USE OF BIG DATA TO UNDERTSTAND REMEDY EFFECTIVENESS AT PETROLEUM SITES IN CALIFORNIA

International Symposium on Bioremediation
and Sustainable Environmental Technologies
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GSI ENVIRONMENTAL

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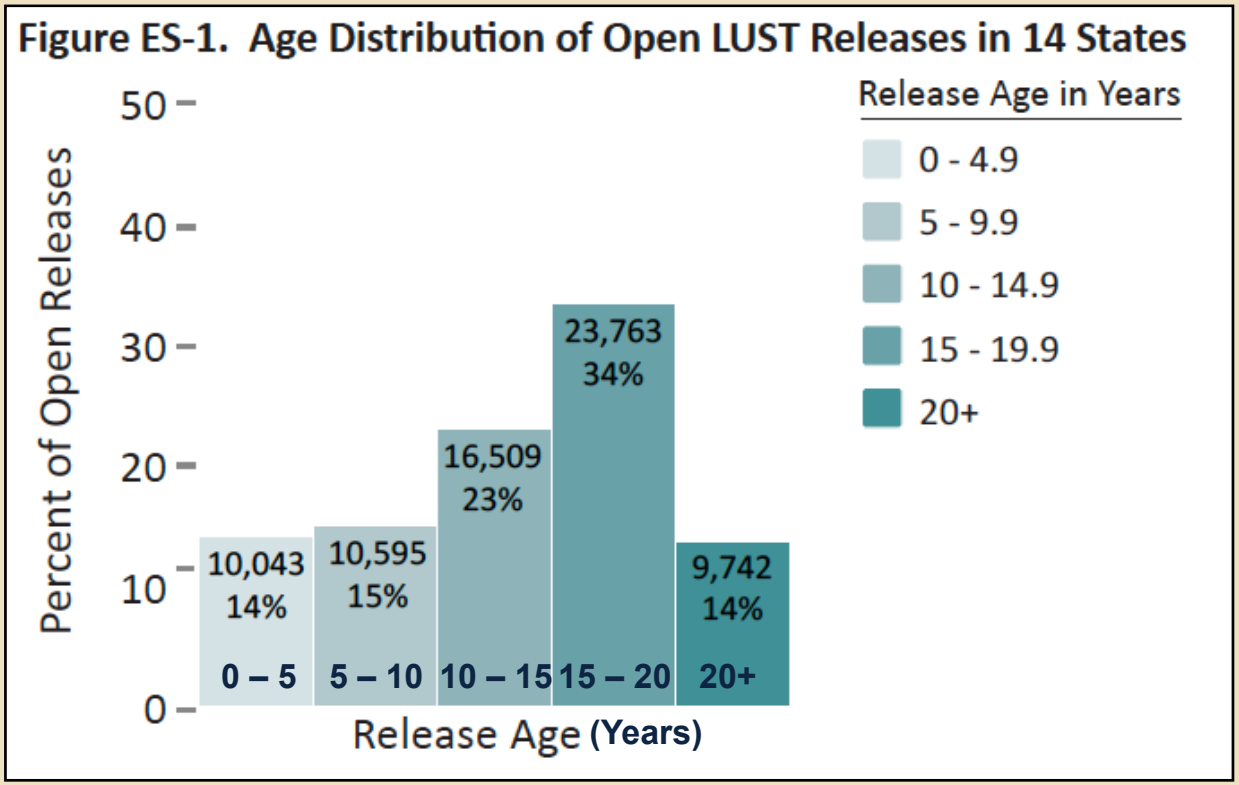
PRESENTATION OUTLINE

Background

- GeoTracker Database
- Remediation Progress
- Technology Effectiveness

BACKGROUND: UST CASE BACKLOG

65,000 UST SITES STILL OPEN



KEY POINT:

71% of open UST cases have been in the regulatory cleanup process for more then 10 years.

Source: The National LUST Cleanup Backlog: A Study of Opportunities USEPA, 2009. Available at: http://www.epa.gov/swerust1/cat/backlog.html

PRESENTATION OUTLINE

- Background
- ***GeoTracker Database***
- Remediation Progress
- Technology Effectiveness

STUDY OBJECTIVES:
EVALUATE REMEDY PROGRESS

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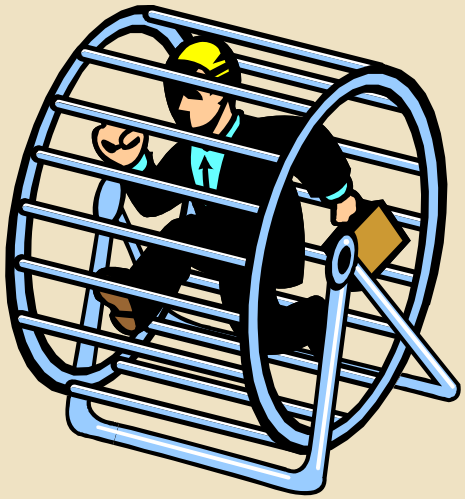
Can't Get There From Here



Remediation Progress

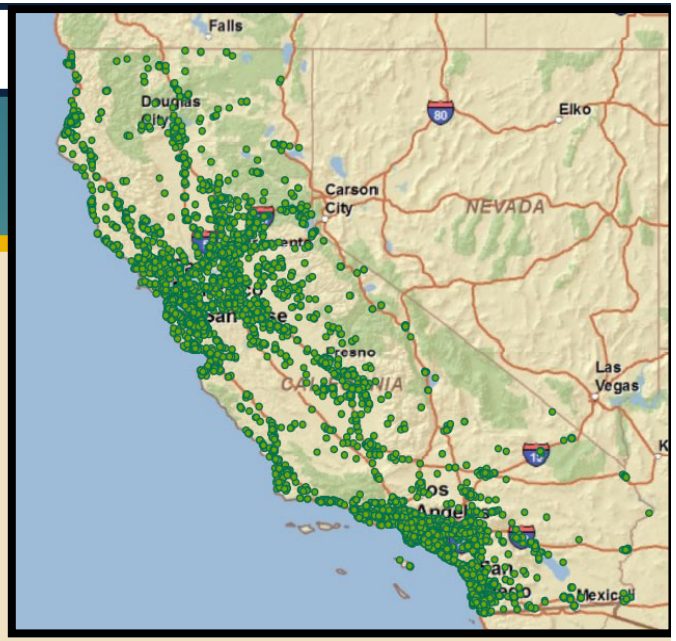
METRIC: **Change in maximum site concentrations of benzene AND MTBE from 2002 to 2018.**

Technology Effectiveness

METRIC: **Differences in source attenuation rates between gasoline constituents with different chemical properties**

Goal: **Use improved understanding of LUFT site conditions to eliminate barriers to closure of low risk sites.**

GEOTRACKER DATABASE



GeoTracker Database

- Data management system for sites in California with affected groundwater

Site Selection

- Site in GeoTracker Database
- Groundwater data before 2012 (i.e., site at least six years old)
- Groundwater data for B, T, E, X and MTBE

Evaluation Dataset

- 7,447 petroleum contaminated GW sites
- >2,000,000 groundwater samples
- 2002 to 2018

PRESENTATION OUTLINE

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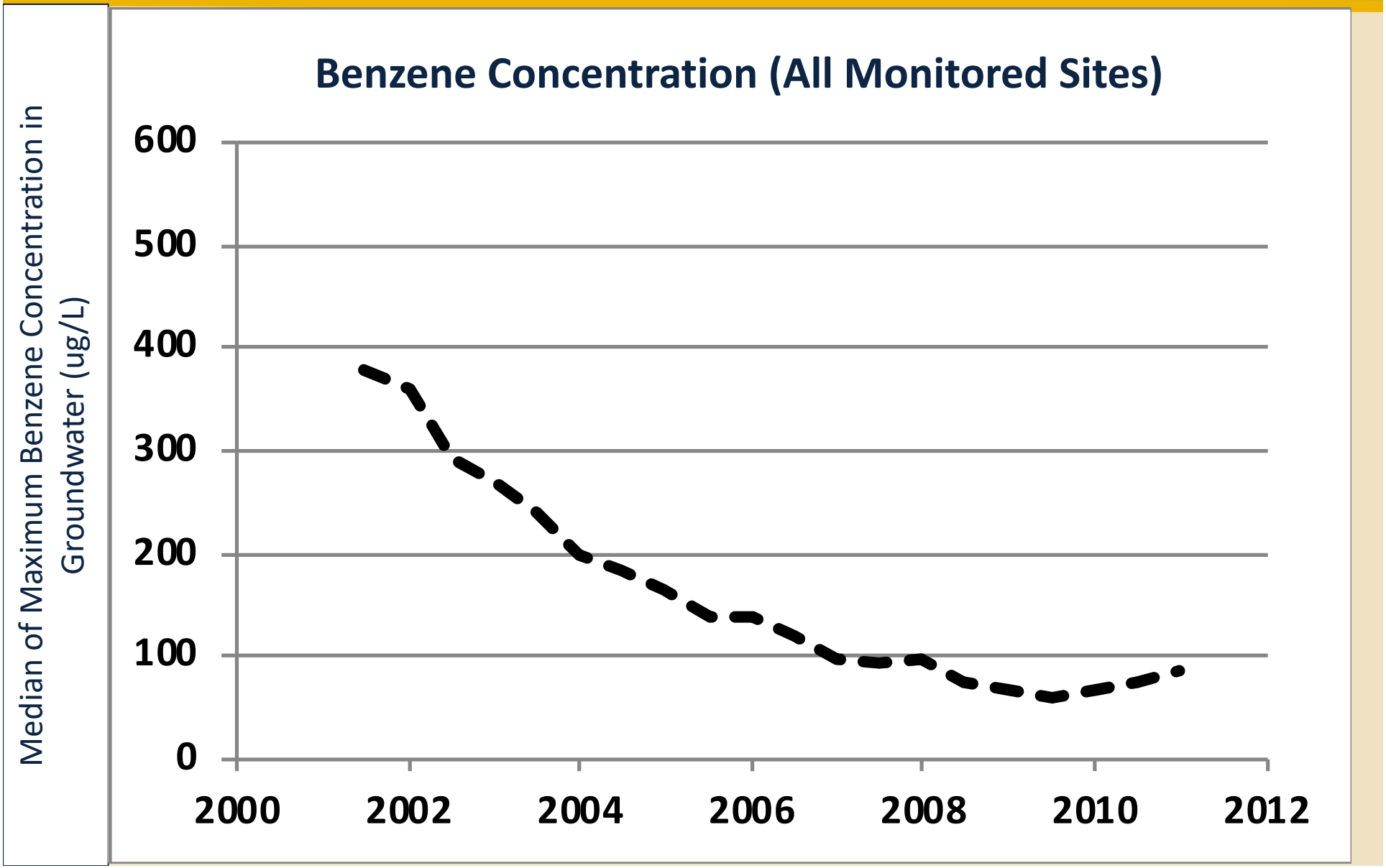
TRENDS THROUGH 2011

Groundwater

Progress in Remediation of Groundwater at Petroleum Sites in California

by Thomas E. McHugh[1], Poonam R. Kulkarni[2], Charles J. Newell[2], John A. Connor[2], and Sanjay Garg[3]



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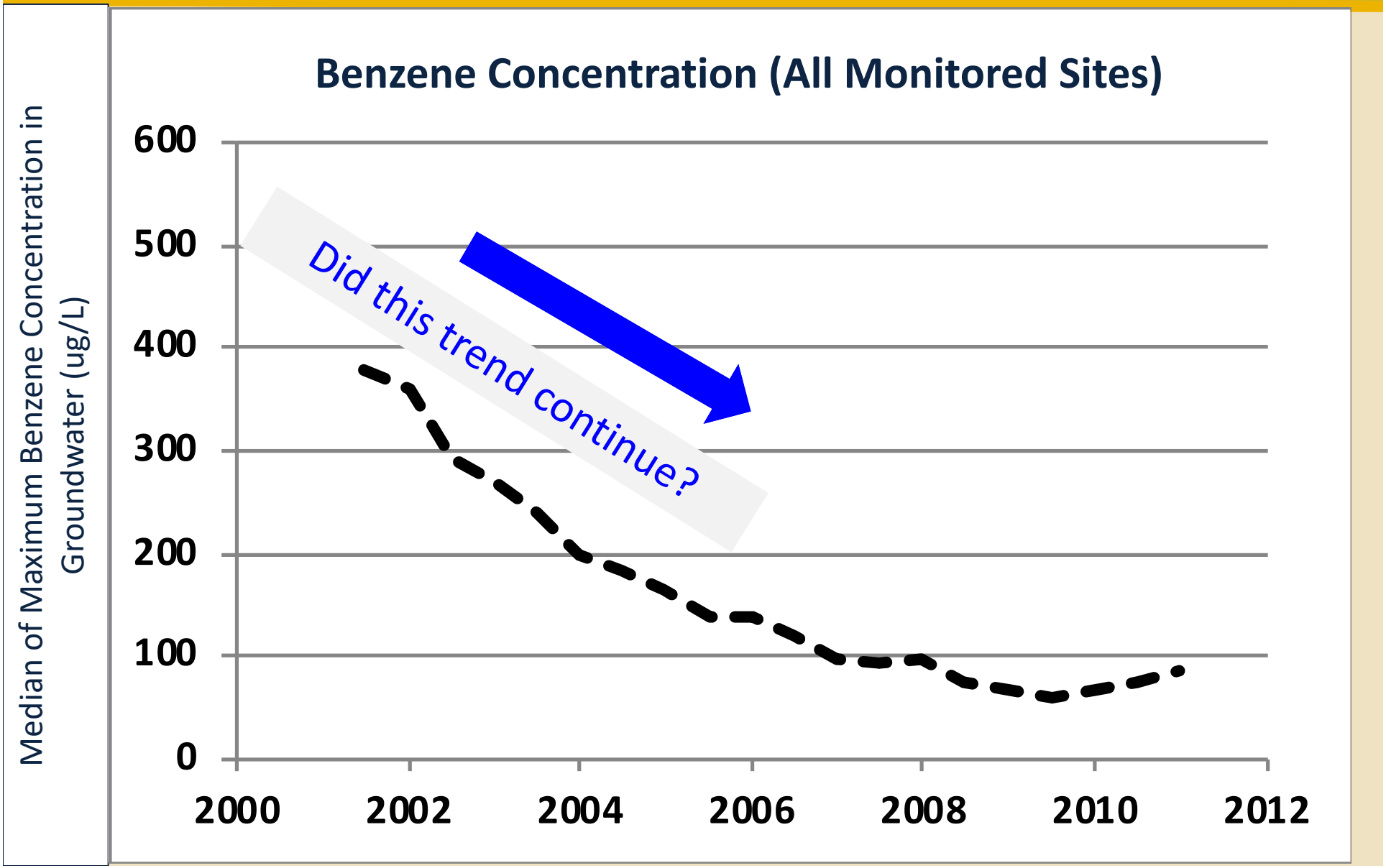

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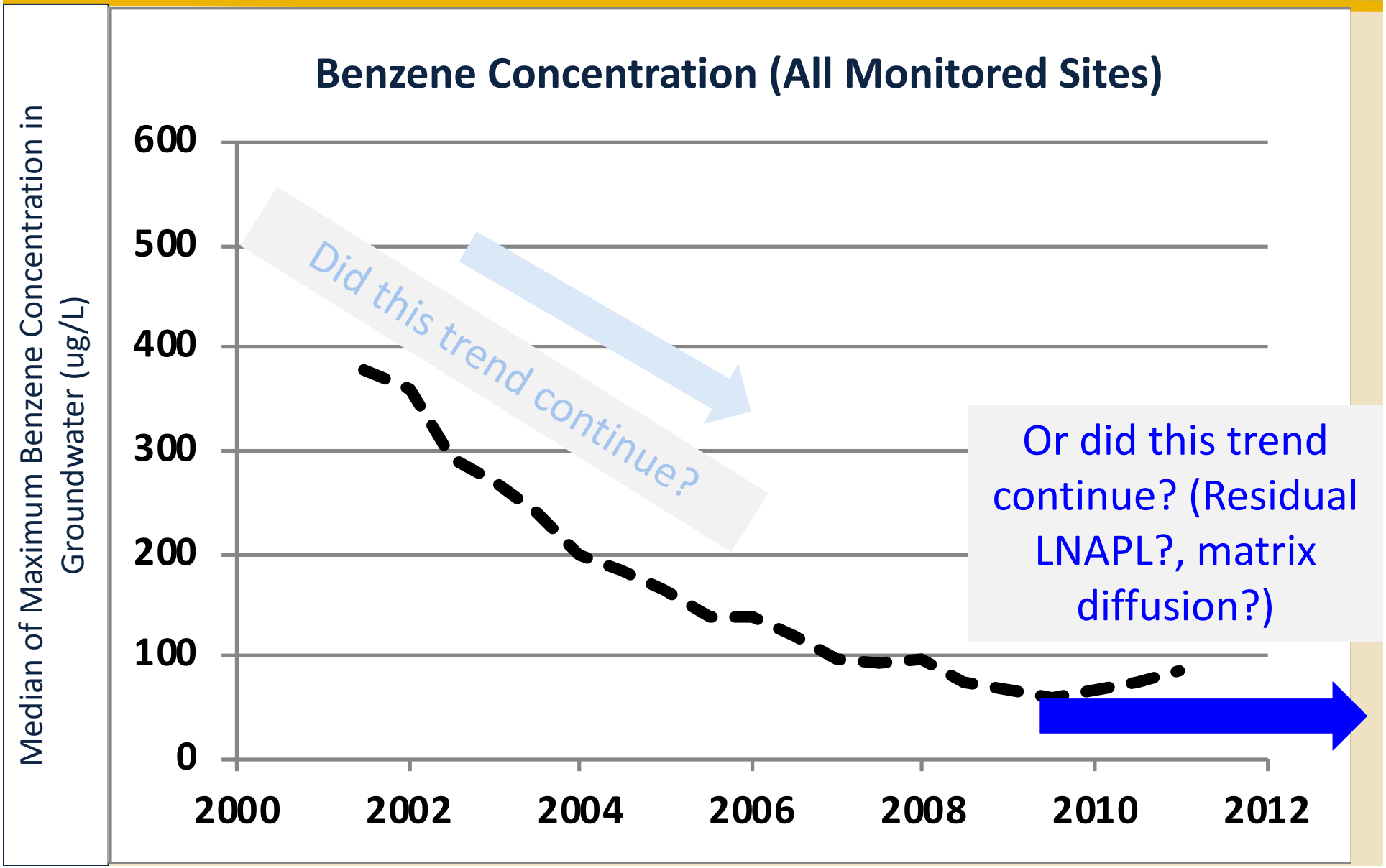
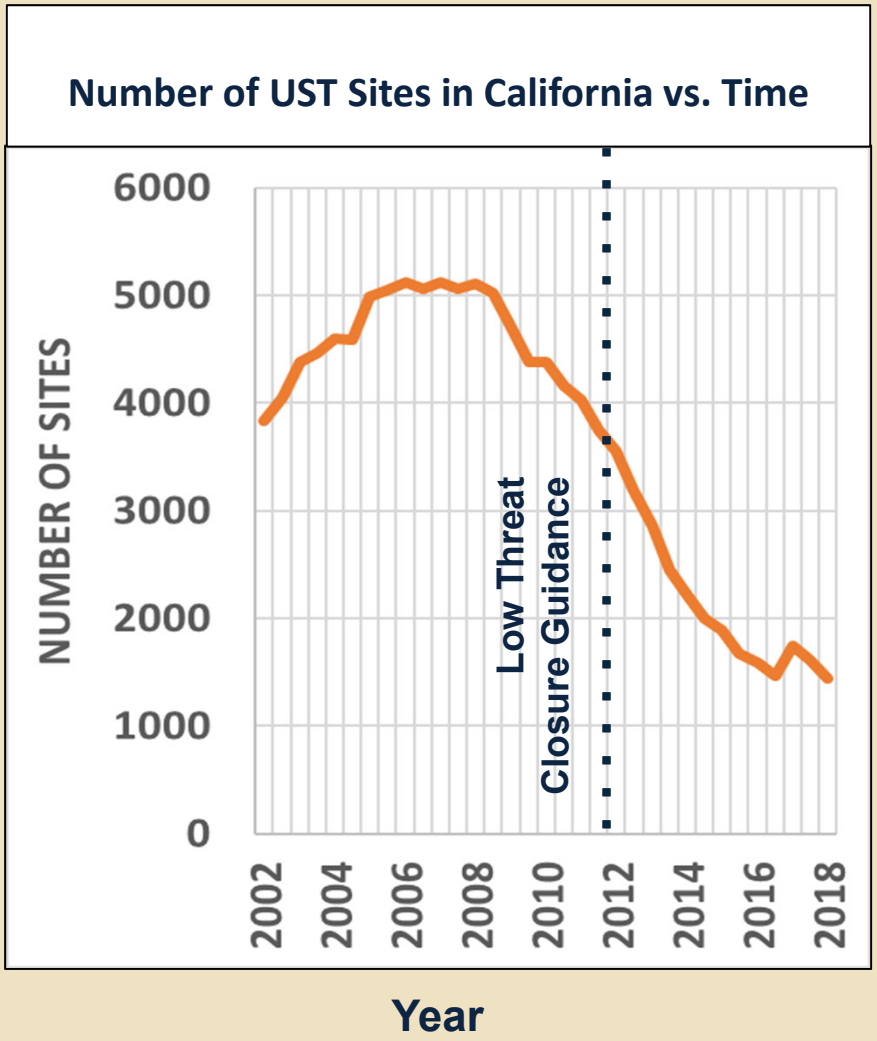
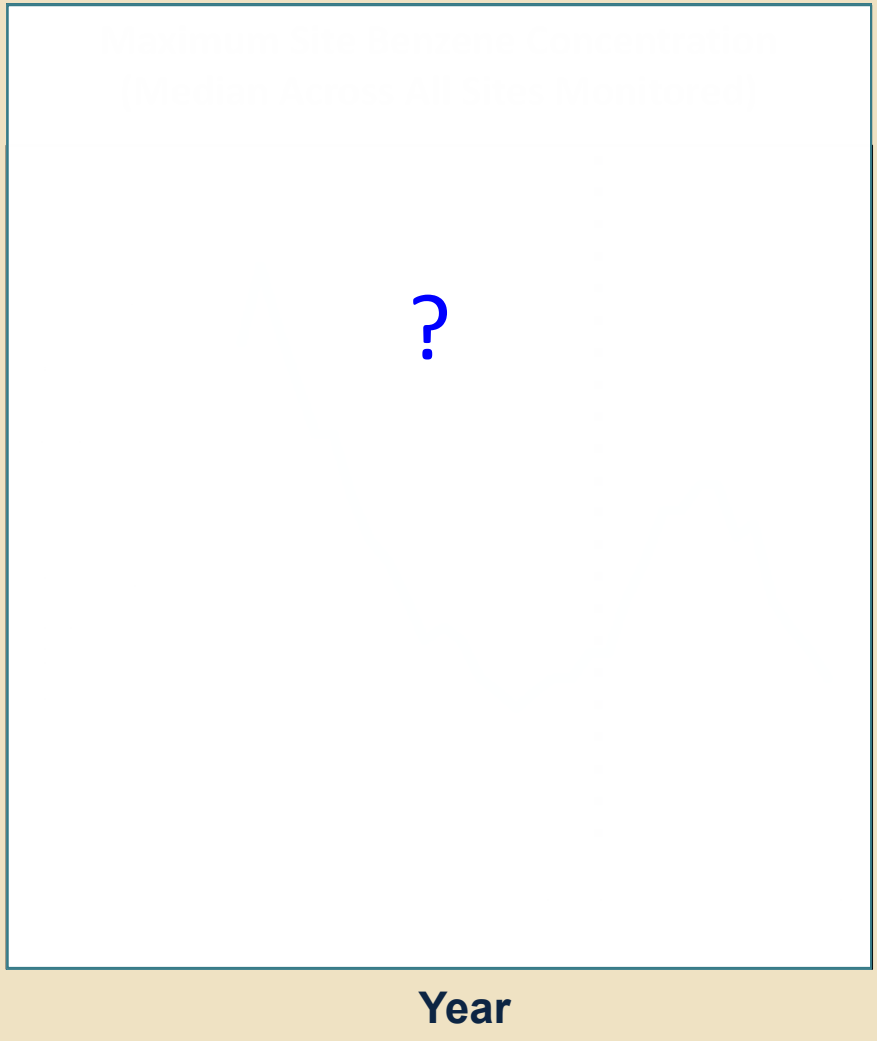


BENZENE CONCENTRATION:
ALL 7,447 SITES





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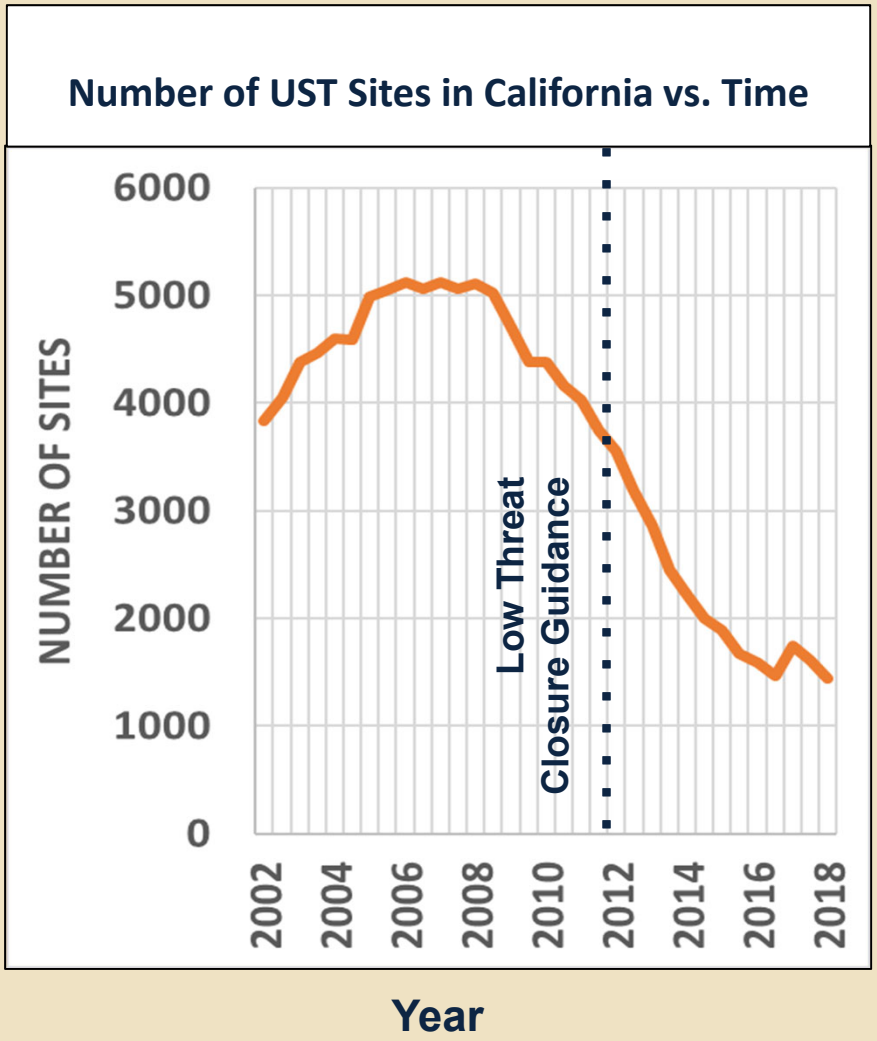

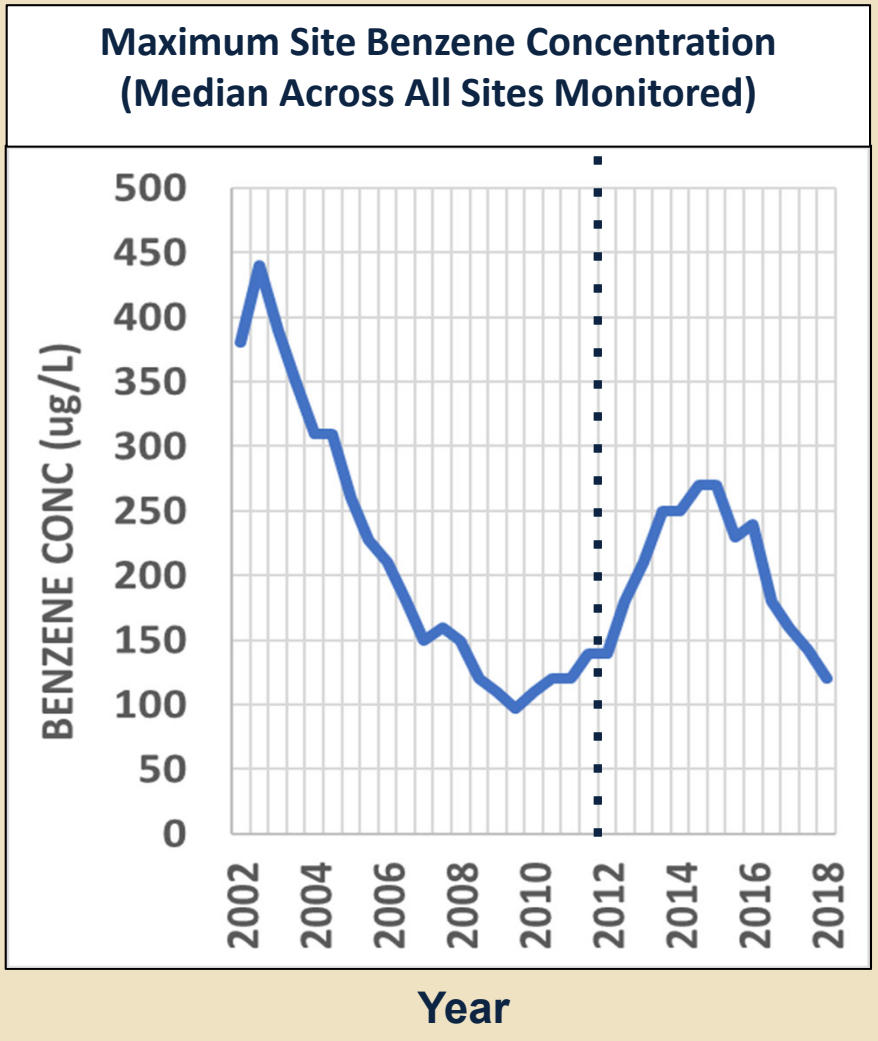

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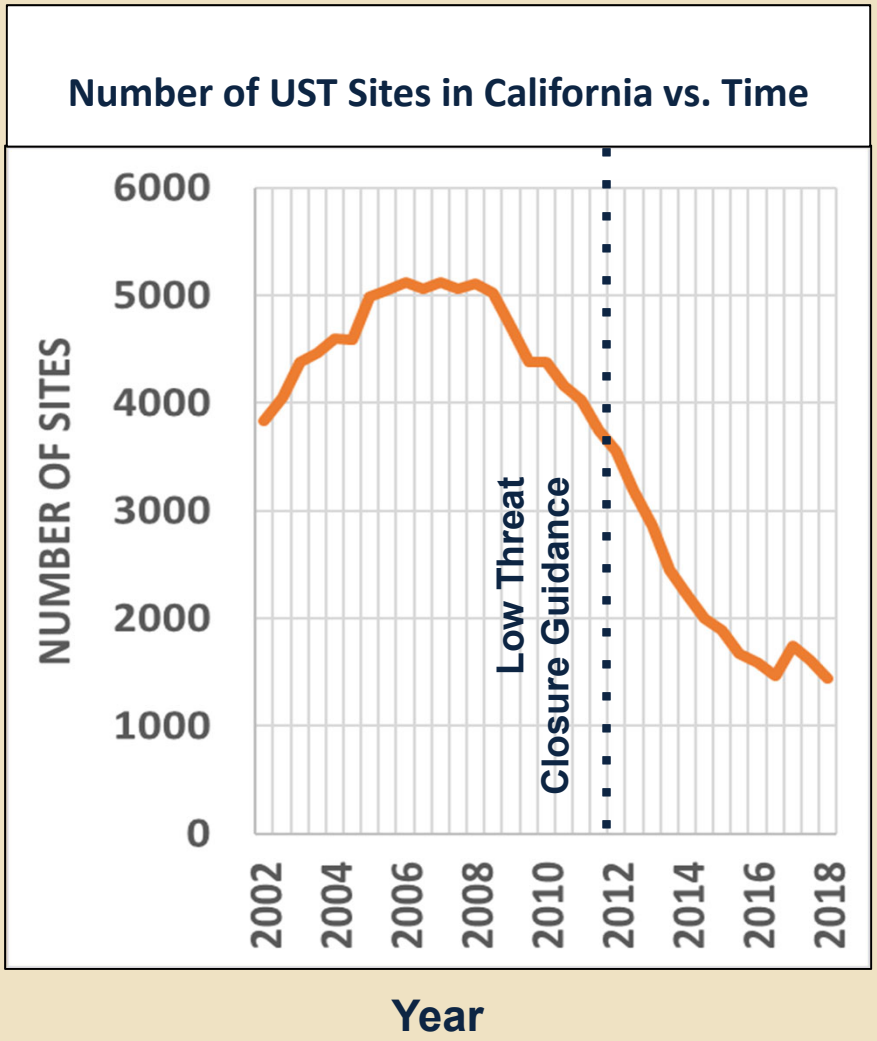
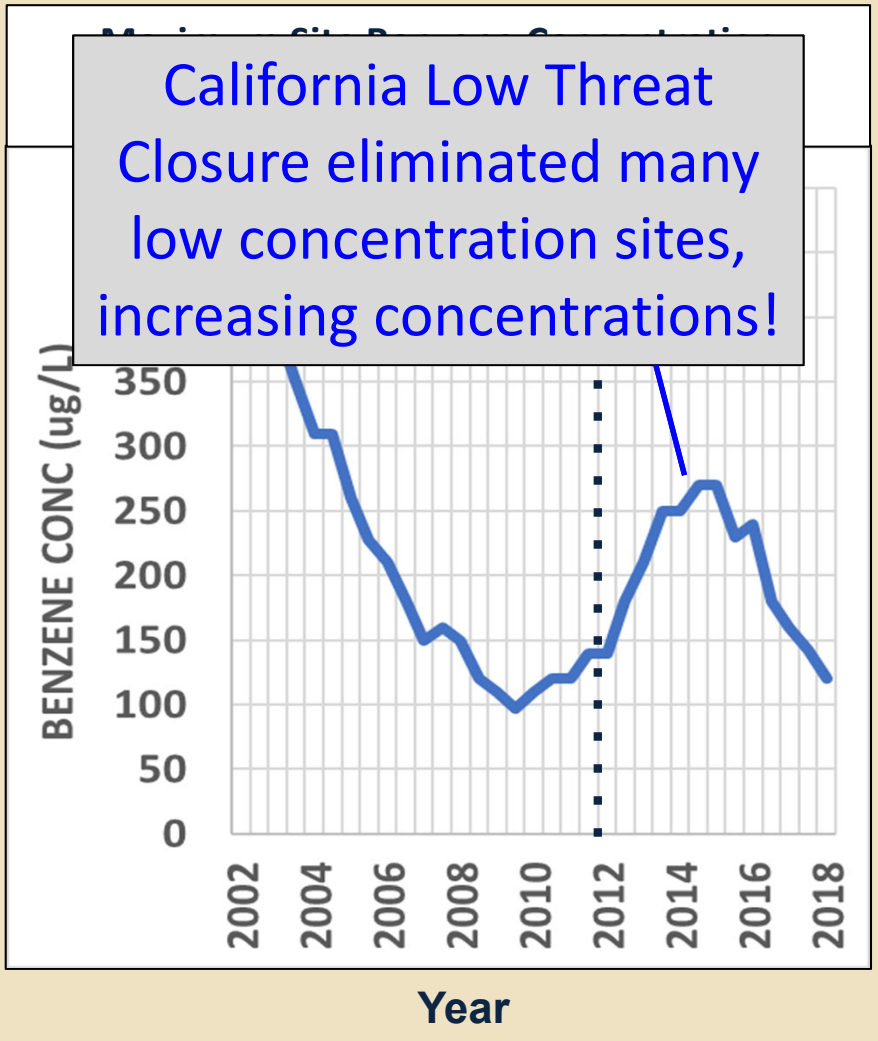
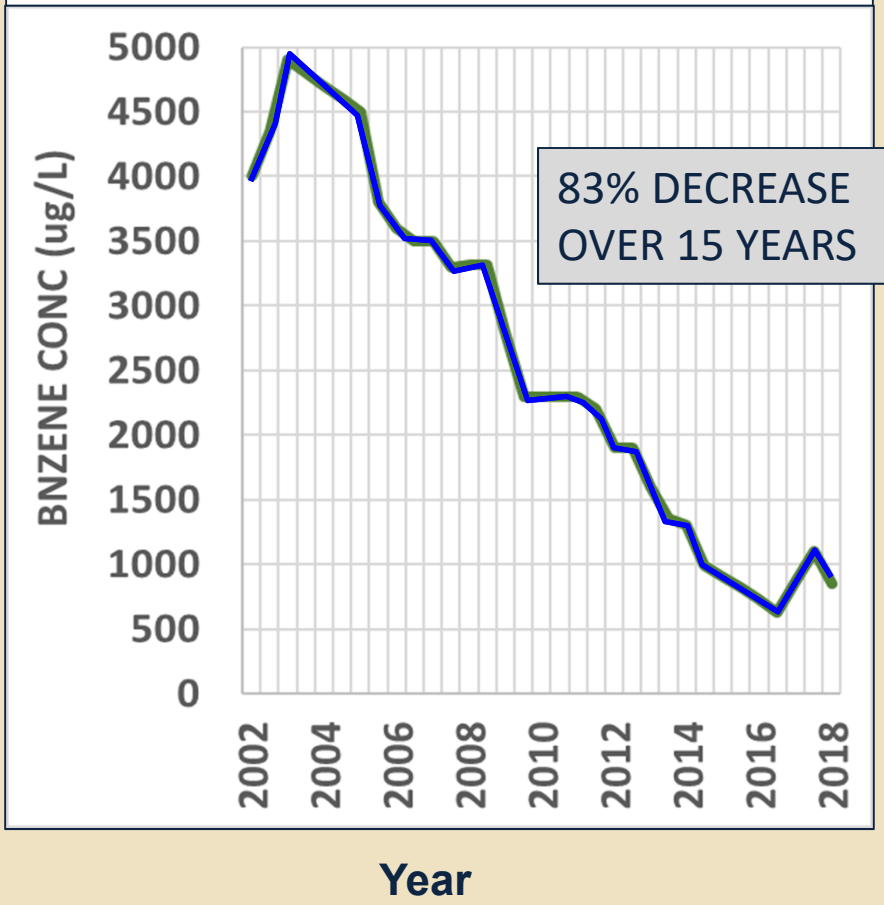




JUST LONG TERM SITES:
BENZENE AND MTBE

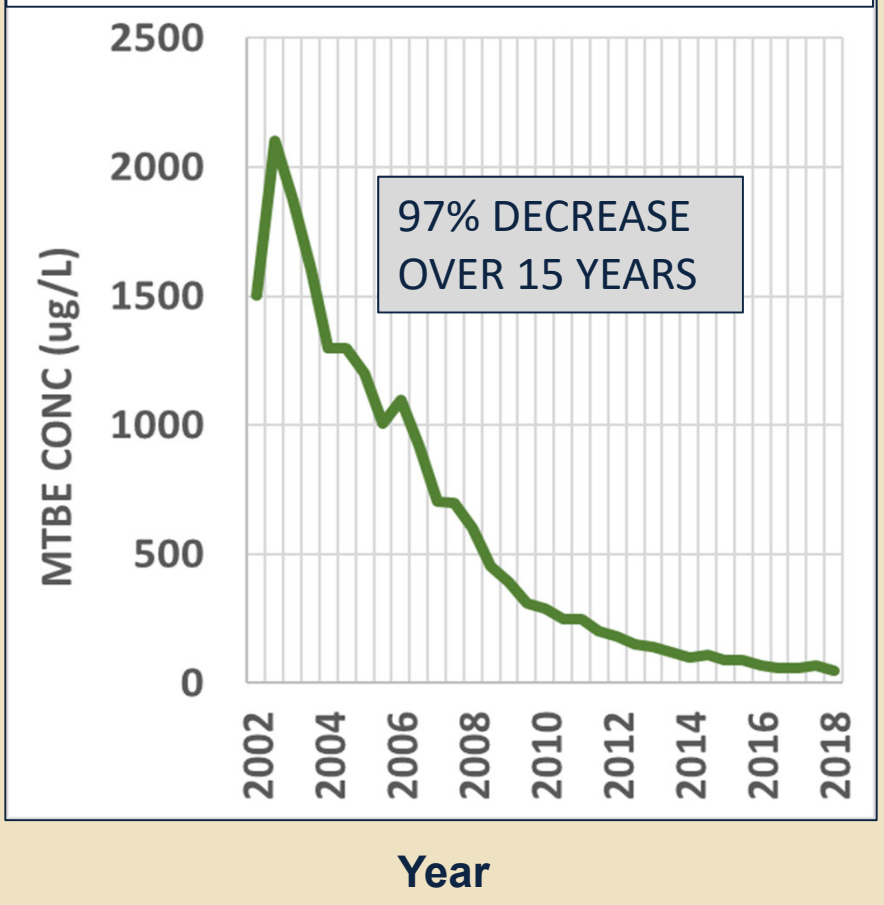
Benzene

Sites With Long Monitoring Records
14+ Years of GW Data (877 SITES)



MTBE

Sites With Long Monitoring Records
14+ Years of GW Data (877 SITES)



UST REMEDIATION PROGRESS:
KEY FINDINGS

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CALIFORNIA CASE BACKLOG

- The number of sites being monitored has decreased by 70% since 2008.
- Higher concentration sites retained (consistent with low threat closure policy).

REMEDIAITON PROGRESS

At sites with long monitoring records (14+ Years), maximum concentrations in groundwater have greatly decreased.

- Benzene: 83% decrease
- MTBE: 97% decrease

PRESENTATION OUTLINE

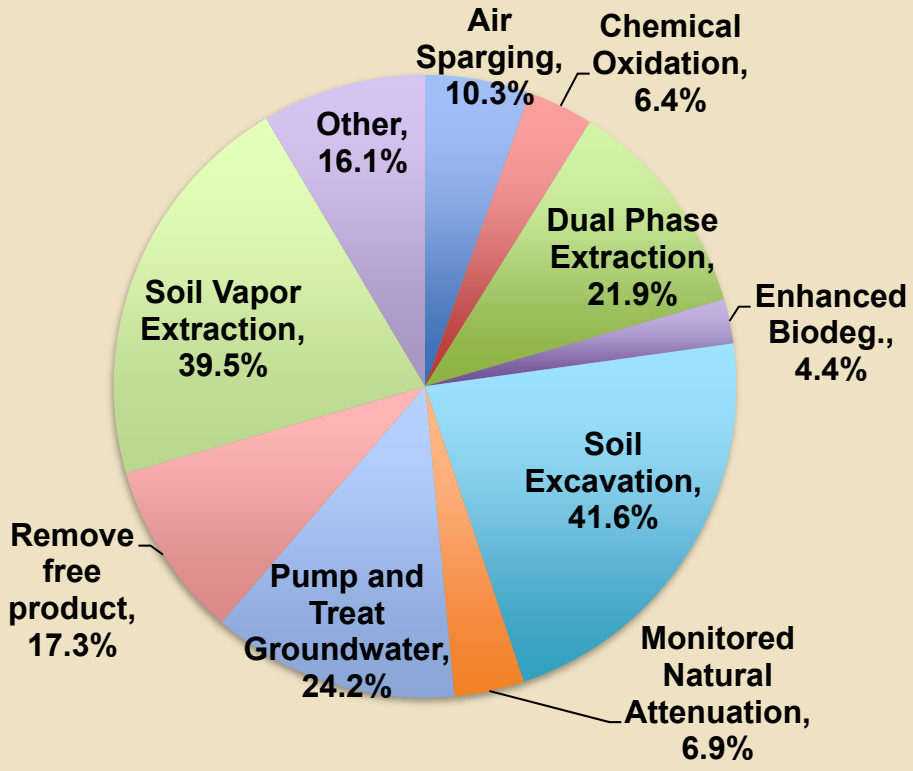
- Background
- GeoTracker Database
- Remediation Progress

Technology Effectiveness

REMEDIATION TECHNOLOGIES:

Can We Use Big Data to Figure out Which Types of Remediation Technologies Are Most Effective for Remediation of Petroleum Sites?

REMEDIATION TECHNOLOGIES:



Top Three Technologies:

- **Soil Excavation**
- **Soil Vapor Extraction**
- **Groundwater P&T**

Note: **Many sites have had more than one remediation technology applied.**

REMEDIATION TECHNOLOGIES:

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Hypothesis: Different Petroleum Compounds Removed by Volatilization Technologies vs. Groundwater Extraction Technologies

COMPOUND	VAPOR PRESSURE (MM HG)	SOLUBILITY (MG/L)
MTBE	249	48,000
BENZENE	95	1770
TOLUENE	28	530
ETHYLBENZENE	9.6	169
XYLENES	8.1	198
NAPHTHALENE	0.09	31

REMEDIATION TECHNOLOGIES:

Hypothesis: Different Petroleum Compounds Removed by Volatilization Technologies vs. Groundwater Extraction Technologies

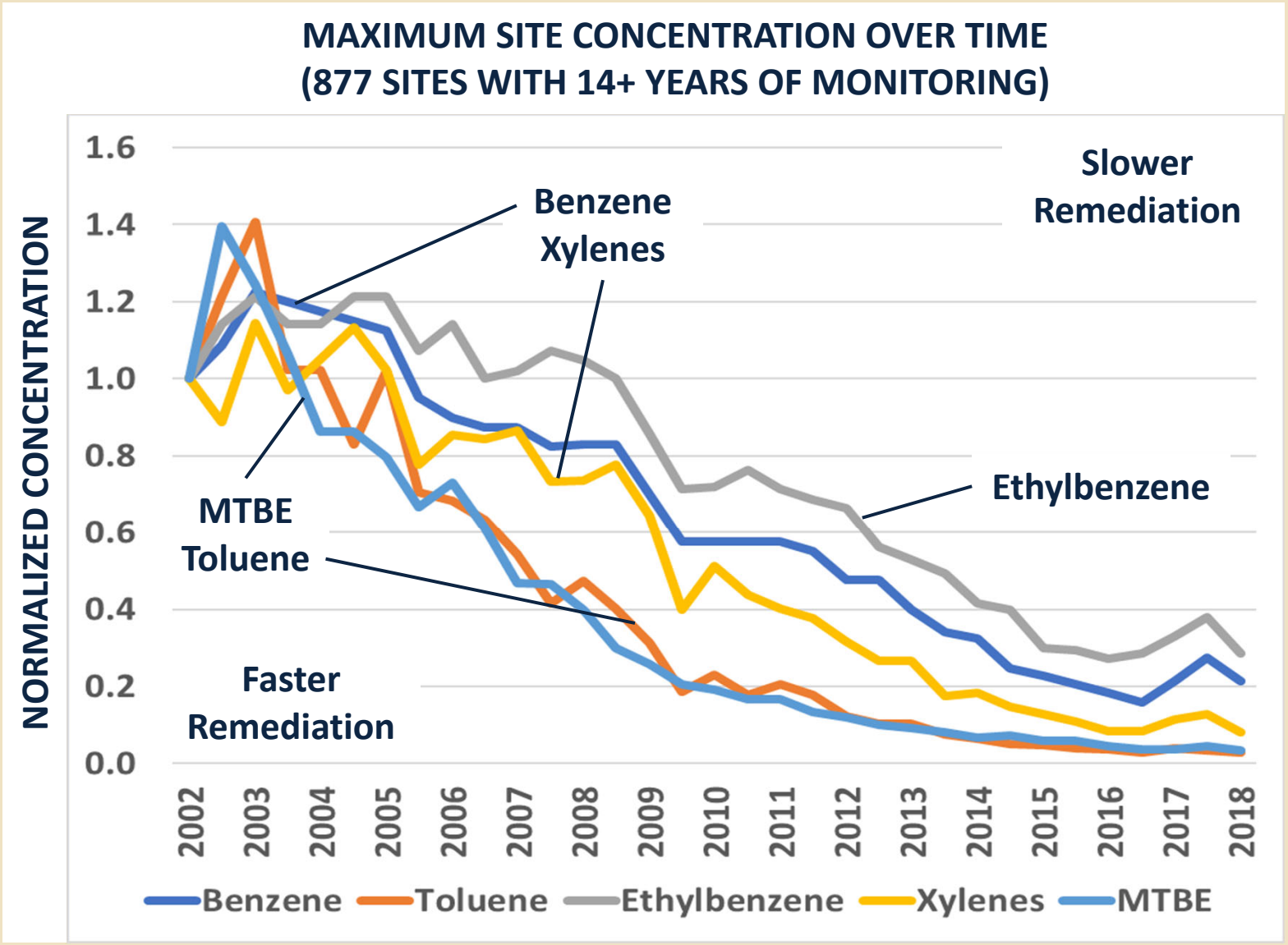
VOLATILIZATION (SVE, AIR SPARGING):

MTBE
↓
BENZENE
↓
TOLUENE
↓
ETHYLBENZENE
XYLENES
↓
NAPHTHALENE

GW EXTRACTION (P&T, DUAL PHASE EXTRACTION):

MTBE
↓
BENZENE
↓
TOLUENE
↓
ETHYLBENZENE
XYLENES
↓
NAPHTHALENE

NORMALIZED CONCENTRATION



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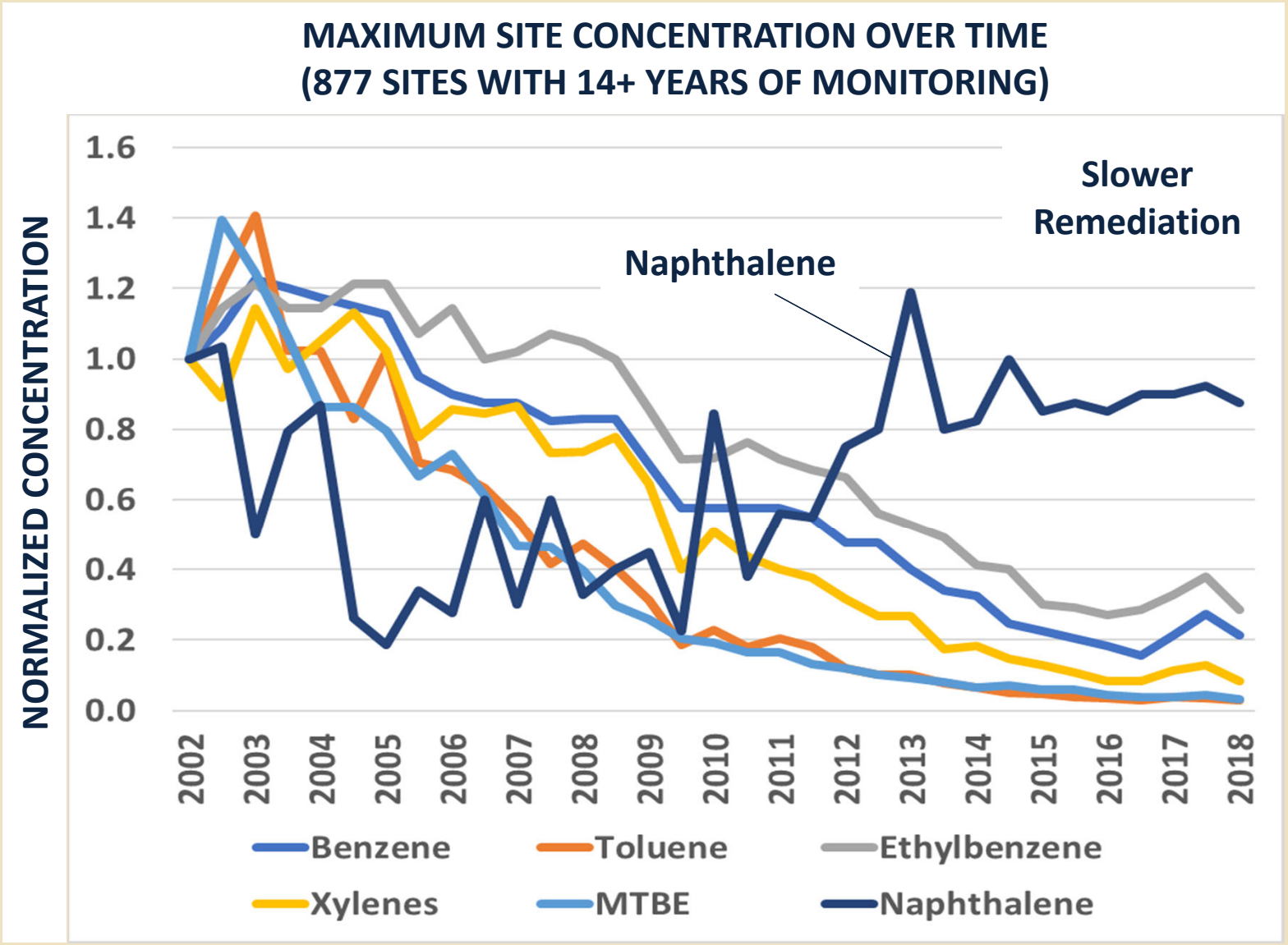


REMEDIATION TECHNOLOGIES:

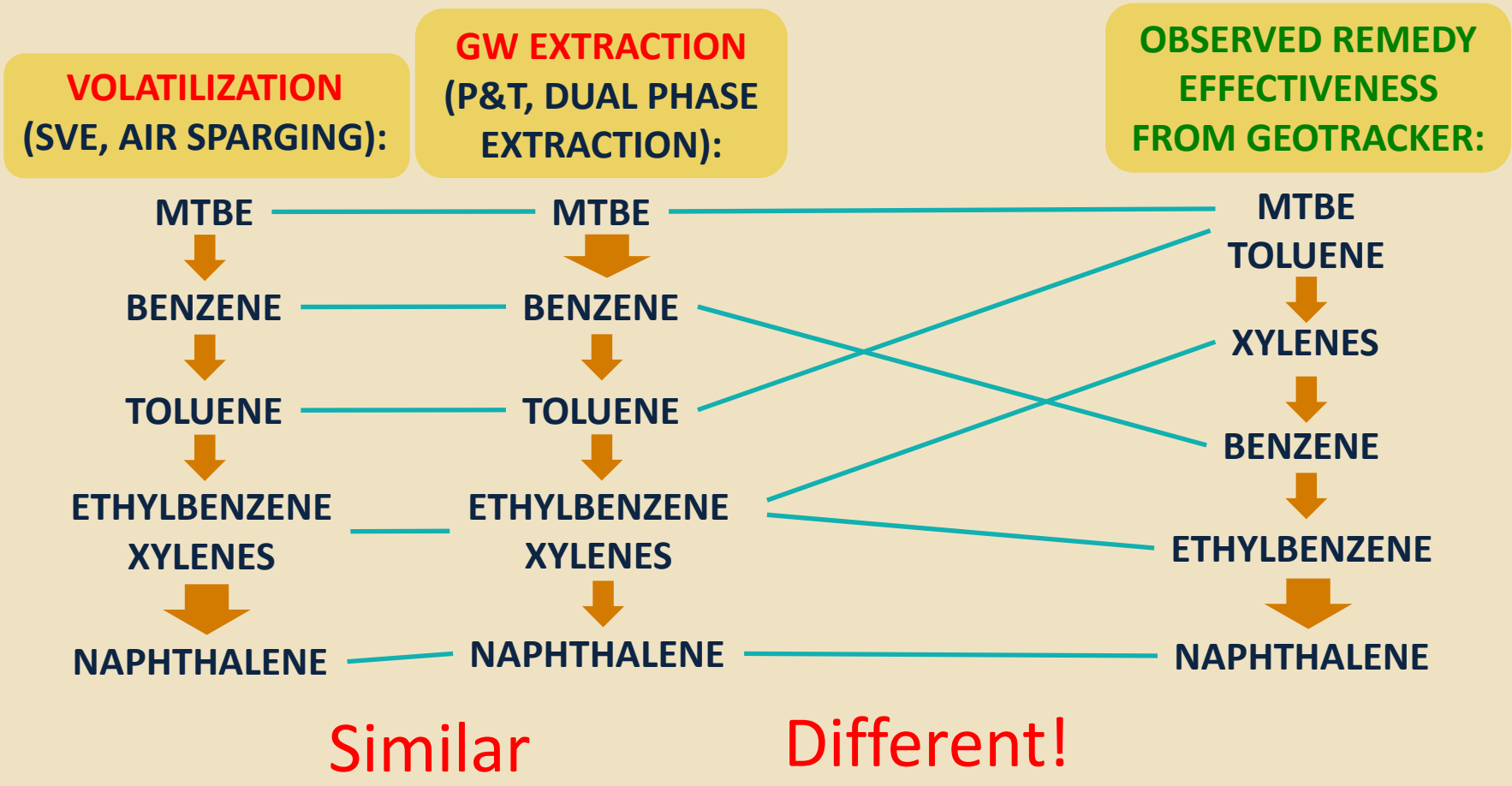
What Remediation Technology Might Explain the Observed Compound-Specific Remedy Effectiveness?

OBSERVED REMEDY EFFECTIVENESS FROM GEOTRACKER:

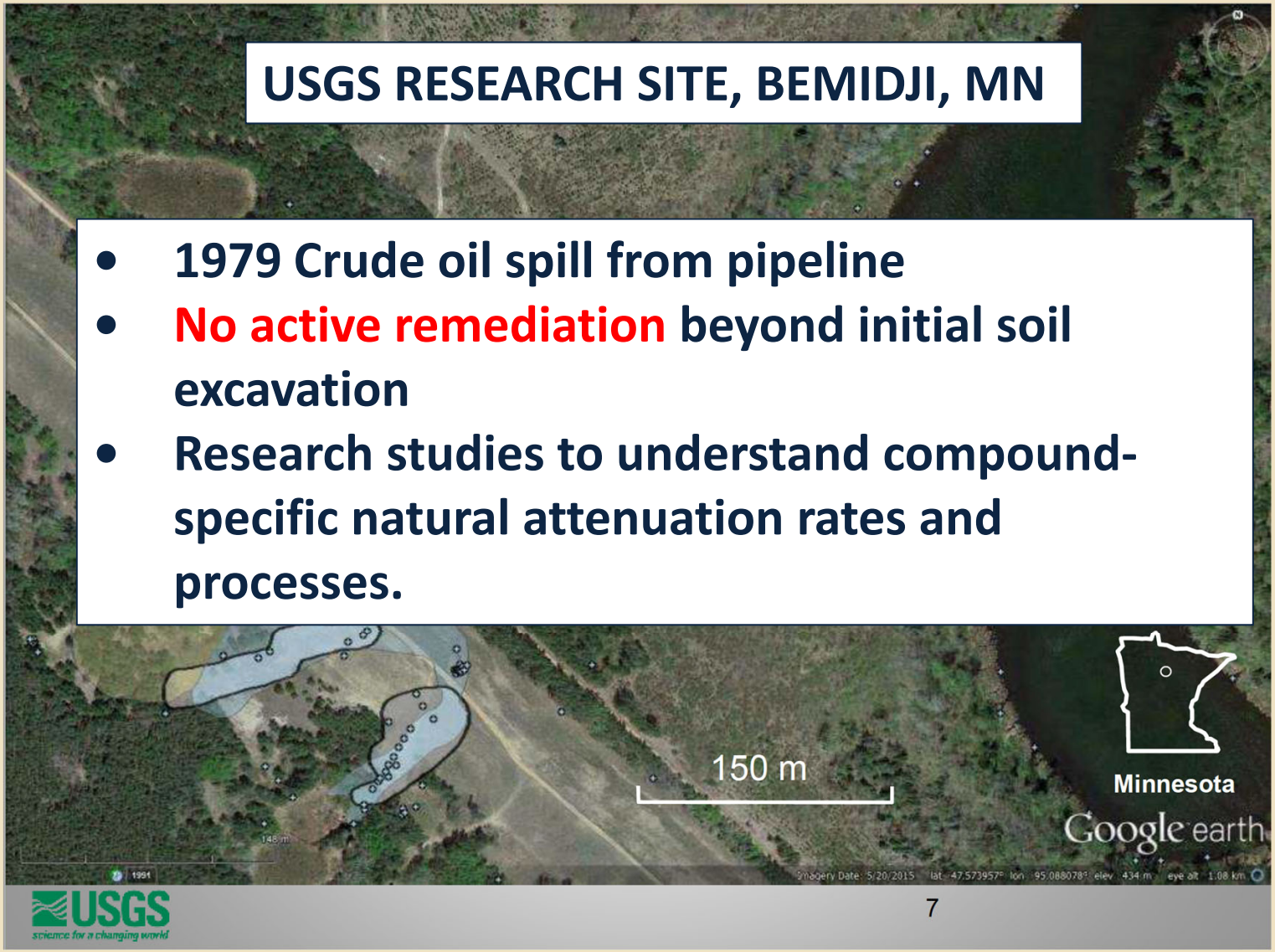
MTBE	97% Decrease
TOLUENE	98% Decrease
↓	↓
XYLENES	93% Decrease
↓	↓
BENZENE	87% Decrease
↓	↓
ETHYLBENZENE	76% Decrease
↓	↓
NAPHTHALENE	15% Decrease

REMEDIATION TECHNOLOGIES:

Conclusion: ***Observed Removal Ranking Does Not Correlate Well to Volatilization or Groundwater Extraction Technologies***



NATURAL ATTENUATION: BEMIDJI



From "Fate of Petroleum Hydrocarbons in Groundwater: Lessons for Hawaii and Red Hill from a Terrestrial Oil Spill Study" by Barbara Bekins, U.S.G.S., June 2018.

NATURAL ATTENUATION: BEMIDJI SITE B. BEKINS USGS

Attenuation of individual petroleum constituents over 30-yr period

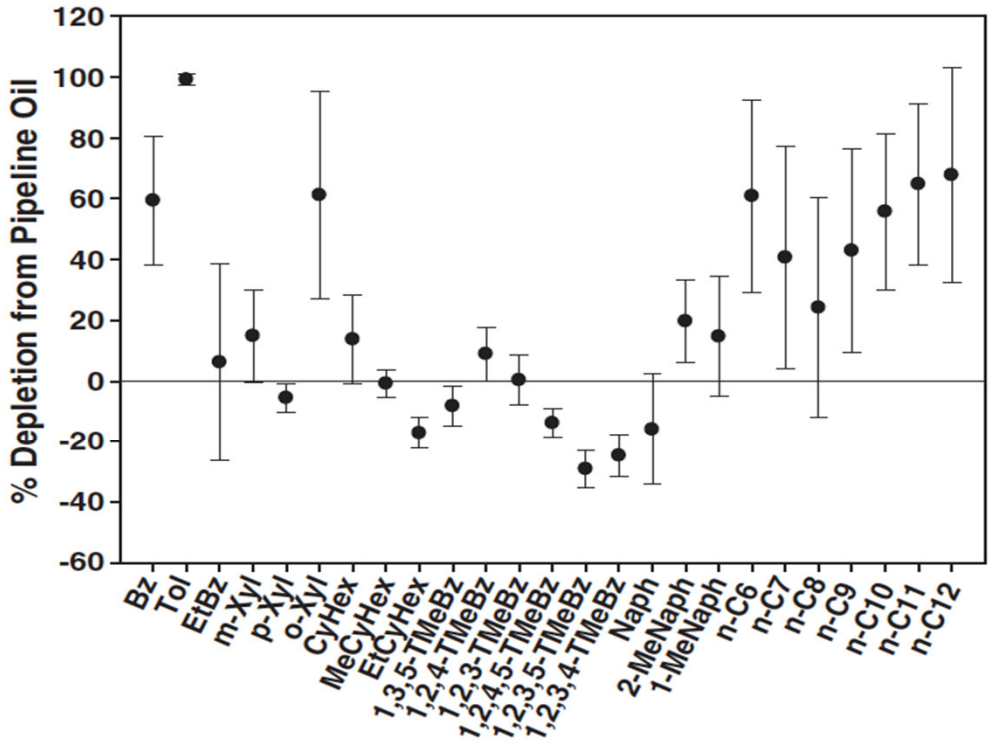


Fig. 7. Summed average % depletion and standard deviation for volatile hydrocarbons in 5 oil samples from the oil pool sampled in 2008 compared to the pipeline oil.

OBSERVED NATURAL ATTENUATION AT BEMIDJI (30 Years):

TOLUENE (99.8% - 100%)

↓

BENZENE (58 – 81%)
o-XYLENES (35 – 95%)

↓

ETHYLBENZENE (6 – 33%)
m,p-XYLENES (4 – 40%)

↓

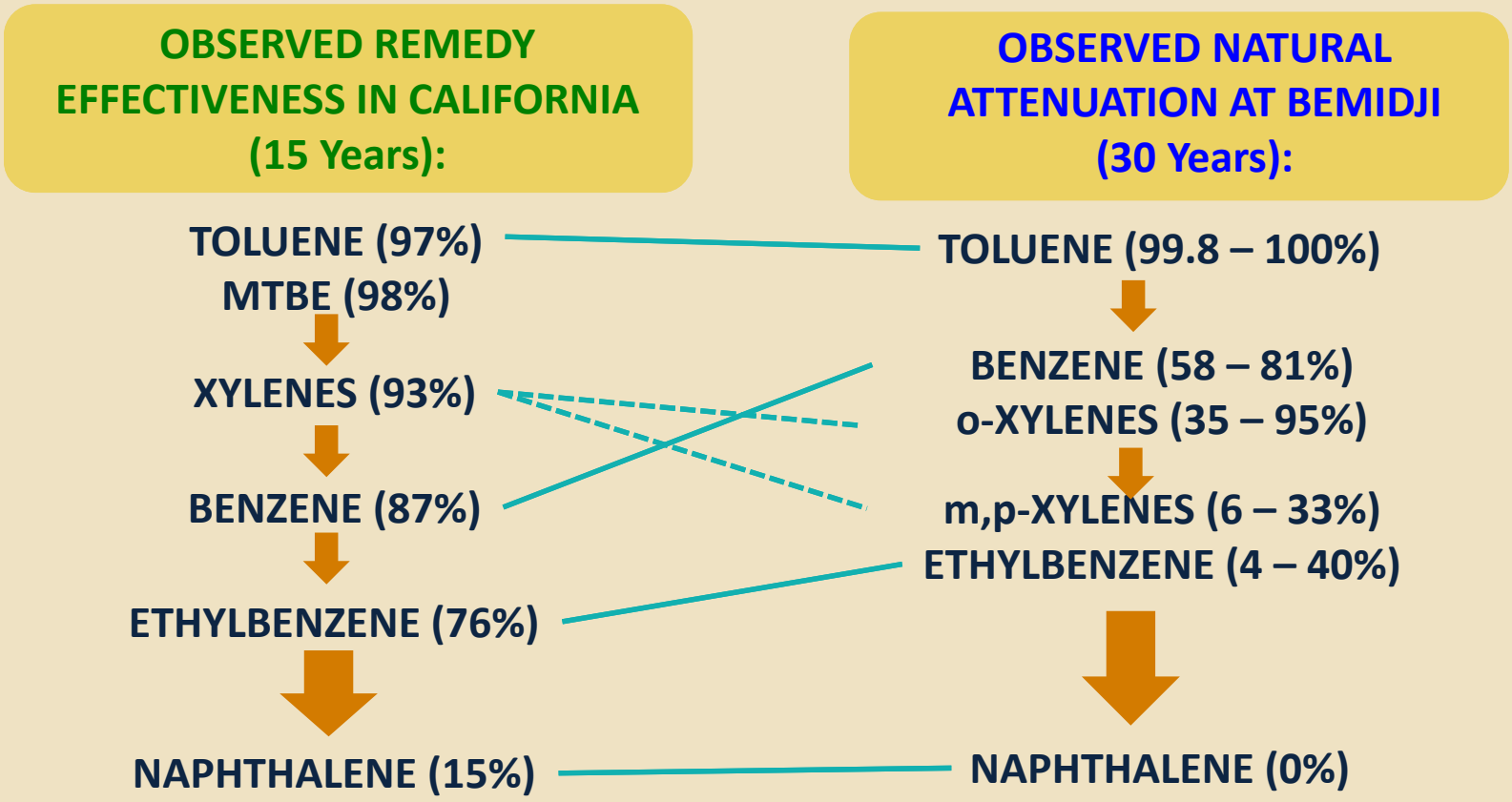
NAPHTHALENE (0%)

Chart from "Loss of volatile hydrocarbons from an LNAPL oil source", Journal of Contaminant Hydrology 126 (2011) 140–152, doi:10.1016/j.jconhyd.2011.06.006.
Individual constituent depletion percentages from Baedecker et al., "Weathering of Oil in a Surficial Aquifer" Groundwater (doi: 10.1111/gwat.12619).

REMEDIATION TECHNOLOGIES:

cjn note: take our Aronson column?

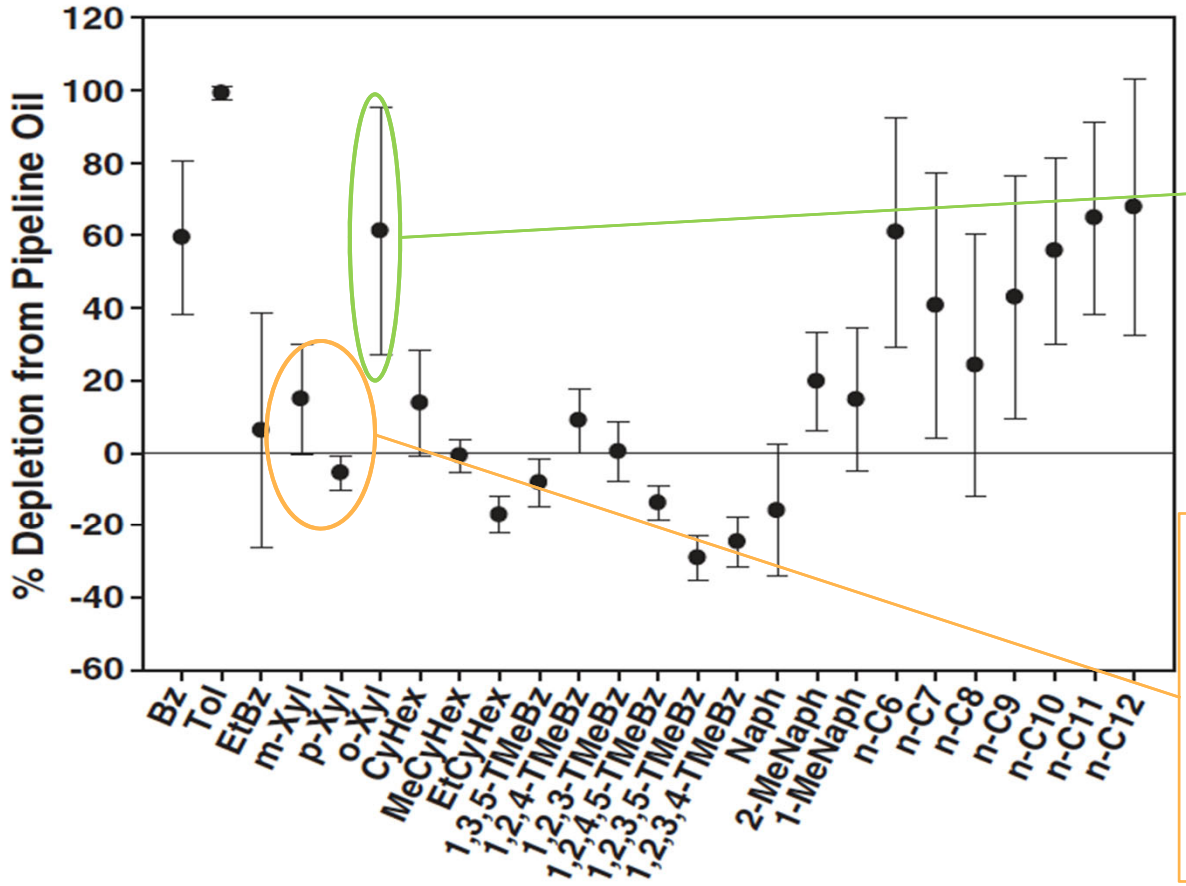
What Remediation Technology Might Explain the Observed Compound-Specific Remedy Effectiveness?



Pretty Similar, but does Xylene make sense?

Individual constituent depletion percentages for Bemidji site from Baedecker et al., "Weathering of Oil in a Surficial Aquifer" Groundwater (doi: 10.1111/gwat.12619).

O-XYLENE VS. M,P-XYLENES:
USGS BEMIDJI RESEARCH SITE



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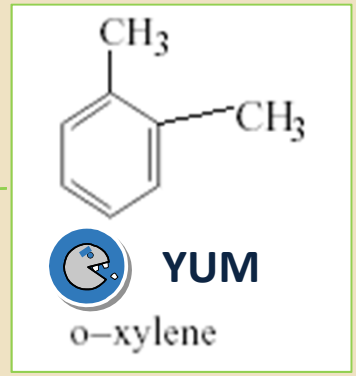

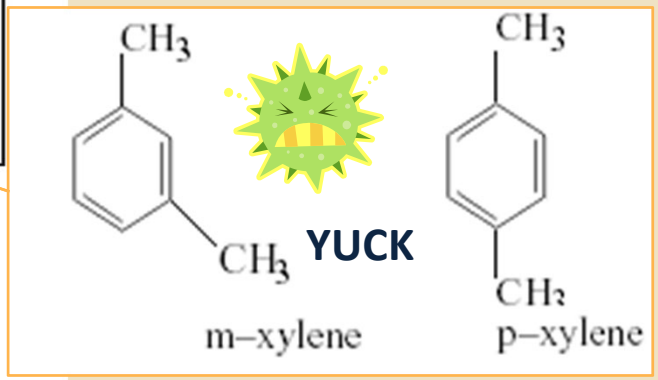

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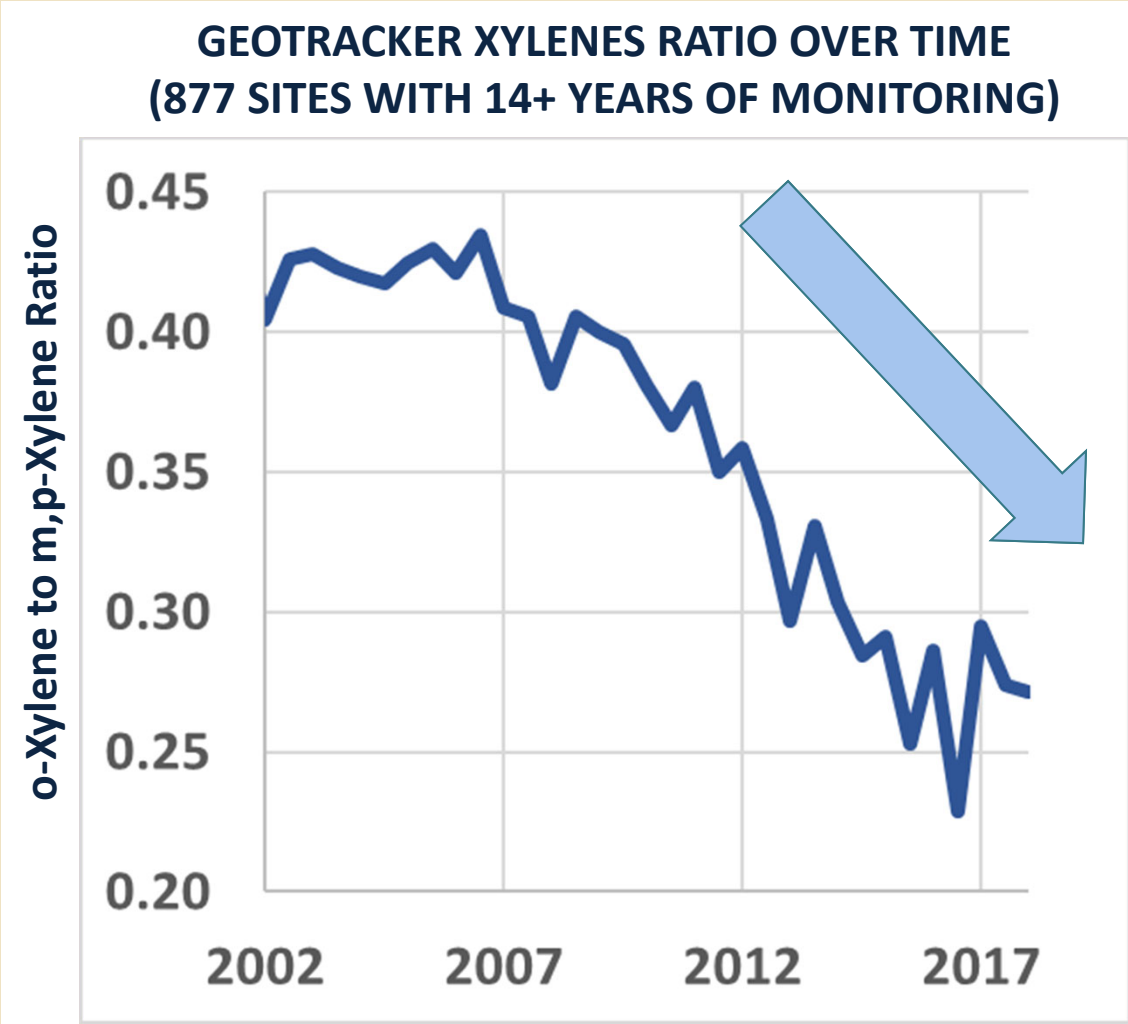
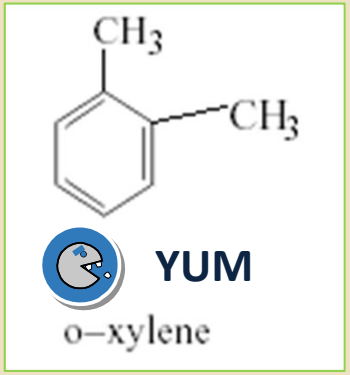
O-XYLENE VS. M,P-XYLENES: GEOTRACKER

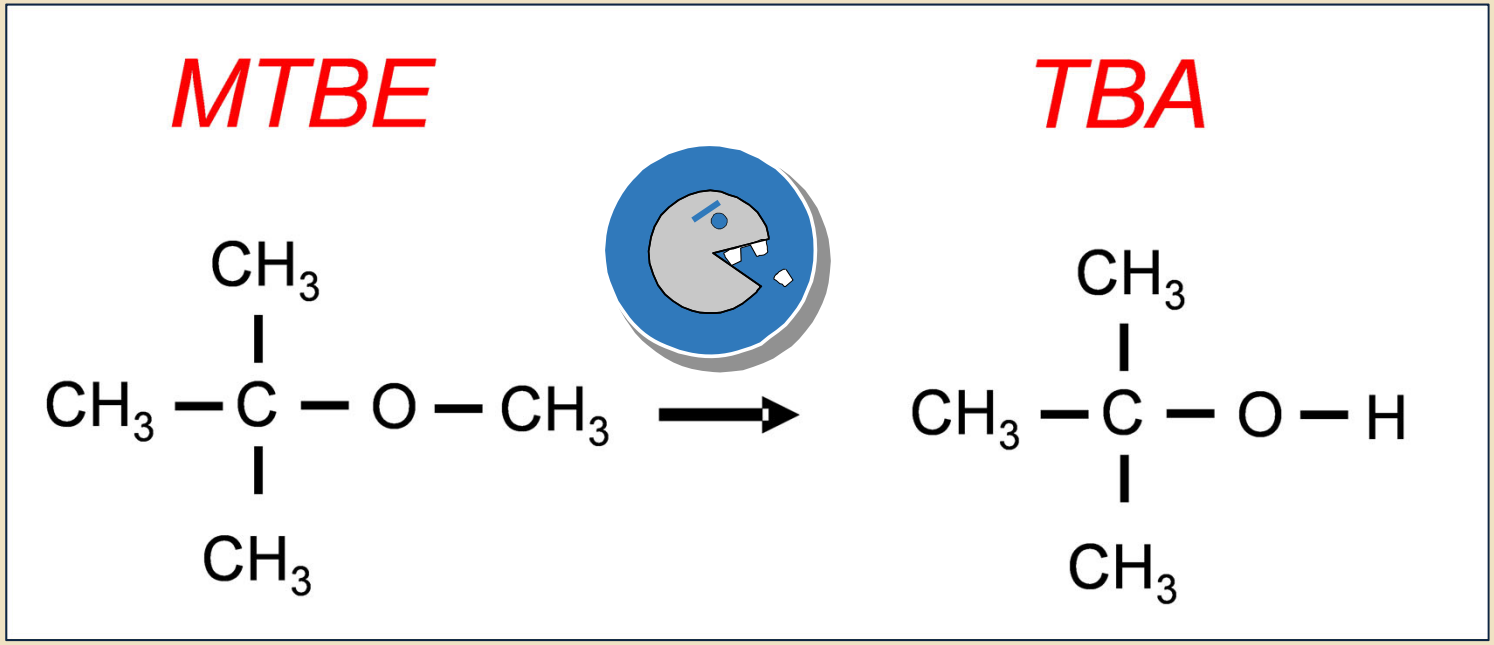


Decreasing ratio indicates faster attenuation of o-xylene compared with m,p-xylene:

Geotracker is consistent with Bemidji study: both say natural attenuation (not active remediation) is likely the key process

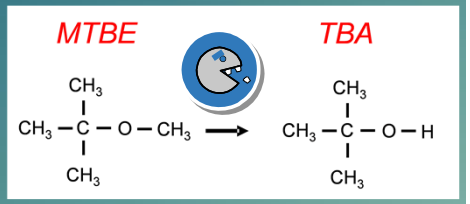


MTBE VS TBA:
GEOTRACKER



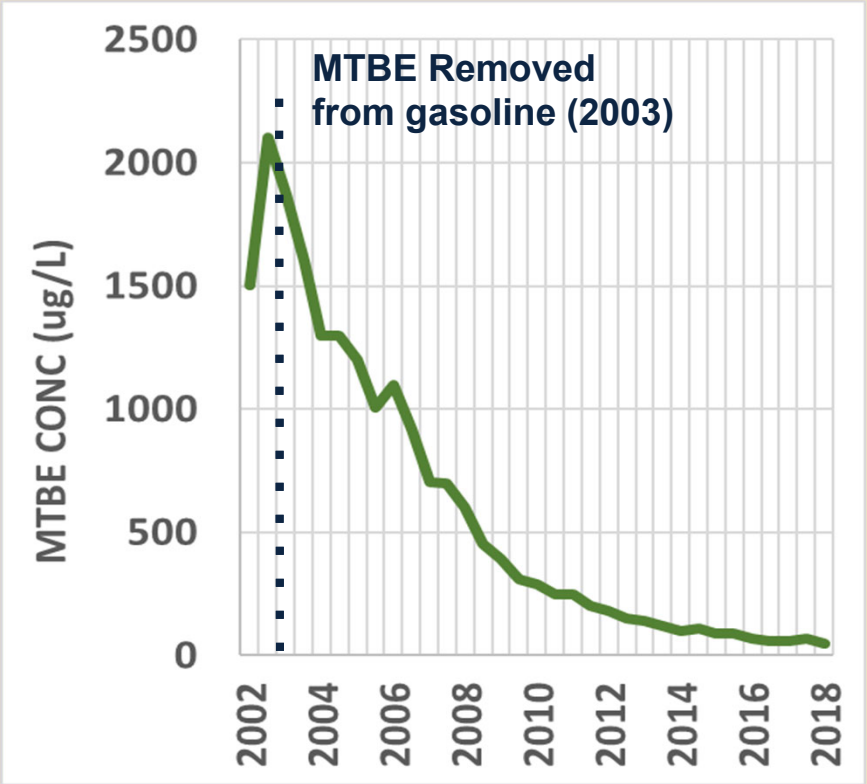
KEY POINT	**Anaerobic biodegradation of MTBE to TBA documented in lab and field sites.**

MTBE VS TBA:
GEOTRACKER

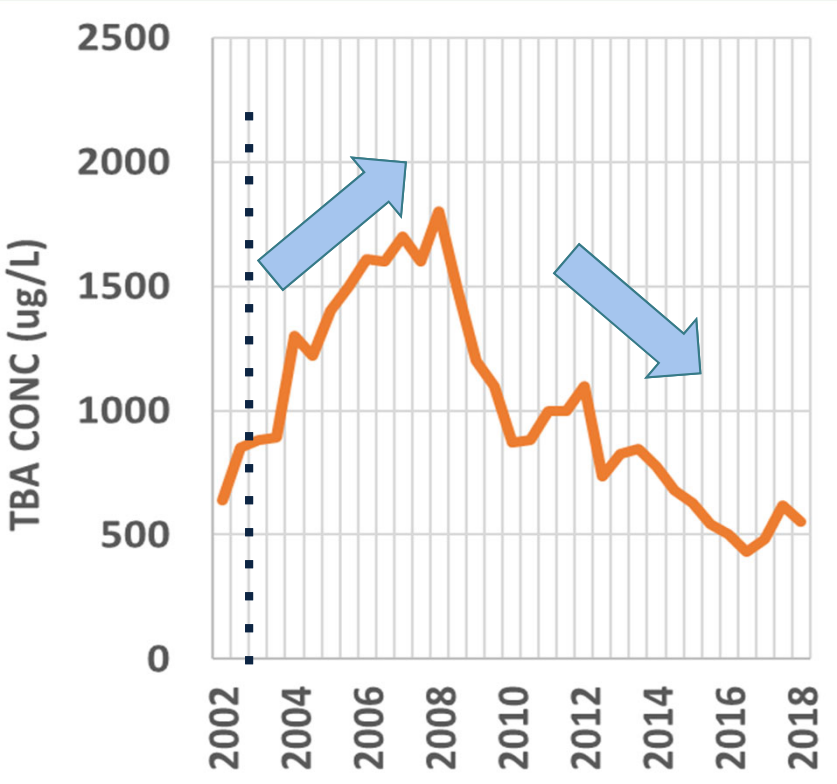


SITES WITH LONG MONITORING RECORDS - 14+ YEARS GW DATA (877 SITES)

MTBE CONCENTRATION



TBA CONCENTRATION



KEY POINT

MTBE / TBA trends consistent with faster biodegradation of MTBE followed by slower biodegradation of TBA (McHugh, 2013 doi: 10.1111/gwat.12136)

REMEDIATION TECHNOLOGIES:
KEY FINDINGS

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Active Remediation

- Applied at large majority of petroleum contaminated sites California

The differences in attenuation of petroleum constituents is NOT consistent with:

- Vapor-phase extraction (SVE, air sparge)
- Water-phase extraction (Pump and Treat, Dual Phase)

Natural Attenuation

- Occurs at 100% petroleum contaminated sites

GW concentration trends ARE consistent with natural attenuation as a primary mechanism mass removal

- Differences in attenuation rates
- o-xylene to m,p-xylene ratio
- MTBE and TBA concentration trends

ACKNOWLEDGEMENTS

STATE WATER RESOURCES CONTROL BOARD
GEOTRACKER

RESEARCH FUNDED, IN PART, BY SHELL GLOBAL SOLUTIONS (US) INC

Shell Global Solutions