose conditions. This simulated condition can be accomplished by the toxic characteristic leachate procedure (TCLP) performed by a certified laboratory. Results of the TCLP may provide data to indicate whether or not naturally-occurring metals (cobalt) is leaching to groundwater accounting for recent detections

Lastly, recent studies have provided supportive evidence that the presence of landfill gas (elevated CO₂) may be creating geochemical conditions that are conducive for cobalt dissolution in the saturated zone at MW-7. Dissolution of cobalt in the saturated zone may be expected due to acidic conditions posed when landfill gas (45-50% CO₂) is geochemically reacting with the saturated zone sediment.

Additionally, soil analytical data helped us evaluate whether cobalt detections in groundwater were indicative of naturally occurring (leaching) conditions, and the result of dissolution in the saturated zone due to the presence of landfill gas

(CO₂). Establishing the source(s) of the cobalt detections provided the basis for future detections at MW-7 and at other monitoring wells at the facility.

Our evaluation consisted of collecting, compiling, and evaluating the following data:

- Historical VOC analytical results from wells MW-7;
- Results of groundwater samples collected from MW-7;
- Results of soil samples collected near MW-7;
- Results from air samples collected from headspace in MW-7;
- A review of boring logs and groundwater levels for MW-7.

Geochemical Analytical Data

Typically, the first step for identifying whether a VOC or metal (cobalt) impact is derived from leachate or landfill gas (or other sources not associated with the landfill) involves evaluating leachate indicator and general chemistry parameters (i.e., trends, general chemistry signature plots, Stiff and Piper diagrams, etc.). The absence of elevated concentrations or significant trends of inorganic leachate indicator parameters is often a good indication that the VOC or metal (cobalt) impacts may be from landfill gas (assuming no other source is present).

Groundwater samples from MW-7 were collected in March 2003 and September 2003. Leachate samples, representative of the unlined facility, were collected from a gas extraction well in 1999. Leachate samples, representative of the lined cells, were obtained from the leachate collection system in April 2000 and April 2001. Samples were analyzed for VOCs and the general inorganic and indicator parameters (Table 2). The objective of this work was to characterize and compare and contrast leachate and groundwater geochemistry.

Organic Analyses: A review of the VOC analytical results demonstrated a distinct difference between leachate and groundwater samples. Leachate from a gas well had detections of aromatic compounds, 2-hexanone, ethylbenzene, and total xylenes, with lower concentrations of 1,4-dichlorobenzene and cis-

1,2 DCE. Leachate from the lined cell consisted of MEK, MIBK, and acetone, with lesser concentrations of methylene chloride and carbon disulfide.

The types and concentrations of VOCs in groundwater suggest that leachate is not the source of VOC detections in MW-7. Some of the same VOCs detected in leachate were also detected in MW-7 samples, but at similar concentrations (with the exception of acetone). If the VOC detections were due to mixing from leachate, then the detected VOCs or their parent products would have to be present in leachate at much higher concentrations relative to groundwater, which was not observed.

The elevated concentration of acetone may be derived from a leachate source but is more likely the result of landfill gas partitioning into groundwater. Absent any increasing trends of acetone or leachate indicator we concluded that the acetone detected (1,200 ppb) in landfill gas at MW-7 is the likely source impacting groundwater. Groundwater VOC analytical results are summarized in Table 1 and landfill gas analytical results are summarized in Table 3.

Inorganic Indicator Parameter Analyses: A comparison of the inorganic analytical data demonstrated a distinct difference between leachate and groundwater geochemistry. For example, chloride concentrations in groundwater were low (<5 mg/L) and there was no difference between the chloride concentrations in background and MW-7. Conversely, leachate, which is saline in nature, has elevated chloride concentrations (>200 to 4040 mg/L). Chloride, which is a supportive indicator parameter and moves at the rate of groundwater flow, show no change concentration between groundwater samples collected during the recent event and prior samples collected earlier (Figure 3).

Overall, leachate has inorganic and indicator concentrations that are two to three orders of magnitude or greater relative to concentrations detected in groundwater. There is virtually no difference in geochemistry between MW-7 and background well MW-11. Except for one unverified alkalinity detection in one of the background wells, there are no elevated concentrations of any of the typical indicator parameters. Elevated alkalinity can sometimes be indicative of landfill gas impacts. An increase in partial pressure of carbon dioxide (CO₂) over a solution will increase alkalinity in solution through dissolution of any available calcium carbonate (Krauskopf, 1978). Subsequent alkalinity

results in well MW-7 were in the range of background.

Stiff plots were developed to demonstrate the similarity in groundwater quality between MW-7, background well MW-11, and the contrast from leachate quality (Figure 4). It should be noted that manganese was substituted for magnesium, because there was insufficient magnesium data for all wells. This affected the one axis on the Stiff plots and Piper diagrams, but a geochemical analysis was still able to be conducted.

The Stiff plots show the low ionic nature of groundwater relative to the highly mineralized nature of the leachate. The Stiff plots of groundwater from MW-7 are thin and show no similarities to leachate. Major anions and cations were plotted on Piper diagrams for comparison purposes (Figure 5). The Piper diagrams show that groundwater in all wells plot in the same general area and away from typical leachate (note that the sample from MW-7, with elevated alkalinity concentrations, plots toward the bicarbonate alkalinity end of the diagram) as identified in Figure 5.

The results of the inorganic data analyses demonstrated that there was no evidence of leachate impacts in MW-7, given the very low levels of indicator parameters.

Cobalt Source Evaluation

Critical to determining whether or not leachate is a potential source of the cobalt detected in MW-7 was analytical evidence available from leachate analyses. Leachate analytical results from 1999, 2000, and 2001 provided no evidence to suggest leachate is the source of cobalt detections in groundwater. Two of the analyses (2000 and 2001) reported non-detects for cobalt, and the 1999 sample had a cobalt concentration of 6.3 ug/L, slightly above the reporting limit.

Given the lack of evidence that leachate was the cause of cobalt detections, soil samples were collected at two (B-1 and B-2) undisturbed locations near MW-7. Samples were collected at B-1 and B-2 to evaluate whether or not cobalt is present at detectable levels in native soil, and to evaluate the capability of cobalt (if present) to leach to groundwater. Soil samples were collected at three vertical intervals at each location, each representing a different soil horizon. The sample depths and lithologic description are provided below:

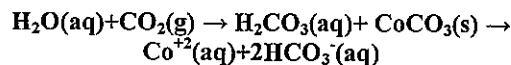
- B-1 – 13.5-15.5-foot bgs: tan to orange sand, to clayey sand;
- B-1 – 21.5-23.5-foot bgs: tan, wet sand;
- B-1 – 30-32-foot bgs: tan sand, to gray silty sand;
- B-2 – 8-10-foot bgs: gray silty clay;
- B-2 – 13-15-foot bgs; tan, orange clayey sand
- B-2 – 20-22-foot bgs; orange sand

Soil samples were submitted for total cobalt analysis by EPA Method 6010B, and a split-sample was collected at each sample location and depth and analyzed applying by the toxic characteristic leaching procedure (TCLP).

Analytical results verified the presence of cobalt at detectable concentrations in native soil at concentrations ranging from not-detect (B-1, 21.5 feet bgs) to 5,300 ug/kg (B-1, 30 feet bgs). TCLP results also verified that the cobalt detected in soil was capable of leaching to groundwater. For example, sample B-2 – 8 feet bgs TCLP results indicated that a soil sample with cobalt concentration as high as 1,000 ug/kg is capable of producing a leachate with cobalt concentrations as high as 19 ug/L. A similar concentration was detected in the groundwater sample collected from MW-7 on October 22, 2003.

To further support our hypothesis that cobalt concentrations detected in groundwater at MW-7 is from a naturally occurring source, we investigated other possible factors that may contribute to the cobalt detections. Previous testing and research at other landfills under similar (landfill gas) conditions indicate that CO₂ in landfill gas can have a direct impact on inorganic chemistry reactions in groundwater. The most water-soluble constituent in landfill gas is CO₂. Carbon dioxide can partition from the gas phase into groundwater due to its Henry Law constant of 0.047 Liter-atm/mole and form carbonic acid (Butler, 1982). Kerfoot (1996) has calculated that landfill gas CO₂ could lower pH in groundwater to as low as 4.7 in the absence of a buffering agent present in aquifer solids (e.g., carbonates). The change in geochemical conditions posed by the presence of landfill gas can preferentially dissolve naturally occurring metals

(cobalt) to groundwater. This chemical reaction can be expressed as:



This equation is similar to the reaction that occurs with calcium carbonate in soil that dissolves calcium to groundwater when interaction with landfill gas occurs.

Landfill Gas Investigation

A second step in the evaluation of intra-well gas to water transfer effects of VOCs at landfill sites involves a two-part method to evaluate:

- The presence of landfill gas within MW-7 (i.e., the detection of VOCs in the well headspace) at sufficient concentrations to drive gas-to-water partitioning, and
- The presence or absence of VOCs in the water-bearing zone outside the well.

The data collected from this procedure consist of VOC or methane concentrations in groundwater and gas within the impacted well(s) and well headspace, and VOC concentrations in groundwater outside the well collected in the absence of headspace (i.e., zero headspace) effects. Comparison of these data can provide conclusive results regarding the significance of intra-well gas to water transfer of VOCs in a given situation and setting.

Methane Monitoring, Gas Sampling and Analysis:

There is evidence of methane gas in the subsurface at the landfill. In December 2000, during the facility's routine methane monitoring event, methane was detected at five locations significantly above the LEL. Using bar-hole probe sampling techniques and a NP-204 natural gas meter, methane was detected in several locations between the landfill and background well MW-5 at concentrations ranging up to 54%.

In 2001, headspace monitoring for presence of landfill gas and VOCs was conducted on monitoring wells MW-5, MW-9, and MW-11. Methane was detected in well MW-9 headspace during the sampling event. Methane was not detected in well MW-5.

Lastly, methane concentrations were measured in MW-7 on three different occasions; April 17, 2003 (30% methane), October 16, 2003 (65% methane) and October 22, 2003 (58% methane). The April 17,

2003 results included constituent-specific, analytical results to support that VOC vapors in the landfill gas is the source of VOC detections measured at MW-7.

The landfill gas headspace sample collected in MW-7 contained all the organic compounds that were detected in groundwater from MW-7. Figure 6 shows the similarity in concentration and type of VOCs detected in headspace and in groundwater. The VOCs detected in groundwater were also the highest ones found in headspace.

Gas Migration Pathways

Critical to evaluating the potential for intra-well headspace gas to water VOC transfer effect, is understanding the methodology of historic groundwater sample collection of the subject monitor well. Several possible conditions exist during routine groundwater sampling events:

1. The water level in the monitor well is above the well screen (fully saturated) and remains fully saturated during groundwater sampling.
2. The water level in the monitor well is above the well screen prior to groundwater sampling, but the screen becomes partially exposed to headspace gas during purging or groundwater sample collection.
3. The water level in the monitor well is below the top of the well screen prior to and during sampling.

Well construction logs and groundwater levels were evaluated to identify potential gas migration pathways. It has been established that landfill gas was detected in the headspace of MW-7. Well logs indicate that MW-7 is screened through 16-foot of sand, and 14-ft of clayey silt or silty clay. Monitoring well MW-7 is screened from 10 to 30 feet below ground surface (bgs). Well logs indicate that the screened interval exposes approximately 14-feet of sand, and 6-feet of clayey silt or silty clay. The water level in MW-7 is generally 26-feet bgs, exposing 14-feet (of the total 16-feet) of sands, providing a potential pathway for landfill gas migration from the landfill into the well. Fluctuating water tables would also likely increase the potential for gas to water interaction.

CONCLUSIONS AND RECOMMENDATIONS

The ASD provided ample evidence that landfill gas was the source of VOC and cobalt detections in groundwater at MW-7. The groundwater and leachate analytical results were evaluated for evidence of leachate in groundwater. Increases in sodium and chloride concentrations, which are indicative of leachate impacts, were not observed. Similarly, there was no observed increased ammonia concentrations coupled with decreased sulfate concentrations from reducing conditions associated with a release. Geochemical changes to groundwater resulting from leachate also affects multiple inorganic parameters, because leachate is comprised of several chemical constituents and not just a single parameter. None of these relationships were observed in the groundwater samples from MW-7. Furthermore, groundwater from well MW-7 is geochemically similar to background well MW-5, and groundwater from both are geochemically distinct from leachate.

The landfill gas headspace sample collected in MW-7 contained all the organic compounds that were detected in groundwater from MW-7. The VOCs in the landfill gas were detected at concentrations indicative of a near source impact rather than from a leachate source at the facility, which exhibits low level VOC concentrations. Partitioning of the VOCs from gas to groundwater using Henry's Law constant was not calculated because they are subject to variability associated with changes in barometric pressure.

This ASD Report presented the following conclusions:

- General inorganic and leachate indicator data demonstrate that leachate is not impacting MW-7.
- Methane was detected in well MW-7.
- Headspace sample analytical results provide strong evidence of landfill gas in the headspace of the monitored wells, based on the similarity in types and concentrations of VOCs in headspace.
- VOC analytical results of leachate and groundwater provide strong evidence that leachate is not the source of VOCs in groundwater, because leachate has a different suite and concentration range of

VOCs relative to those detected in groundwater.

- Leachate analytical results from 1999, 2000, and 2001 provide no evidence to suggest leachate is the source of cobalt detections in groundwater.
- Analytical results verified the presence of cobalt in undisturbed soil near MW-7 at concentrations ranging from not detect (B-1, 21.5 feet bgs) to 5,300 ug/kg (B-1, 30 feet bgs). TCLP results also verified that the cobalt detected in soil was capable of leaching cobalt at concentrations consistent with the concentrations measured in groundwater.
- The change in geochemical conditions posed by the presence of landfill gas can preferentially dissolve naturally occurring metals into groundwater. Cobalt may be expected in groundwater due to the acidic conditions posed when landfill gas (45-50% CO₂) geochemically reacts with saturated zone sediment.

Properly performed, ASDs can be used as an effective investigation tool to determine whether or not landfill gas is impacting groundwater quality at landfills. Furthermore, data collected during ASD investigations can be used to design controls for landfill gas migration to minimize the potential for intra-well headspace gas-to-water VOC transfer effects.

As a result of this investigation, the facility implemented upgrades to the existing gas collection and control system (GCCS). These upgrades included additional gas wells, connecting the leachate risers to the GCCS, and dewatering existing gas wells. Since these activities both total VOC concentrations and alkalinity concentrations have decreased dramatically (Figure 5).

**TABLES
AND
FIGURES**

Table 1
Historical Volatile Organic Compound Detections

Constituent	Units	Well	Date	Result	Limit
Cis-1,2-dichloroethene	<u>UG/L</u>	MW-2	3/29/1996	14.0000	5.0000
Acetone	UG/L	MW-4A	8/24/2000	8.30000	5.0000
Acetone	UG/L	MW-7	3/04/2003	16.0000	5.0000
Acetone	UG/L	MW-7	9/03/2003	36.0000	5.0000
Benzene	UG/L	MW-7	9/03/2003	20.0000	5.0000
Cis-1,2-dichloroethene	UG/L	MW-7	9/03/2003	24.0000	5.0000
Ethylbenzene	UG/L	MW-7	3/04/2003	12.0000	5.0000
Ethylbenzene	UG/L	MW-7	9/03/2003	70.0000	5.0000
Toluene	UG/L	MW-7	9/03/2003	38.0000	5.0000
Total xylenes	UG/L	MW-7	3/04/2003	18.0000	5.0000
Total xylenes	UG/L	MW-7	9/03/2003	120.0000	5.0000
Vinyl chloride	UG/L	MW-7	3/20/2002	2.7000	2.0000
Vinyl chloride	UG/L	MW-7	5/03/2002	3.0000	2.0000
Vinyl chloride	UG/L	MW-7	3/04/2003	2.4000	2.0000
Vinyl chloride	UG/L	MW-7	9/03/2003	9.2000	2.0000

Detections are shown for constituents selected in the VOC list and all selected wells.
The Limit column refers to the laboratory reporting limit.

Table 2
 VOCs Concentrations in Groundwater vs Leachate

Analyte	Gas Well Leachate Aug-99 GEW:8-99 ug/L	Gas Well Leachate Sep- 99 GEW:9-99 ug/L	Sub D Leachate Apr-01 Lcht: 4-01 ug/L	MW7 March 03 ug/L	MW7 April 03 ug/L	MW7 Sept. 03 ug/L	MW7v Headspace Sept. 03 ppbv
1,1 Dichloroethane							
1,4 Dichlorobenzene	22	18					
2-Hexanone	130						
Acetone			1800	16	15	36	1200
Benzene	ND	ND	ND			20	890
Carbon Disulfide			6.9				
Cis-1,2-Dichloroethene	23	12				24	510
Ethybenzene	54	54		12	50	70	3000
Methyl Ethyl Ketone			4100				
Methyl Isobutyl Ketone			70				
Methylene chloride			7.4				
Styrene		11					
Toluene	130	120	7.7			38	1700
Xylenes	180	180		18	89	120	3830
Vinyl Chloride				2.4	7.2	9.2	1700

Table 3**VOCs detected in the well headspace gas at MW-7 on April 17, 2003**

Organics Detected	Concentration (ppb)
1,1-Dichloroethane	140
1,2,4-Trimethylbenzene	290
1,3,5-Trimethylbenzene	220
4-Ethyltoluene	340
Acetone	1,200
Benzene	890
Chloroethane	65
<i>cis</i> -1,2-Dichloroethene	510
<i>cis</i> -1,3-Dichloropropene	40
Cyclohexane	1,600
Dichlorodifluoromethane	870
Dichlorotetrafluoroethane	81
Ethylbenzene	3,000
Heptane	1,800
Hexane	1,100
Isooctane	820
<i>(m and p)</i> -Xylenes	3,400
Methyl isobutyl ketone	1,900
<i>o</i> -Xylenes	430
Toluene	1,700
Vinyl chloride	1,700

Time Series Plot for MW-7

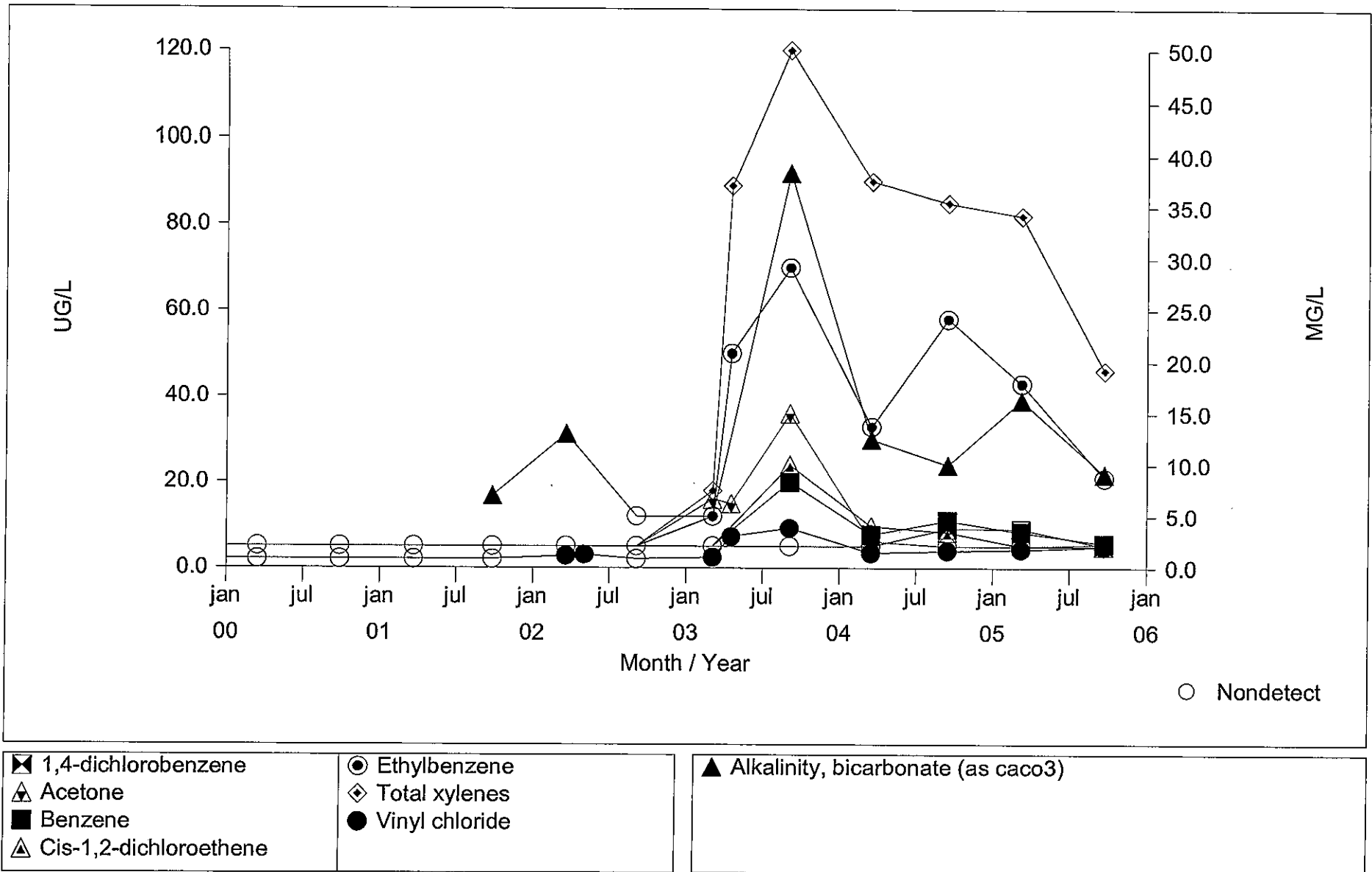


Figure 1

Time Series Plot for MW-7

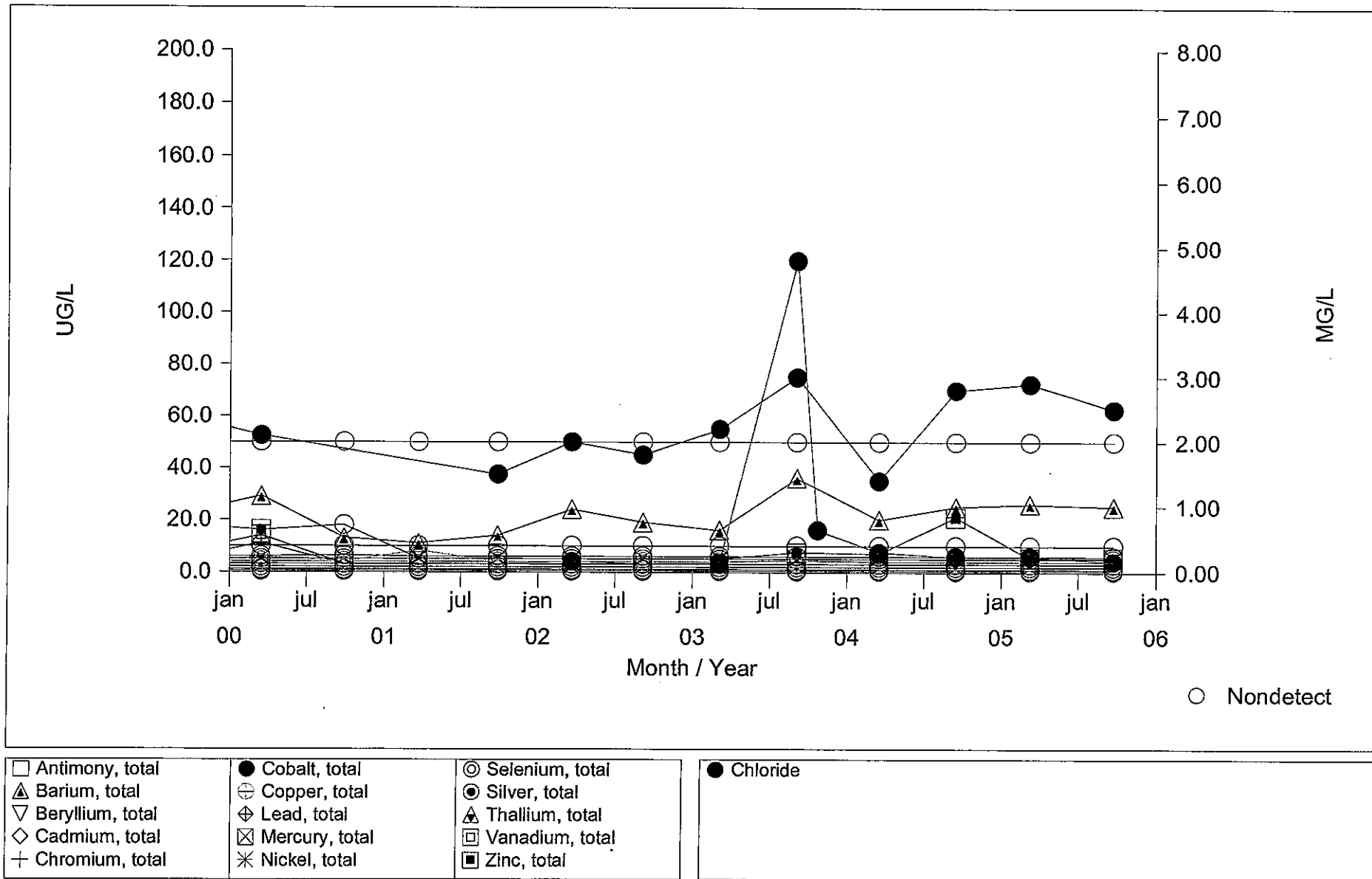


Figure 2

Time Series Plot for MW-7

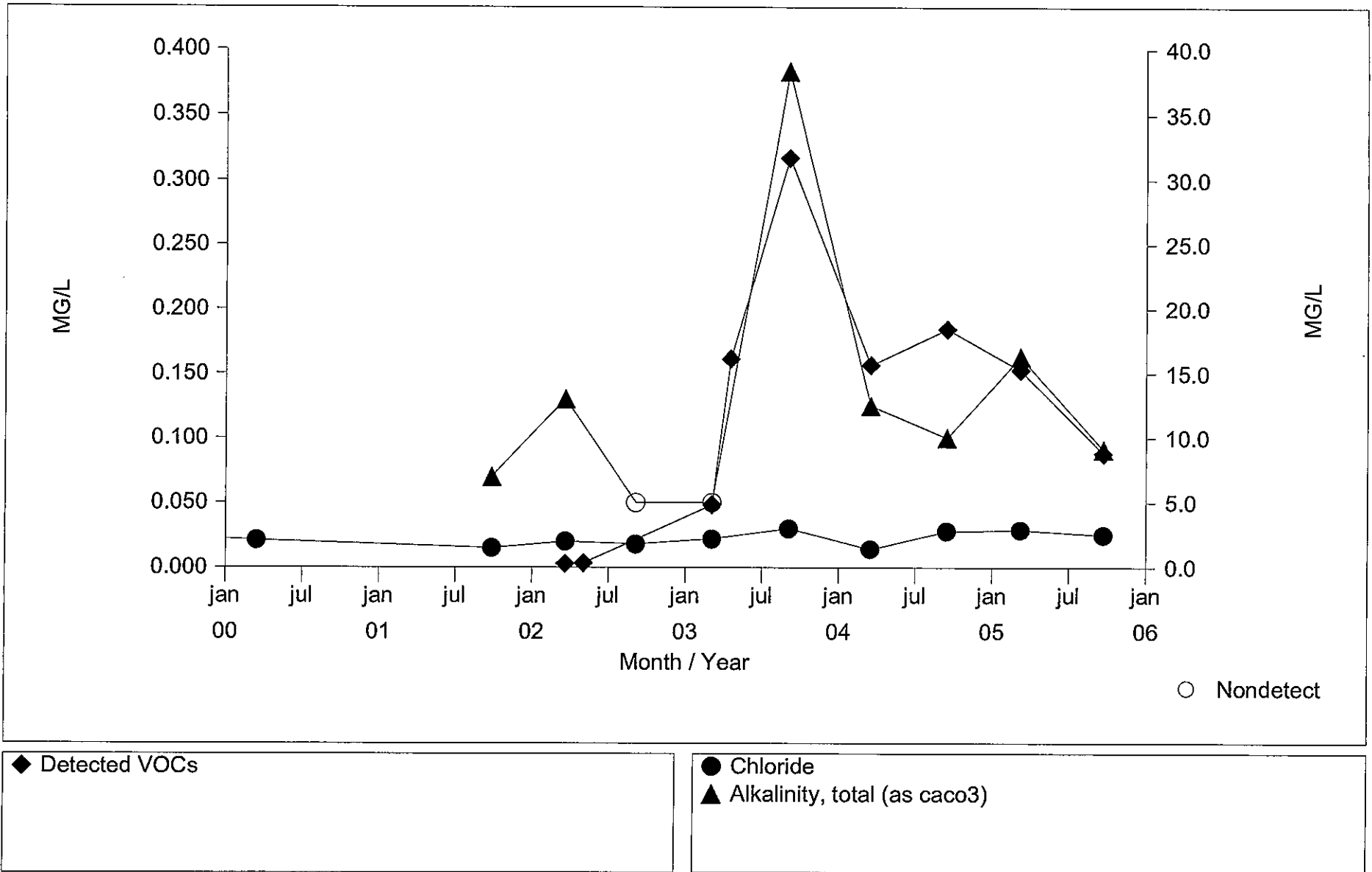


Figure 3

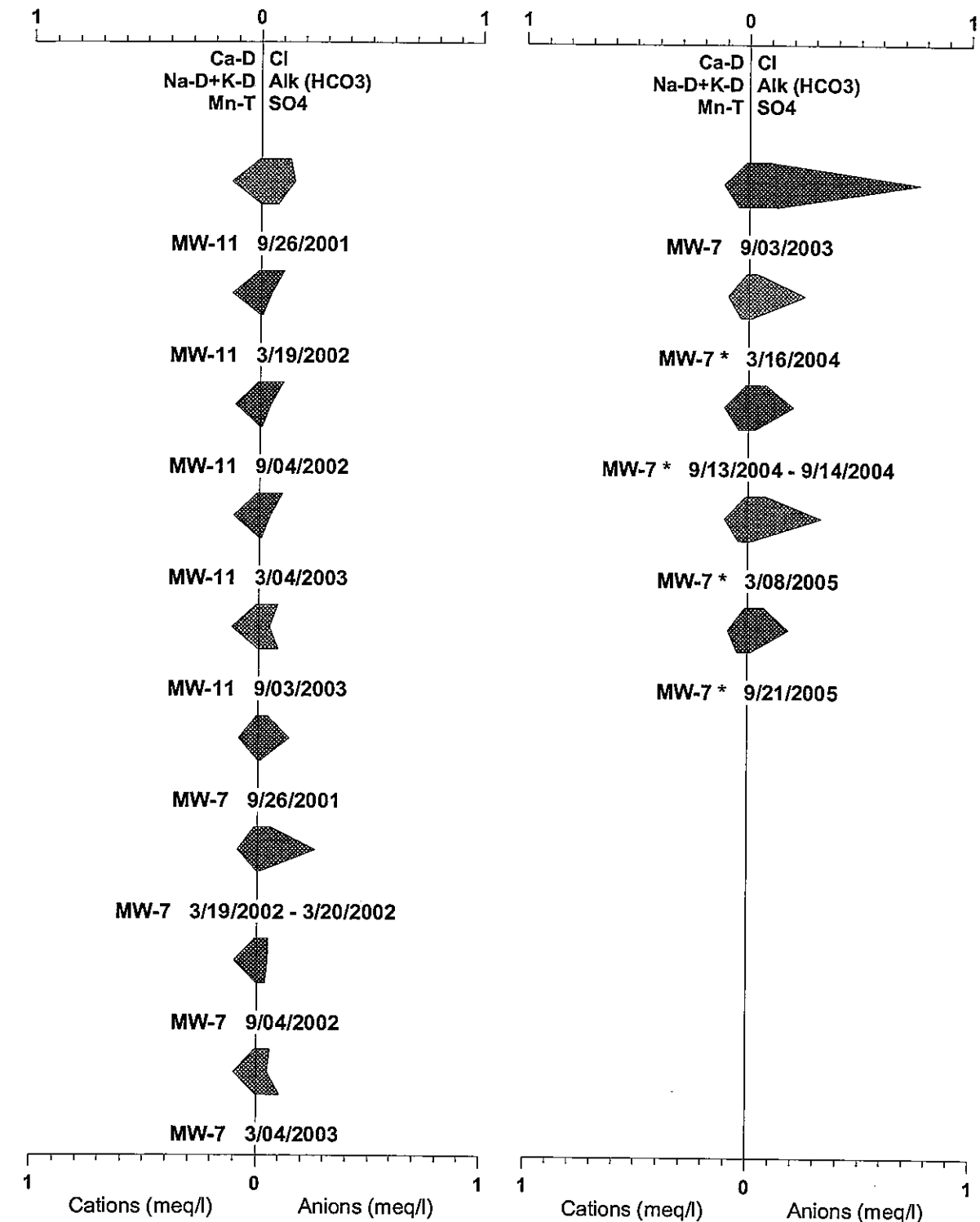
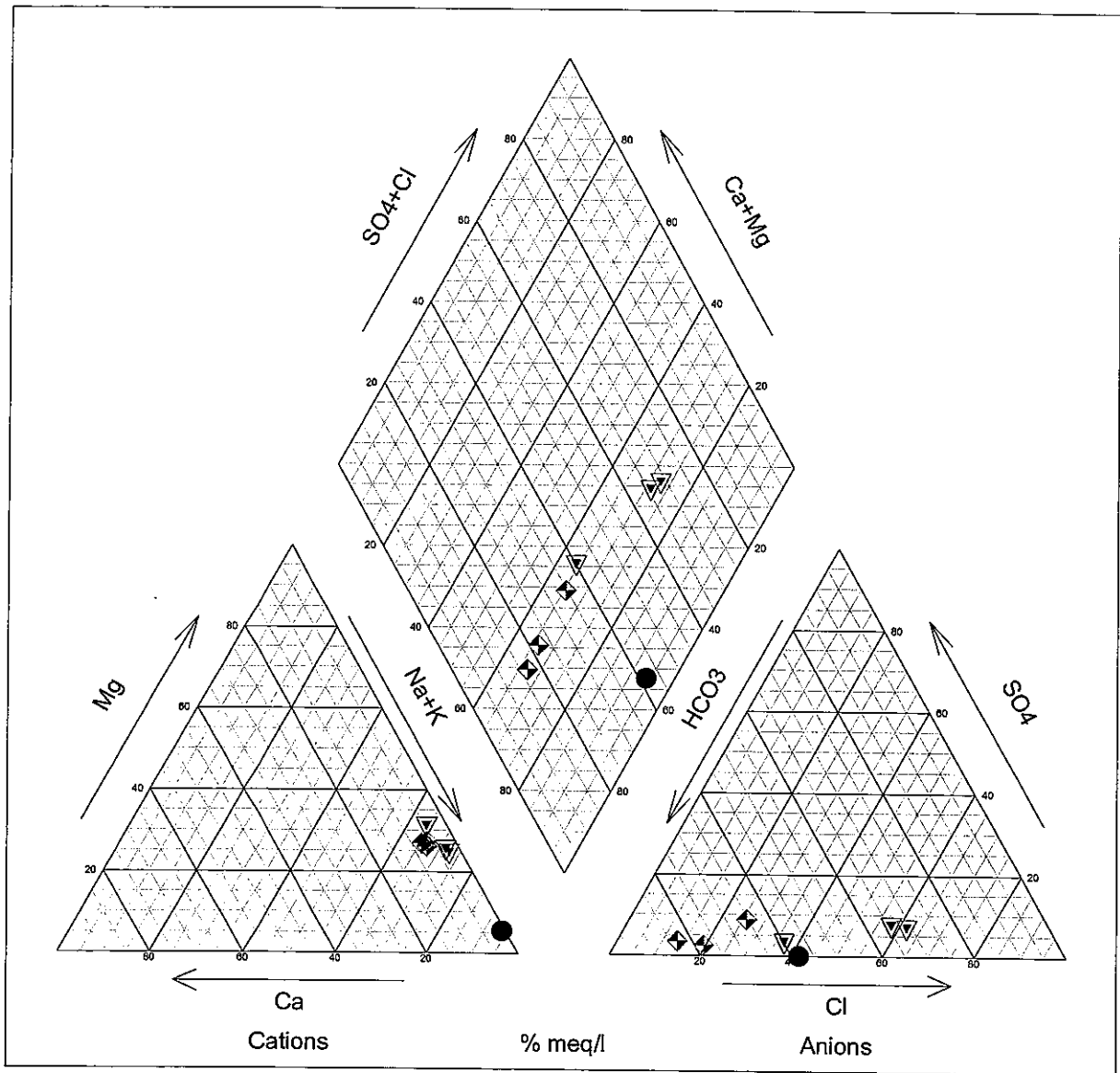
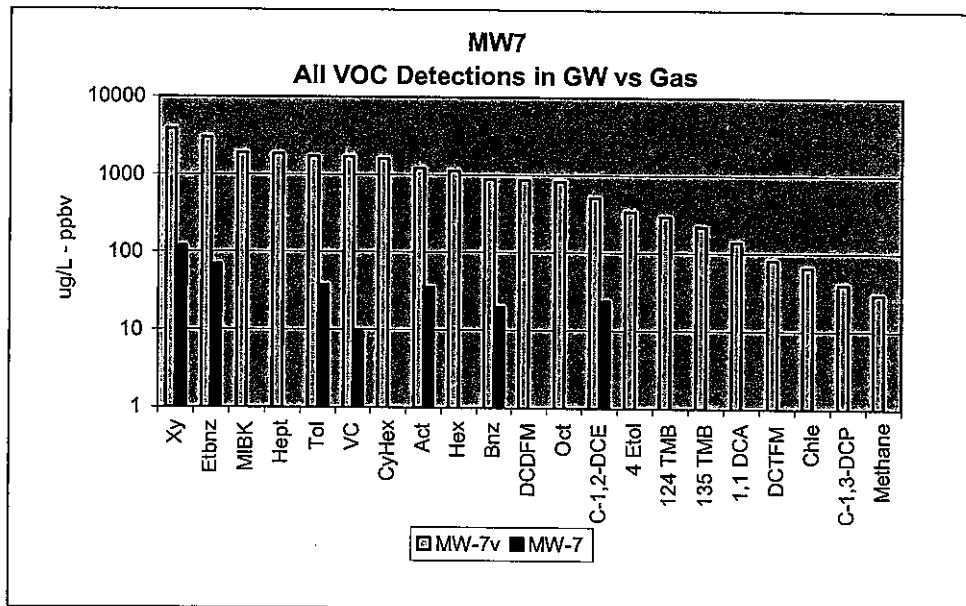
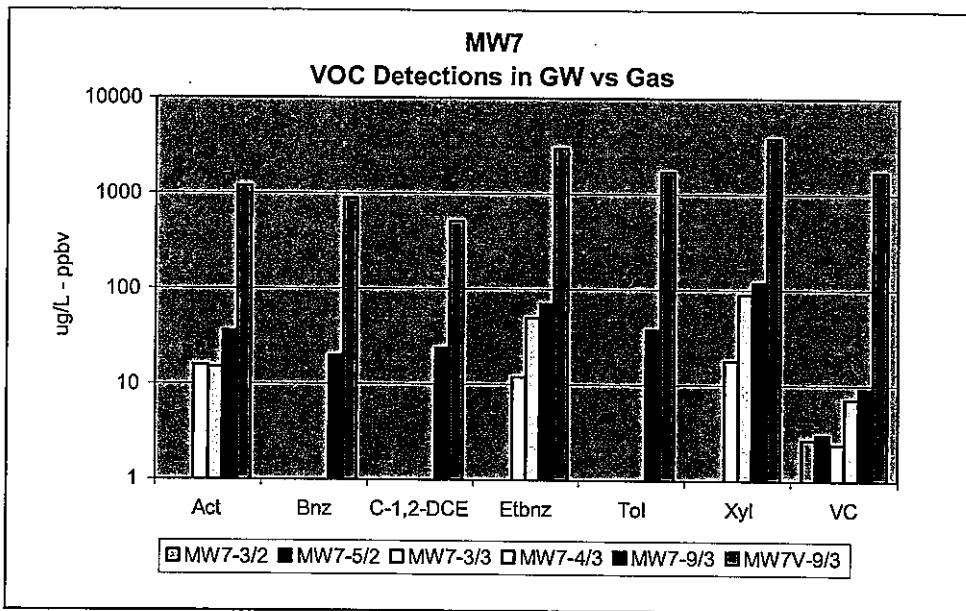


Figure 4



▽ MW-11	3/16/2004
▽ MW-11	9/13/2004 - 9/14/2004
▽ MW-11	3/08/2005
◇ MW-7	3/16/2004
◇ MW-7	3/08/2005
◇ MW-7	9/13/2004 - 9/14/2004
● LEACHATE 1	9/09/1999



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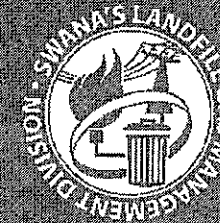
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