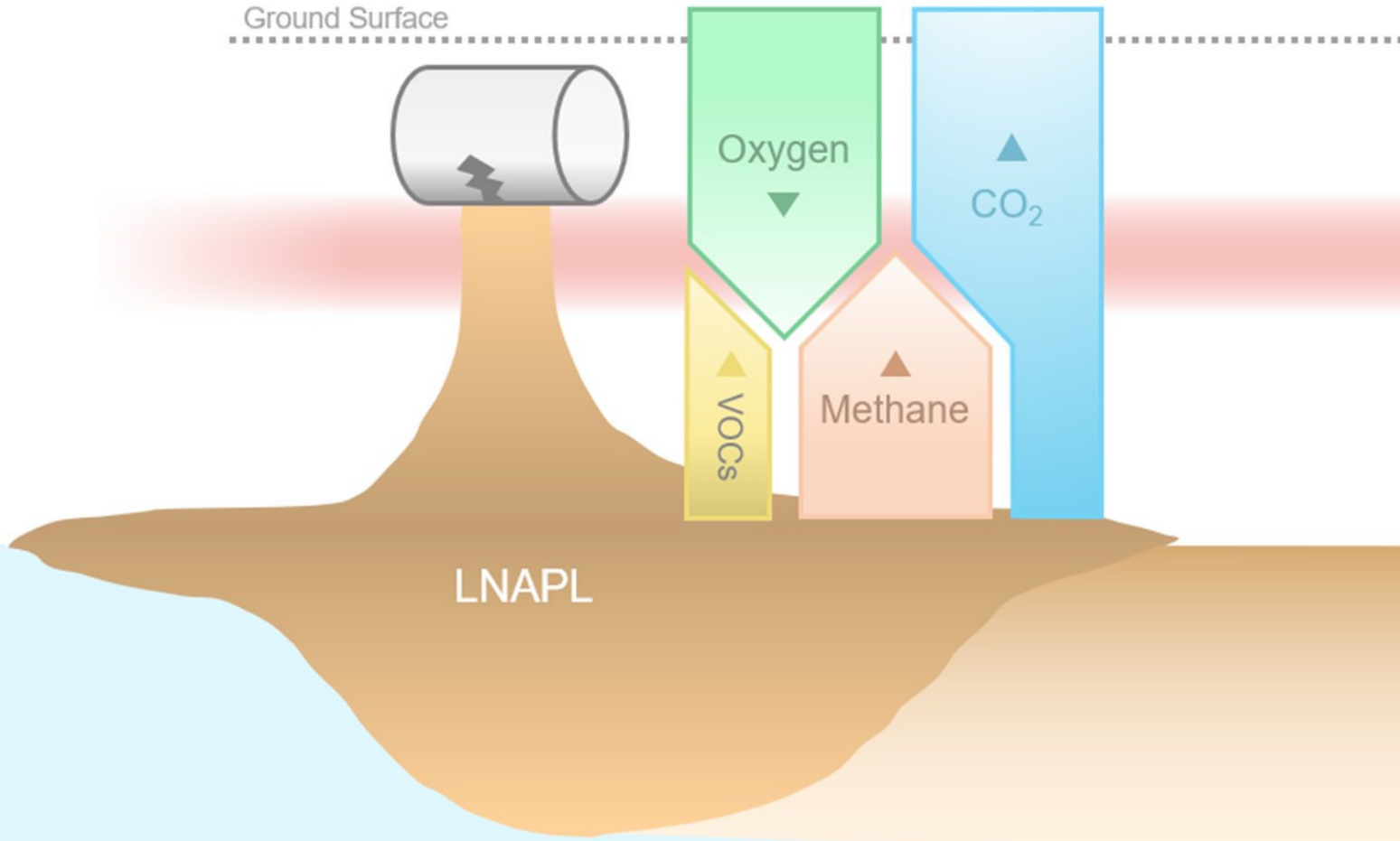
# Correcting Common Misperceptions about NSZD

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# Have you ever heard…

**“NSZD is just the latest ‘magic dust’”…**

**“NSZD is just MNA” …**

**“Those NSZD rates are too high to be true”**

# NSZD is just the latest ‘magic dust’

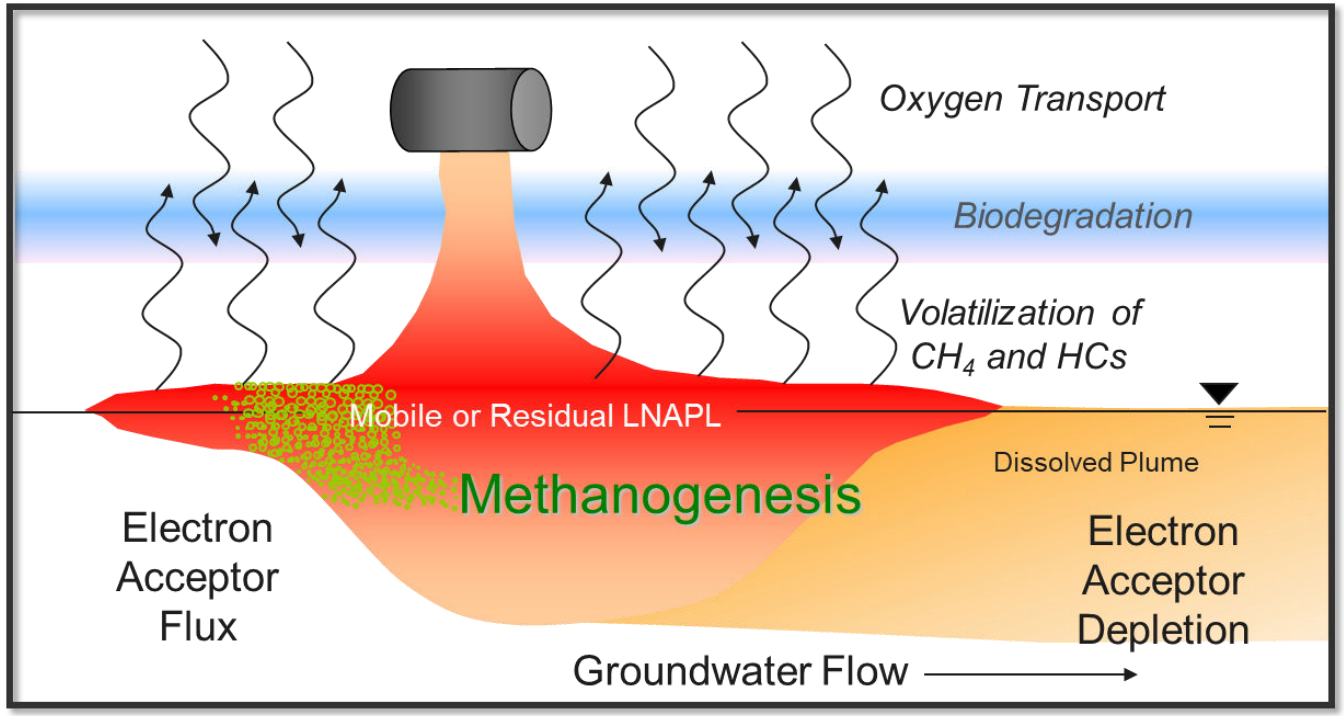
…right?

# NSZD is a well-understood set of processes with a solid scientific grounding

**What is a petroleum LNAPL body?**

- Water, NAPL, and vapors mixed together
- A surplus of organic carbon
- A relatively steady, controlled environment with naturally occurring bacteria present

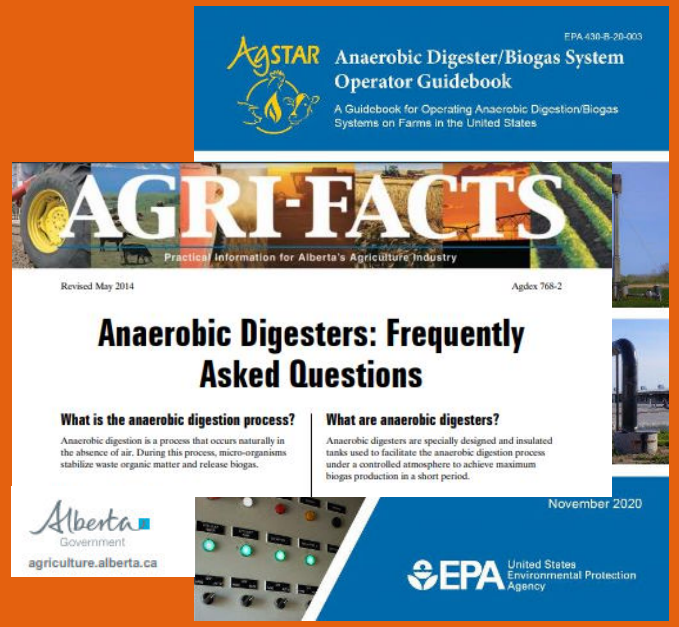
**In other words… a bioreactor**




Modified from ITRC, 2010 and Ririe, 2013

# Analogues to NSZD

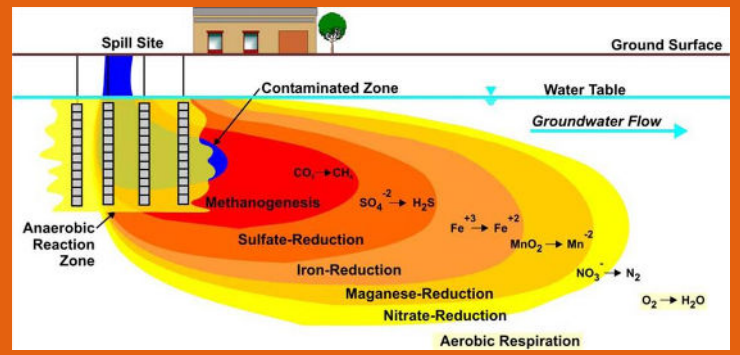
## Wastewater Treatment - Anaerobic Digestion




## Landfill Management


Landfill owners and operators collect landfill gas (LFG) for various reasons, including using LFG for energy, complying with local/state/federal regulations and controlling odors. Regardless of the motivation, owners and operators want to maximize the amount of LFG that is collected while minimizing the amount lost as fugitive or odorous emissions. In general, minimizing fugitive emissions and maximizing collection efficiency improves environmental benefits such as reducing hazardous and greenhouse gas (GHG) emissions and controlling odors and preventing them from migrating off site. Maximizing collection efficiency also improves economic return for LFG energy projects.

## Enhanced Reductive Dechlorination (EVO, Molasses, Lactate Injection)





These images reflect just a few of the established federal, provincial, and academic documents on these topics.

See **Garg et al. (2017)** for a thorough chronology and bibliography of our understanding of the underlying science.

# How do these analogues help?

- Confidence in site dynamics, site trajectory, and CSM
- Explanation for empirical observations
- Performance monitoring planning and interpretation
- Adding certainty and context can improve stakeholder acceptance of NSZD and reduce perceived unknowns

# Site Example

Rail yard in central US; diesel fuel NAPL body in central part of yard; stable, with no offsite impacts

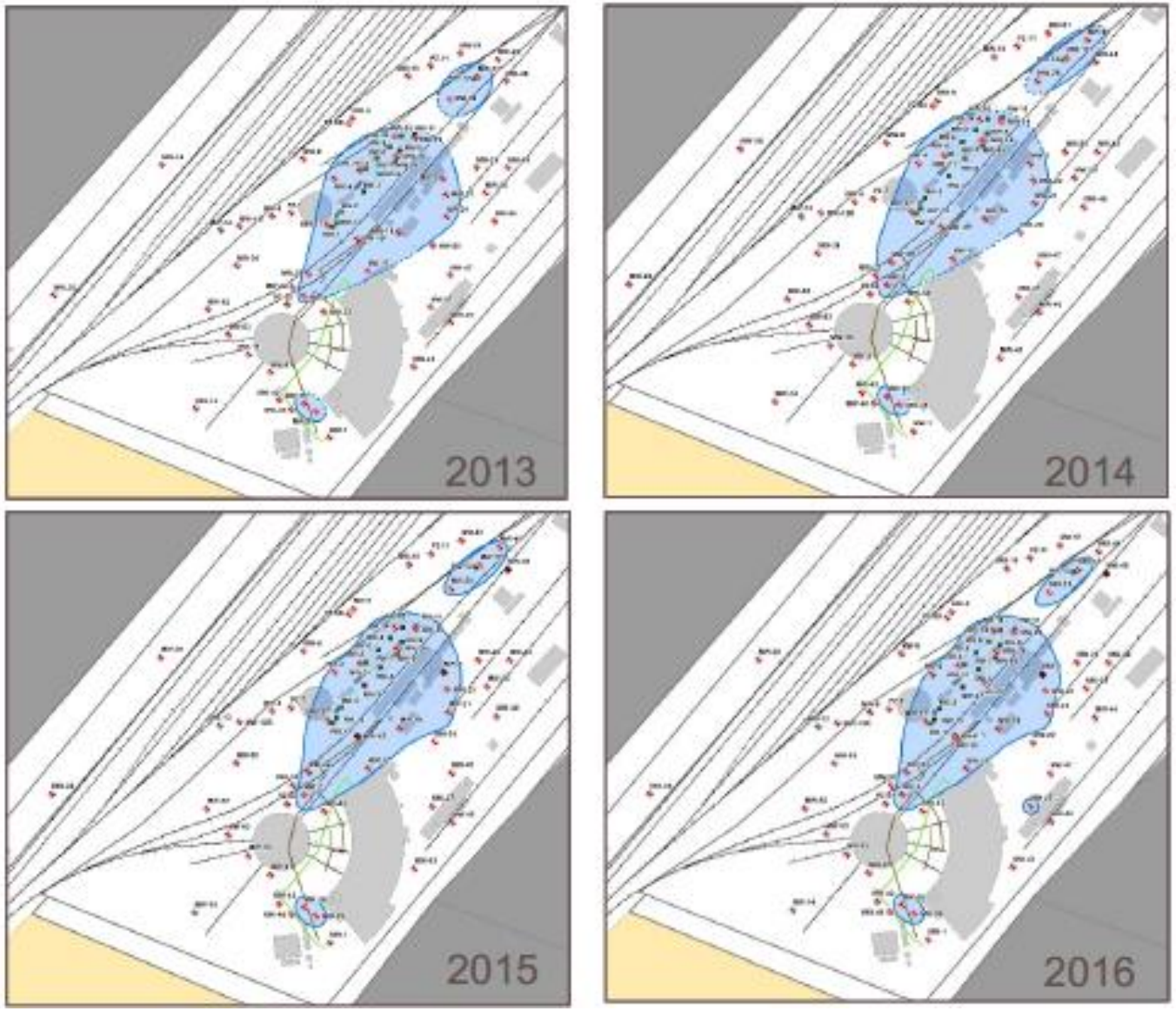
Series of NAPL remedial efforts

- Short-term vacuum extraction
- NAPL skimming to reasonable recovery endpoints
- Opportunistic excavation during construction

Then what?

**NSZD assessment post-excavation, combined with ongoing monitoring, showed significant degradation of remaining mass**

**NSZD was a key part of the 'treatment train' for this site, remedy transition, and overall site management.**



# NSZD is just MNA…

…right?

# NSZD relies on similar processes, but applies them to a different setting

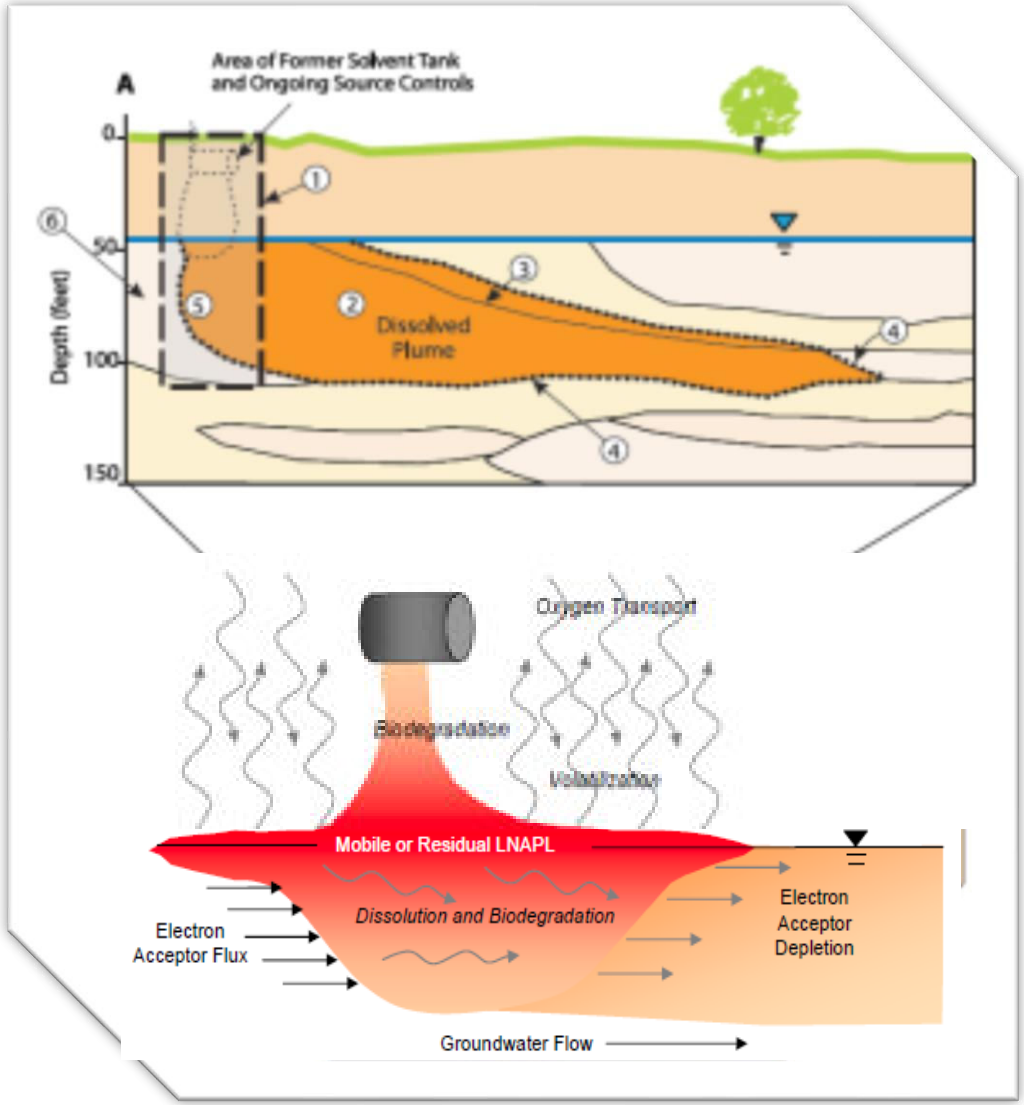
- Aerobic and anaerobic biodegradation
- Phase transfer and subsequent biodegradation
- Physical dispersion and redistribution

All of these are parts of natural attenuation and closely tied to concept of stability

NSZD recognizes a broader set of processes than traditional MNA

NSZD fills a different role in overall site management (for example, a weathered diesel fuel NAPL site with no appreciable dissolved-phase hydrocarbon plume)

**NSZD and MNA can work together for sites with appreciable dissolved-phase plumes**



# NSZD and MNA

## Natural Attenuation

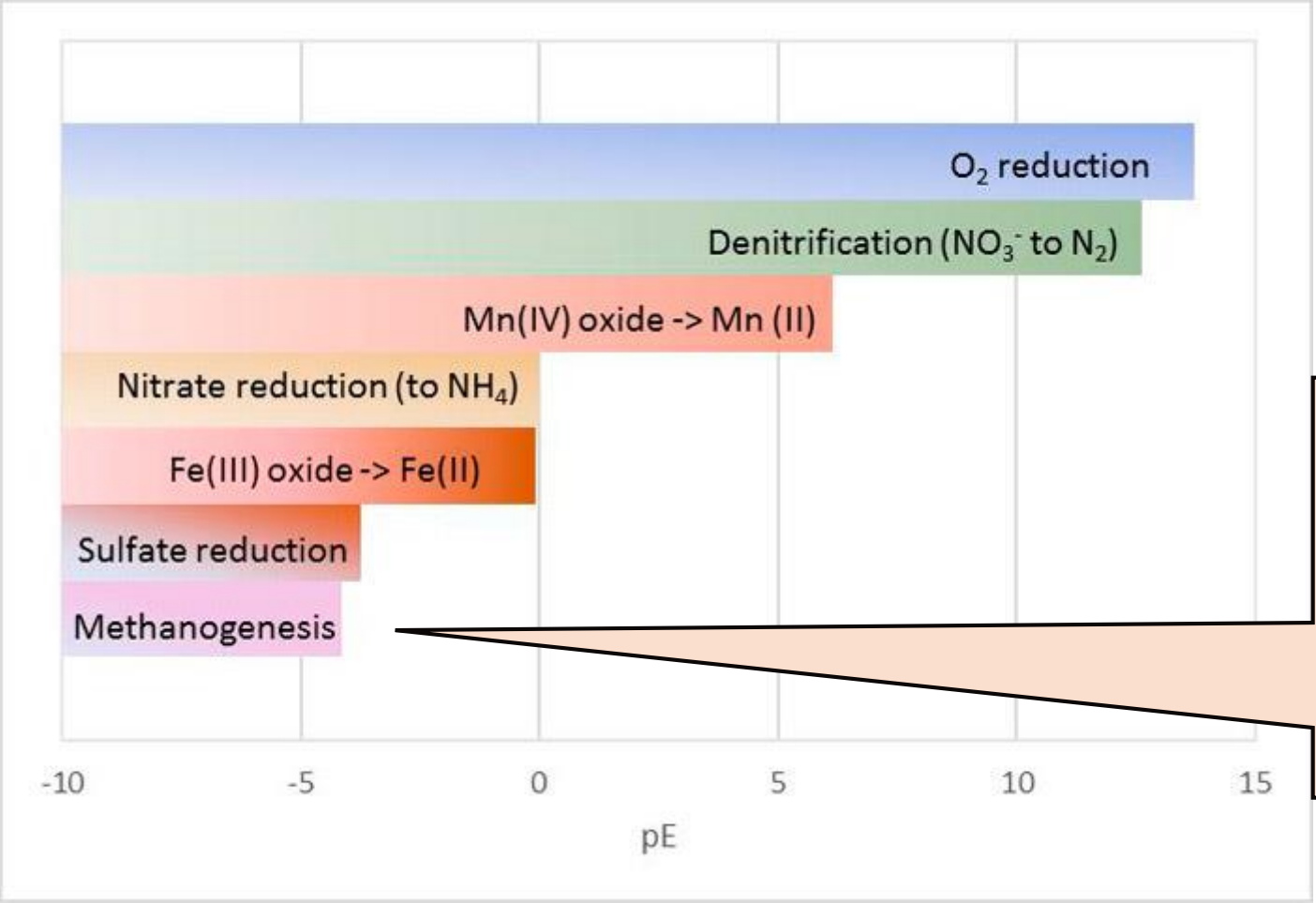
### MNA

- Focuses on **dissolved-phase** attenuation
- Focuses on incoming **terminal electron acceptor flux**
- Tracked and measured through concentration trends
- Defined regulatory management strategy with related guidance
- Often relies on assumption that source is removed

### NSZD

- Includes **dissolved-phase, vapor-phase, and NAPL-phase** attenuation
- **Methanogenesis** is a key process
- Measured through end products and expressions (heat, $CO_2$, etc.)
- Less formal guidance at the present
- Specific to source zones

# Dissolved-phase NSZD is a small part of the picture




Groundwater sampling for iron, sulfate, etc. can give **qualitative** indications of NSZD, but often captures only 1-10% of the actual NAPL degradation activity.

Methanogenesis has typically been thought of as the 'dregs' of biodegradation, when everything else more favorable is consumed. However, it makes up the bulk of natural hydrocarbon degradation at most sites.

**Those NSZD rates are too high – they can’t be true…**

**…right?**

# Typical NSZD Rates

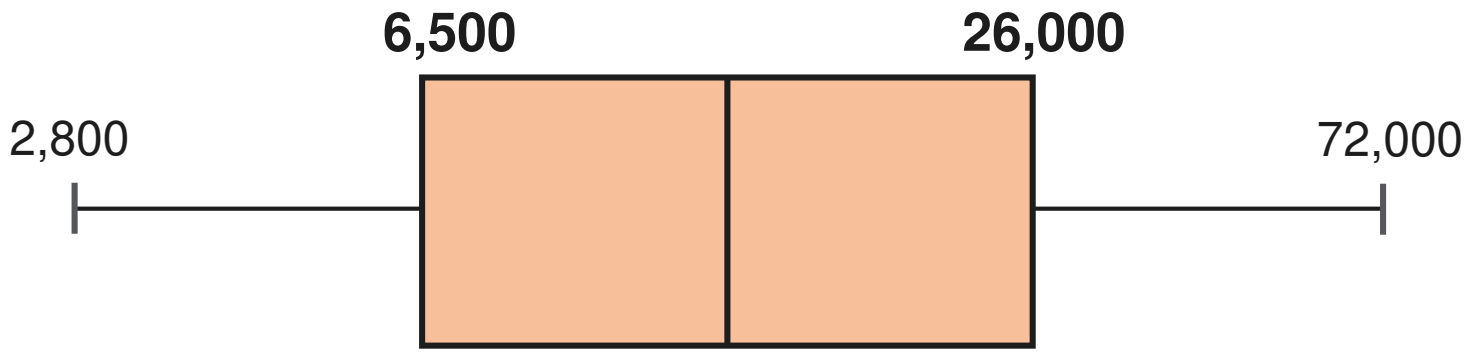
Garg et al. (2017) surveyed results from 25 sites

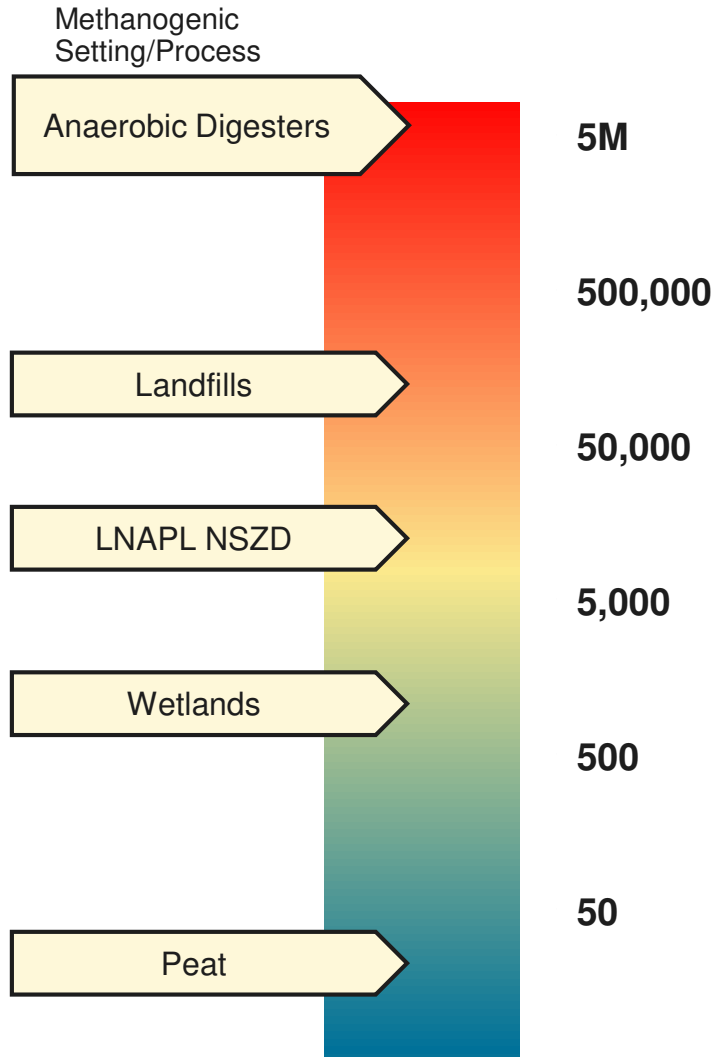
Middle 50% of sitewide rates ranged from **6,500 to 26,000** liters/hectare/year

Emerging understanding of average rates – on the order of 1,000 gallons/acre/year or 10,000 L/Ha/Yr

Tending to decrease rates….
Cold temps
Minimal mass
Acetate/pH issues

Tending to increase rates….
Warm temps
Thick smear zones



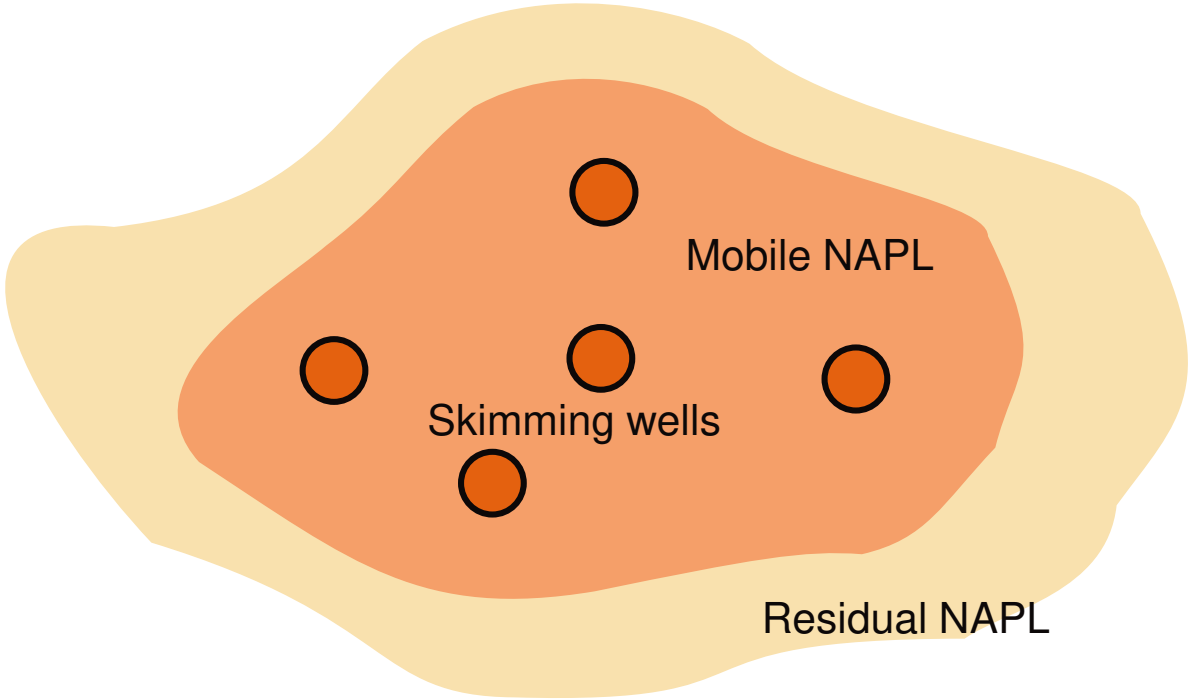

Based on Garg et al. 2017

# NSZD Rates in Context

Imagine a 1-hectare LNAPL body with a measured NSZD rate of 10,000 L/Ha/yr.

A system of five NAPL skimming wells is operating, but seeing declining returns. The system removes about 1,000 L/yr.

**Why is the NSZD rate far higher than our skimming rate? Is it realistic?**




NSZD acts on all the mass, including the residual NAPL around, above, below, and within the mobile NAPL zone.

NSZD is not subject to the limitations of permeability and hydraulics that typical pumping recovery technologies are.

# But what about…?

Early NSZD studies sometimes yielded very high rates – for example, up to the order of 100,000 L/Ha/yr.

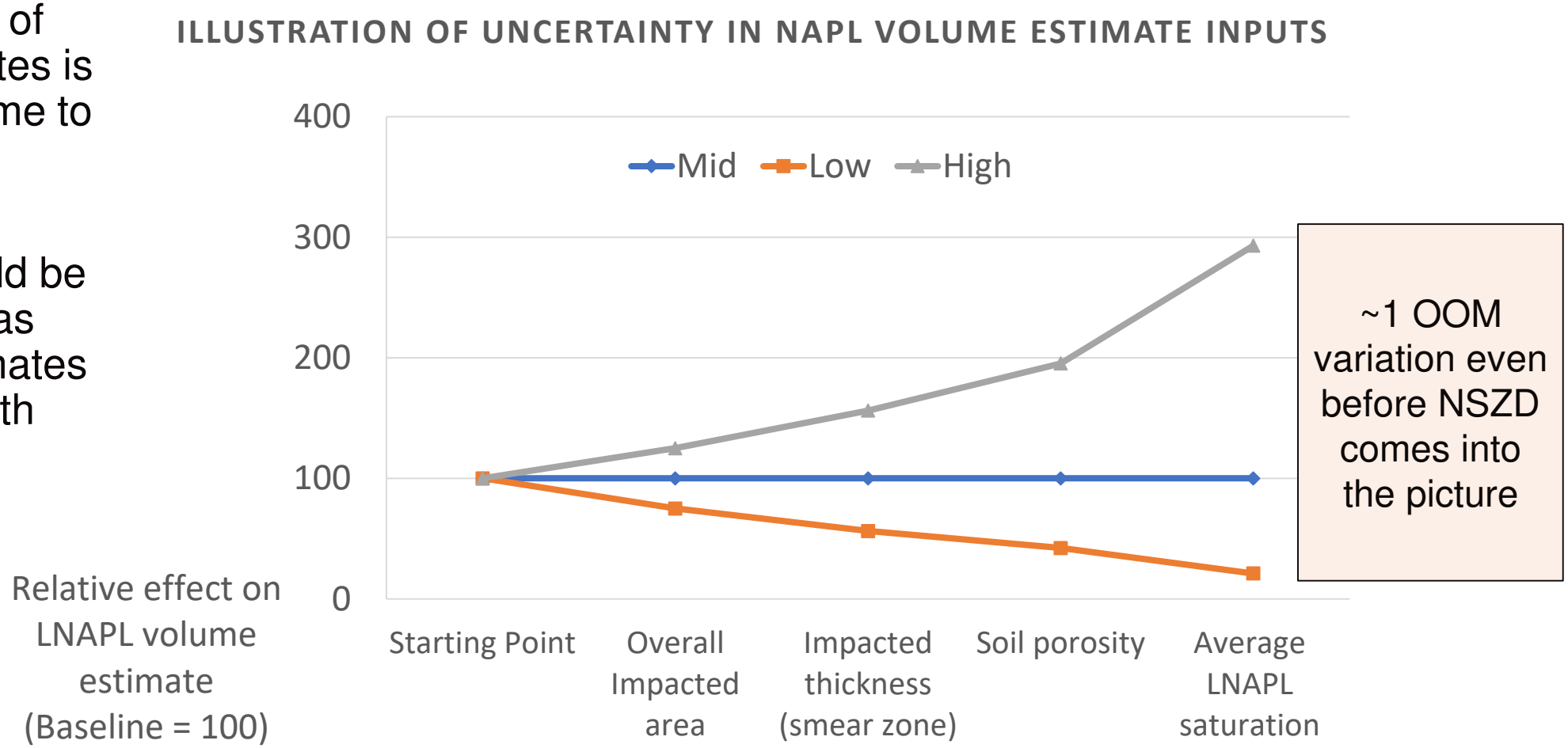
**What's changed since then?**

- Better understanding of background corrections
- Better understanding of potential interferences (chimney effect on soil gas flux)
- Better identification of outliers
- **Smaller and less complex sites coming into the data set**

# NSZD Rates and NAPL Mass/Volume Estimates

A natural extension of looking at NSZD rates is to predict a timeframe to deplete all NAPL.

However, this should be done with caution, as NAPL volume estimates and NSZD rates both entail significant uncertainty.



# Key Takeaways

- NSZD is a well-understood set of processes that draws on established knowledge of biodegradation
- NSZD is similar to MNA in some respects, but involves other processes outside of established MNA guidance, and occupies a different regulatory niche
- NSZD rates may seem high, but are reasonable when considering that NSZD acts on all NAPL mass – including residual mass that might not be traditionally thought of as NAPL
- Caution should be used when relating NSZD rates to remedial timeframes and volume estimates; the fluctuation of NSZD rates over time is an area of ongoing study

# Thank you!

## Questions and Discussion