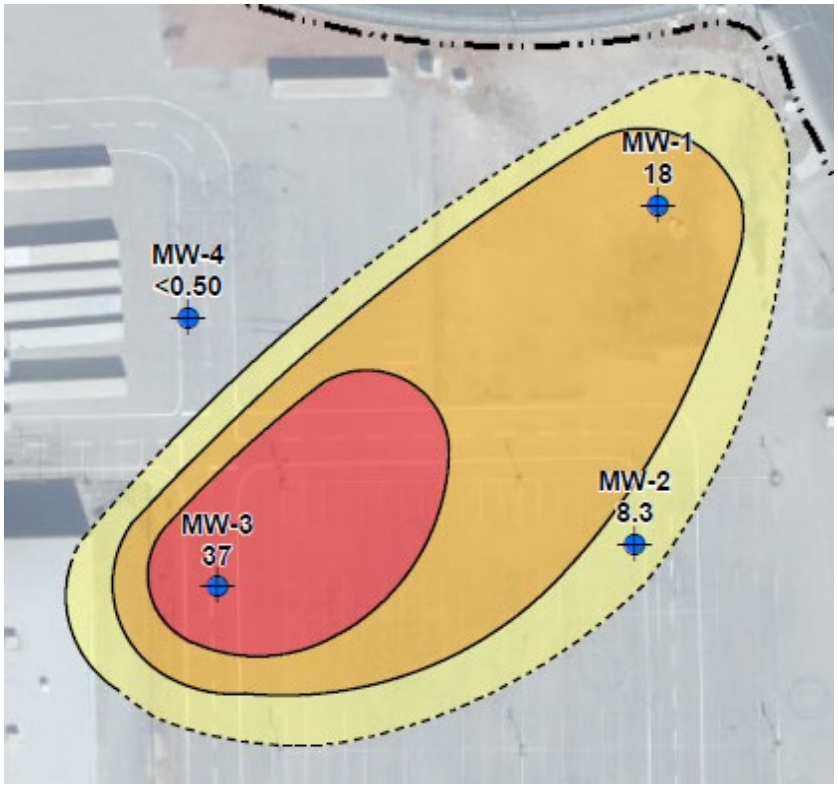

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION

Nevada Department of CONSERVATION & NATURAL RESOURCES

"Hydrogeology of Shallow Groundwater Contaminant Plumes in the Las Vegas Valley, NV and NDEP Cleanup Prioritization"

Ben Moan, P.E.

Supervisor, Nevada Division of Environmental Protection (NDEP) Bureau of Corrective Actions (BCA)

January 12, 2021

Association of Environmental and Engineering Geologists Southern Nevada Chapter
January 2021 Virtual Meeting

ndep.nv.gov

NDEP Organization

- 11 Bureaus
- Primary office – Carson City
- Satellite office – Las Vegas
- Contact Information:
  - ndep.nv.gov
  - Spill Hotline: 1-888-331-NDEP
  - Carson City:
    775-687-4670
    901 S. Stewart Street, Suite 4001, Carson City, NV 89701
  - Las Vegas:
    702-668-3900
    375 E. Warm Spring Road, Suite 200, Las Vegas, NV 89119

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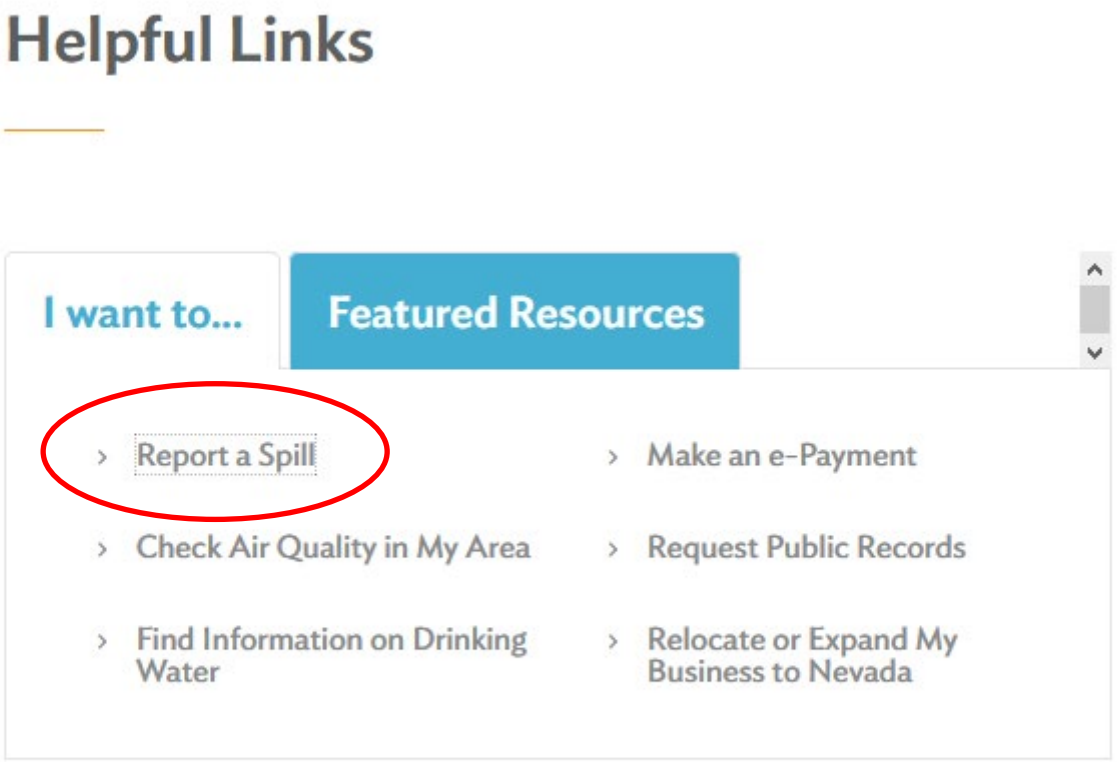
Reporting a Spill/Release

- Hazardous substances released to soil or groundwater must be reported to NDEP within 1 working day or as soon as practicable in accordance with Nevada Administrative Code (NAC) 445A.345 to 445A.348
- >25 gallons or >200 pounds
- >3 cubic yards of soil
- Any detection in groundwater in exceedance of reportable concentrations
- A confirmed release from an underground storage tank (UST)
  - Spill Hotline: 1-888-331-NDEP
  - ndep.nv.gov, use “I want to… Report a Spill”

Reporting a Spill/Release
ndep.nv.gov



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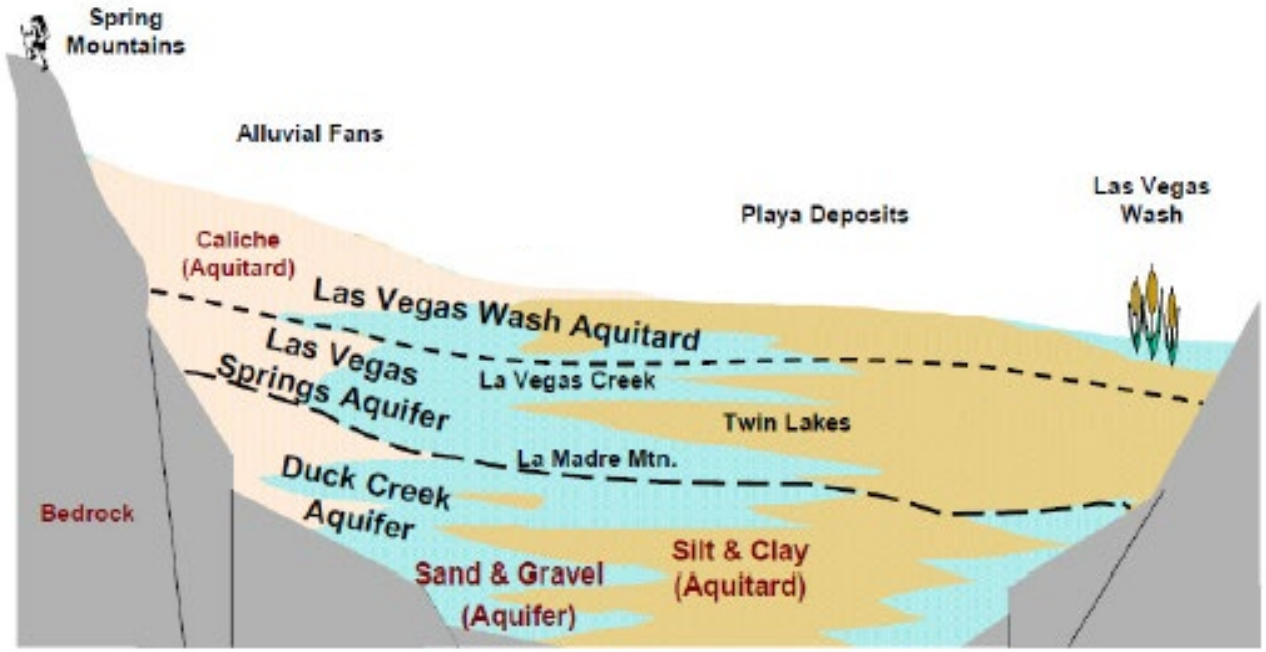
Regional Hydrogeology

- Spring Mountains are primary recharge area
- General groundwater flow is west to east, to Las Vegas Wash – Lake Mead
- Slight upward vertical gradient in most places
- Municipal wells screened ~300-1500 feet below ground surface (bgs)



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Regional Hydrogeology

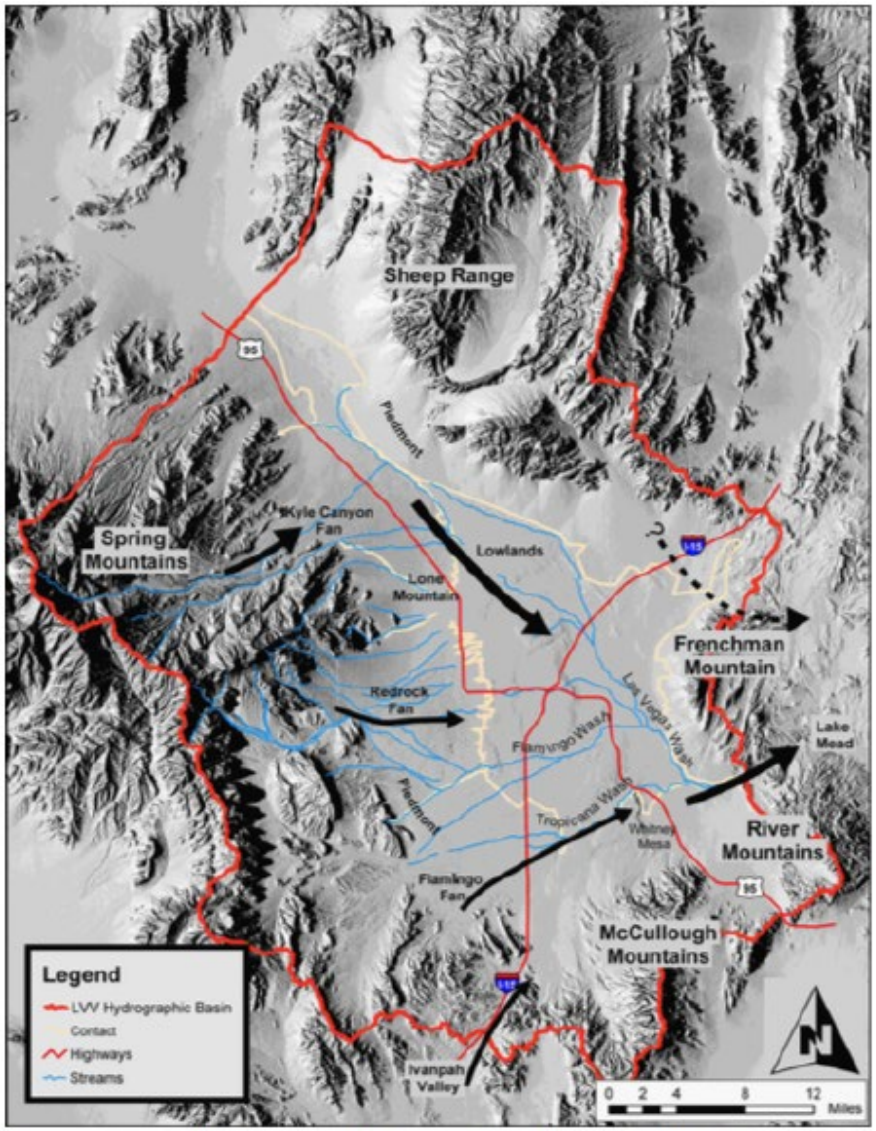


Figure 5. Las Vegas Valley Physiographic Features and Groundwater Flow Directions.

From Liesing, 2004

NDEP

Shallow Groundwater

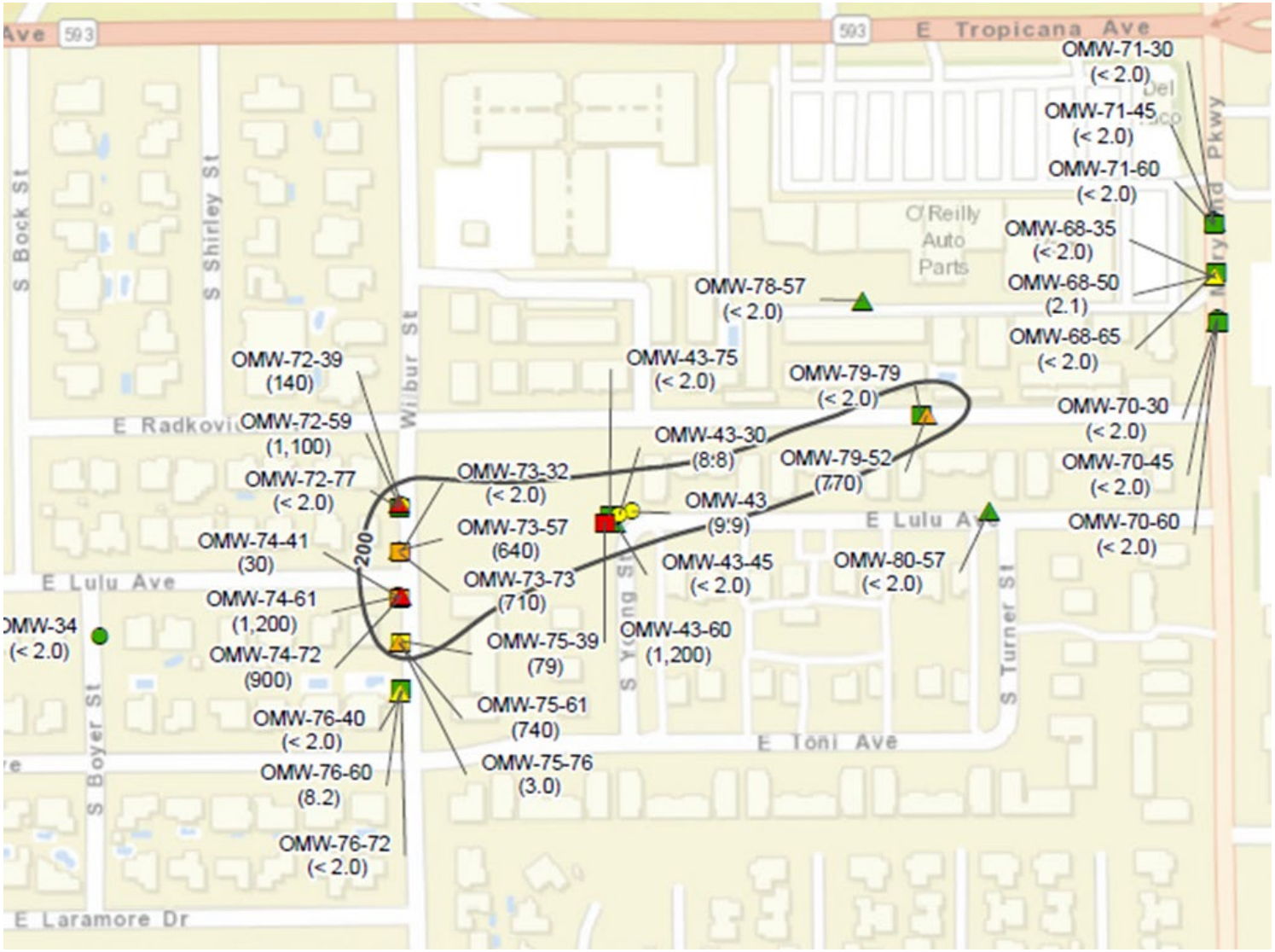
- Depth to water is ~10-30 feet bgs across most of the Las Vegas Valley
- Dominated by horizontal flow, generally to the east/northeast
- Some groundwater may be perched
- Low quality, high dissolved solids due to landscape irrigation
- Some grandfathered domestic wells exist, usually screened at various intervals between 50 and 300 feet bgs

Primary Constituents of Concern

- Petroleum spills
  - Mobile
  - Leaking UST
    - Light non-aqueous phase liquid (LNAPL)
    - Benzene, toluene, ethylbenzene, xylenes (BTEX), primarily benzene
    - Methyl tertiary butyl ether (MTBE)
- Dry cleaning operations
  - Tetrachloroethene (PCE)
  - Daughter products such as trichloroethene (TCE)

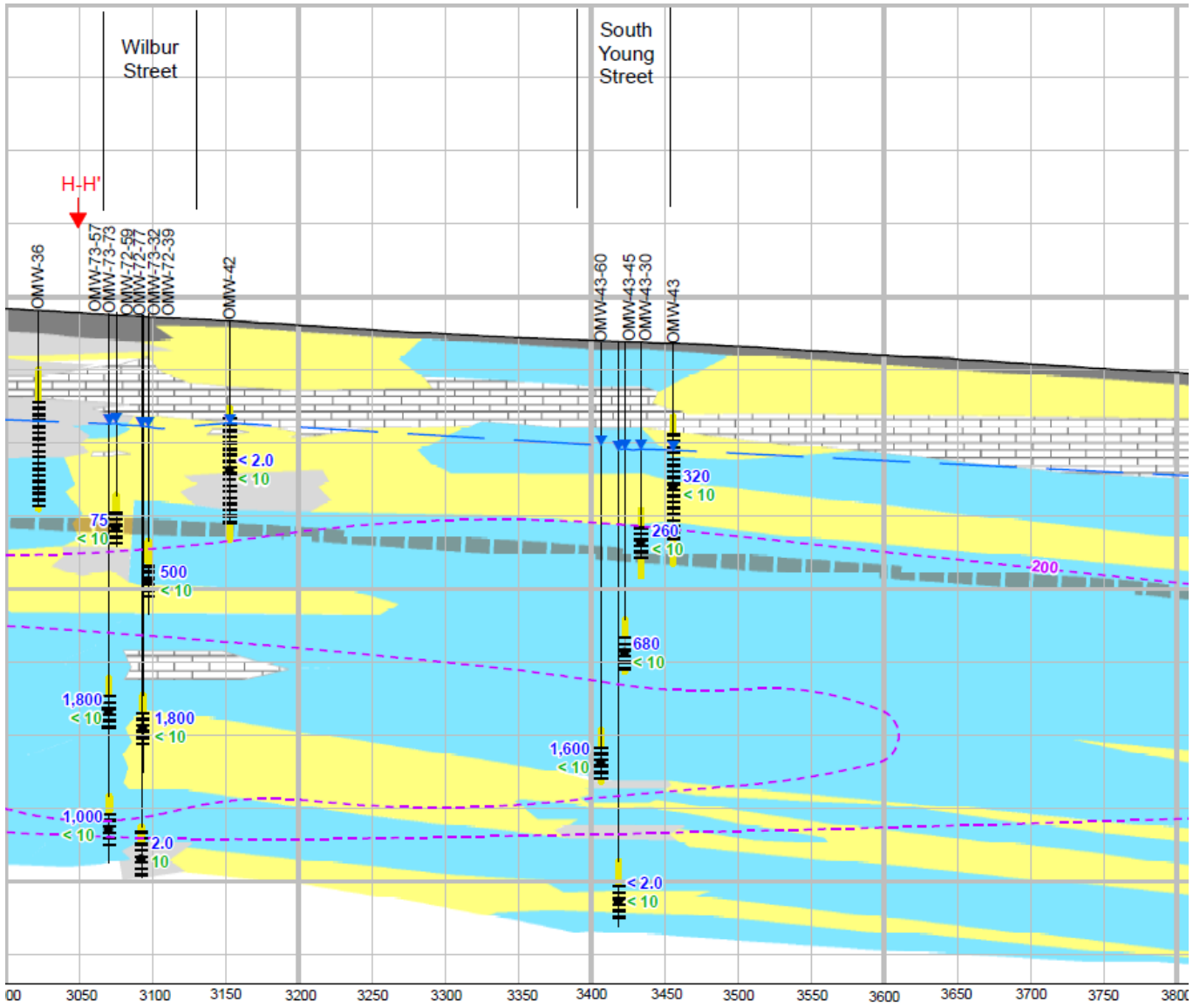
Plume Characterization

Delineation - Horizontal



Plume Characterization

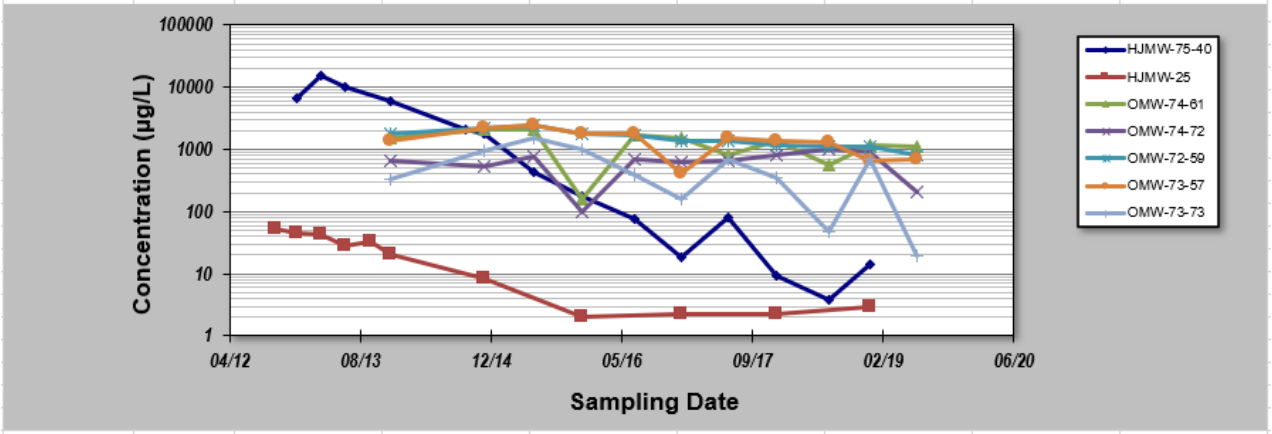
Delineation - Vertical



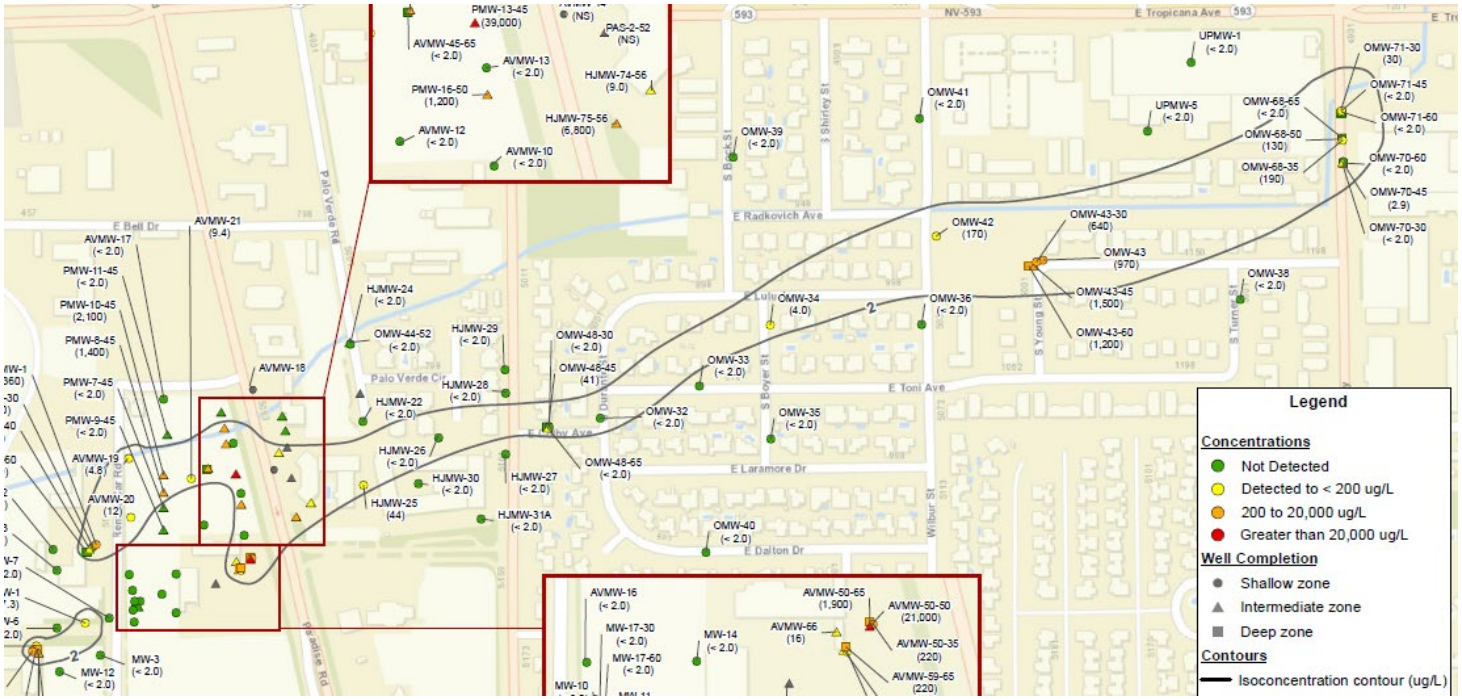
Plume Characterization

Contaminant Concentration Trends

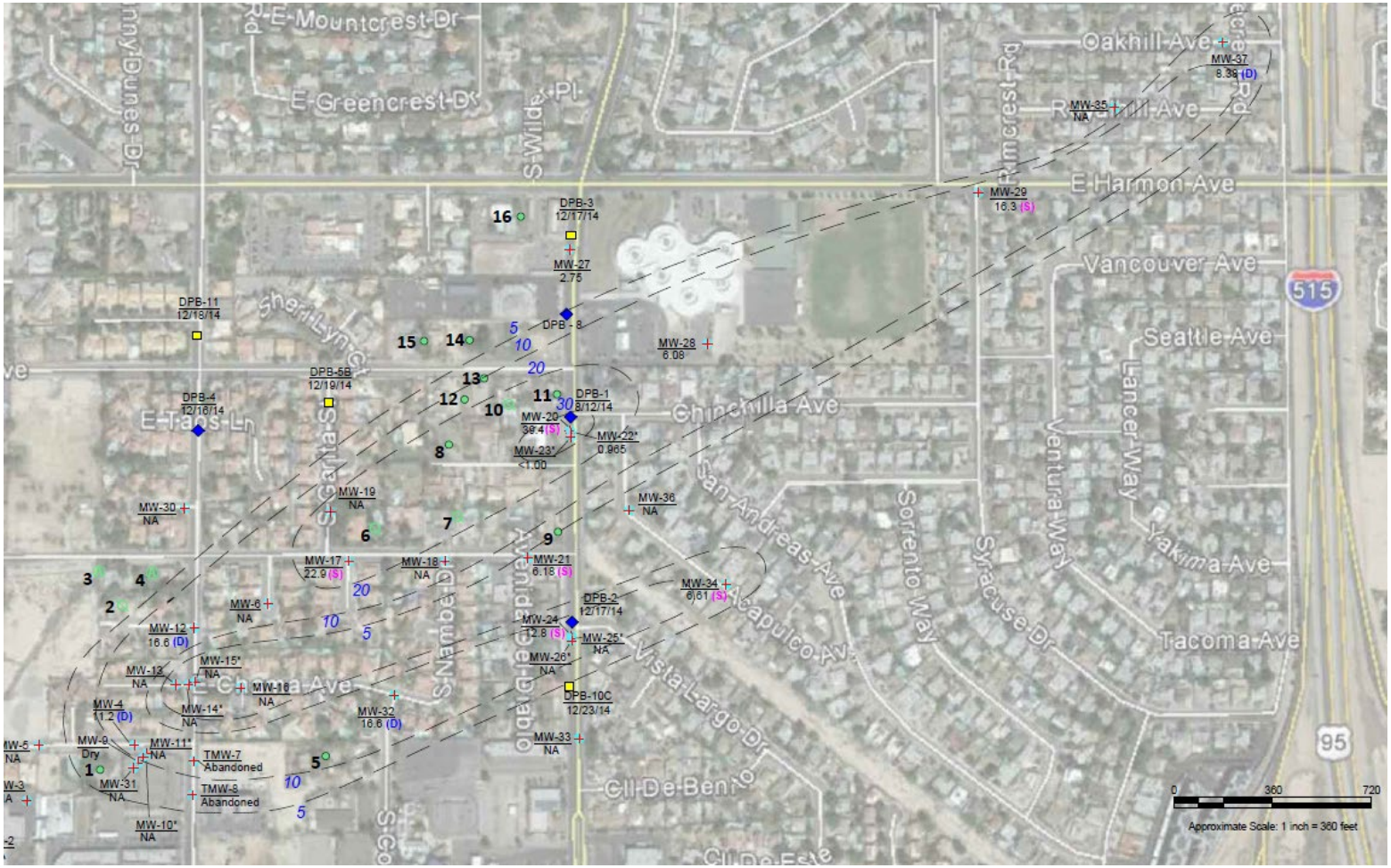
Sampling Point ID:		HJMW-75-40	HJMW-25	OMW-74-61	OMW-74-72	OMW-72-59	OMW-73-57	OMW-73-73
Sampling Event	Sampling Date	MTBE CONCENTRATION (µg/L)						
1	24-Sep-12		53					
2	12-Dec-12	6800	44					
3	14-Mar-13	15000	42					
4	18-Jun-13	10000	28					
5	23-Sep-13		33					
6	9-Dec-13	6000	21	1500	660	1800	1400	330
7	18-Sep-14	2100						
8	2-Dec-14	1800	8.6	2100	540	2200	2200	950
9	25-Mar-15							
10	9-Jun-15	430		2100	780	2500	2400	1500
11	23-Sep-15							
12	10-Dec-15	180	2	160	100	1800	1800	1000
13	29-Mar-16							
14	28-Jun-16	78		1700	680	1700	1800	390
15	22-Sep-16							
16	21-Dec-16	18	2.2	1500	620	1400	410	160
17	15-Mar-17							
18	23-Jun-17	79		810	640	1400	1500	690
19	22-Sep-17							
20	20-Dec-17	9.3	2.3	1400	830	1200	1400	350
21	10-Jul-18	3.8		560	1000	1100	1300	47
22	15-Dec-18	14	3	1200	900	1100	640	710
23	15-Jun-19			1100	210	790	700	19
24								
25								
Coefficient of Variation:		1.54	0.89	0.47	0.43	0.33	0.45	0.82
Mann-Kendall Statistic (S):		-79	-41	-23	13	-46	-29	-21
Confidence Factor:		>99.9%	100.0%	95.7%	82.1%	>99.9%	98.7%	94.0%
Concentration Trend:		Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	Prob. Decreasing



Plume Shape - MTBE



Plume Shape - PCE



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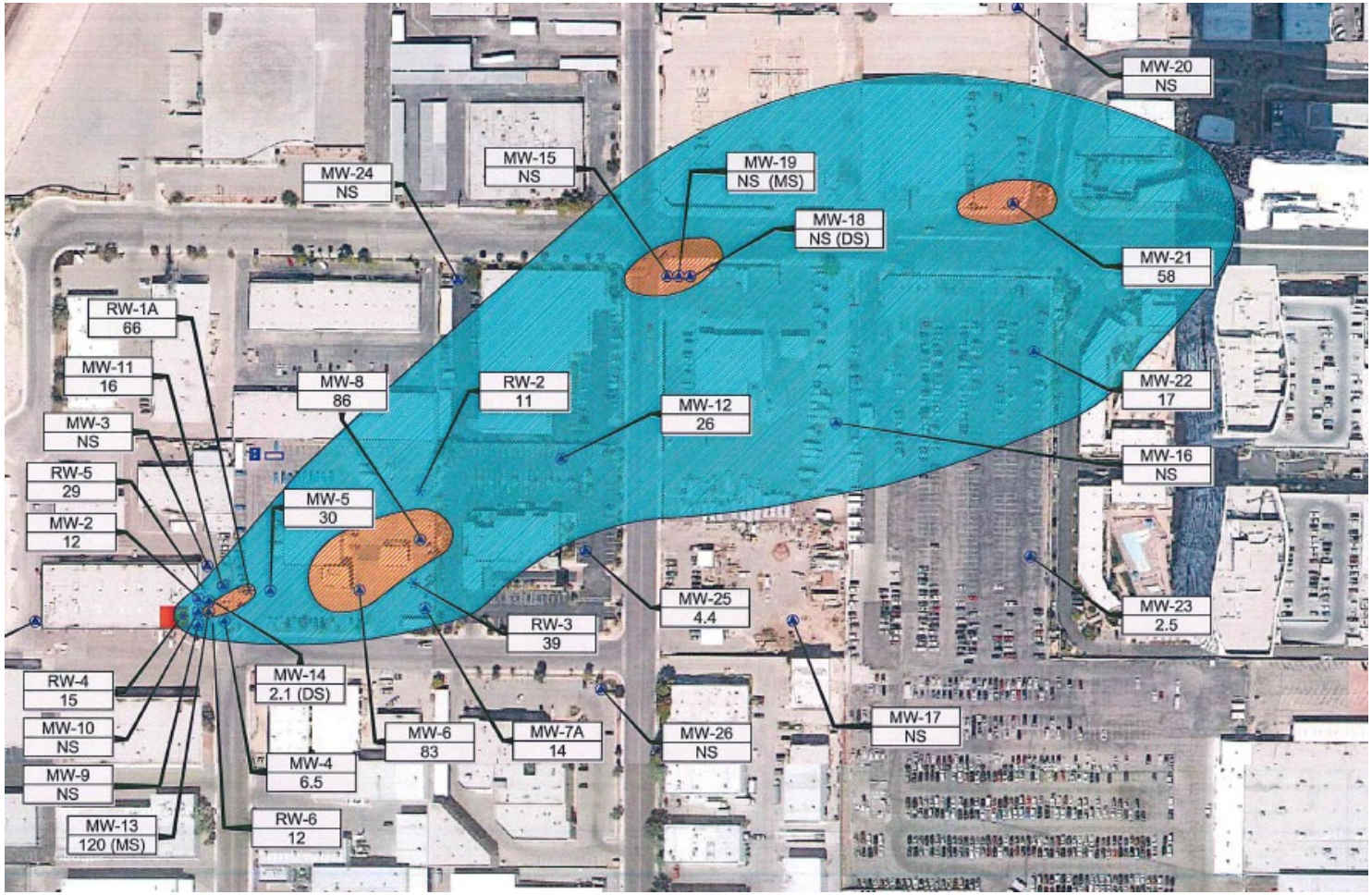
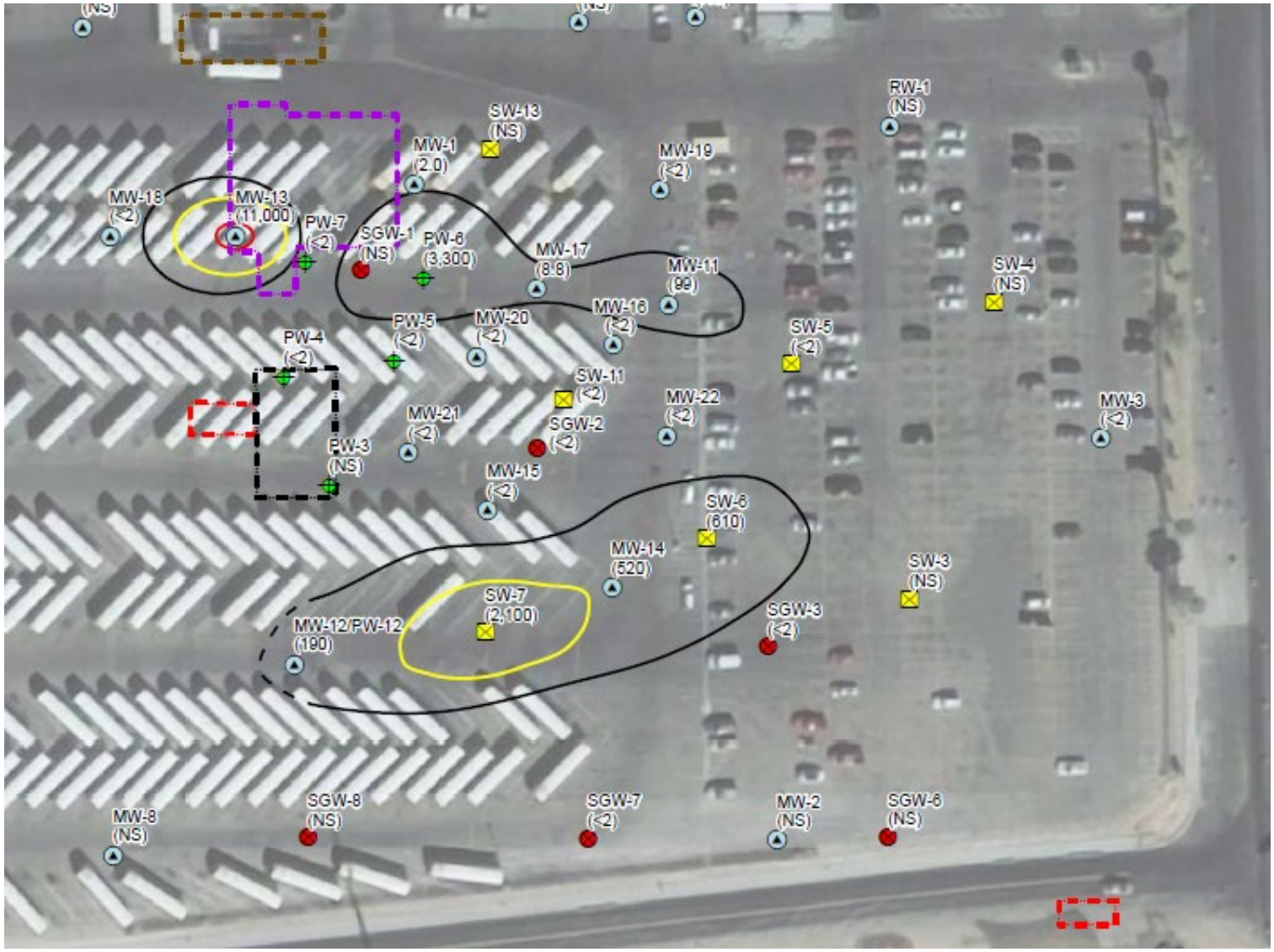
Plume Shape - PCE



Plume Shape - Benzene



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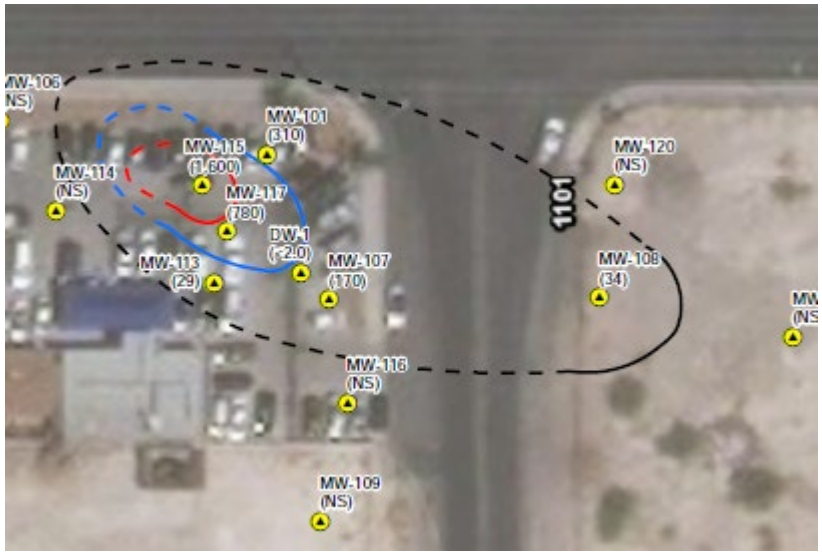
Plume Shape – Benzene and MTBE



Groundwater Contamination – Fate & Transport

- Benzene and MTBE:
  - Aerobic biodegradation
  - Anaerobic biodegradation

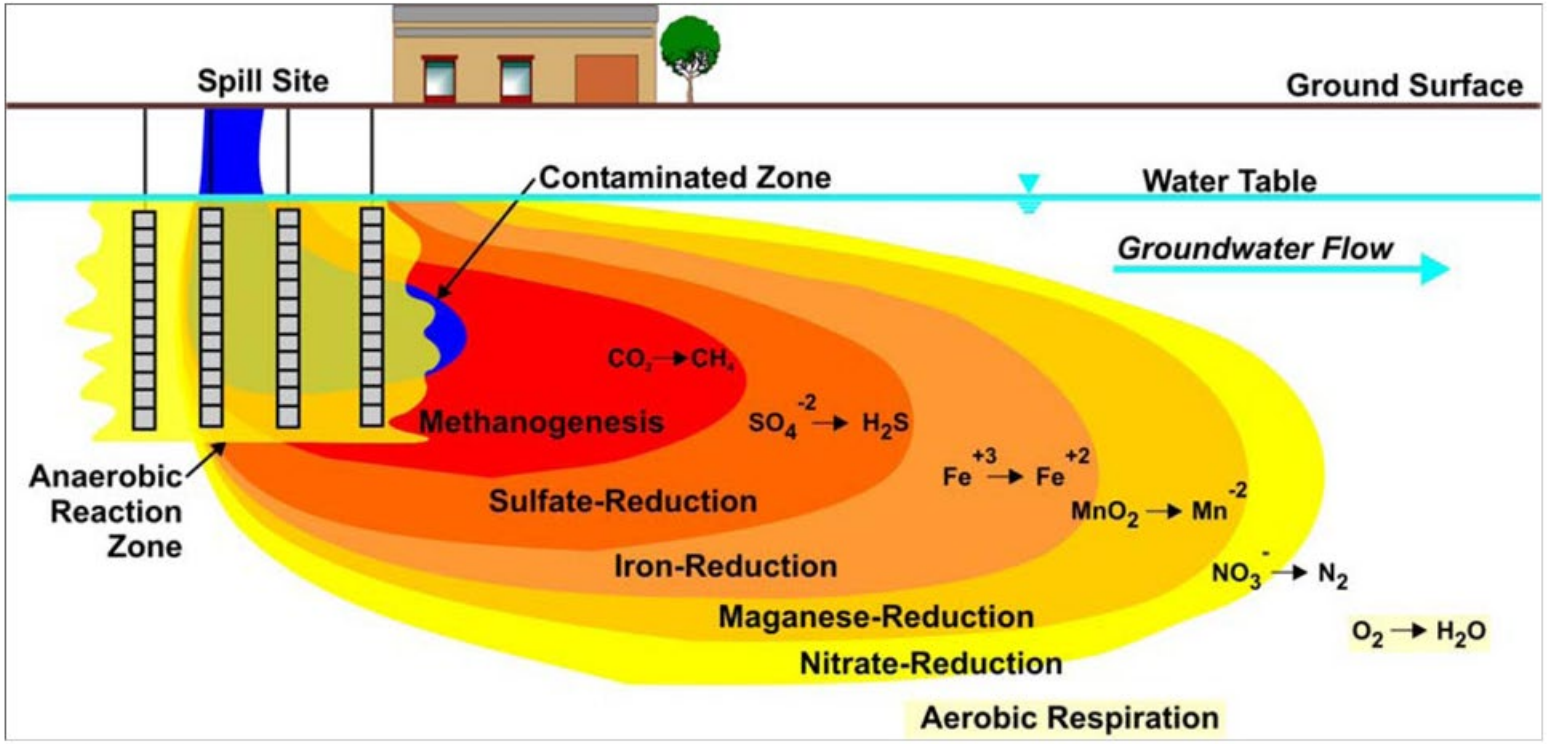


Figure 2. Anaerobic microbes use electron acceptors in preferential order: nitrate, manganese, ferric iron oxyhydroxides, sulfate, and carbon dioxide (Source: Parsons 2004).

Groundwater Contamination – Fate & Transport

- PCE and other chlorinated solvents – biodegradation is very slow in most cases
- Biodegradation is sometimes faster where a chlorinated solvent plume migrates into petroleum hydrocarbon contamination

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Groundwater Contamination – Fate & Transport

- Contaminants migrate in the direction of groundwater flow
- MTBE and PCE travel just slightly slower than groundwater and can make very long plumes, 1000s of feet to >1 mile
- Benzene travels considerably slower and plumes are usually <300 feet in length and very rarely are >600 feet in length
- Biodegradation is very slow
  - For benzene, a half-life of 2-4 years is fast
  - For MTBE, PCE, and benzene under most conditions, a half-life of 5-10 years is common
- Very little natural organic matter
- Other limiting factors could include low O_2, low nutrients, lower temperatures in winter
- Other processes can lead to concentration declines once the source is removed: dispersion, dilution, absorption, adsorption, volatilization

Risk Assessment

- Determined by exposure pathway:
  - Dermal
  - Ingestion
  - Inhalation
- Plumes that have the potential to migrate to drinking water wells and/or plumes that present a vapor intrusion issue are the highest priority for cleanup

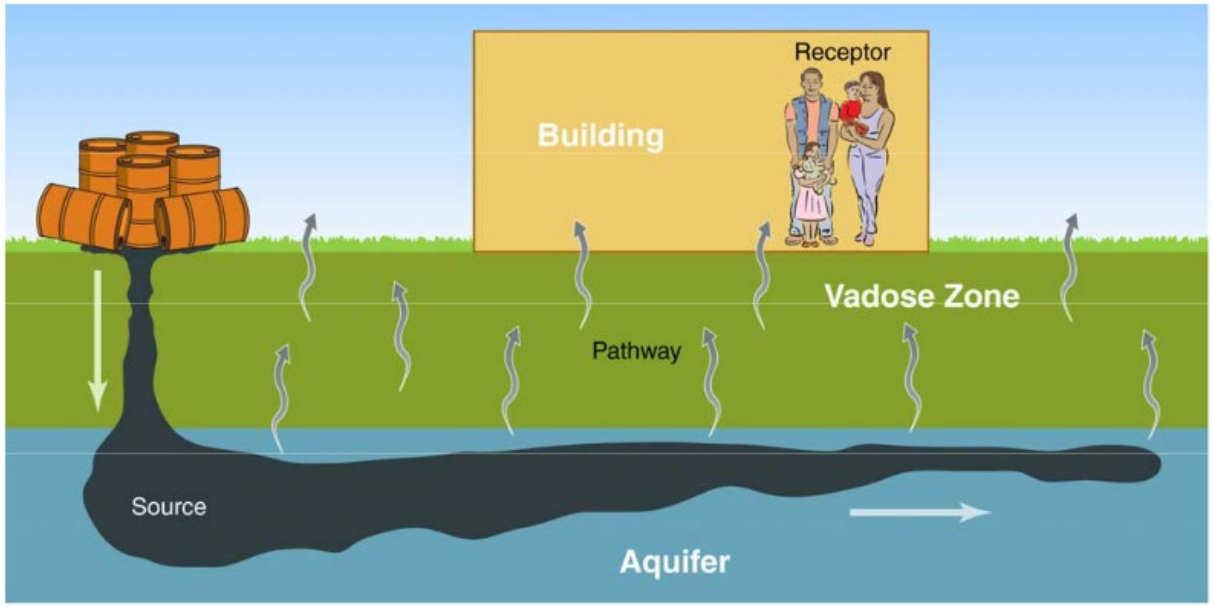

Figure 1-2 Potential source, migration route, and receptor for vapor intrusion.

Risk Assessment – Vapor Intrusion

- Indoor air can be sampled and contaminant concentrations measured directly
- Potential concentrations can be modelled – Johnson and Ettinger

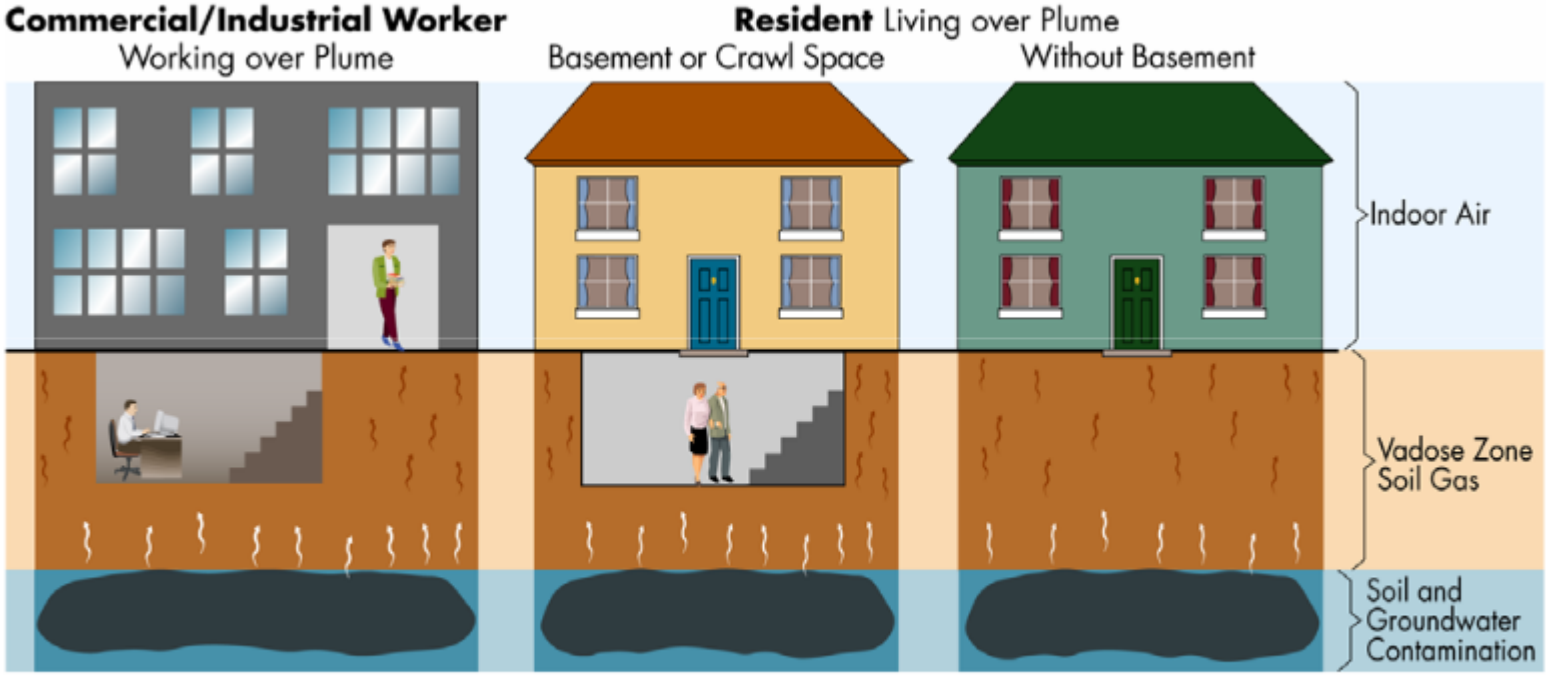

Figure 1-1. Typical conceptual model of vapor intrusion.

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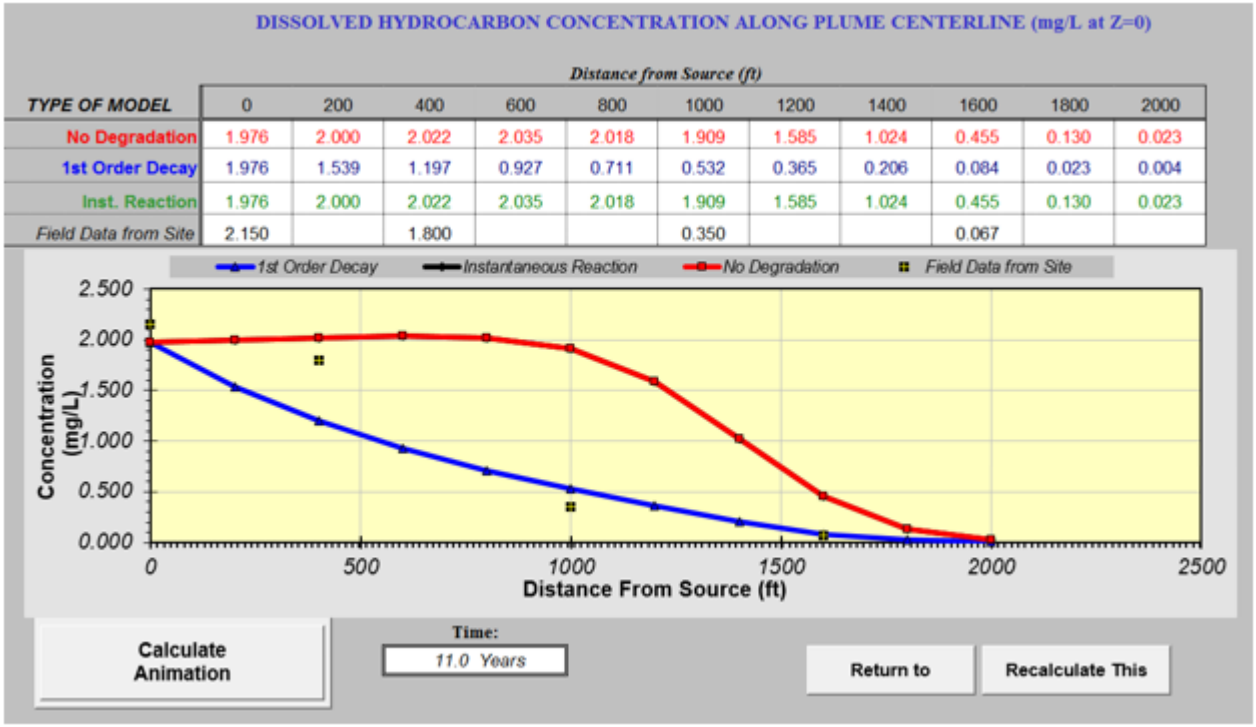
Groundwater Remediation

- Soil vapor extraction (SVE) – with or without air sparging (AS)
- Pump and treat
- In situ oxidation
- In situ reduction
- Natural Attenuation*



TYPE OF MODEL	0	200	400	600	800	1000	1200	1400	1600	1800	2000
No Degradation	1.976	2.000	2.022	2.035	2.018	1.909	1.585	1.024	0.455	0.130	0.023
1st Order Decay	1.976	1.539	1.197	0.927	0.711	0.532	0.365	0.206	0.084	0.023	0.004
Inst. Reaction	1.976	2.000	2.022	2.035	2.018	1.909	1.585	1.024	0.455	0.130	0.023
Field Data from Site	2.150		1.800			0.350			0.067		

* Natural Attenuation is not an active remediation technology, but modeling can help determine potential plume length

Case Study – McCarran Airport Car Rental Facilities

- Multiple car rental facilities had UST leaks discovered in the 90s
- The largest releases were from Avis and Allstate/Payless
- LNAPL did not leave the sites
- Benzene migrated about 1,000 feet
- MTBE migrated at least 4,500 feet
- Remediation included soil excavation, AS/SVE, hydrogen peroxide injections, and PulseOx™ which is hydrogen peroxide and ozone injected together: ~$10 M

Case Study – McCarran Airport Car Rental Facilities

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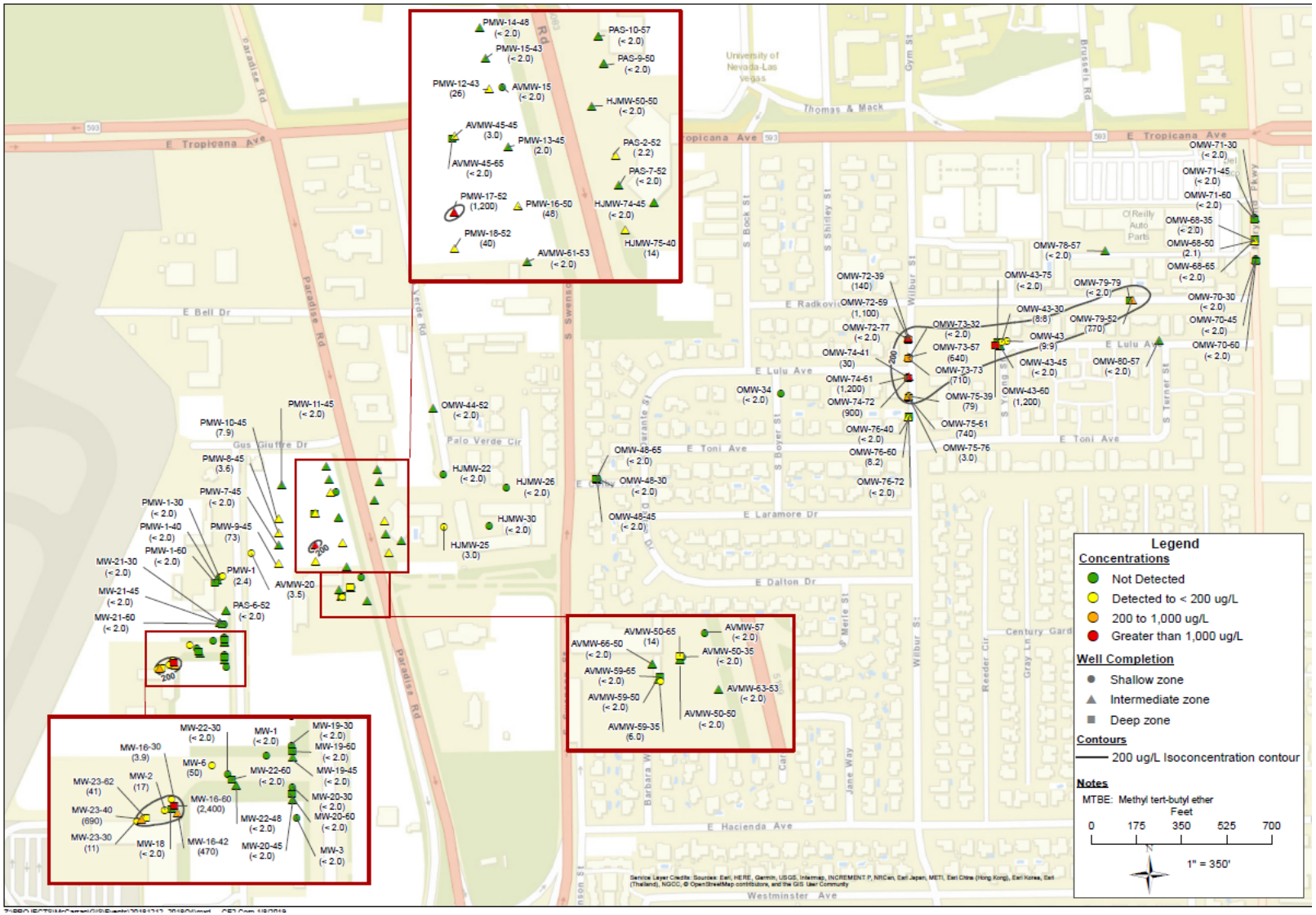
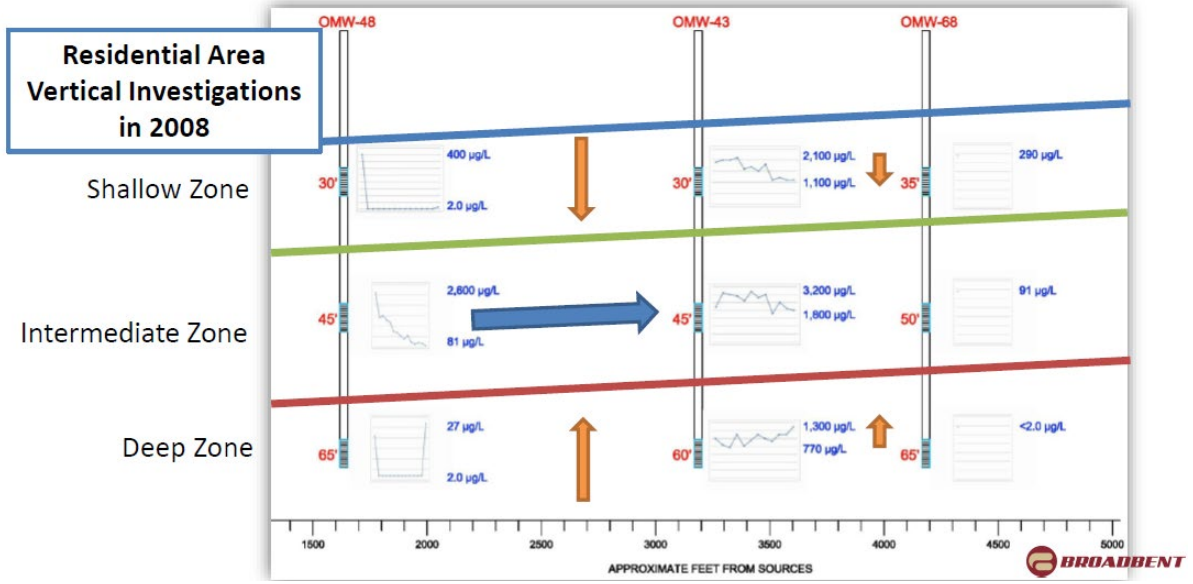
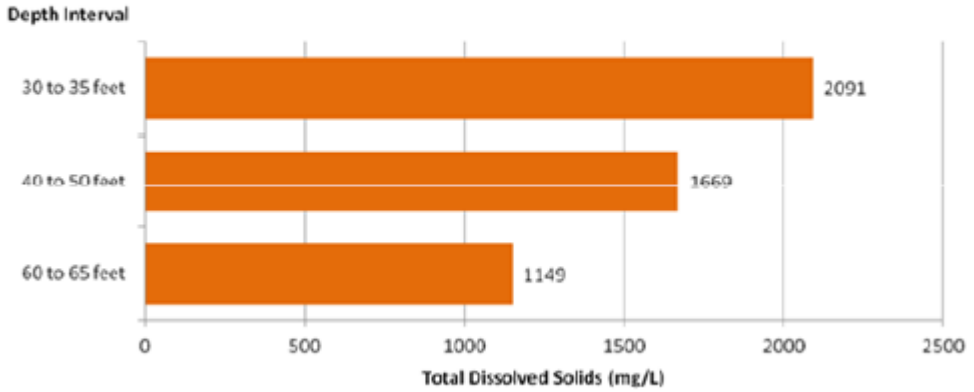


Case Study – McCarran Airport Car Rental Facilities

McCarran Rental Car Facilities History



Average TDS vs Depth



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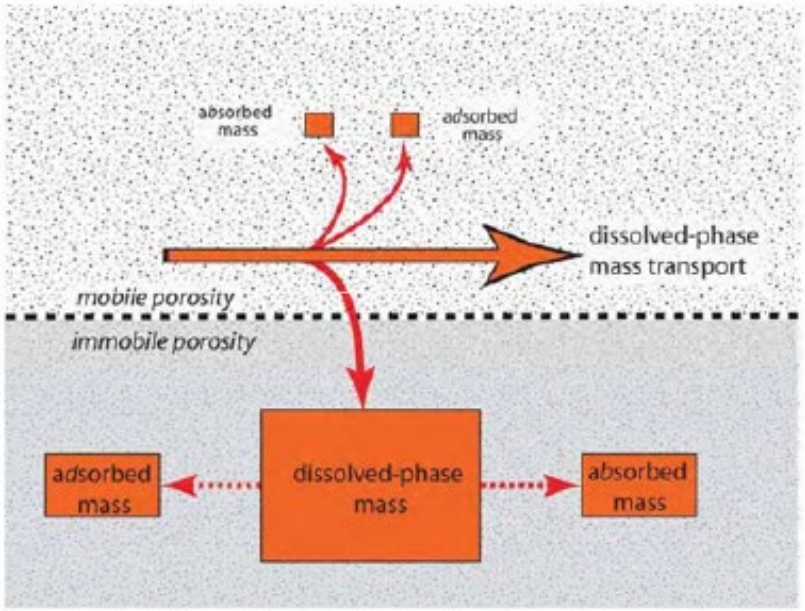
- Down gradient from the source area, hydraulic conductivity is significantly higher in the shallowest screened wells
- Lower hydraulic conductivity with depth

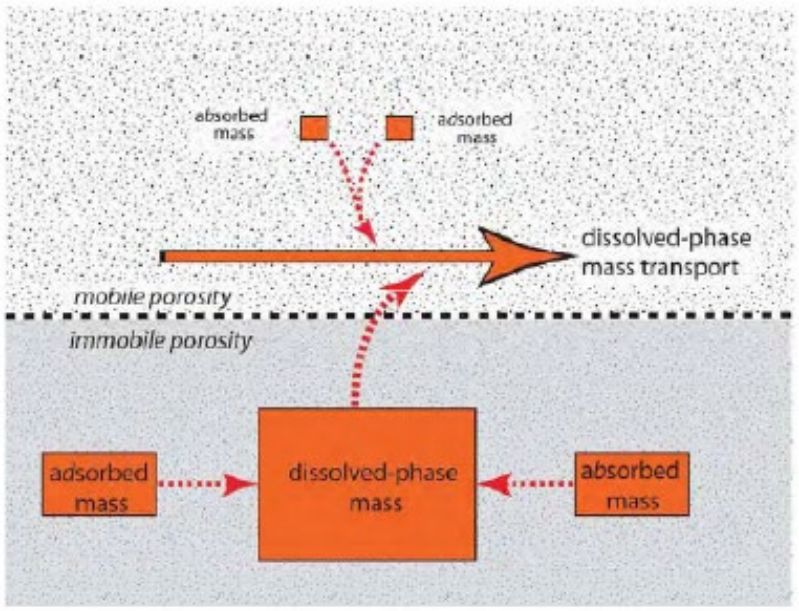
Well	Screened Interval (ft bgs)	Test Phase	Hydraulic conductivity (cm/sec)	Hydraulic conductivity (ft/d)	Comments
PMW-1a	55-60	Slug in	1.11E-04	0.31	Excellent curve match
PMW-1a	55-60	Slug out	9.51E-05	0.27	Excellent curve match
PMW-1b	45-50	Slug in	2.54E-04	0.72	Excellent curve match
PMW-1b	45-50	Slug out	2.61E-04	0.74	Excellent curve match
PMW-1c	25-30	Slug in	2.34E-04	0.66	Fair curve match
PMW-1c	25-30	Slug out	2.00E-04	0.57	Good curve match
OMW-43a	55-60	Slug in	9.58E-04	2.71	Excellent curve match
OMW-43a	55-60	Slug out	1.02E-03	2.90	Excellent curve match
OMW-43b	45-50	Slug in	2.93E-03	8.30	Excellent curve match
OMW-43b	45-50	Slug out	2.76E-03	7.83	Excellent curve match
OMW-43c	25-30	Slug in	No solution	No solution	Poor curve match[1]
OMW-43c	25-30	Slug out	1.33E-02	37.78	Poor curve match[1]

Notes:
(1) The water level recovery rate for well OMW-43A was too rapid to allow sufficient data to be collected for a reliable estimate of hydraulic conductivity. Data indicate a very high conductivity.

Case Study – McCarran Airport Car Rental Facilities

- Flow is dominated by coarser paleochannels
- Contamination diffuses from higher concentration water into adjacent clay layers as the plume first migrates
- Cleaner groundwater later advances through the coarse layers and contamination back diffuses out of the clays based on concentration gradient





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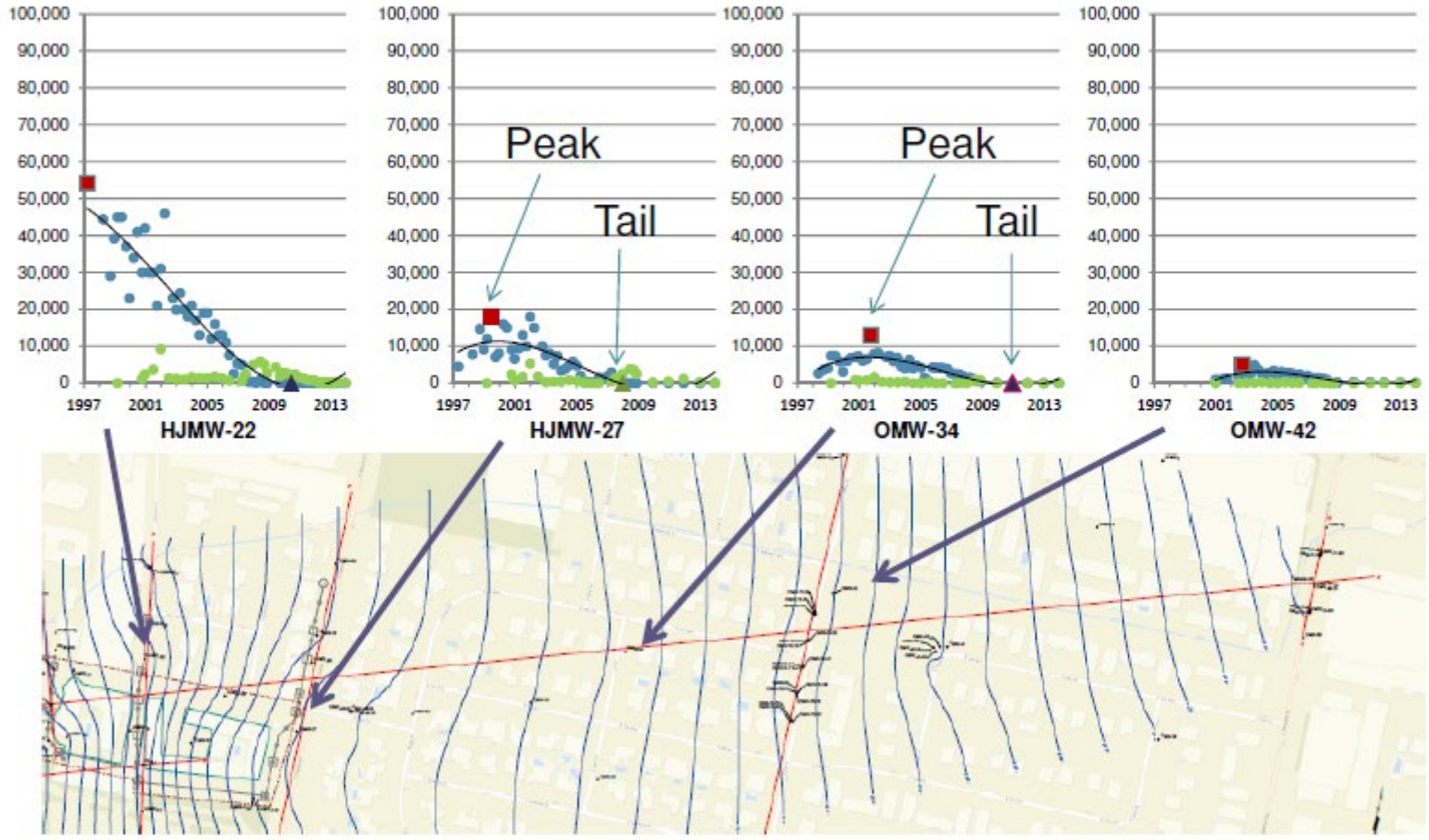
Upper HSU: Palo Verde to Wilbur



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Upper HSU: MTBE Arrival Times and Concentration-Distance Curve

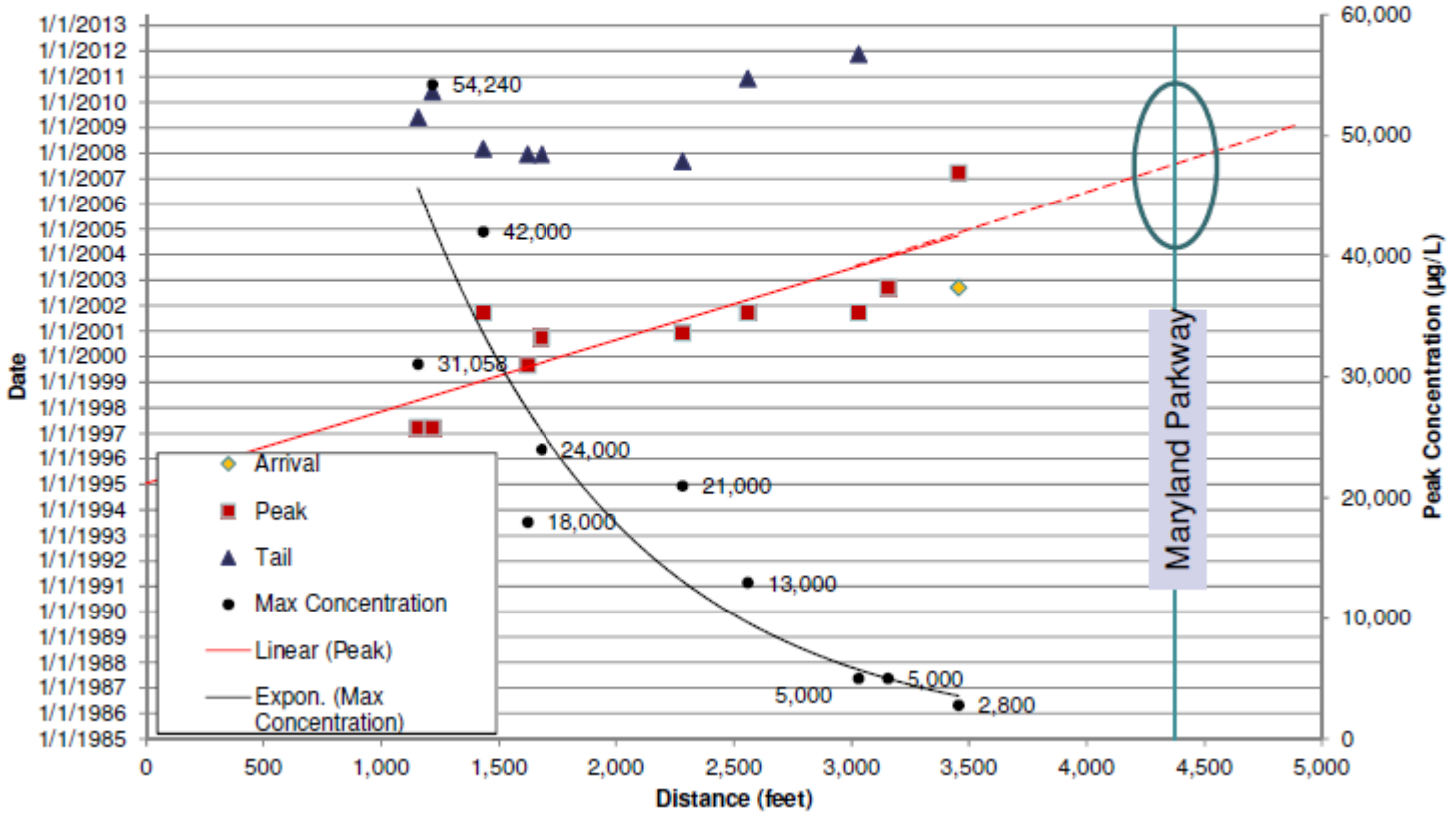

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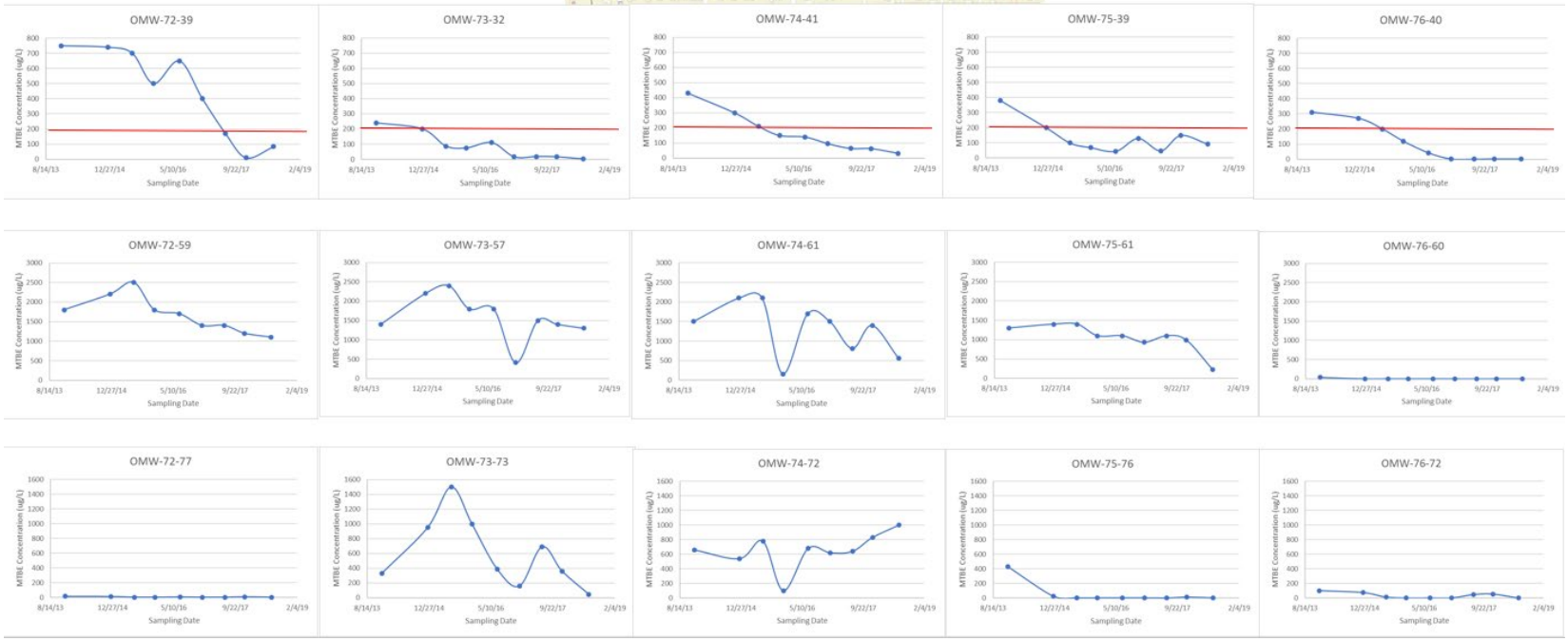
Figure 5: MTBE concentration vs time for monitoring well clusters along the Wilbur transect, near the trailing edge of the current Off-site Plume. Map modified from 2017 4th Quarter MTBE map by CE2 Corporation. The top row graphs are for shallow wells, the middle row graphs are for intermediate wells and the bottom row graphs are for deeper wells. NDEP 2/20/19.



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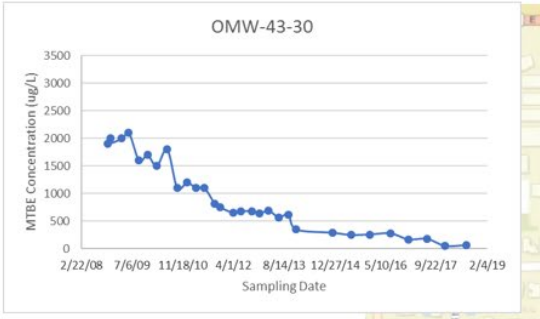

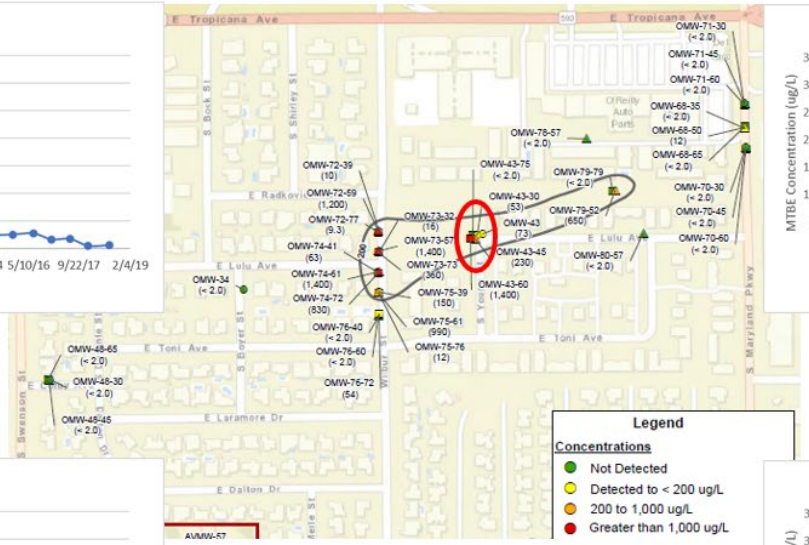

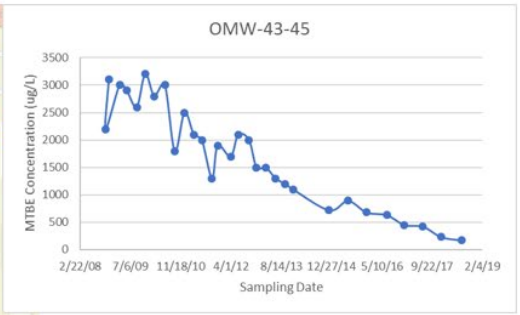

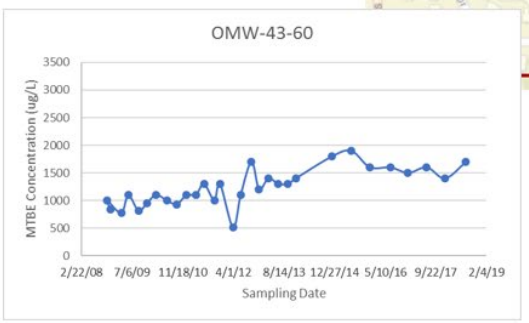

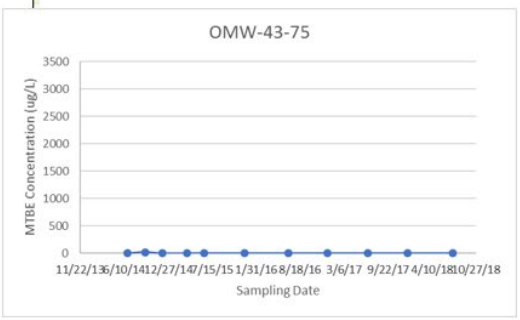

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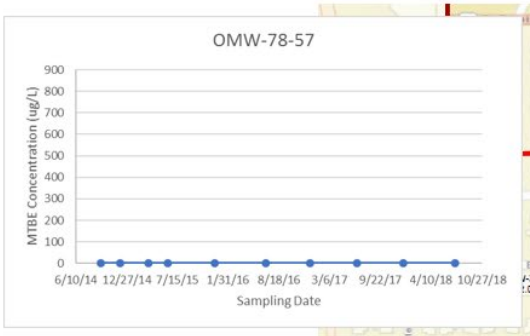

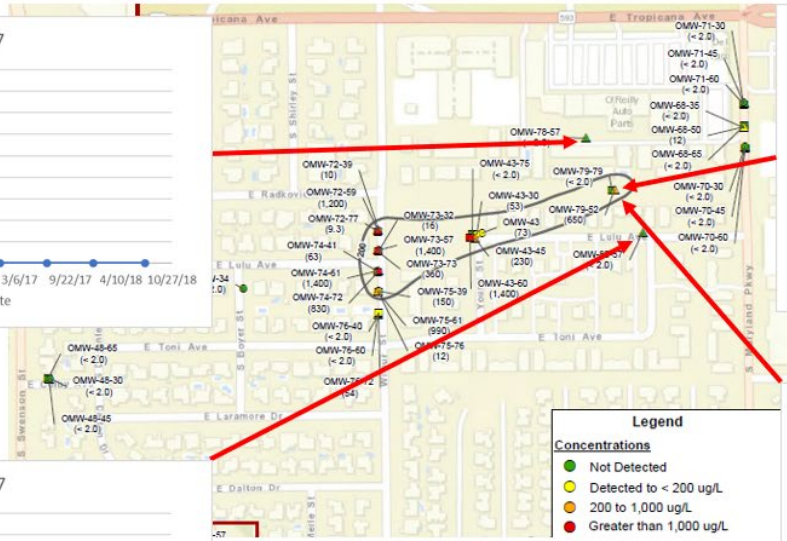

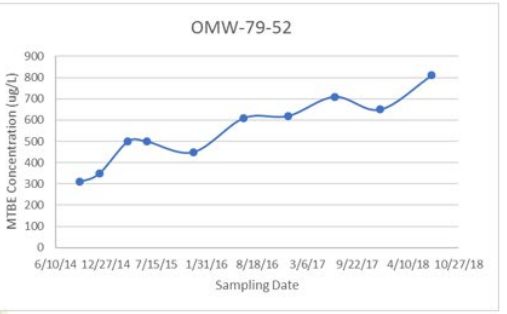

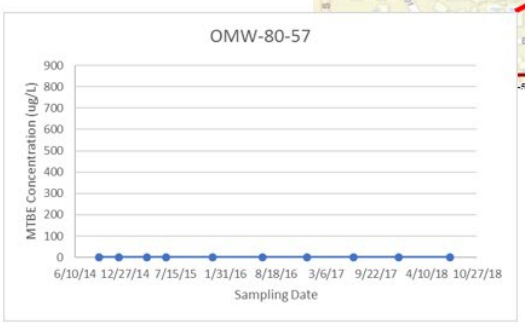

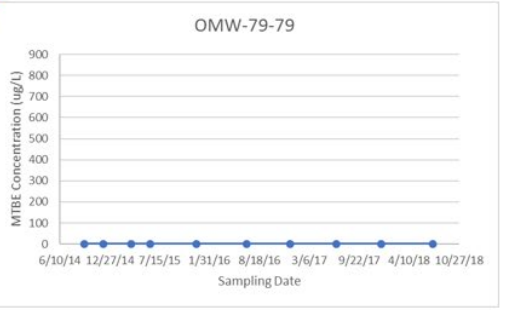

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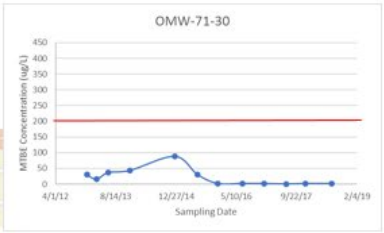

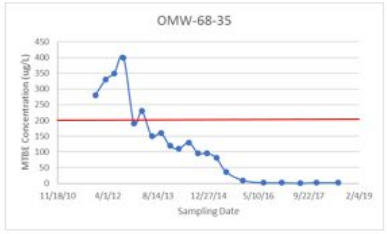

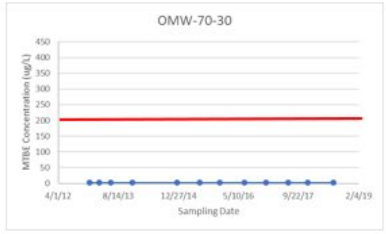

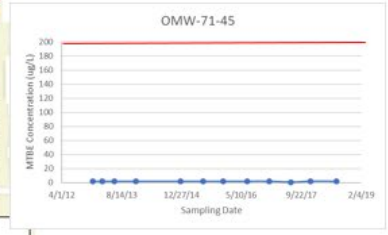

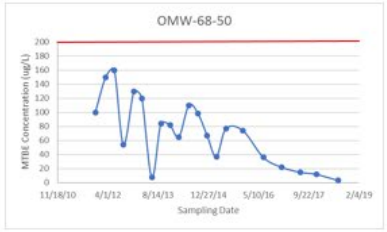

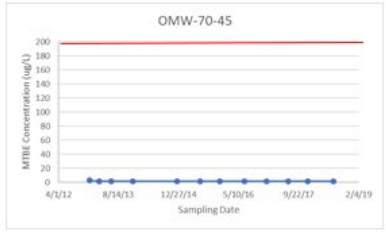

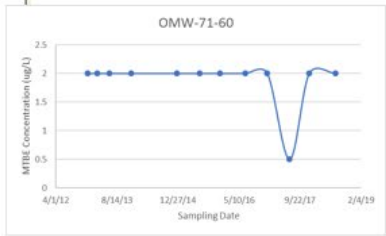

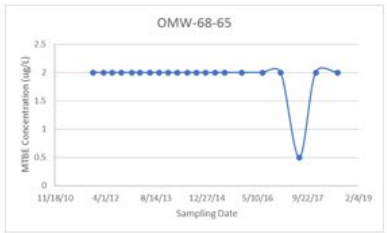

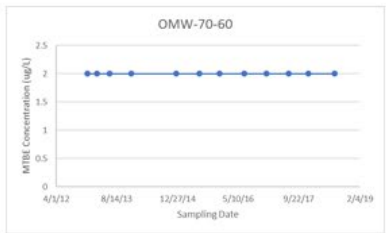

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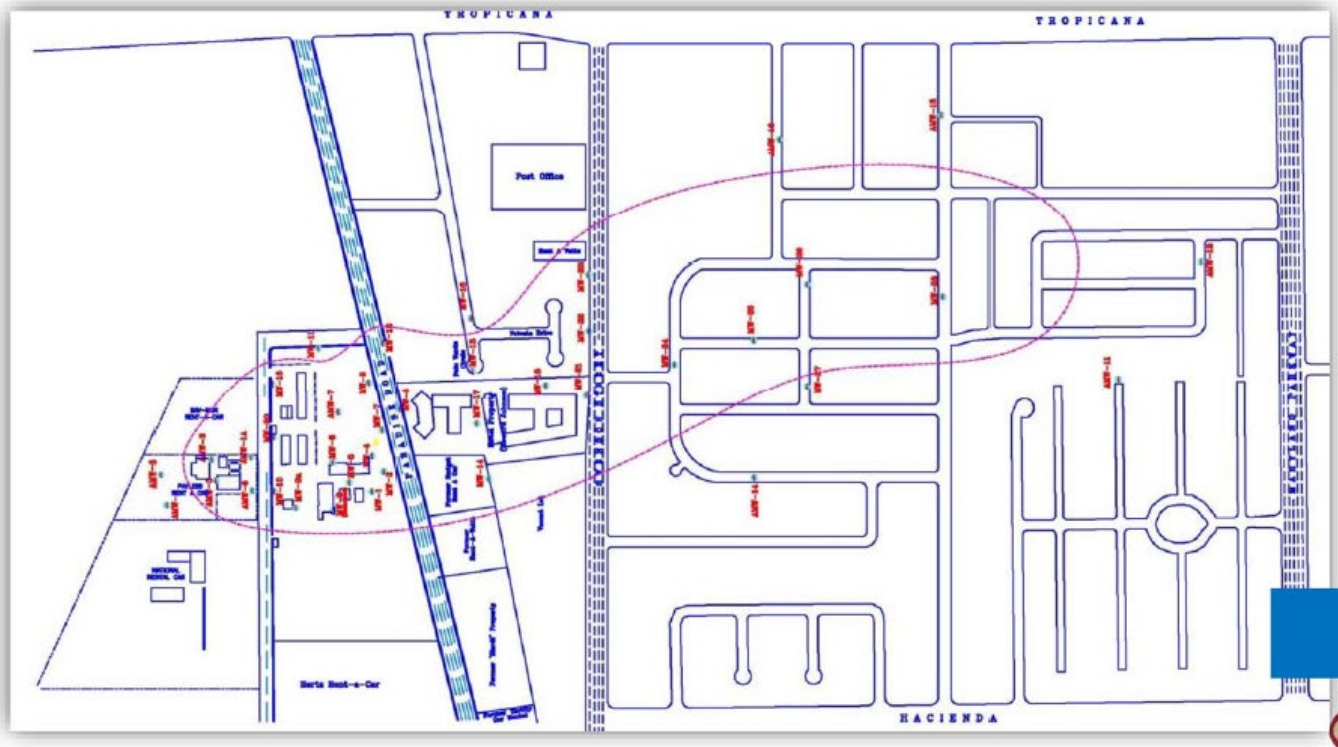
- **Shallow Commingled MTBE Plume Historically ~5,000 feet**



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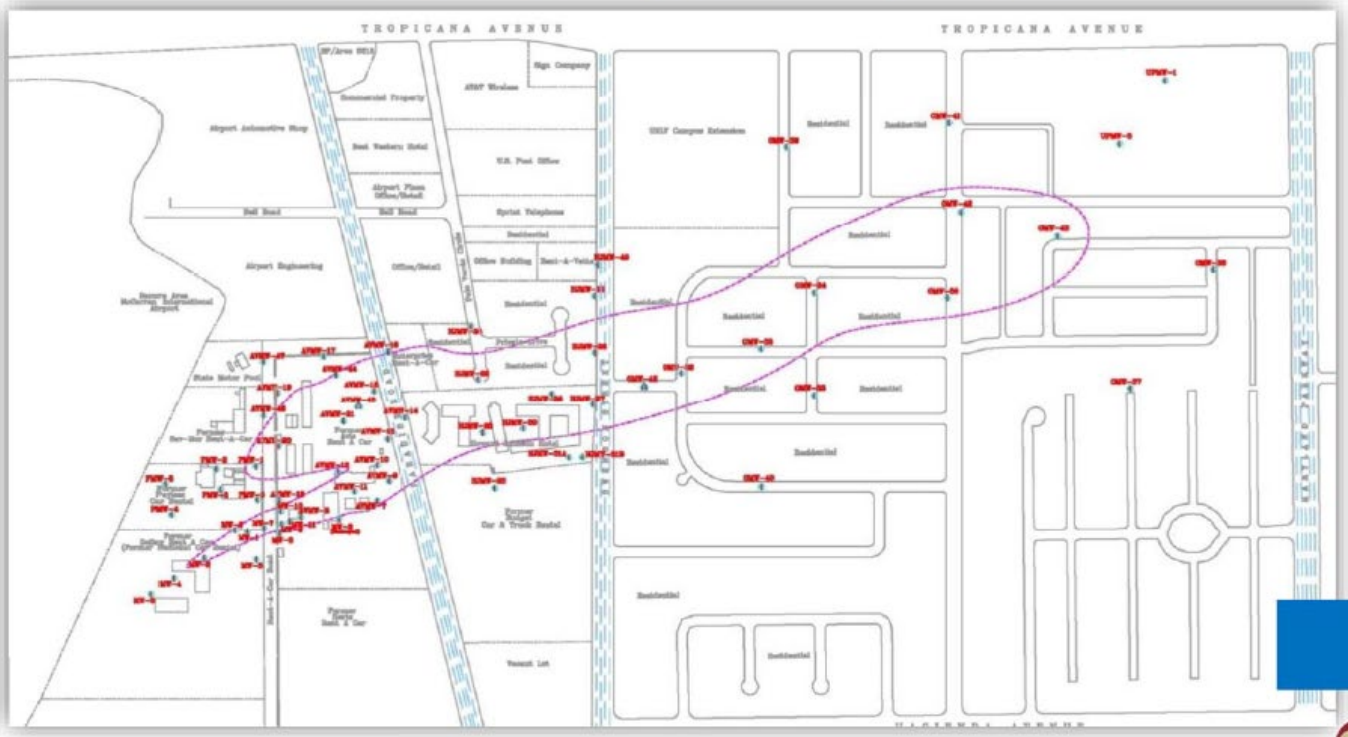
- **Shallow Commingled MTBE Plume Historically ~5,000 feet**



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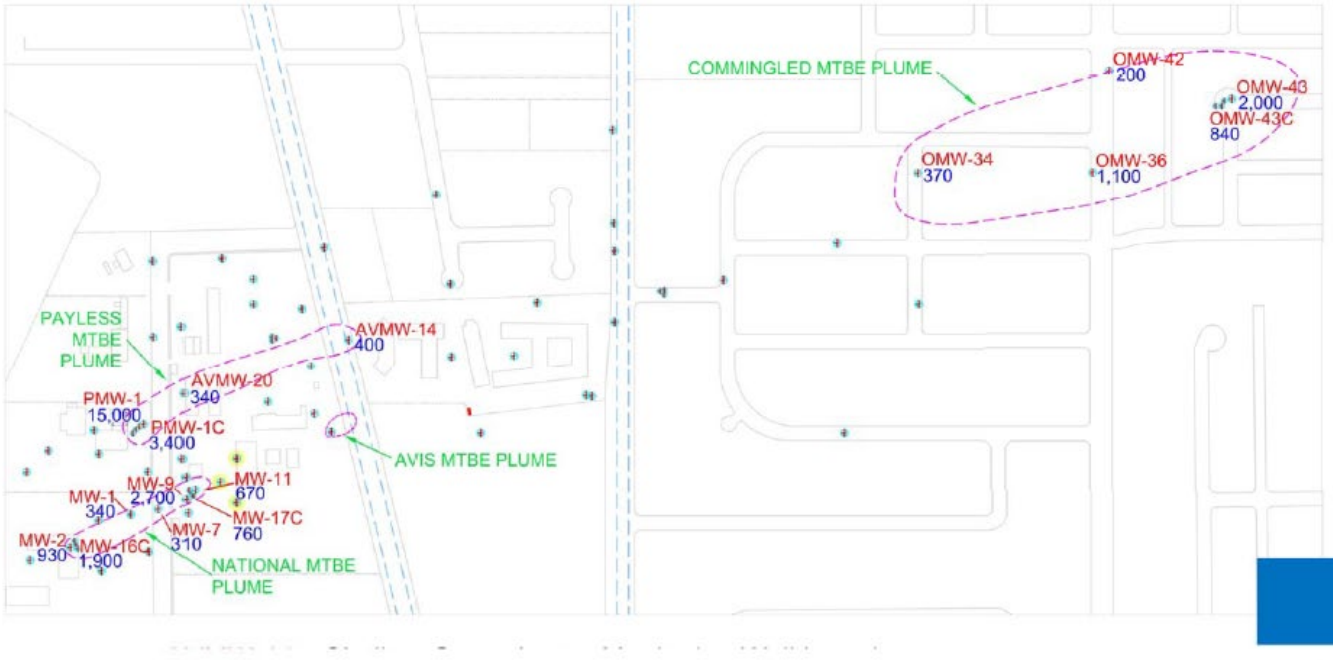
- **Shallow Commingled MTBE Plume Historically ~5,000 feet**



2008

BROADBENT

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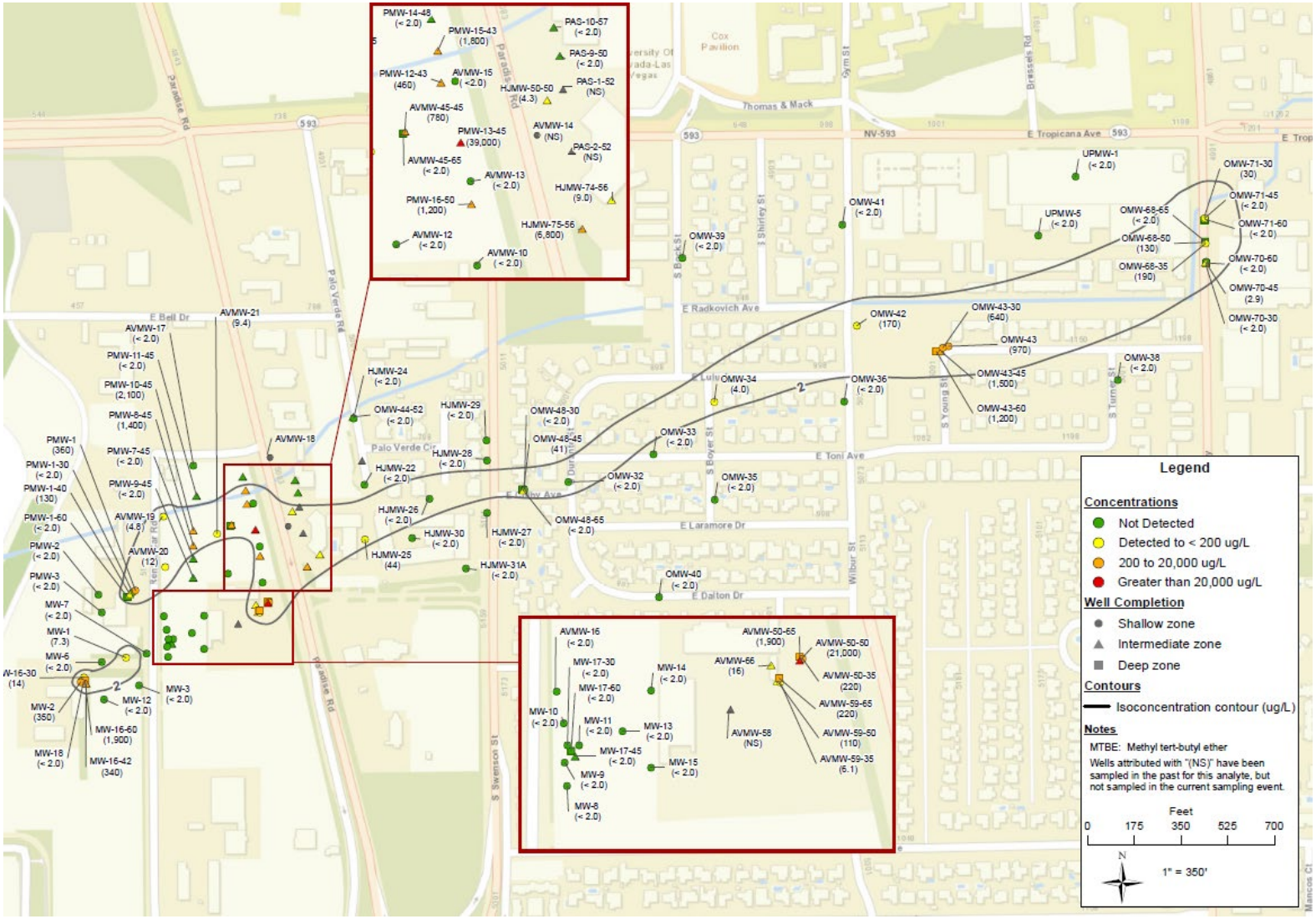

2012

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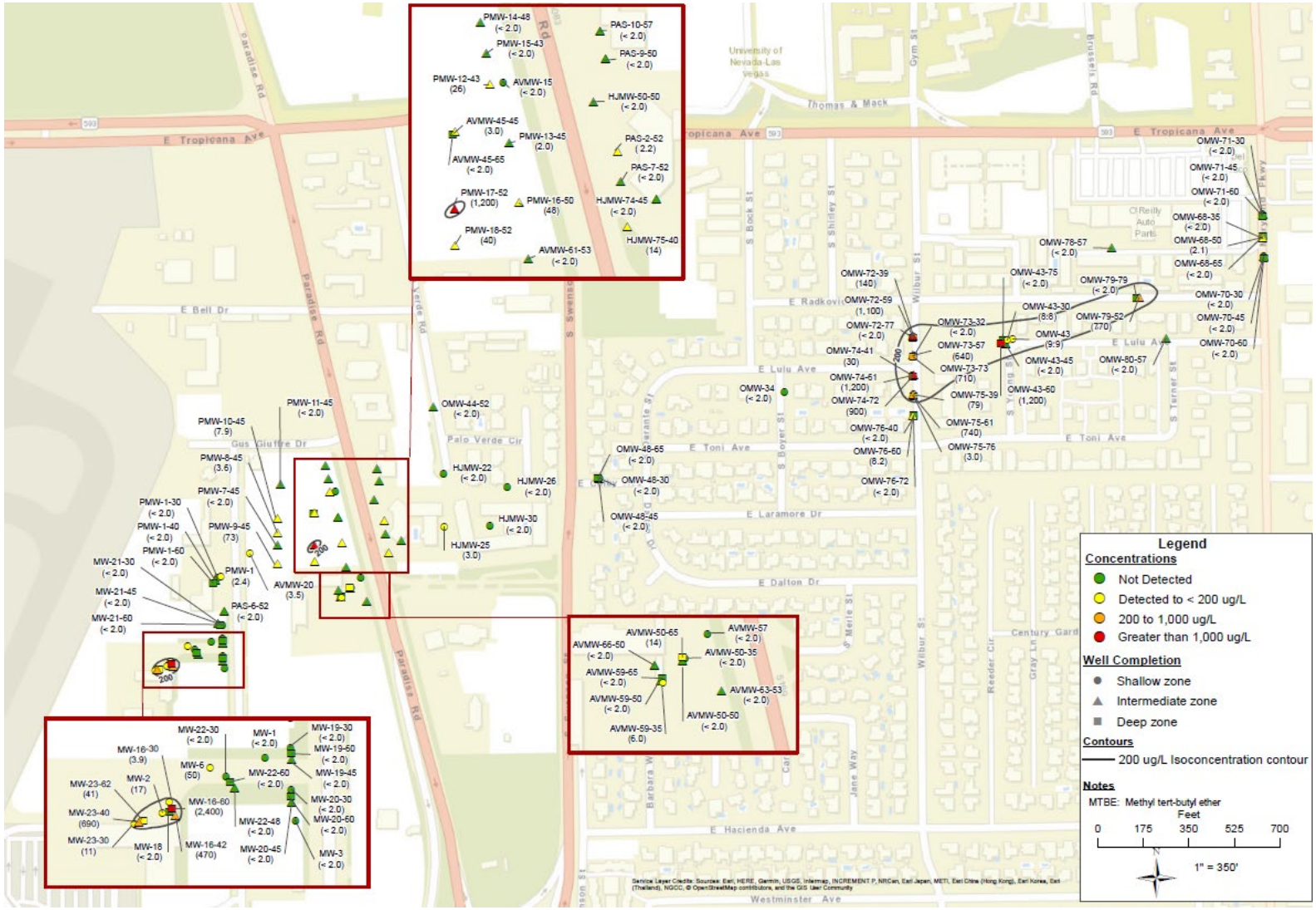

2018

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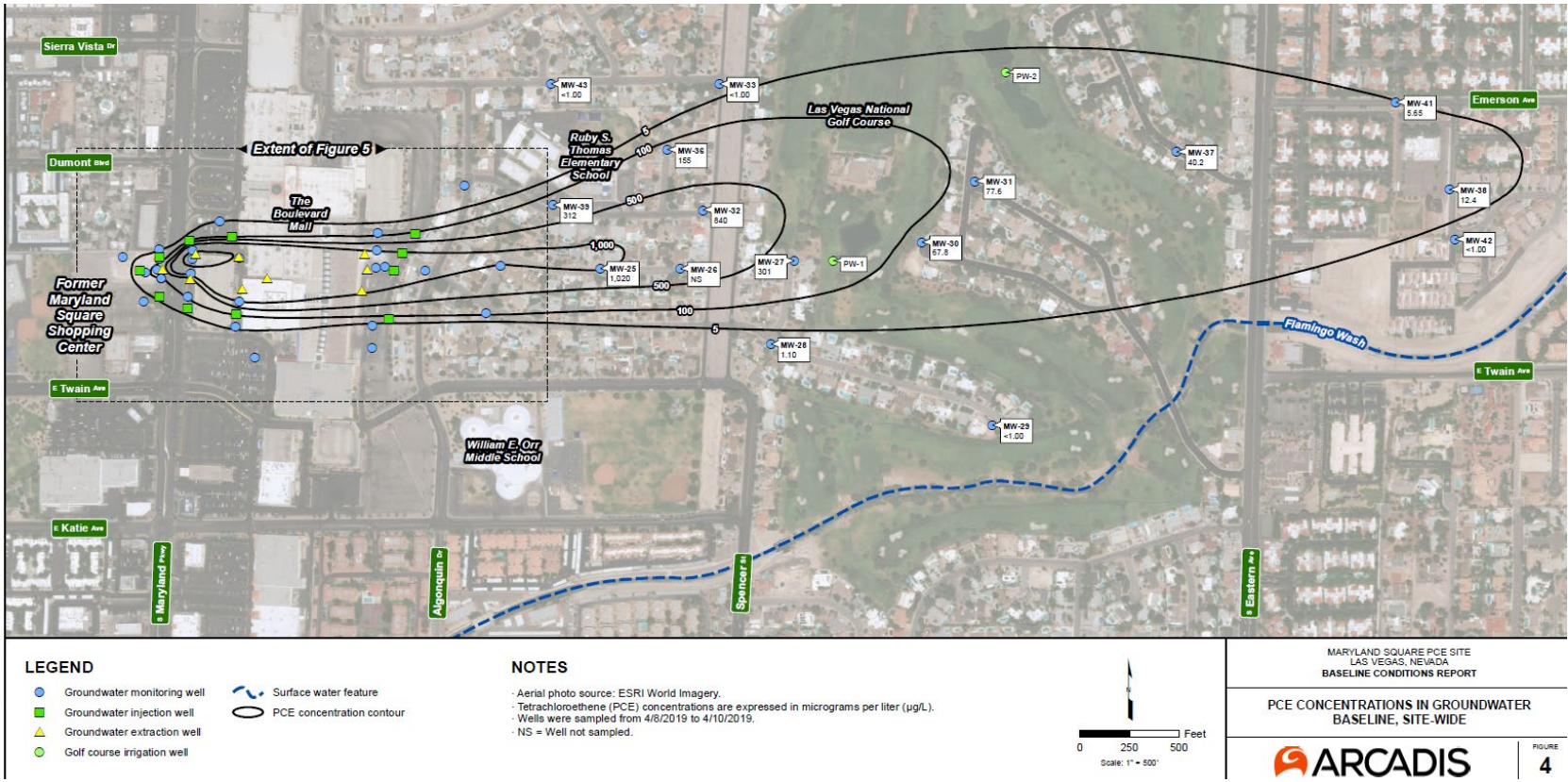
	Average Annual MTBE Concentration (ug/L)					
Year	**OMW-72-59**	**OMW-73-57**	**OMW-74-61**	**OMW-75-61**		
2014	2,200	2,200	2,100	1,400		
2015	2,150	2,100	1,130	1,250		
2016	1,550	1,105	1,600	1,015		
2017	1,300	1,450	1,105	1,045		
2018	1,100	970	880	485		
4-year	50%	56%	58%	65%	57%	average
Annual	13%	14%	15%	16%	14.3%	average

Case Study – Maryland Square

- Dry cleaner, branded as Al Phillips the Cleaner, operated from 1969 to 2000. Numerous PCE releases, including one documented indoor release of 100 gallons (1982)
- PCE in groundwater reported to NDEP in 2000, discovered during Phase II ESA sampling
- Plume ~7,000 feet long by 1,000 feet wide
- Pre-remediation concentrations near the source as high as 35,000 micrograms per liter (µg/L). Large plume >100 µg/L under residential area. NDEP has determined that concentrations >100 µg/L pose a potential vapor intrusion risk
- Drinking water standard: 5 µg/L maximum contaminant level
- Pump and treat remediation started in 2019
- Over 27,000,000 gallons of groundwater treated through the 3rd quarter of 2020
- Currently treating ~55 gallons per minute
- Approximately 232 pounds of PCE removed through the 3rd quarter of 2020
- Estimated 10-year cost of $6-8M

Case Study – Maryland Square



Case Study – Maryland Square

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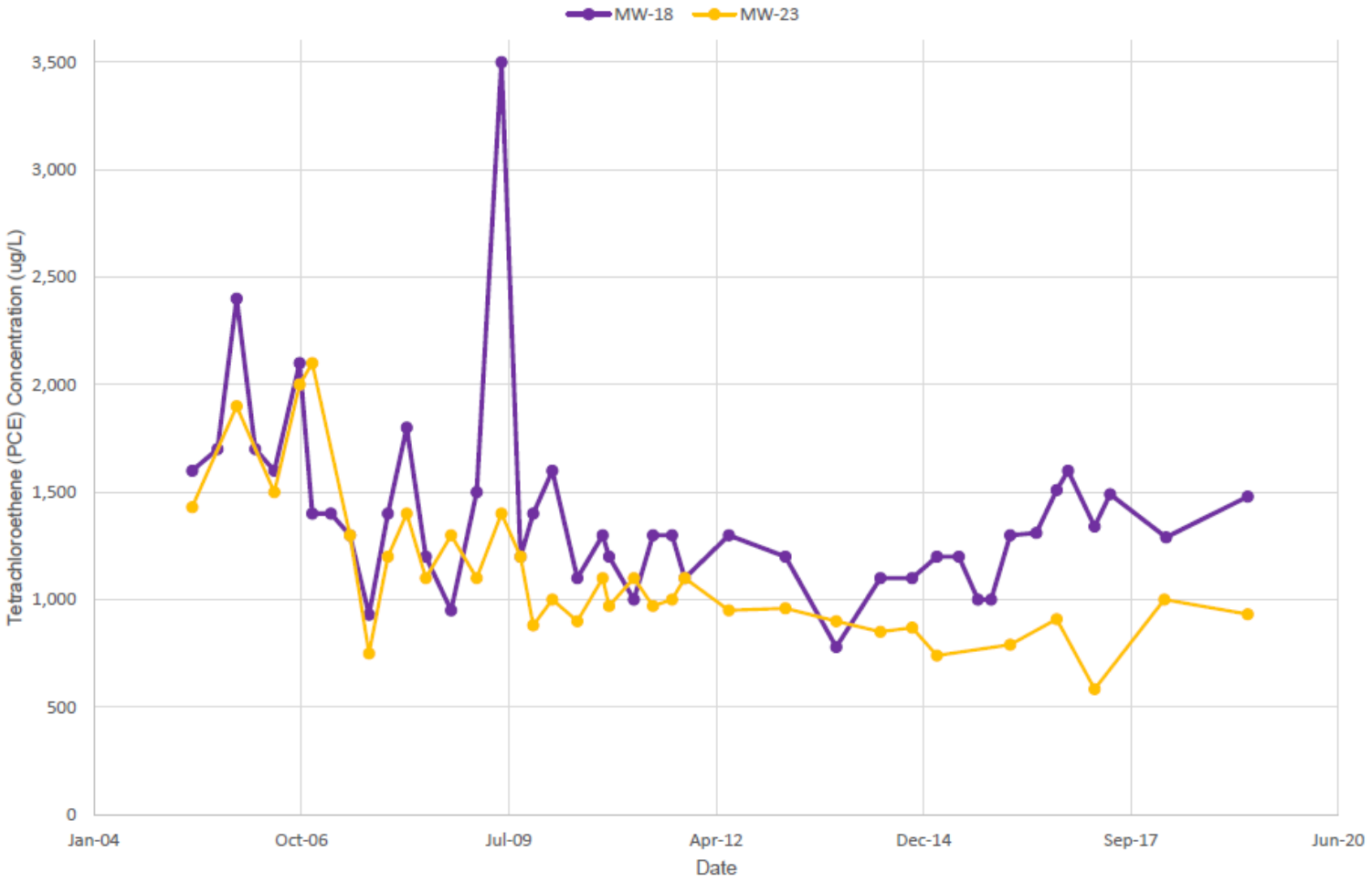
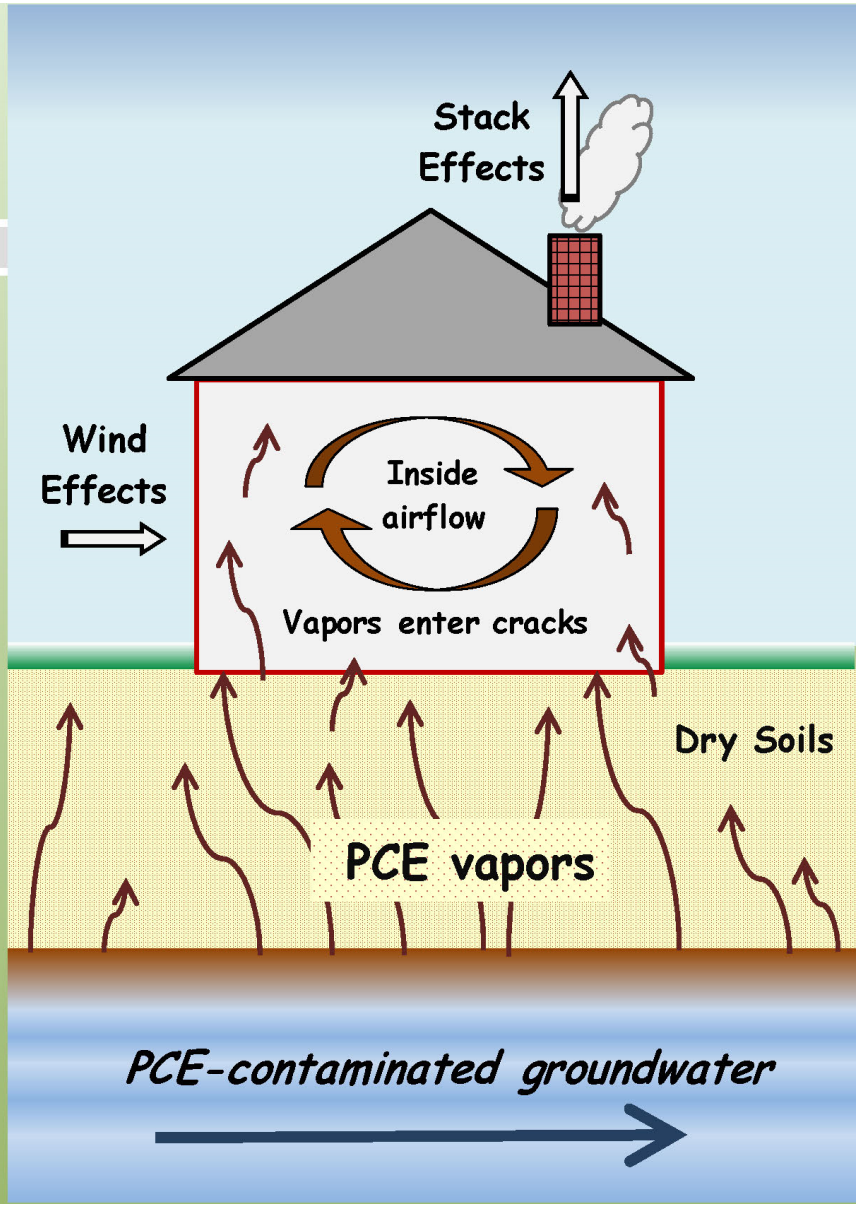
FIGURE 6
PCE CONCENTRATIONS VERSUS TIME
MARYLAND SQUARE PCE SITE
LAS VEGAS, NEVADA



Case Study – Maryland Square

"Vapor Intrusion"

- PCE evaporates from groundwater
- PCE vapors travel upward through soil
- The PCE vapors can enter into homes and contaminate indoor air
- Exposure occurs by breathing contaminated indoor air



Case Study – Maryland Square

Table 7-3. Estimated Cancer Risk and Non-cancer Hazard, using Maximum Concentrations

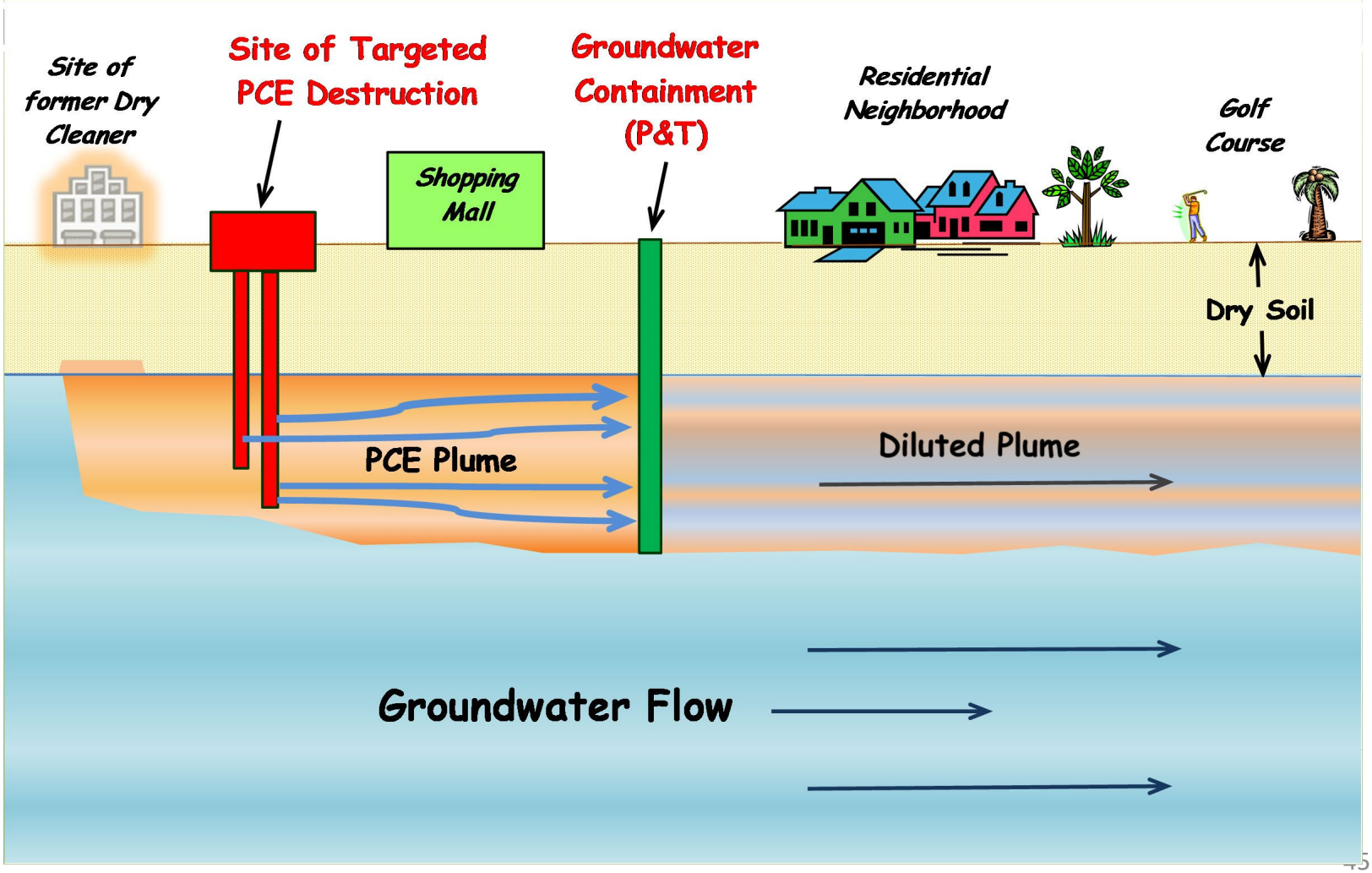
Chemical	Maximum Indoor Air ($\mu g/m^3$)	Cancer RSL ($\mu g/m^3$)	Non-Cancer RSL ($\mu g/m^3$)	Estimated Excess Cancer Risk	Estimated Non-Cancer Hazard
Tetrachloroethylene	110	9.4	42	1.20E-05	2.6
Trichloroethylene	9.4	0.43	2.1	2.20E-05	4.5
Vinyl chloride	0.075	0.16	100	4.70E-07	0.0008
Cumulative Cancer Risk and Non-Cancer Hazard				3.00E-05	7

$\mu g/m^3$ - Micrograms per cubic meter

- Cancer risk >1.00E-06 generally requires corrective action
- Hazard index >1.0 is unacceptable
- Remediation goals:
  - Reduce PCE concentrations in groundwater to <100 µg/L
  - Reduce indoor air PCE concentrations to <9.4 $\mu g/m^3$
  - Reduce indoor air TCE concentrations to <2.0 $\mu g/m^3$

Case Study – Maryland Square

Overview of the Preferred Remedy:
Containment & Targeted Mass Reduction



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Case Closure Options

- Reduce groundwater contaminant concentrations to below drinking water maximum contaminant levels (MCLs)
- Achieve the remedial action objects (RAOs) established in a record of decision or consent decree
- Meet the groundwater exemption requirements in NAC 445A.22725(2):
  - Source of contamination is identified and controlled
  - Plume is delineated
  - Concentrations trends from >3 years of quarterly monitoring do not indicate increasing trends in the body of the plume
  - Natural attenuation will prevent plume from migrating to a receptor
  - The groundwater is not a source of drinking water and is not likely to become one
  - The plume does not pose an unacceptable cancer or non-cancer risk

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Summary

- Hazardous substances released to groundwater can be detrimental to human health even if the groundwater in the immediate area of the release is not a source of drinking water
- Benzene, MTBE, and PCE are the primary chemicals of concern in most Las Vegas Valley Corrective Actions cases
- Plumes travel generally to the east, at rates ranging from <10 feet per year to several hundred feet per year
- MTBE and PCE plumes tend to be longer than benzene plumes
- Cleanup is prioritized based on:
  - Plumes that are not controlled and are continuing to migrate
  - Potential to reach drinking water wells
  - Vapor intrusion risk
  - Other risk to human health and the environment
  - Degradation of water quality
- Case closure options are:
  - Remediate until MCLs or other goals have been reached
  - Meet the conditions for exemption closure based on low risk

NDEP

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Questions?

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