DESIGNING FOR GROUNDWATER CONTAMINANT MITIGATION AS THE CLIMATE CHANGES

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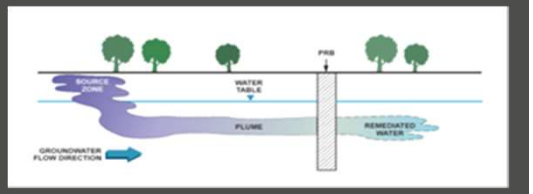
Ramboll

RemTech Expo 2020

22 September 2020



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International event on Remediation, Coasts, Floods, Climate, Seismic, Regeneration, Industry
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digital edition

HONOURING CARETAKERS OF THE LAND

We acknowledge the Traditional Custodians of the land in which we reside and pay our respect to Elders past, present and emerging.

We extend this acknowledgement to the Awabakal people of the land in which the Callaghan campus resides and which we work.

We extend this acknowledgement to the Miwok people of the land in coastal Northern California in which the lead author resides and works.

Organization for Today's Discussion

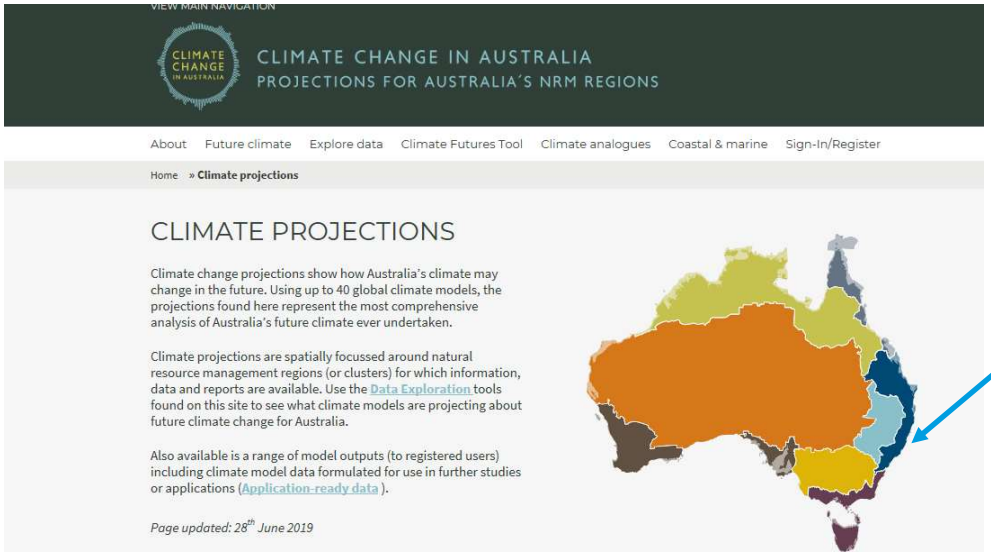
- **Why this Topic / What is Different**
- **Sustainability & Resiliency => Adaptive Capacity & Durability for Groundwater Treatment Remedies**
- **Effect of Changing Climate on Remedy**
- **Coping and Closing**

Background:

Marin County, California USA after record rains, March 2019

Inset: Air quality degradation Northern California Wildfires, September 2020

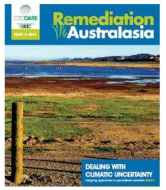
CLIMATE CHANGE FOR AUSTRALIA - PREDICTION FOR EASTERN AUSTRALIA



- Ave Temp increase (*very high confidence*).
- Ave winter and spring rainfall decrease (*medium confidence)*.
- Increased intensity of extreme rainfall events is projected (*high confidence)*.
- *Natural variability in the climate system can either mask or enhance the long-term human induced trend, particularly in the next 20 years.*
- *Sea level rise will continue with increased extreme sea-rise events*

https://www.climatechangeinaustralia.gov.au/en/climate-projections/

AND IN THE UNITED STATES…



ENGLISH 中文 (CHINESE) ESPAÑOL

The New York Times

Tuesday, February 6, 2018 | Today's Paper | Video | 77°F | Shanghai -3.35%

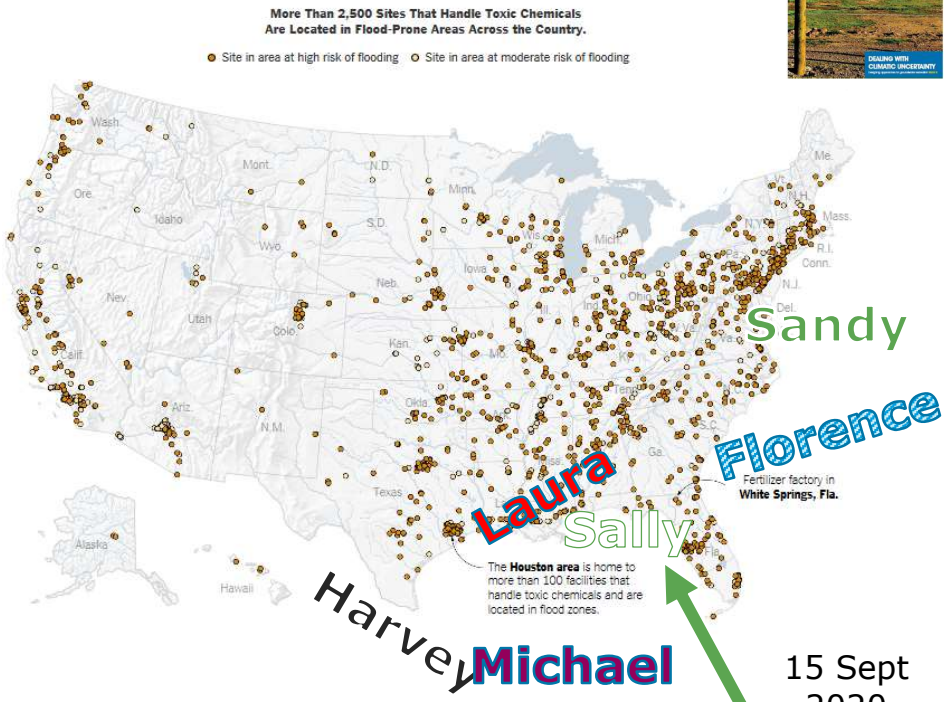
Floods Are Getting Worse, and 2,500 Chemical Sites Lie in the Water's Path

By HIROKO TABUCHI, NADJA POPOVICH, BLACKI MIGLIOZZI and ANDREW W. LEHREN FEB. 6, 2018

Anchored in flood-prone areas in every American state are more than 2,500 sites that handle toxic chemicals, a New York Times analysis of federal floodplain and industrial data shows. About 1,400 are located in areas at highest risk of flooding.

As flood danger grows — the consequence of a warming climate — the risk is that there will be more toxic spills like the one that struck Baytown, Tex., where Hurricane Harvey swamped a chemicals plant, releasing lye. Or like the ones at a Florida fertilizer plant that leaked phosphoric acid and an Ohio refinery that released benzene.

Source: NYT, February 6, 2018



15 Sept 2020

CLIMATE CHANGE AND THE CONCEPTUAL SITE MODEL (CSM)
WE ARE IN THE ANTHROPOCENE - ANTHROECOVERSE

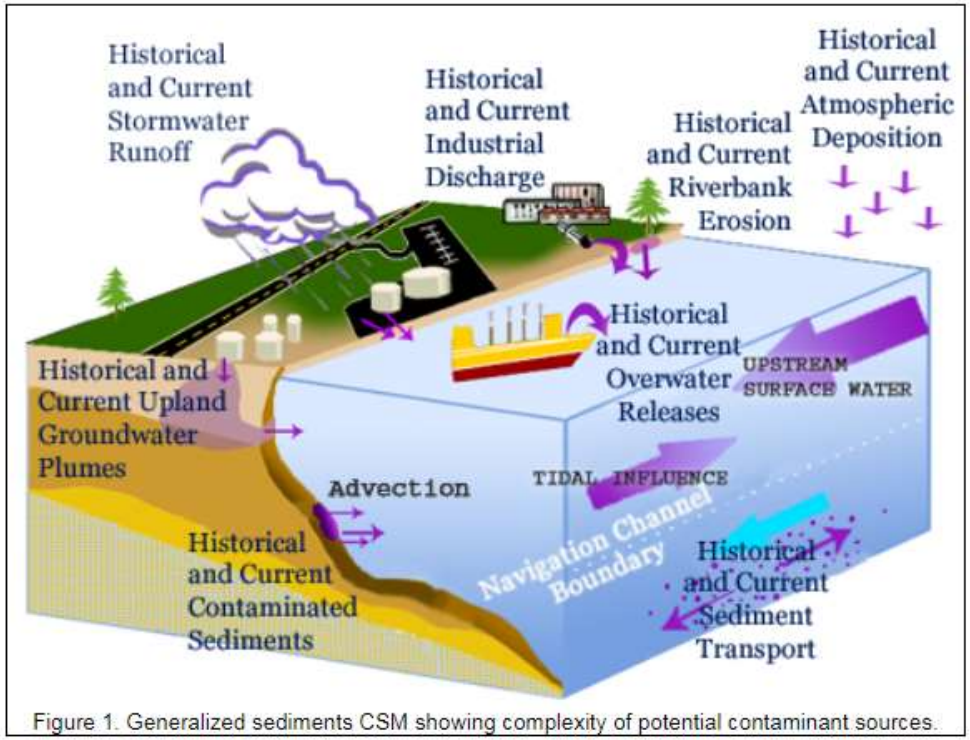
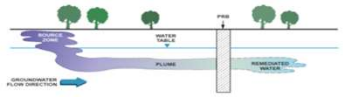


Figure 1. Generalized sediments CSM showing complexity of potential contaminant sources.

https://clu-in.org/contaminantfocus/default.focus/sec/Sediments/cat/Conceptual_Site_Models/



CSM – the Anthro-CSM

(anthrohydrology, -biology, -geochem)

Considerations on Remedy

Extreme (acute) recharge and long-term(chronic) increase/decrease in recharge impacts to aquifer hydraulics and ecology:

Groundwater (and surface water) quality effects during:

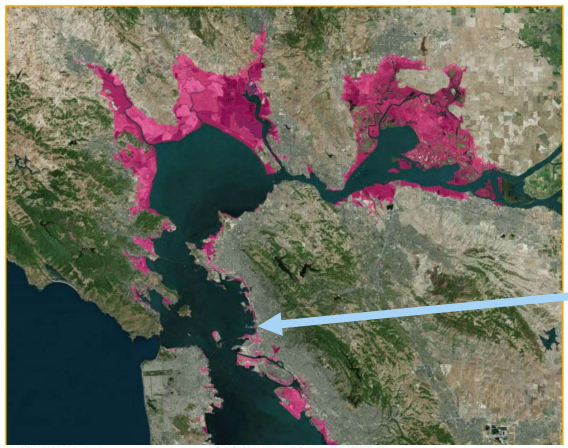
(a) drought/lower hydraulic head

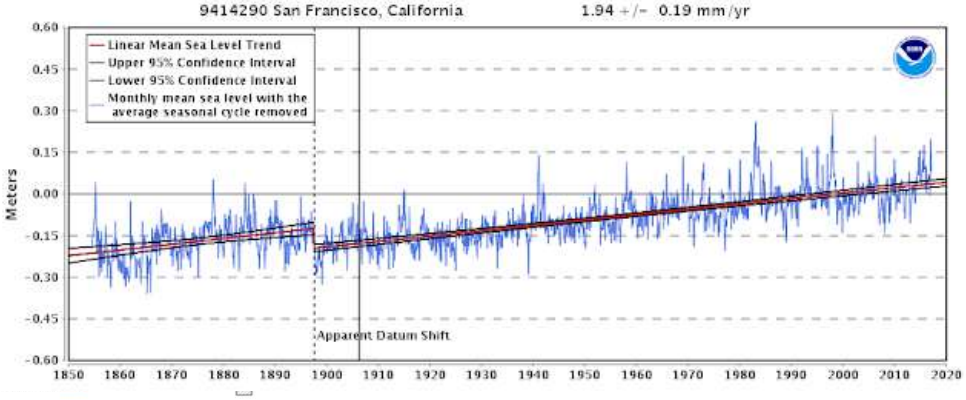
(b) Sea level rise/higher hydraulic head near shore

(c) **Land use changes to hydrology and drainage**

CASE IN POINT:
SEA LEVEL/GROUNDWATER LEVEL RISE WHERE SITES EXIST

Zone of possible sea level rise or impact.





San Francisco Bay, USA *Approximately 3000 clean-up sites may potentially be affected by sea level rise and groundwater rise.*

SUSTAINABILITY, RESILIENCY, DURABILITY

Sustainability: (ITRC, 2011)

"The site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while… balancing community goals, economic impacts, and environmental effects."

Resiliency: (https://www.unisdr.org/)

"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a such a shock"

Durability (US Presidential Memo, 2015)

"A state in which the measurable environmental benefits of mitigation will be sustained…for as long as the associated harmful impacts of the authorized activity continue."

https://obamawhitehouse.archives.gov/the-press-office/2015/11/03/mitigating-impacts-natural-resources-development-and-encouraging-related

Emeryville Marina,

SF Bay, California, USA

Sydney Harbour from Harbour Bridge 2019

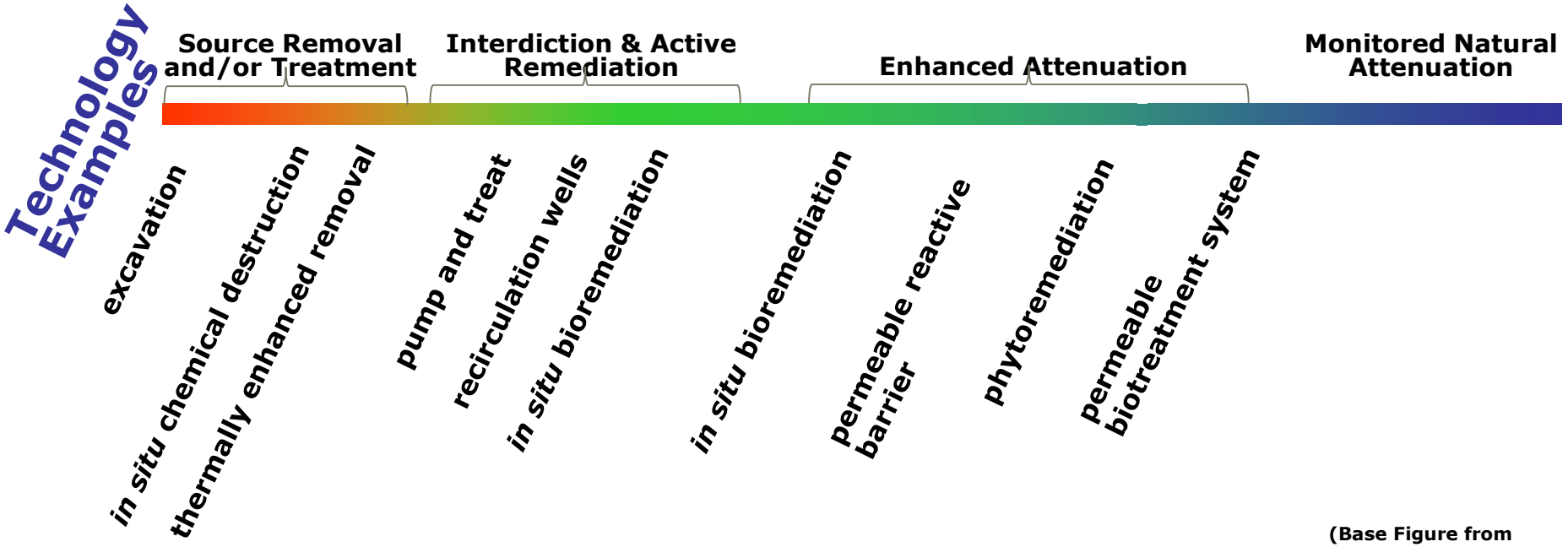
Sustainability w/o Resiliency =

Potential for incomplete long-term remedial performance (even with the "green" advantage") particularly in the face of climatic or hydrologic shock

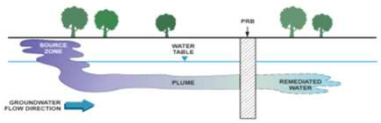
Sustainability + Resiliency = Durability

Adaptive Capacity

REMEDIAL MEASURES FOR CONTAMINANT MITIGATION SUSCEPTIBILITY TO HYDROLOGIC CHANGES



(Base Figure from ITRC EACO-1, 2008)

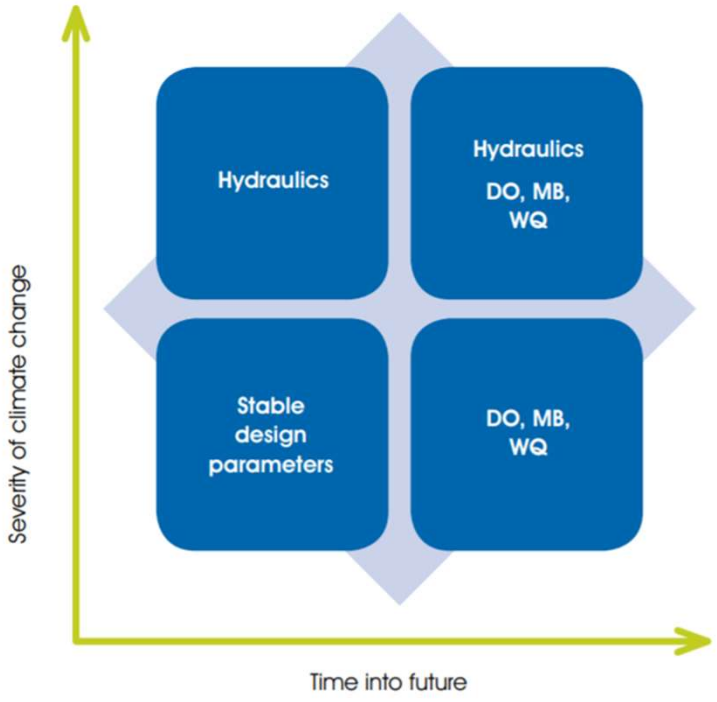


? Resilience ?

Active → *Passive*

Climate → *Susceptibility*

CLIMATE-INDUCED POTENTIAL CHANGES CRITICAL TO REMEDIAL PERFORMANCE



DO = Dissolved oxygen

MB = Microbiology

WQ = Water quality parameters (pH, specific conductance, temperature)

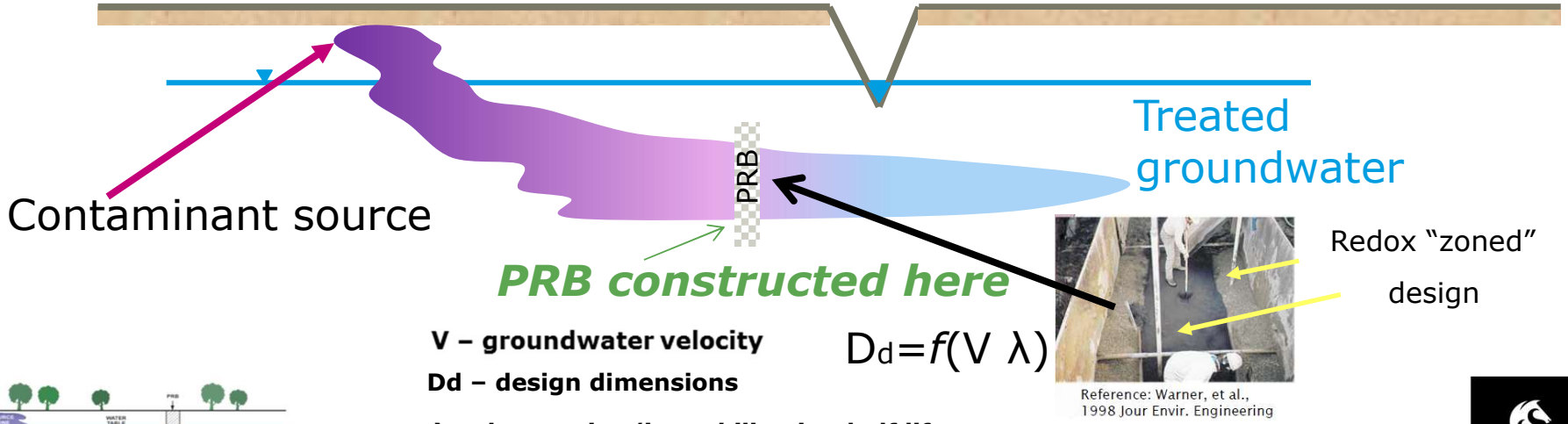
Hydraulics = hydraulic gradient (magnitude and direction), water velocity, water levels

Figure 1: Necessity of assessing remedy design parameters as severity of climate change influence increases.

Warner (2014). Remediation Australasia No. 16 https://www.crccare.com/files/dmfile/RemediationAustralasia161.pdf

EXAMPLE REMEDY
SUSCEPTIBILITY TO HYDRAULIC VARIABILITY

The Permeable Reactive Barrier (in situ treatment) is intended for long-term mitigation of a contaminant plume – hydraulically passive.

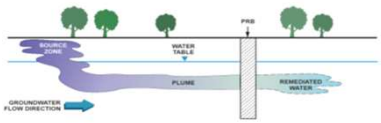


V – groundwater velocity

Dd – design dimensions

λ – destruction/immobilization half life

$D_d = f(V\ \lambda)$



SUSCEPTIBILITY TO HYDRAULIC VARIABILITY FOR PRB DESIGN

$D_d = f(V\ \lambda)$

$D_d = f(V\ \lambda\ \psi) / t$

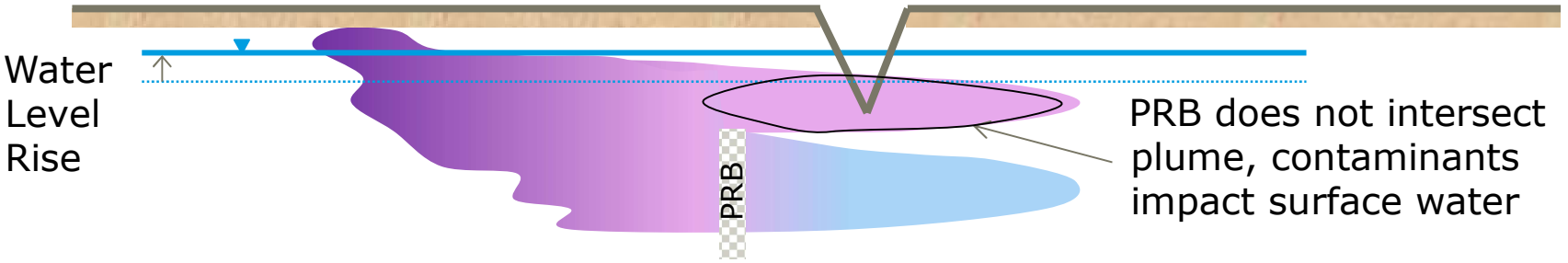
Dd – design dimensions

V – groundwater velocity

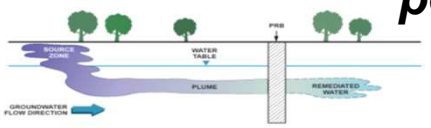
λ – destruction/immobilization half life

Ψ - resilience or change component

t - time



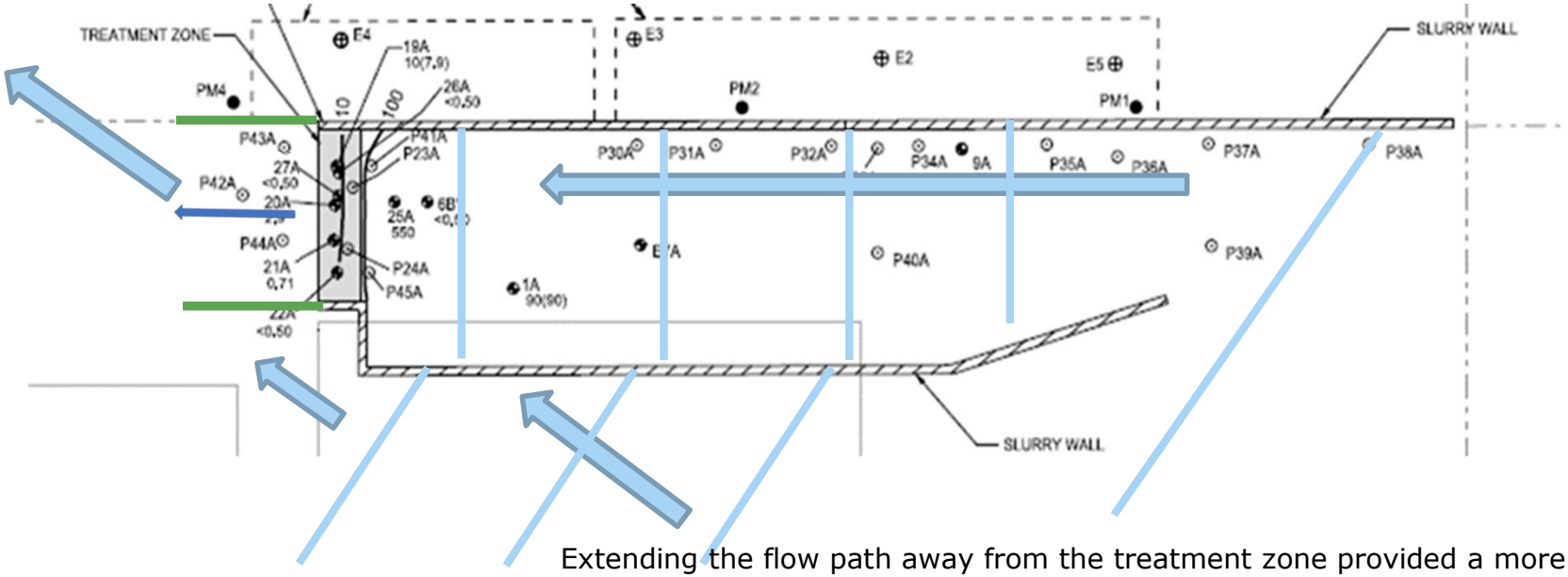
A change in gradient directions, or potentiometric head, or groundwater temperature may result in under performance or failure – and may impact geochemistry!



REDUCING SUSCEPTIBILITY TO HYDRAULIC CHANGE FOR PRB DESIGN

(PRB IS REPRESENTATIVE OF OTHER ADVECTIVE-TYPE IN SITU TREATMENTS)

Reference: Warner, et al., 1998 Jour Envir. Engineering



Extending the flow path away from the treatment zone provided a more uniform velocity regime that keeps the treatment process intact to meet residence time criteria. Design from 1993-1995 – site still functioning

REMEDY COPING ANALYSIS

"Climate Adaptive Design" Level for Remediation

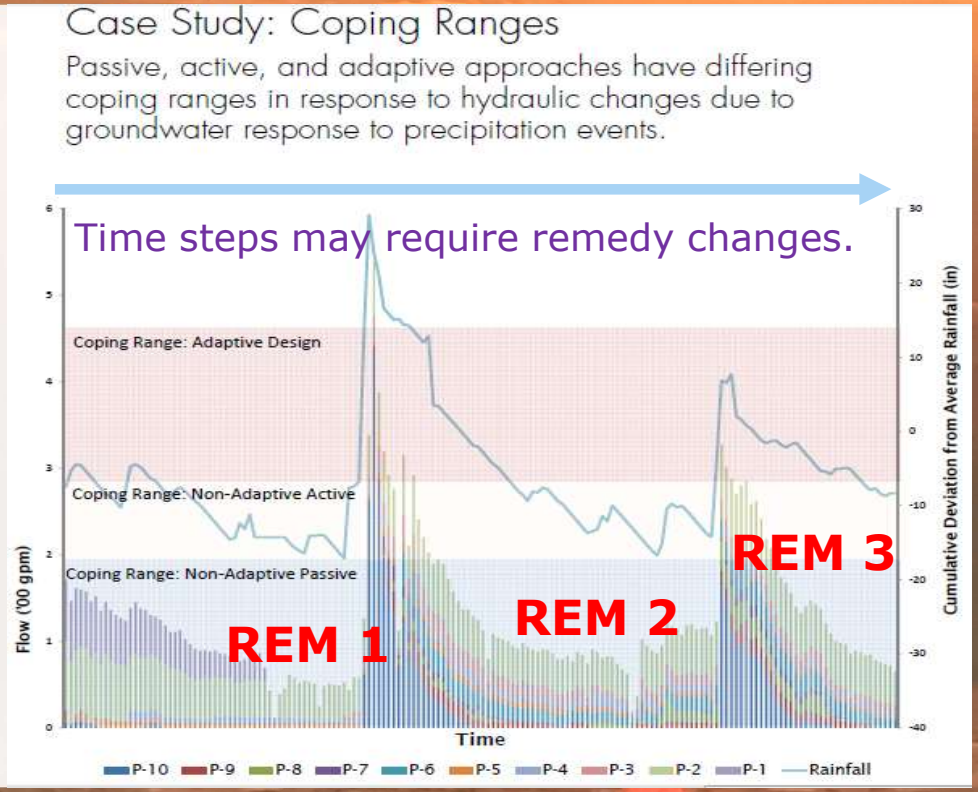
Mass flux today v Mass flux future

Ability to mitigate mass flux increase or path change due to hydraulic impact

A. Non-adaptive design

B. Transition (either)

C. Adaptive design recommended



Different remedies may be needed to take a site completely to closure - for example:
REM 1 = excavation and mass removal;
REM 2 = hydraulic control with in situ chemical reduction ;

CONSIDERATIONS

- Future changes to salinity and groundwater levels near coast:
  - *Phytoremediation – salt tolerant vegetation sooner than later*

- Hydraulic gradient changes to PRB or bioremediation system
  - *Extending passive hydraulic controls*
  - *Considering treatment mixture optimization to reduce DO/geochem impacts with changed hydraulics*
  - *Redox zone design for vertical and lateral changes*

- Redundant hydraulic capture systems

- Treatment buffer zones

- Monitoring innovations to anticipate geochemical / hydraulic changes
  - *In situ continuous redox measurements, long-term groundwater gauging*

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THANK YOU

"Slow down and listen to the earth spin"

Eastern Sierra Nevada, California USA, 2019

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