URS

LFG Impacts on Groundwater

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LFG Impacts on Groundwater

US – Late 1980s

- Researchers note that volatile organic compounds (VOCs) are the most common groundwater constituent at landfills
- US landfill groundwater monitoring requirements modified to include VOCs as 'indicator parameters', due to frequency and mobility
- VOCs in groundwater from landfill gas (LFG) had not been envisioned
- Due to much lower cost for gas control than leachate control, differentiating gas from leachate important.

LFG Impacts on Groundwater

- Case Study 1 – Use of radioisotopes to assess LFG impacts on groundwater (http://www.ncbi.nlm.nih.gov/pubmed/14710929) and inorganic effects of LFG on groundwater (http://info.ngwa.org/gwol/pdf/040278119.pdf)
- Case Study 2 – Comparison of gas and aqueous data to assess the direction of partitioning in a monitoring well; In-well LFG effects (http://www.ncbi.nlm.nih.gov/pubmed/15736343)
- Within-well *vs* Out-of-well LFG impacts
- Time to cleanup

LFG Impacts on Groundwater

- Case Study 1 – Use of radioisotopes to assess LFG impacts and inorganic effects of LFG on groundwater
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LFG Impacts on Groundwater

Case Study 1: MSW Landfill: LA Area

- Spreading grounds (MAR) upgradient
- Quarry downgradient
- Partially lined, partially unlined
- Persistent low-level VOC detections – DCDFM, TCE - upgradient and cross-gradient…
- Others -- GW and gas VOCs 'at equilibrium'
- Permit renewal at stake

LFG Impacts on Groundwater

Isotope evaluation performed:

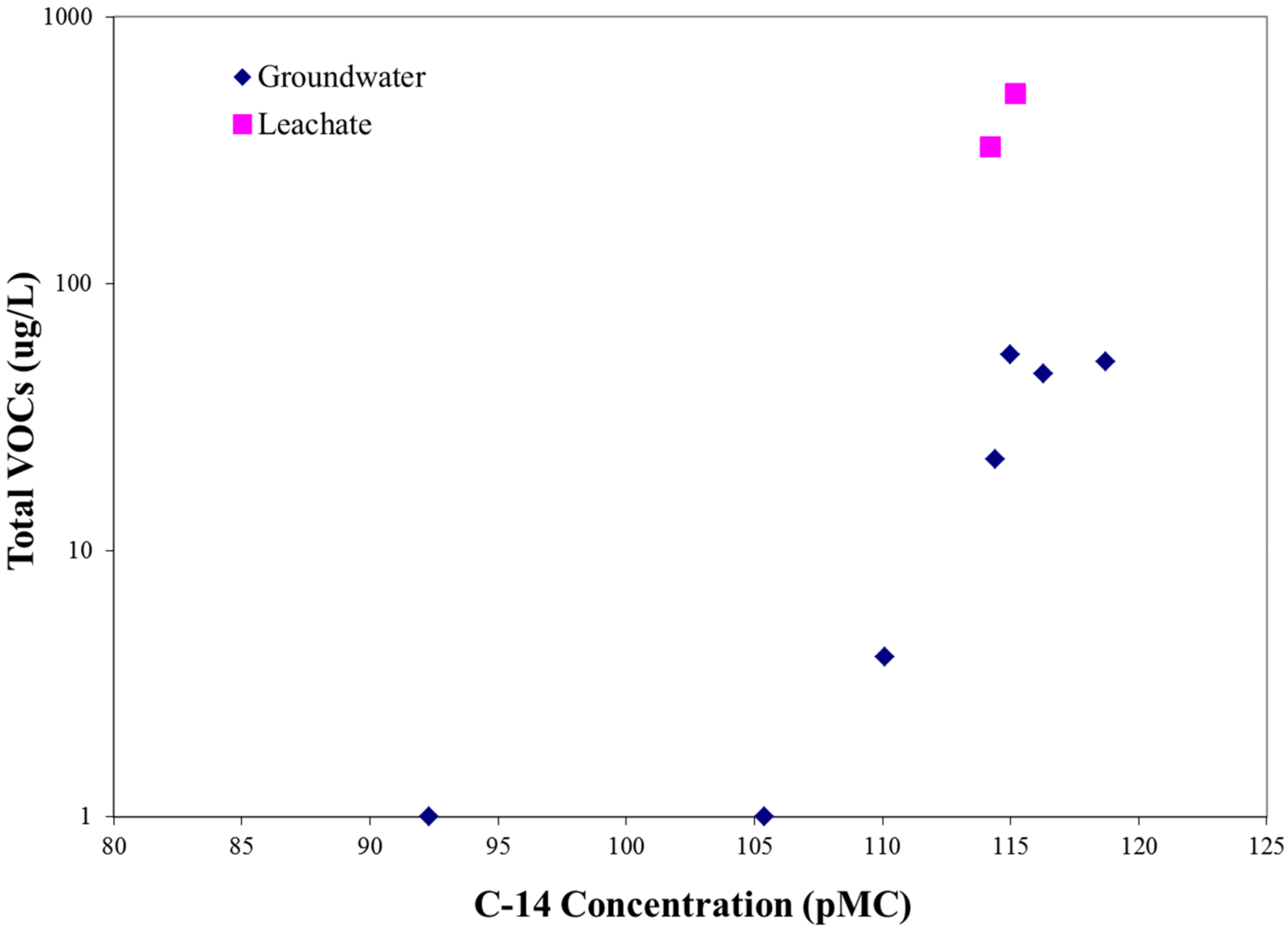
A. Dissolved inorganic carbon (Carbonates) from LFG CO_2 or leachate alkalinity -- modern, high ^{14}C level vs. background carbonates

B. Leachate water likely has elevated tritium (^3H)

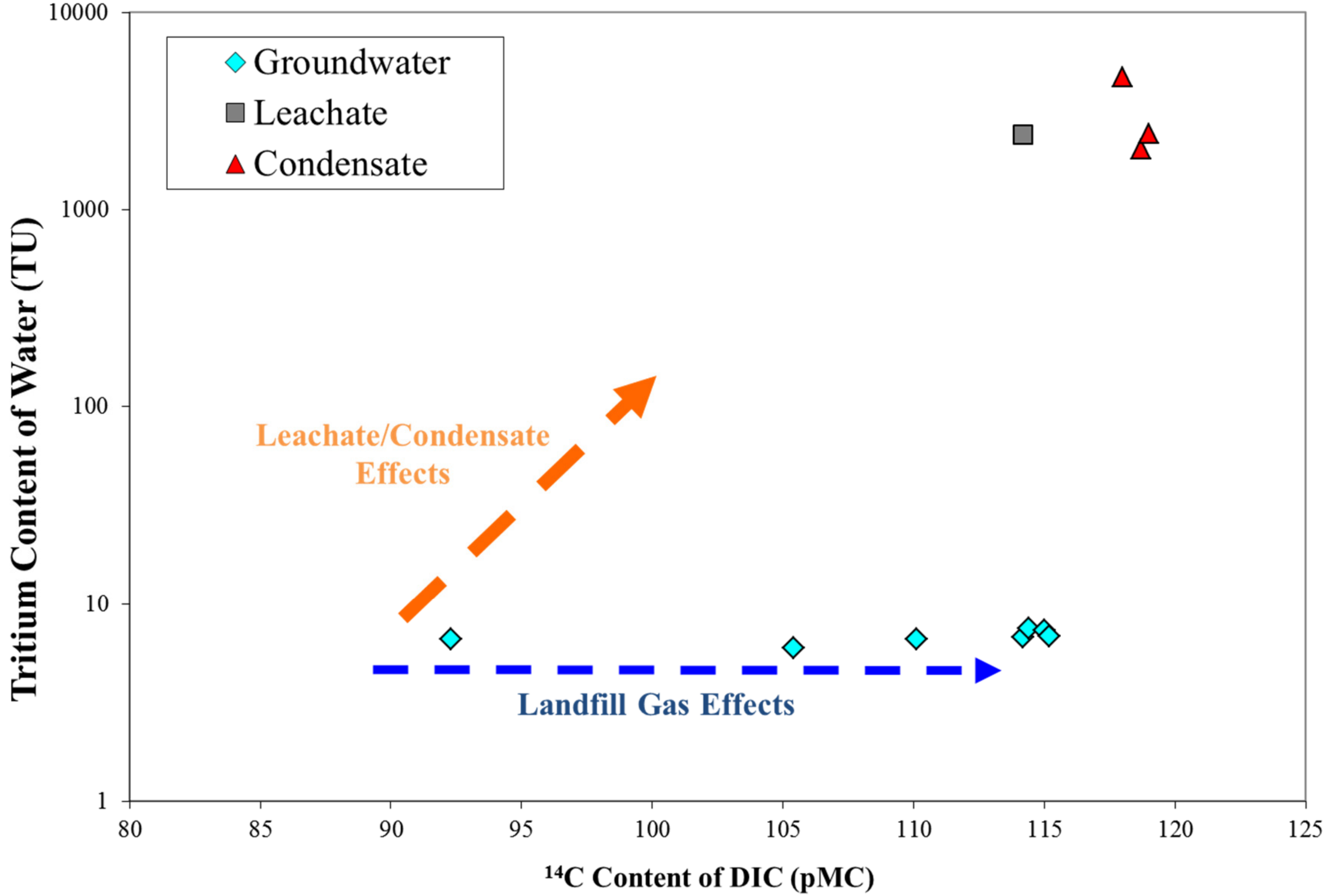
Elevated ^{14}C and tritium -> Leachate;

Elevated ^{14}C only -> LFG

LFG Impacts on Groundwater



LFG Impacts on Groundwater



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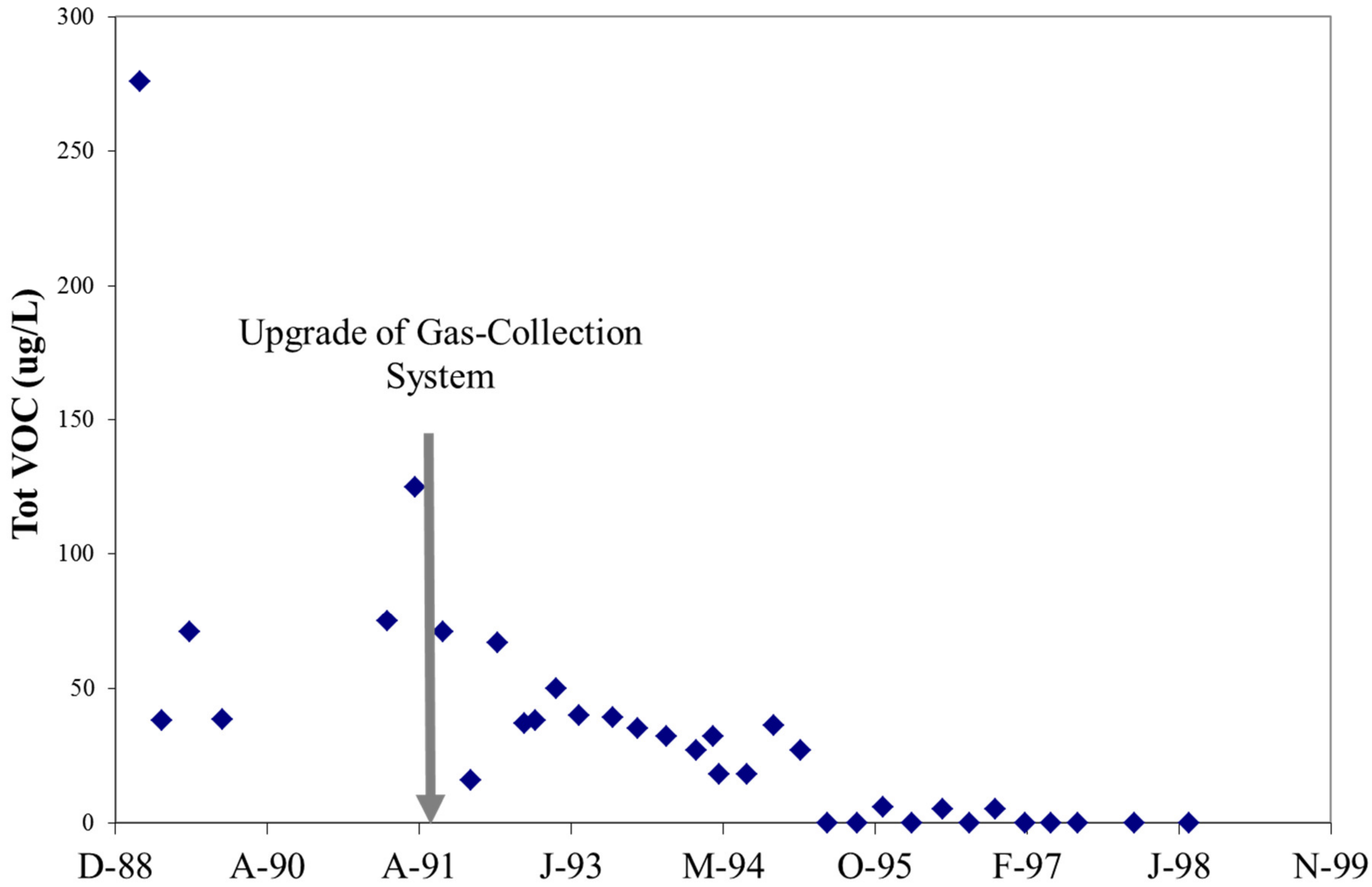
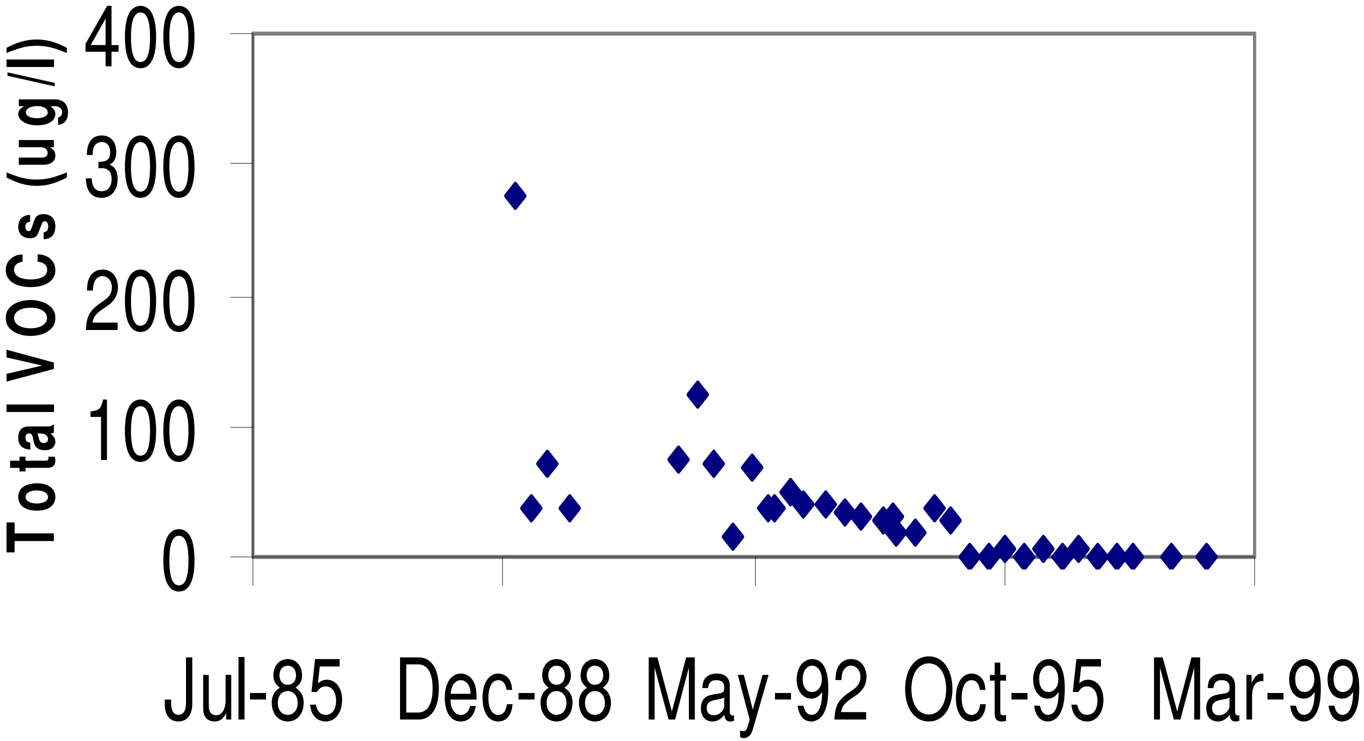


Inorganic/LFG Correlations

Evaluated changes in inorganic constituents during and after LFG effects on groundwater

LFG Effects



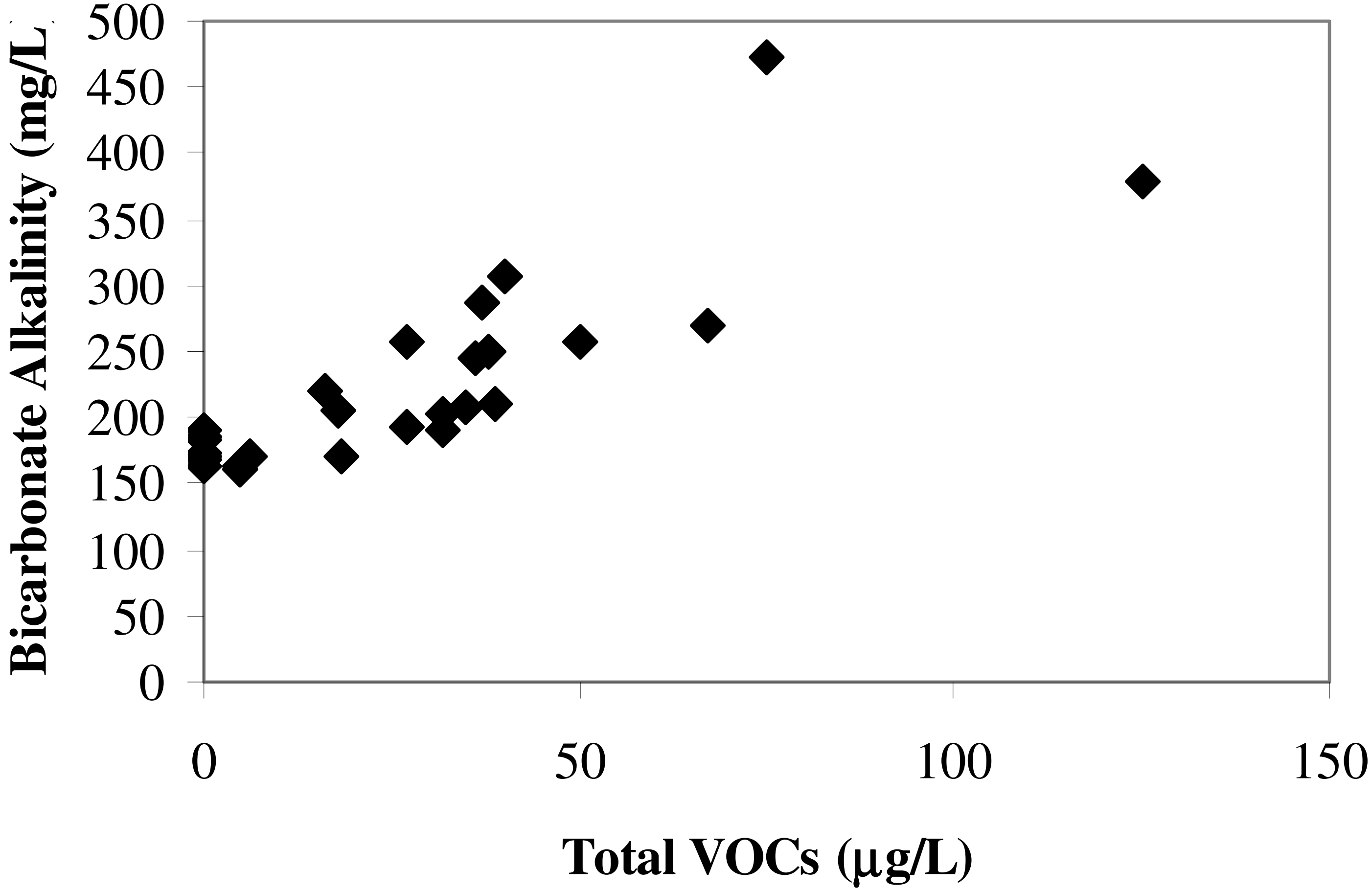
Total VOCs (ug/l)
400
300
200
100
0
Jul-85
Dec-88
May-92
Oct-95
Mar-99

Inorganic/LFG Correlations

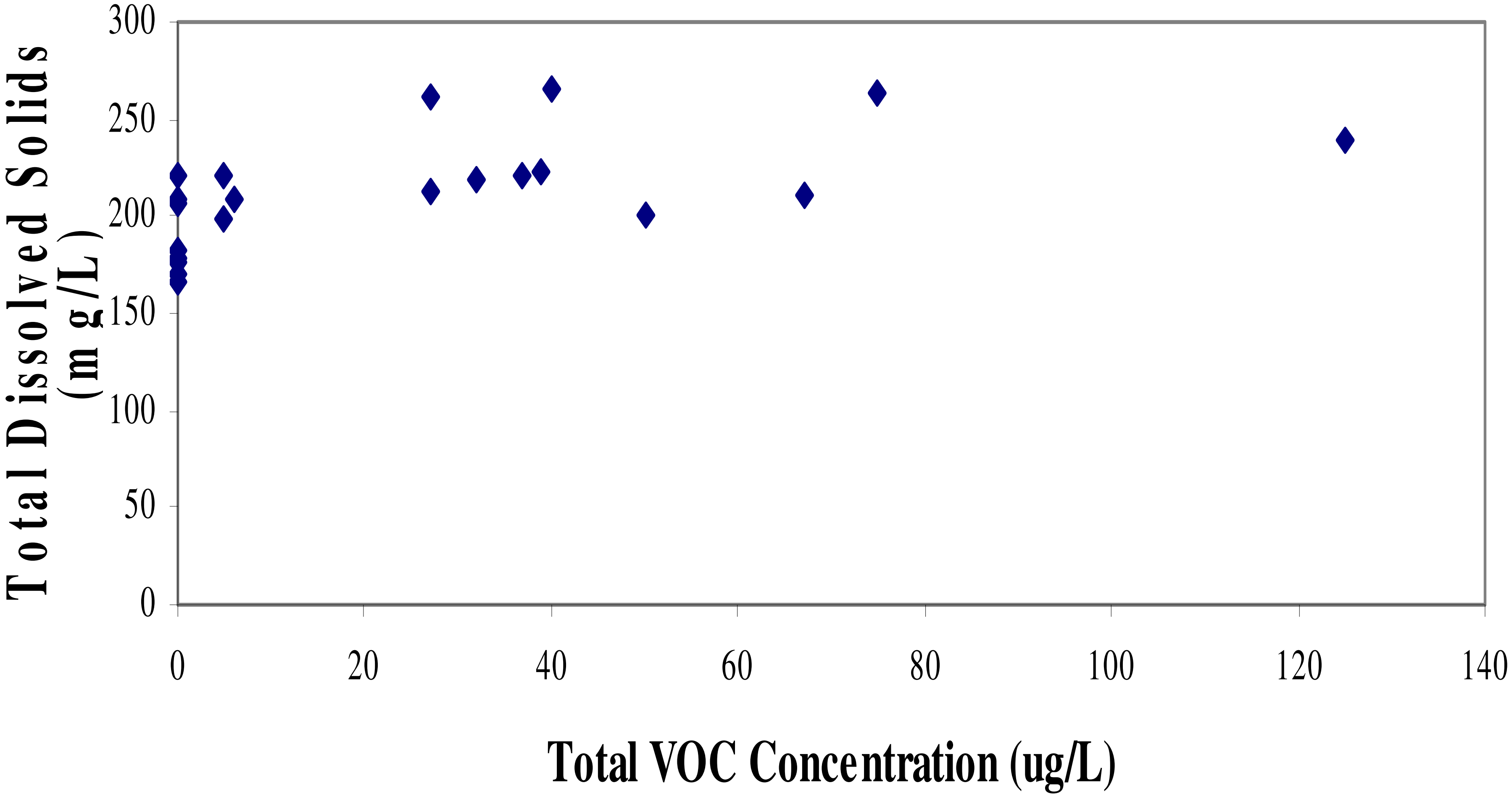
Parameters Evaluated:

- Alkalinity
- TDS
- Fe and Mn
- Na, SO4 and Cl
- Ca and Mg

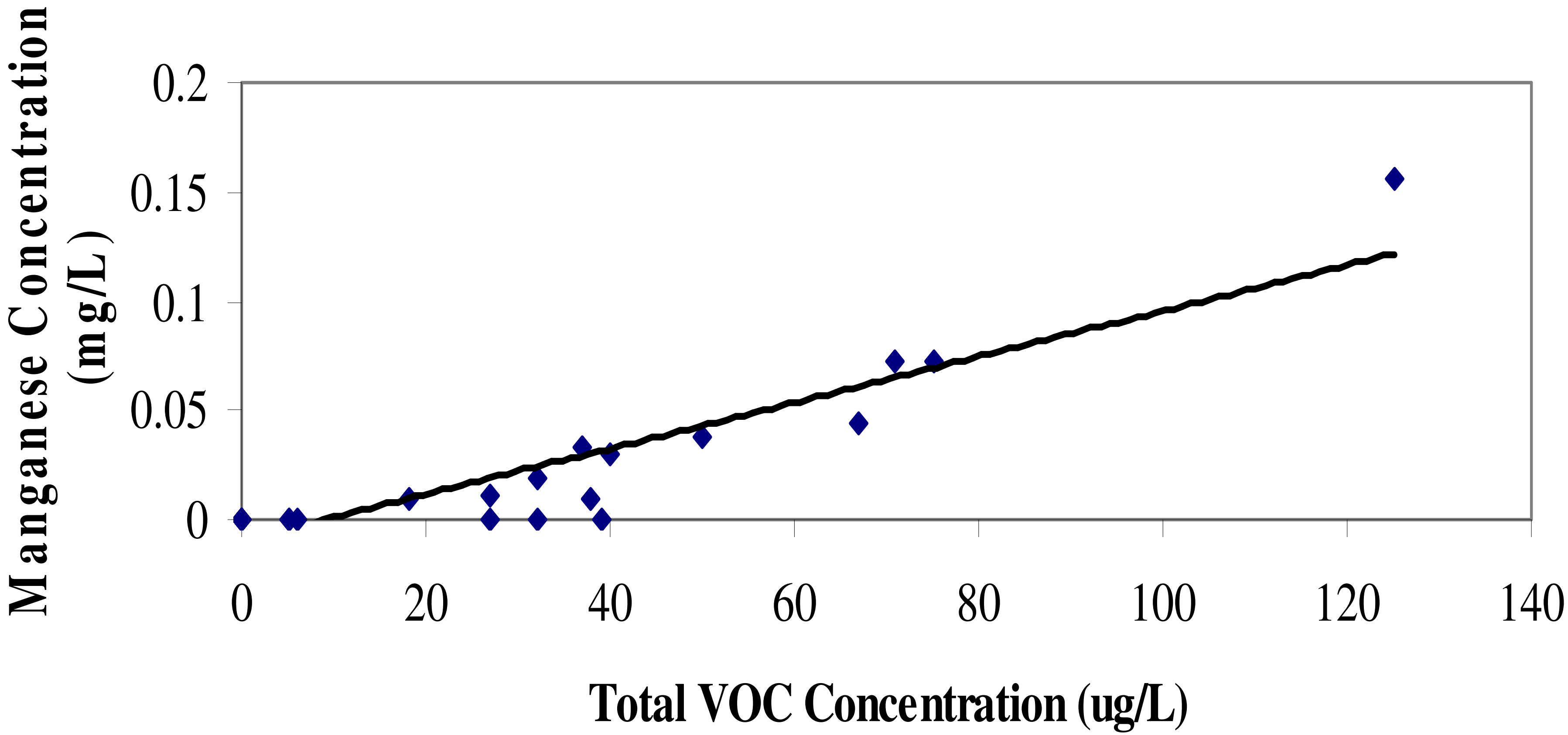
Alkalinity and Total VOCs



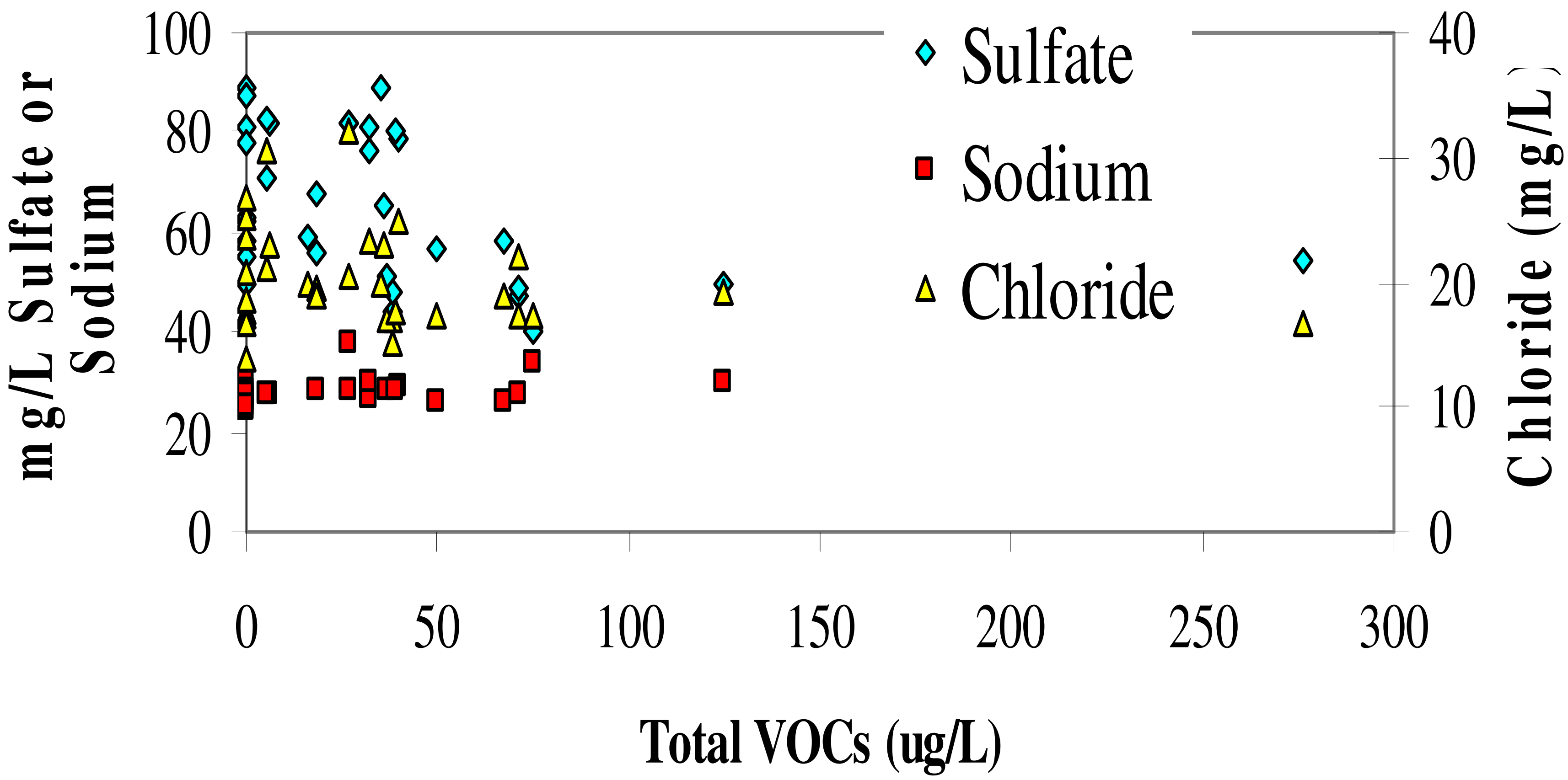
TDS and Total VOCs



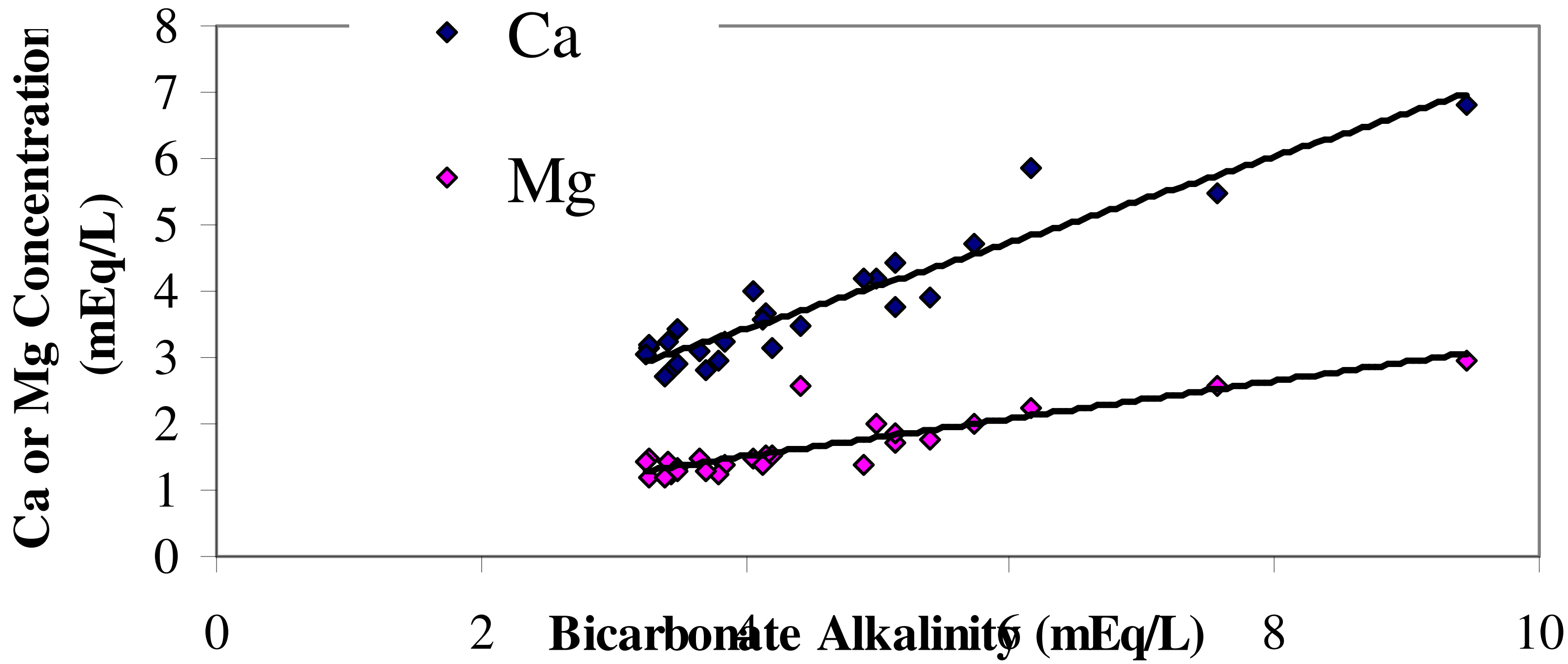
Manganese and Total VOCs



Sodium, Sulfate, Chloride



Calcium and Magnesium and Alkalinity



Inorganic/LFG Correlations

LFG Can Cause Changes in Non-Volatile Constituents

- Alkalinity
- Ca and Mg
- Manganese
- No Effect on Sodium, Chloride

LFG Impacts on Groundwater

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In-Well Gas Effects

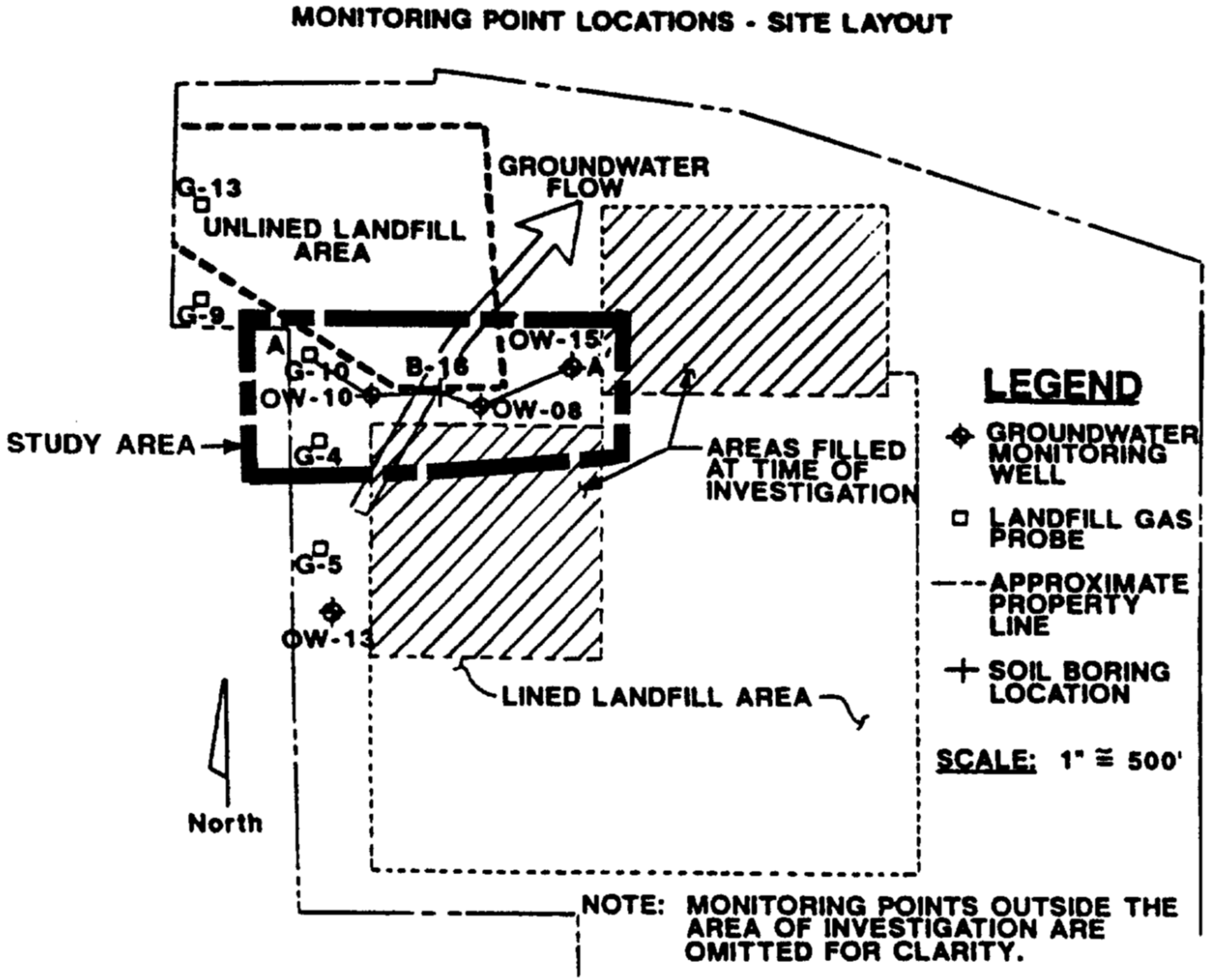
- Operating unlined landfill
- New low-permeability cap and landfill gas extraction system (LFGCCS) installed
- Before LFGCCS operation began, detections of volatile organic compounds cross-gradient and upgradient from waste
- Regulators required explanation for detections

In-Well Gas Effects

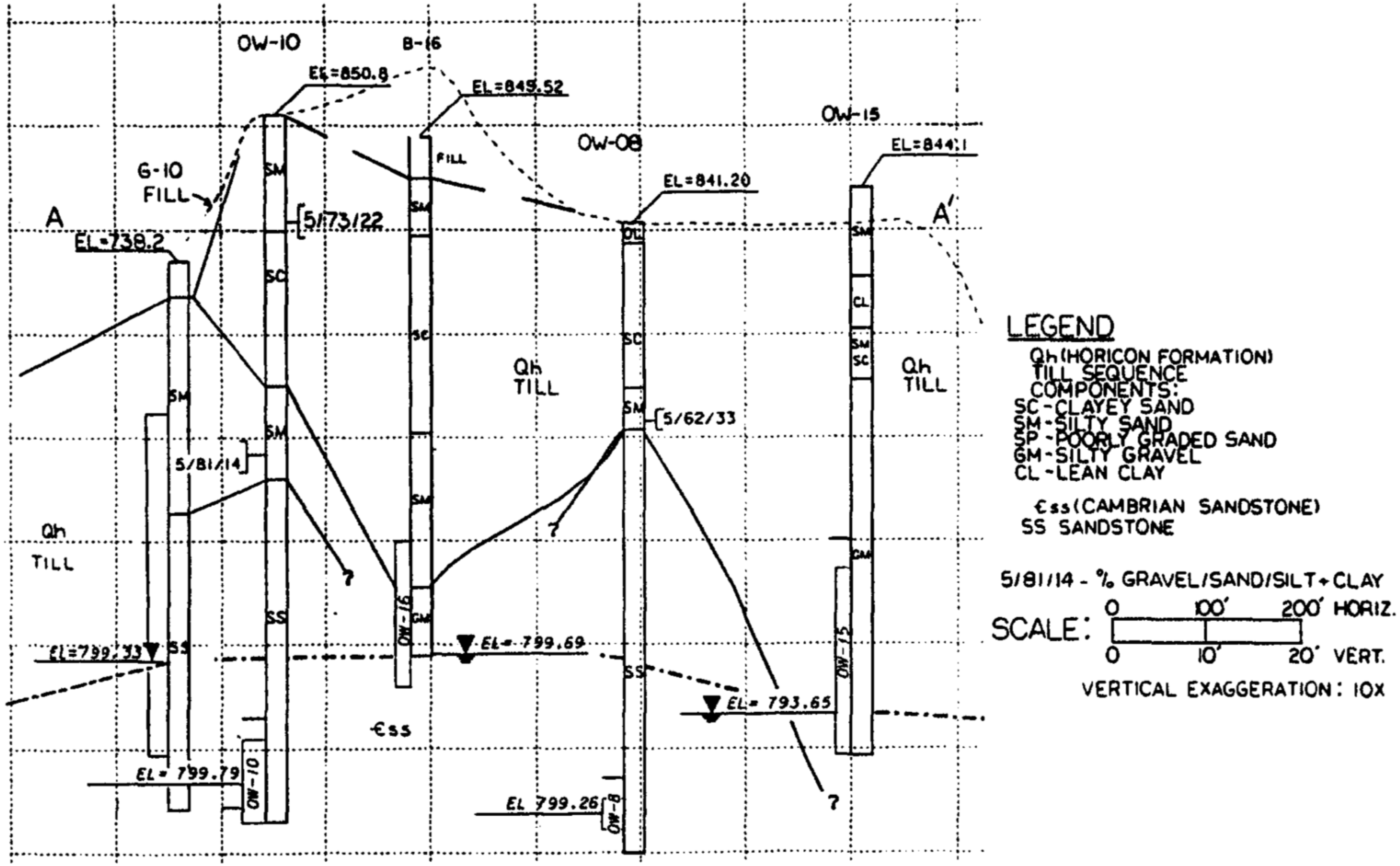
Volatile Organic Compounds Detected
In Ground-Water Samples

Compound	Henry's Law Coefficient	OW-08 (ug/L)	OW-10 (ug/L)	OW-13 (ug/L)	OW-15 (ug/L)
cis-1,2-Dichlchloroethene	0.31	ND(10)[a]	10	ND(10)	10
1,1-Dichloroethane	0.23	ND(5)[a]	7	ND(5)	10
Dichloromethane	0.11	ND(5)	ND(5)	ND(5)	8
Trichloroethene	0.37	ND(1.4)	2	ND(1.4)	3
Tetrachloroethene	0.93	ND(1.1)	3	ND(1.1)	5

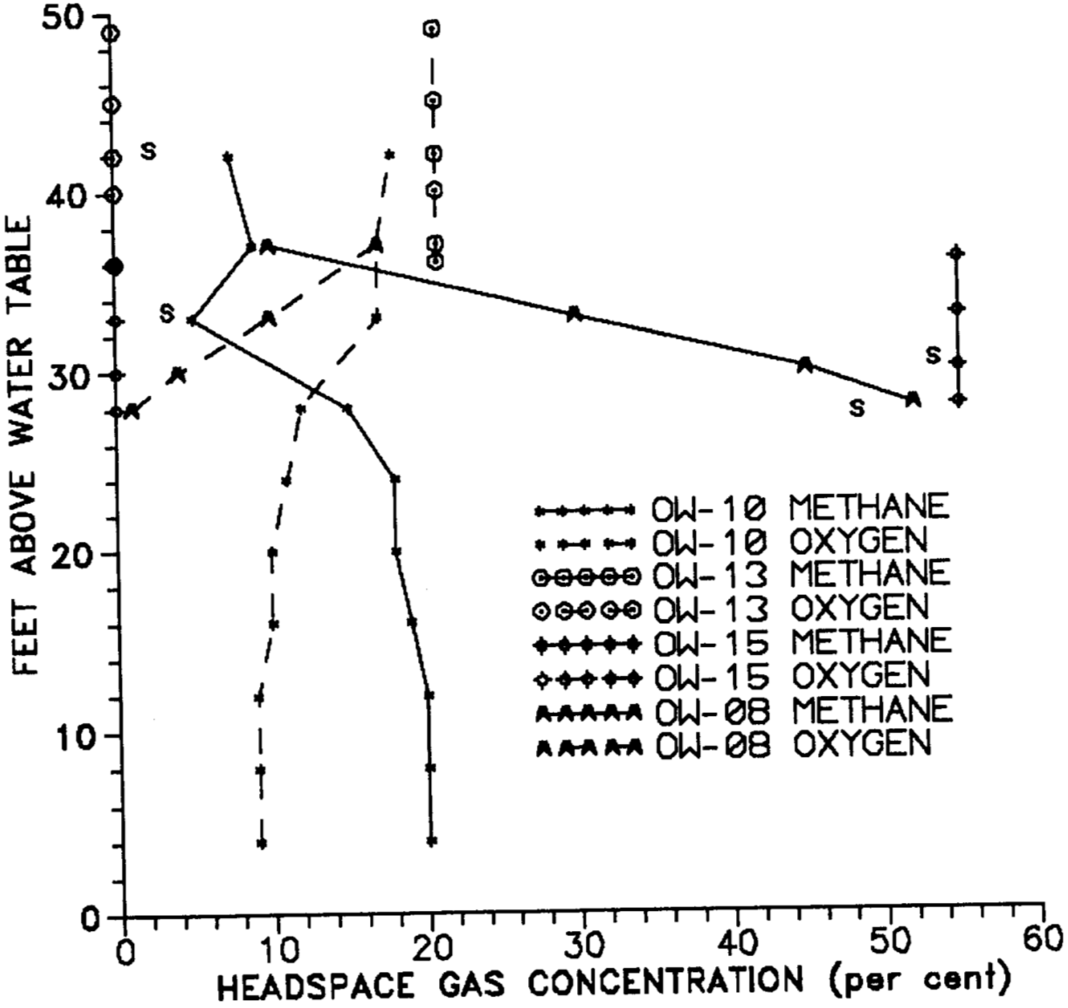
In-Well Gas Effects



In-Well Gas Effects



In-Well Gas Effects



In-Well Gas Effects

Evaluating gas/water equilibrium by comparing gas and aqueous concentrations

EQUILIBRIUM (No net phase transfer):

$$C_g = H\ C_w$$

Gas-to-Water Transfer:

$$C_g > H\ C_w$$

Water-to-Gas Transfer:

$$C_g < H\ C_w$$

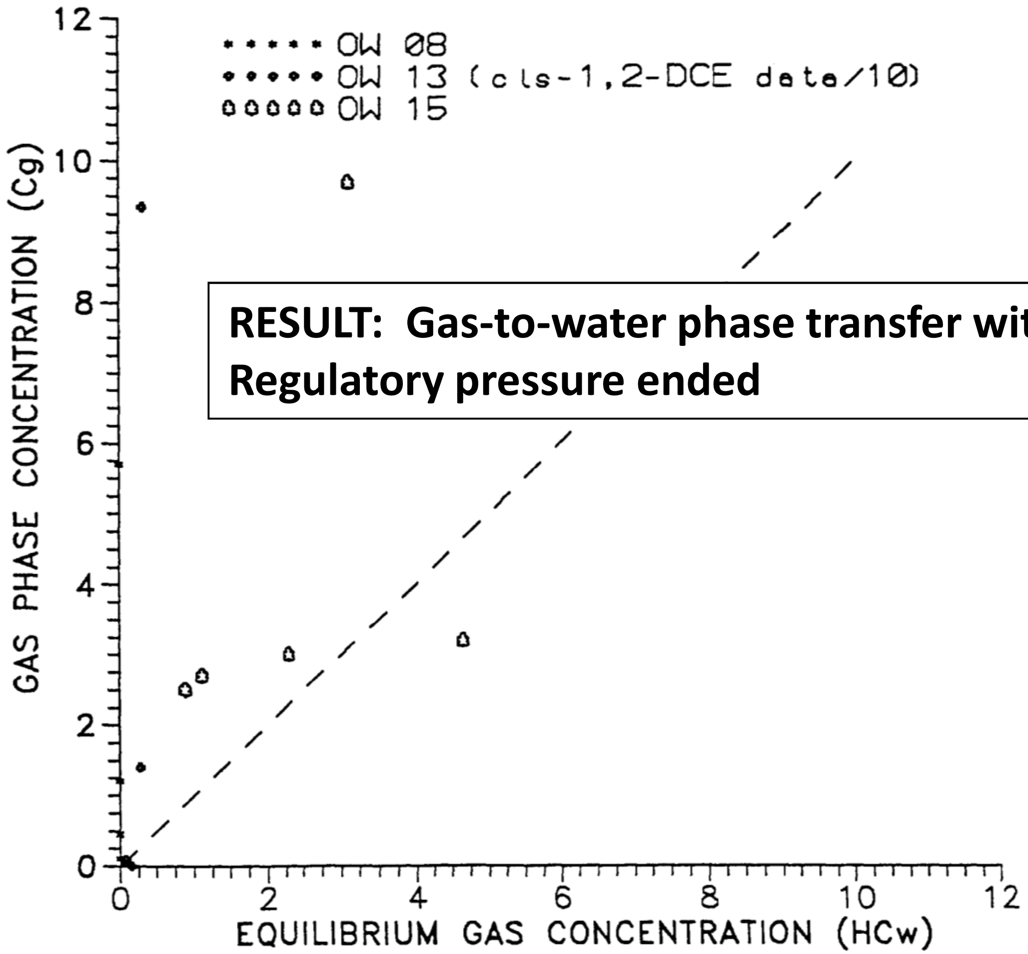
In-Well Gas Effects

Table 3. Gas Concentrations(ng/cm^3) and Evaluation of Gas/Water Equilibrium of Volatile Organic Compounds[a]

Well	cis-1,2-DCE (H=0.31)		1,1-DCA (H=0.23)		$MeCl_2$ (H=0.11)		TCE (H=0.37)		PCE (H=0.93)	
		$\frac{HC_w}{C_g}$		$\frac{HC_w}{C_g}$		$\frac{HC_w}{C_g}$		$\frac{HC_w}{C_g}$		$\frac{HC_w}{C_g}$
OW-08		NW[c]		NW[c]		NG[d]		NW[c]		NW[c]
OW-10		0.03		NG[d]		NG		0.8		0.19
OW-13		NG		NG[d]		NG		NG[d]		NA
OW-15		0.32		0.77		0.35		0.41		1.4

[a] Gas concentrations (C_g) in ng/cm^3; HC_w/C_g dimensionless
[b] Non-detect; See Methods and Materials for detection limits
[c] Entries of NW represent non-detectable water concentrations with detectable gas concentrations
[d] Entries of NG represent non-detectable gas concentrations

In-Well Gas Effects



RESULT: Gas-to-water phase transfer within well. Regulatory pressure ended

In-Well Gas Effects

Table 4. Concentrations (ng/cm³) of Compounds Detected in Monitoring-Well Headspace Gases but Absent from all Ground-Water Samples

Compound	OW-08	OW-10	OW-13	OW-15
Dichlorodifluoromethane	1.2	1.4	ND(0.003)[a]	ND(0.002)[a]
1,2-Dichloro-1,1,2,2-Tetra fluoroethane	0.42	ND(0.0009)	ND(0.007)[a]	0.29
Vinyl Chloride	1.9	0.69	ND(0.002)[a]	2.3
Chloroethane	1.6	ND(0.0008)[a]	ND(0.003)[a]	3.2
Trichlorofluoromethane	0.007	0.31	ND(0.002)[a]	0.90
1,1,2-Trichloro-1,2,2-trifluoroethane	0.09	ND(0.001)[a]	ND(0.005)[a]	0.23
trans-1,2-Dichloroethene	ND(0.005)[a]	ND(0.001)[a]	ND(0.005)[a]	0.17
1,1-Dichloroethene	ND(0.003)[a]	ND(0.005)[a]	ND(0.003)[a]	0.10
Chloroform	ND(0.003)[a]	ND(0.0006)[a]	ND(0.003)[a]	0.12
Benzene	1.2	0.35	ND(0.003)[a]	2.0
1,2-Dichloroethane	ND(0.003)[a]	ND(0.005)[a]	ND(0.003)[a]	0.09
Toluene	0.11	1.0	0.079	3.4
Chlorobenzene	ND(0.004)[a]	ND(0.008)[a]	ND(0.004)[a]	0.12
Ethylbenzene	ND(0.003)[a]	0.35	ND(0.004)[a]	2.1
Total Xylenes	1.1	0.61	0.065	7.8

[a]ND = Not Detected; Detection limit in ng/cm³ in parentheses.

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Timeframe of Corrective Actions for LFG Effects

In-Well Effects

- In-well LFG effects: When gas/water contact is limited to within the bore

Out-of-Well Effects

- Out-of-well LFG effects: When gas/water contact occurs outside (upgradient) of the bore

Timeframe of Corrective Actions for LFG Effects

In-Well Effects

- Can be due to well construction, stratigraphy -- Gas/water contact area (in well) known
- Corrective action can potentially be targeted to intercept transport pathway
- Due to limited gas/water contact area, MNA possible

Out-of-Well Effects

- A potentially dispersed and unknown gas/water contact area (possibly beneath waste)
- Enhanced landfill gas collection (source control) best approach

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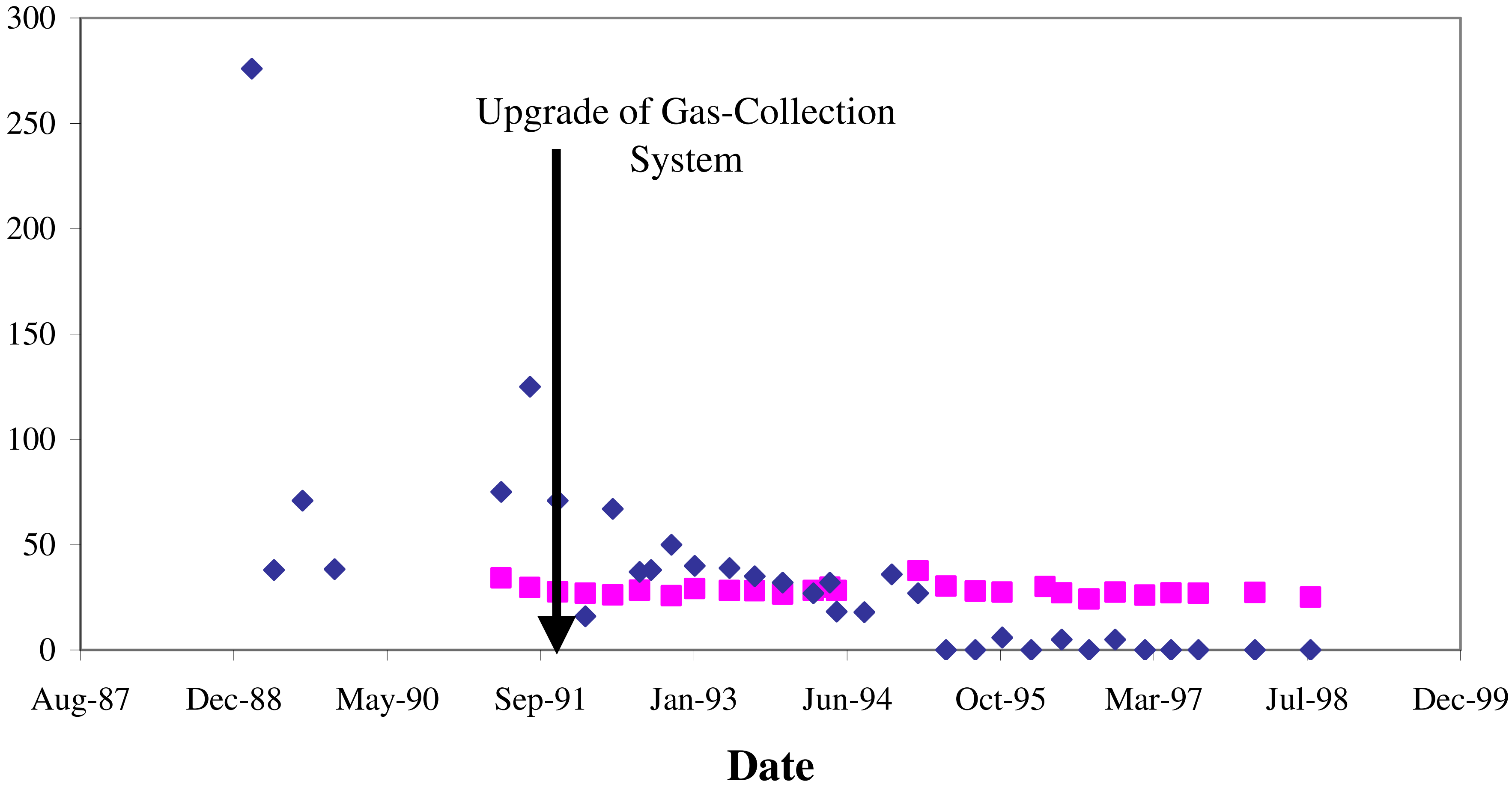
Time to Re-Establish Compliance Influenced by:

- GW Concentrations;
- GW Flow Velocity;
- Vadose Zone Properties;
- Residuals of LFG; and
- Others

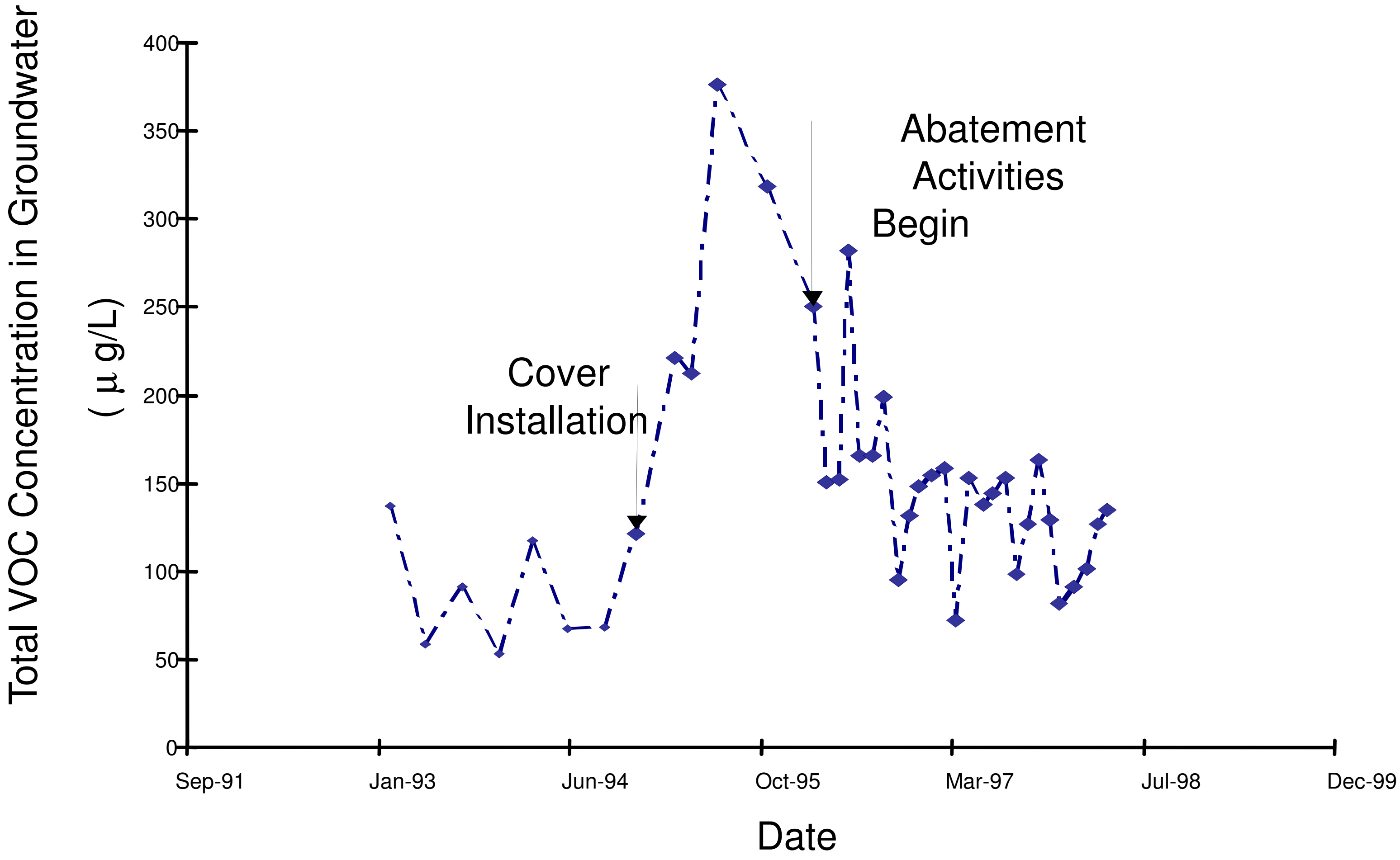
Out-of-Well Gas Effects



Out-of-Well Gas Effects

- Very Rapid GW Flow
- Deep Vadose Zone
- Highly Variable Concentrations During Time of LFG Effects
- Approximately 48 Months for Recovery to ND in one case

In-Well Gas Effects



Questions?

Thank you

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