Jacobs

Challenging today.
Reinventing tomorrow.

Using NSZD in the Development of Sustainable NAPL Remediation Strategies at Active Oil and Gas Facilities

Andrea Hachkowski, P.Eng.

Tom Palaia, P.Eng.

13 October 2021

Remediation Technologies Symposium 2021

Agenda

1 NSZD Overview

2 How can NSZD measurements be used in different stages of a project?

3 How does NSZD fit into a remediation/ risk management framework?

Introduction

What is NSZD?

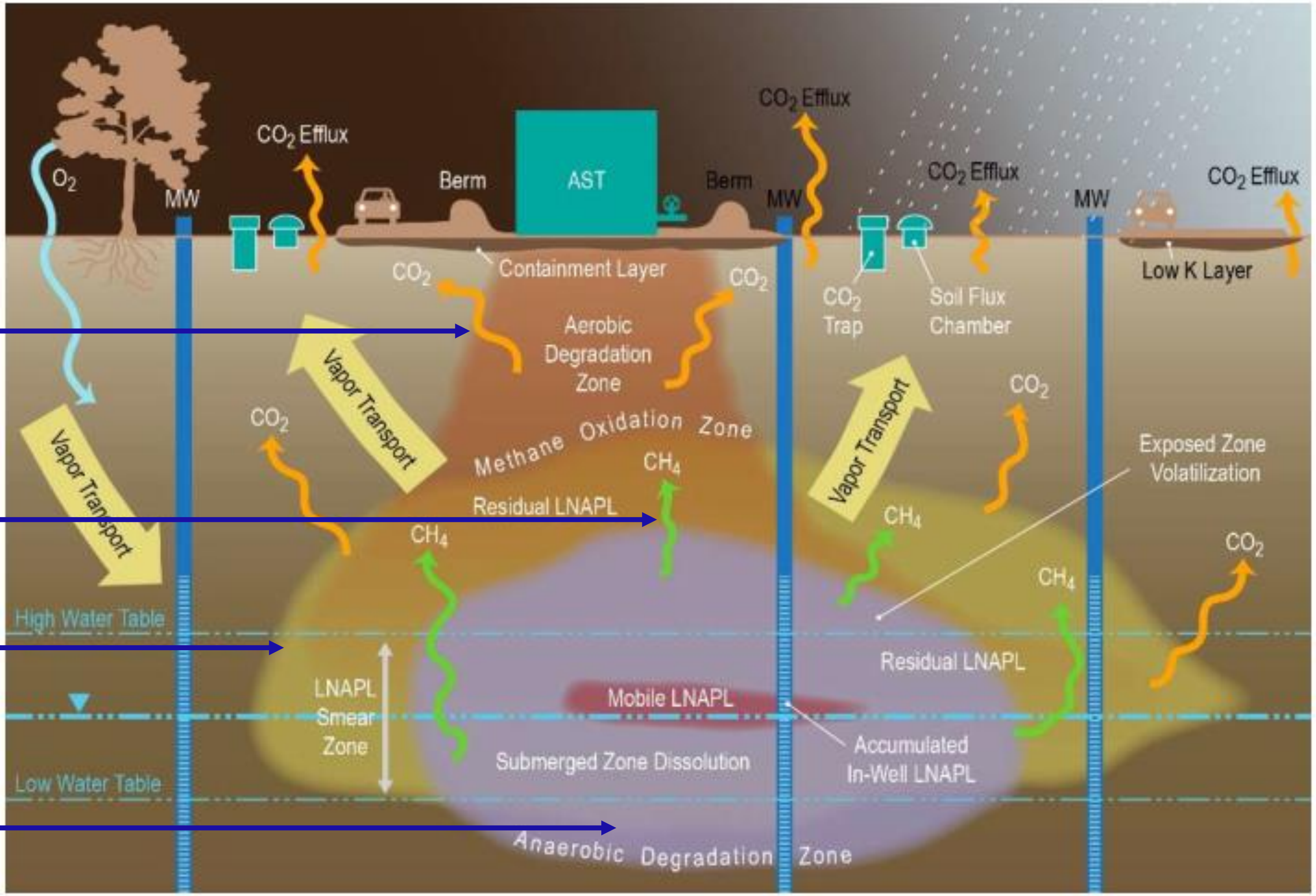
The cumulative effect of the natural processes – volatilization, dissolution, sorption, biodegradation – on the depletion of NAPL bodies.

Zone 1 – soil respiration
Organic carbon + $O_2 \rightarrow CO_2$

Zone 2 – methane oxidation
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Zone 3 – methanogenesis
Hydrocarbons + $H_2O \rightarrow CO_2 + CH_4$

Zone 4
Hydrocarbon + electron acceptor
(NO_3^-, Fe^{3+}, SO_4^{2-})→ CO_2



Why NSZD?

- We have always known that petroleum hydrocarbons degrade via aerobic and anaerobic processes
- Historically, discussion on biodegradation has focused on the lower saturated zone, where the electron exchange happens.
  - We now know the importance of methanogenesis in the degradation of LNAPL in the smear zone and vadose zone
  - We also now have ways of measuring CO_2 efflux through the vadose zone

Using NSZD Measurements through the Project Life-Cycle

Site Investigation

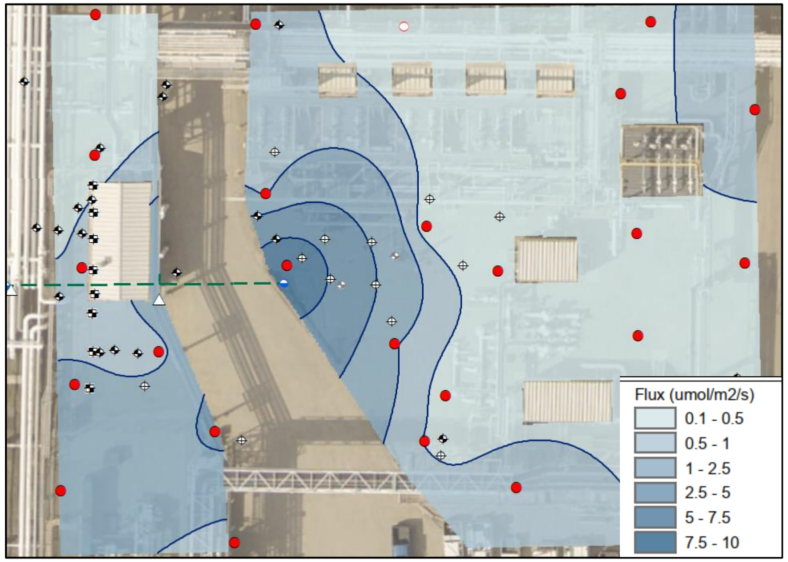
Problem:

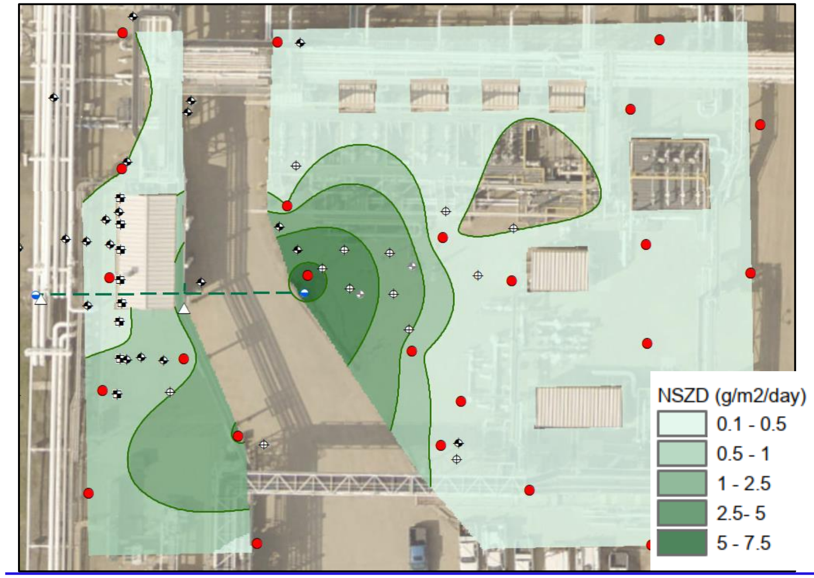
- Active facilities present several impediments to "traditional" plume investigation.
  - Increased health and safety requirements
  - Ground disturbance protocol
  - Access agreements
- The typical workaround is soil sampling in hydrovac holes and installation of an (over)abundance of monitoring wells.

Solution:

- CO_2 efflux can be used to delineate LNAPL plumes, minimizing borehole and optimizing monitoring well installation locations. It is also cost effective.

Investigation Results – Site 1

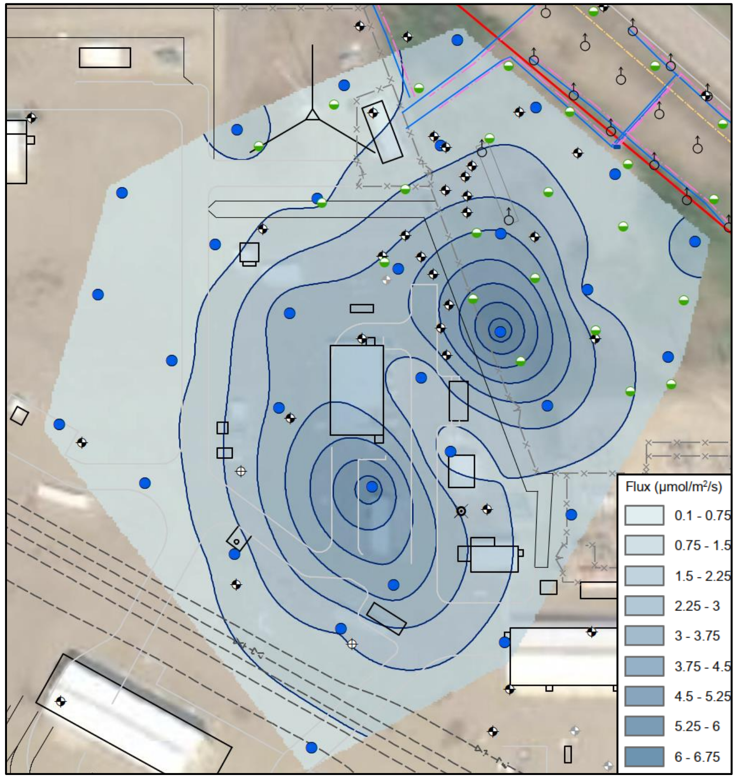


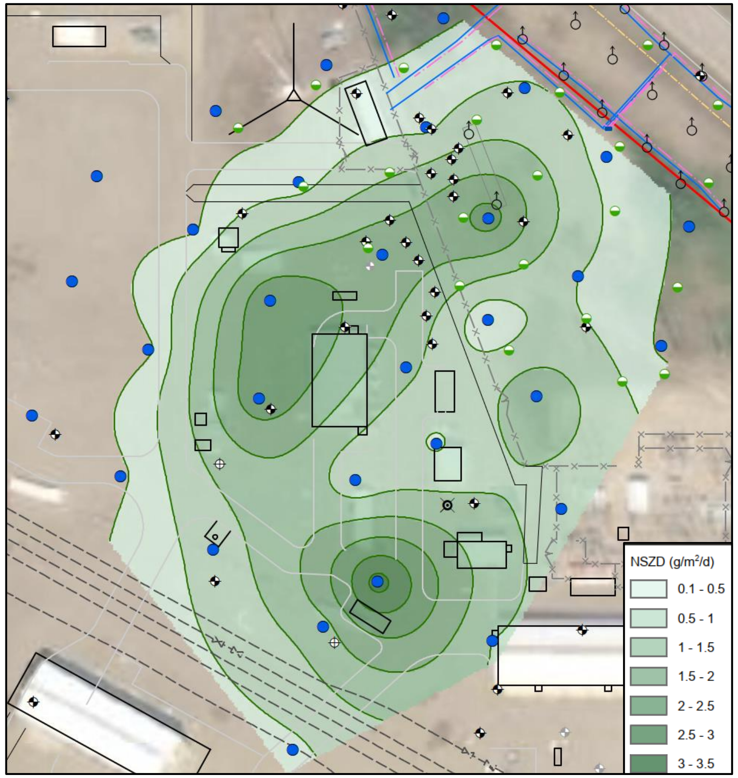


- Active facility, mixed LNAPL plume – multiple product leak based on chromatograms
- Soil type – heterogeneous; primarily silty sand
- Scope - 22 LI-COR survey points, 5 field days
- Estimated site-wide NSZD rate ~200 kg/y
- Understanding of LNAPL distribution and longevity gained and NSZD rates can be used to address plume stability/mobility and risk in CSM.
- Overall cost ~$40,000

Investigation Results – Site 2

- Active facility, laser-induced fluorescence survey confirmed medium crude source (unknown location)
- Soil type – sand/silty sand
- Scope – 31 LI-COR survey points
- 7 field days
- Estimated site-wide NSZD rate = 5,400 to 9,500 kg/yr
- Overall cost ~$53,000





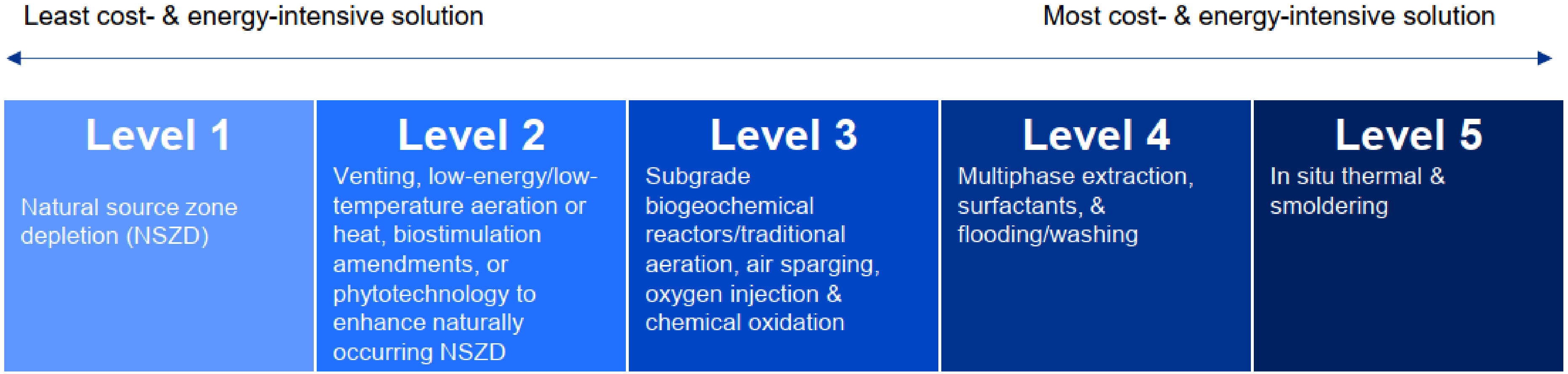
Site Conditions Conducive to CO_2 Efflux Monitoring and NSZD Evaluation

- All soil types
- All petroleum hydrocarbon types
- Limiting factors:
  - Soil moisture – too wet limits gas diffusion
  - Temperature – rates are normally highest in the fall. Microbial activity slows near 0 °C, and the upper tolerance for microbes is ~ 35 °C.
  - Meteorological conditions – barometric conditions and wind can affect gas emission at ground surface

Using NSZD in Remediation Decision-Making

Remedial Options Analysis

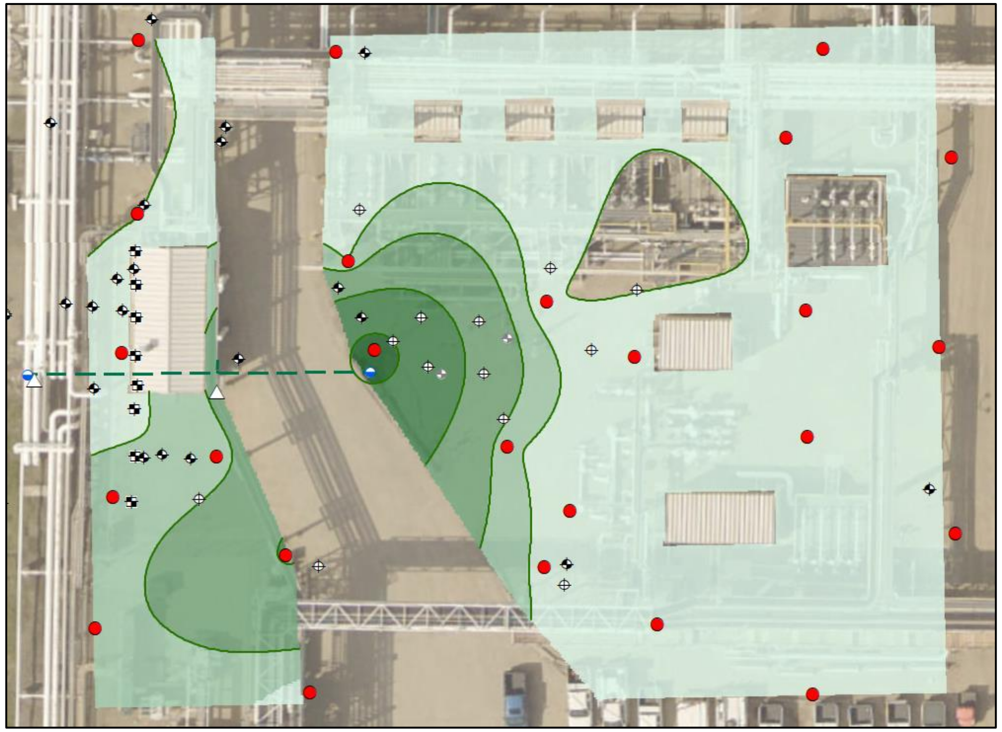
- NSZD rates serve as the basis for comparison for the evaluation of proposed remedial options
  - LNAPL mass loss rates for mechanical remediation methods must exceed NSZD rates by a factor that justifies the expenditure
  - From a practical standpoint, mechanical remediation is only necessary if NSZD does not adequately manage risk (because the timeline for NSZD is inherently long).



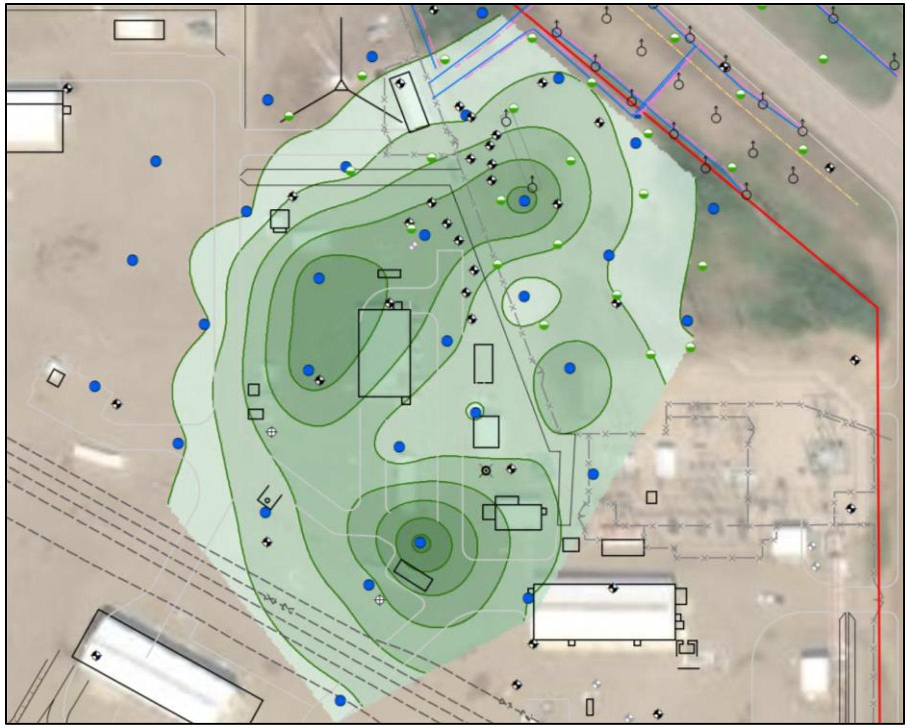
Preference tends towards lower levels when technology meets regulatory needs.

- NSZD can either be the sole remedial technology or a transition technology

Mechanical Remediation Rates vs. NSZD Rates

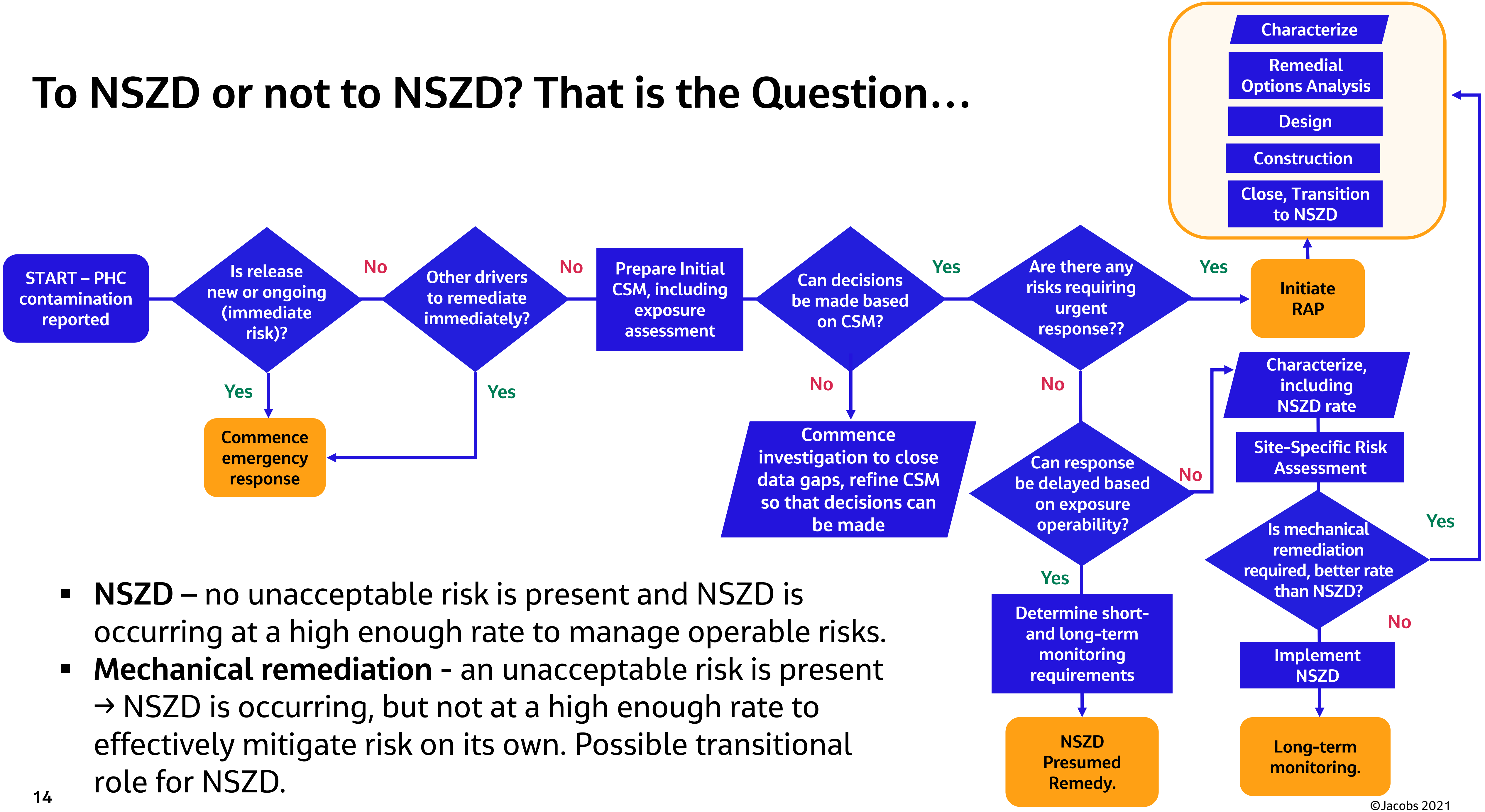


- Site-Wide NSZD Rate = 200 kg/y
- Groundwater extraction/treatment pilot test = 200 to 400 kg/y



- Site-Wide NSZD Rate = 5,400 to 9,500 kg/y
- MPE = 9000 kg recovered over 9 years of operation; 80% of that recovered in the first 3 years of operation → ~2,400 kg/y Year 1 to 3, ~300 kg/y thereafter.

To NSZD or not to NSZD? That is the Question…



- **NSZD** – no unacceptable risk is present and NSZD is occurring at a high enough rate to manage operable risks.
- **Mechanical remediation** - an unacceptable risk is present → NSZD is occurring, but not at a high enough rate to effectively mitigate risk on its own. Possible transitional role for NSZD.

Key Points

- CO_2 efflux surveys can be effectively used to delineate the source and extent of LNAPL plumes, critical to development of a preliminary CSM.
- NSZD rates can be used as the basis for evaluating the effectiveness of various remedial methods during options analysis.
- When combined with risk assessment, NSZD can be an important part of practical management strategies, with mechanical remediation only applied when risks are unacceptable.

Copyright Notice

Challenging today.
Reinventing tomorrow.