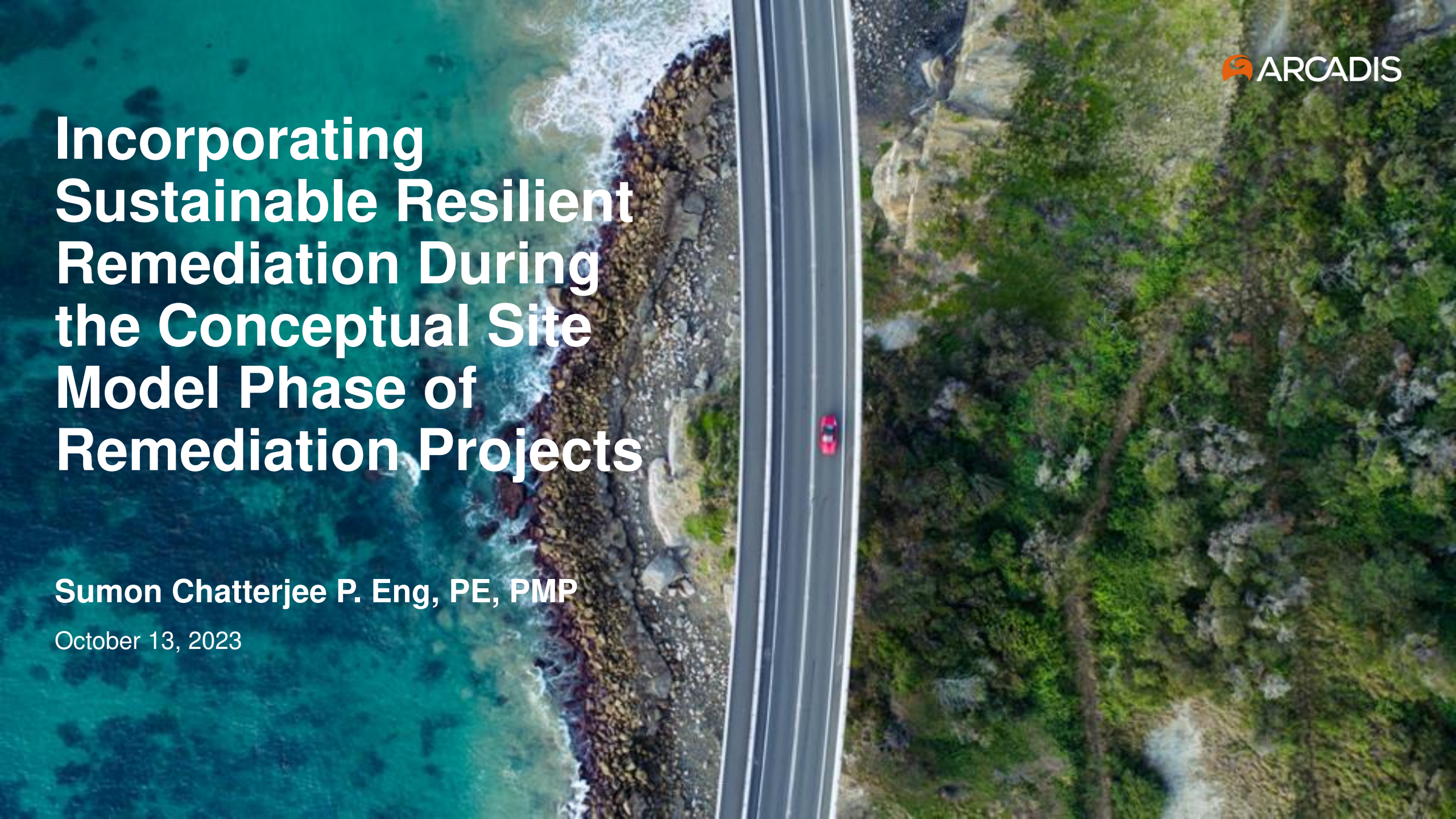


Incorporating Sustainable Resilient Remediation During the Conceptual Site Model Phase of Remediation Projects

Sumon Chatterjee P. Eng, PE, PMP

October 13, 2023

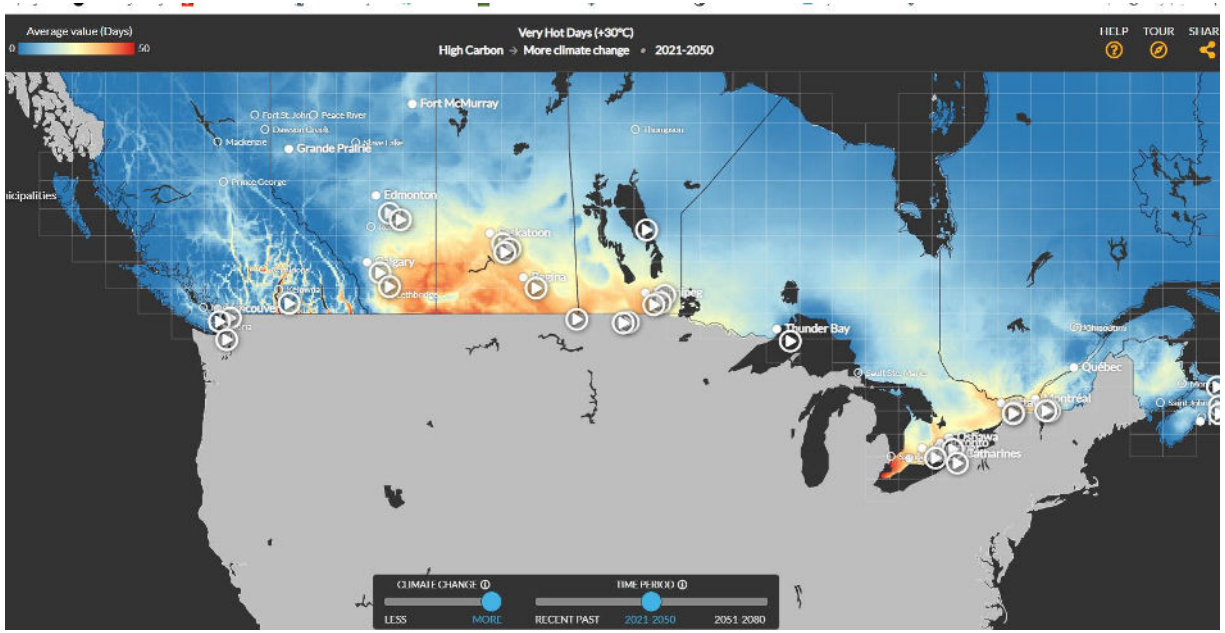
Agenda

1. Potential Climate Change Hazards
2. Impacts on Contaminated Sites
3. Case Studies – Impacts
4. Sustainable Resilient Remediation Introduction
5. Sustainable Resilient Remediation Incorporation
6. Case Studies – Sustainability & Resilience

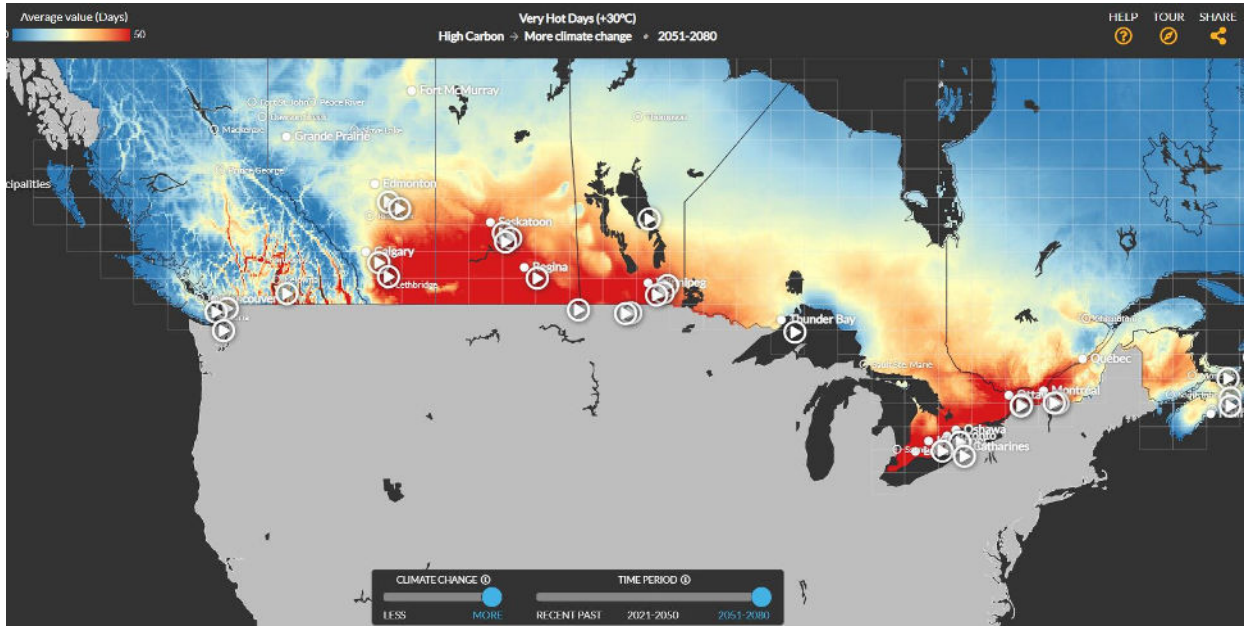
Potential Climate Change Hazards and Vulnerable Sites

- Sea Level Rise
- Groundwater elevations fluctuating
- Permafrost Melting
- Changes in precipitation and flooding events
- Increase in forest fires
- Saltwater intrusion
- Storm surge

Climate Atlas Canada



Very Hot Days (+30C) – **2021 to 2050**



2051 to 2080

Emissions continue to increase at current rates.

This is the "business as usual" scenario, and assumes that world greenhouse gas emissions continue to increase at current rates through the end of the century. This large amount of greenhouse gas emissions results in more severe global warming. This is also called the "high carbon" future, and is based on the RCP 8.5 emissions scenario.

Source: https://climateatlas.ca/map/canada/plus30_2030_85#

Impacts on Contaminated Sites and Remediation Projects in Canada

- Cleanup sites located in low-lying coastal areas, beaches, sites vulnerable to erosion
- Remediation sites that have contamination left in place intended for permanent isolation or undergoing in-situ treatment
- Long-term monitoring/timeframe sites
- Closed or abandoned landfills
- Underground storage tanks
- Sediment caps

Case Studies – Climate Change Impact Permafrost melting (1/4)

Landfill installation in Arctic (Confidential Site, NU)

Arcadis conducted inspection/monitoring of nine landfills to assess the performance and stability from an environmental and geotechnical perspective.

Frozen core keeps landfill wastes stable

- Permafrost thaw causing loss of leachate and impacts integrity of landfills, potential contaminant releases
- More intense rain events impacting stability of landfills
- Sea-level rise (proximity to ocean) causing inundation of landfills

Case Studies – Climate Change Impact
Changes in rainfall patterns (2/4)

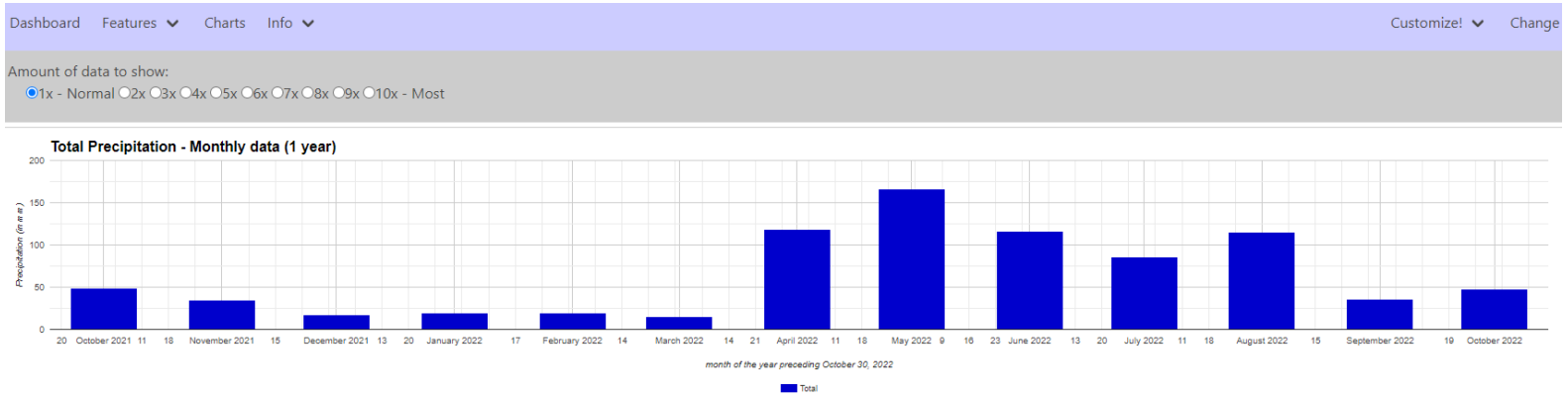
LNAPL groundwater (Confidential Site, MB)

Well screens were installed to monitor seasonal water table fluctuations to always “straddle” the water table, so that part of the screen is below the water table.

Especially important for LNAPL monitoring.

More volume of water required to be pumped

Consider anticipated seasonal high and low water-table conditions.



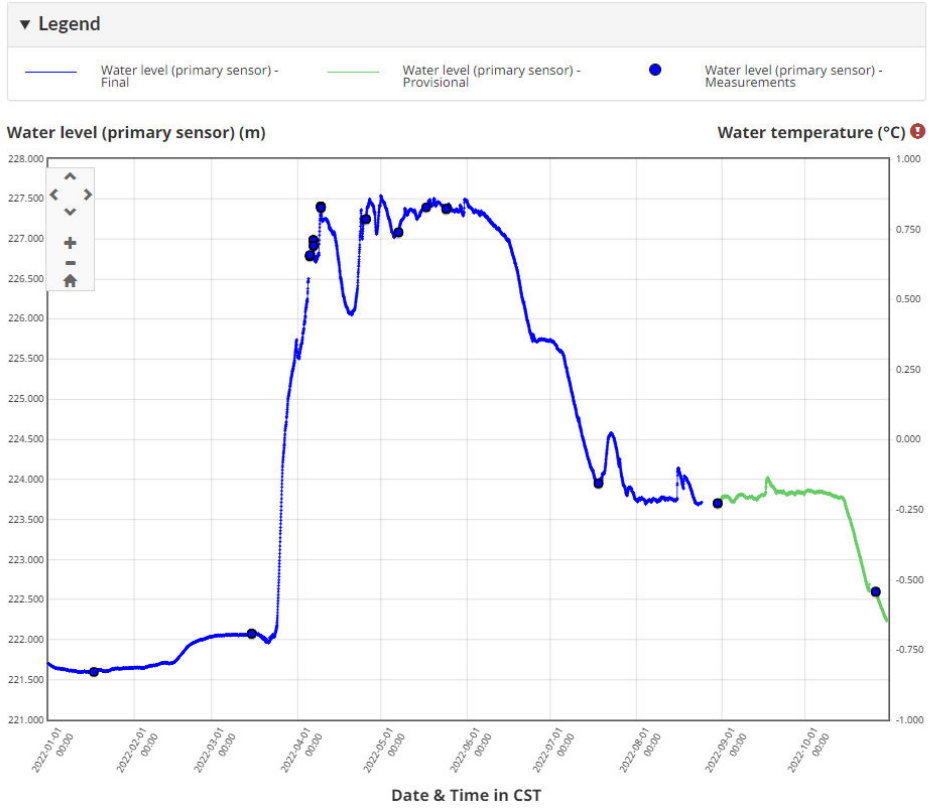
Case Studies – Climate Change Impact Extreme weather events (3/4)

Groundwater direction and groundwater/surface water interaction

Confidential PFAS site, change in groundwater flow direction

Flooding occurrences and change in piezometric levels

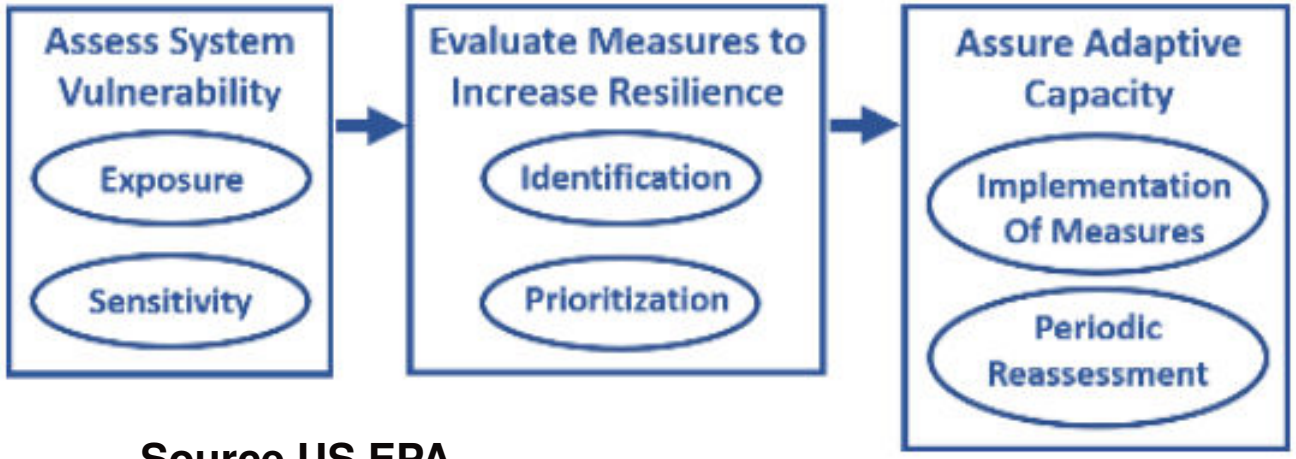
Hydraulic conductivity and hydrologic balance



Case Studies – Climate Change Impact Changes in temperature (4/4)

Considerations for R/RM Method Evaluation

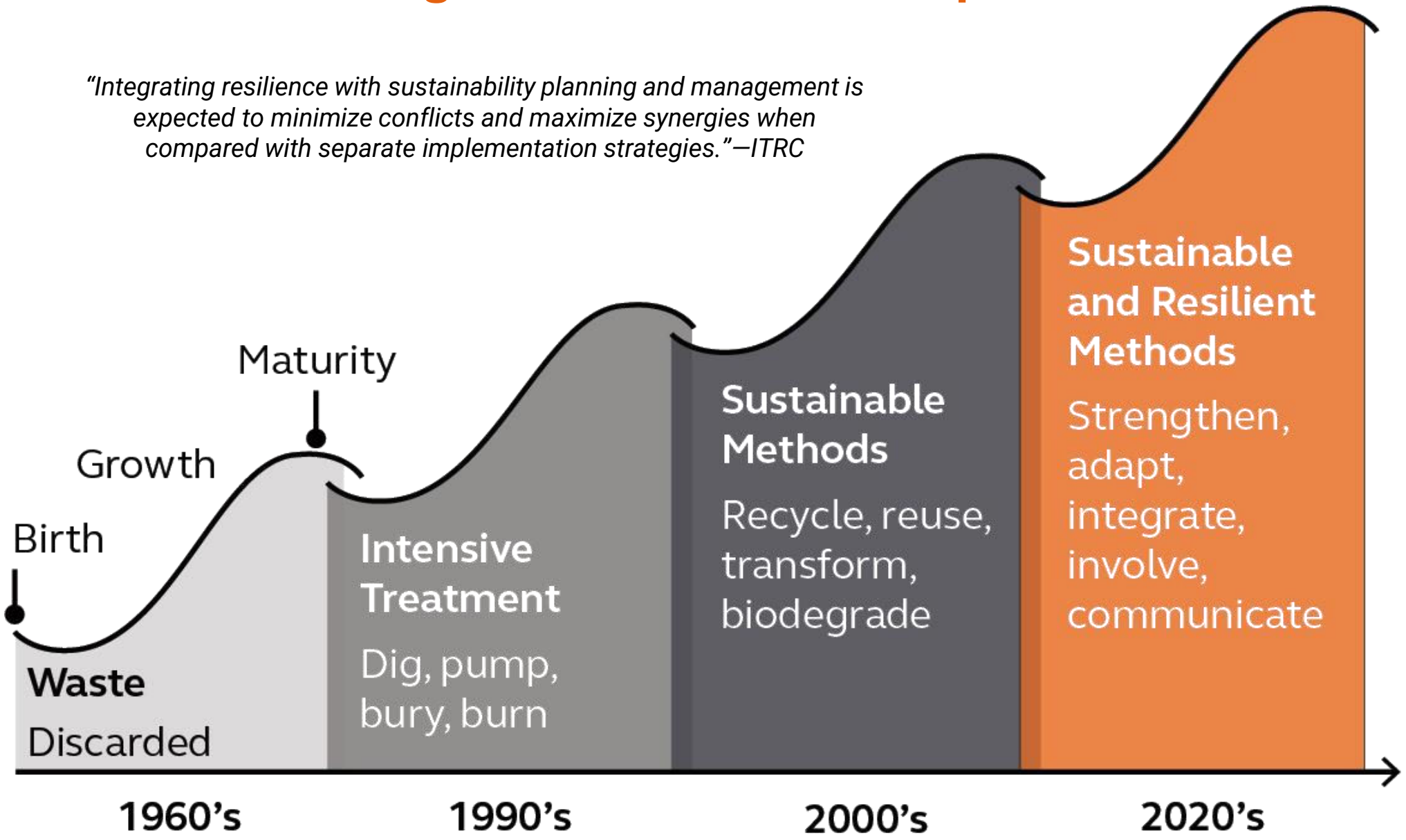
- Enhanced Bioremediation – Biodegradation rates and increased temperatures
- Soil Vapour Extraction – Soil moisture and sorption capacity
- Landfill aping – Integrity of surface cover and infiltration
- Long-term monitoring and monitored natural attenuation – Timelines
- Phytoremediation and Constructed wetlands



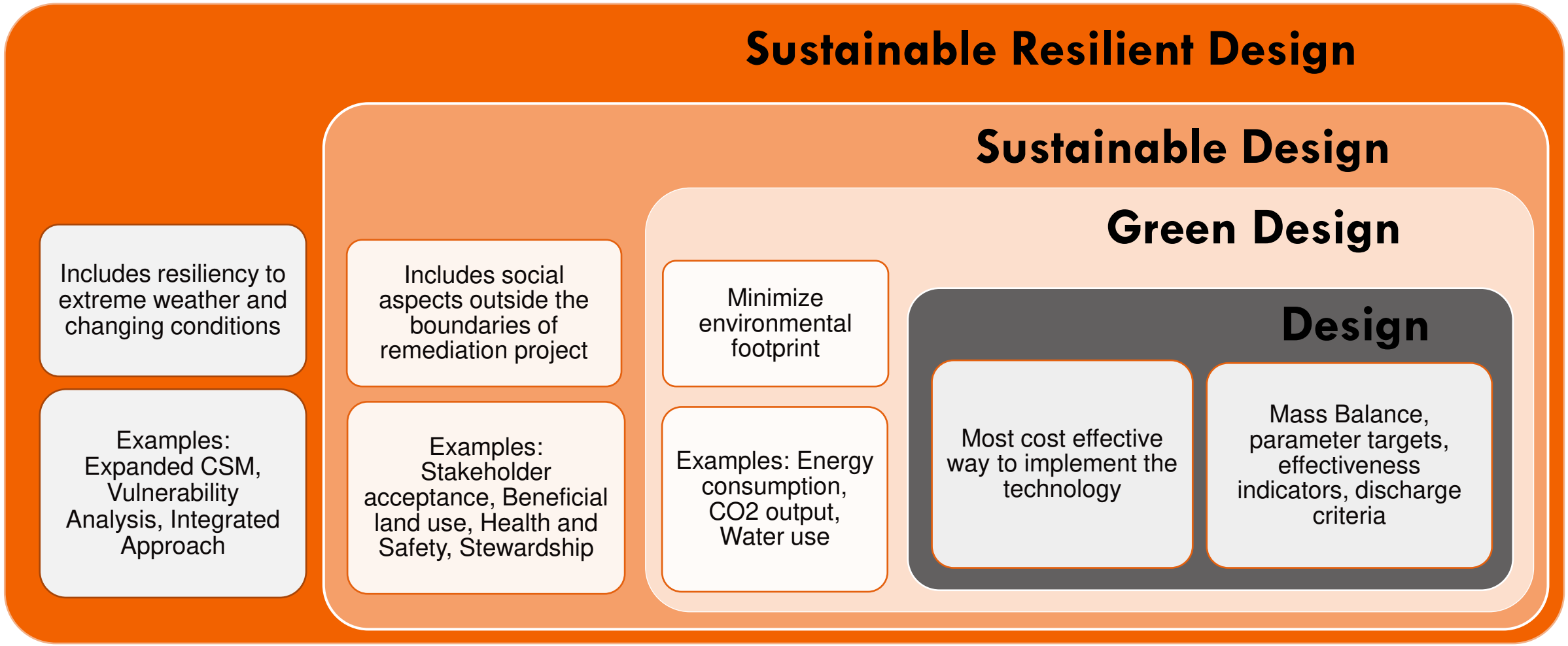
Source US EPA

Evolution of thinking in waste and cleanups….

"Integrating resilience with sustainability planning and management is expected to minimize conflicts and maximize synergies when compared with separate implementation strategies."—ITRC

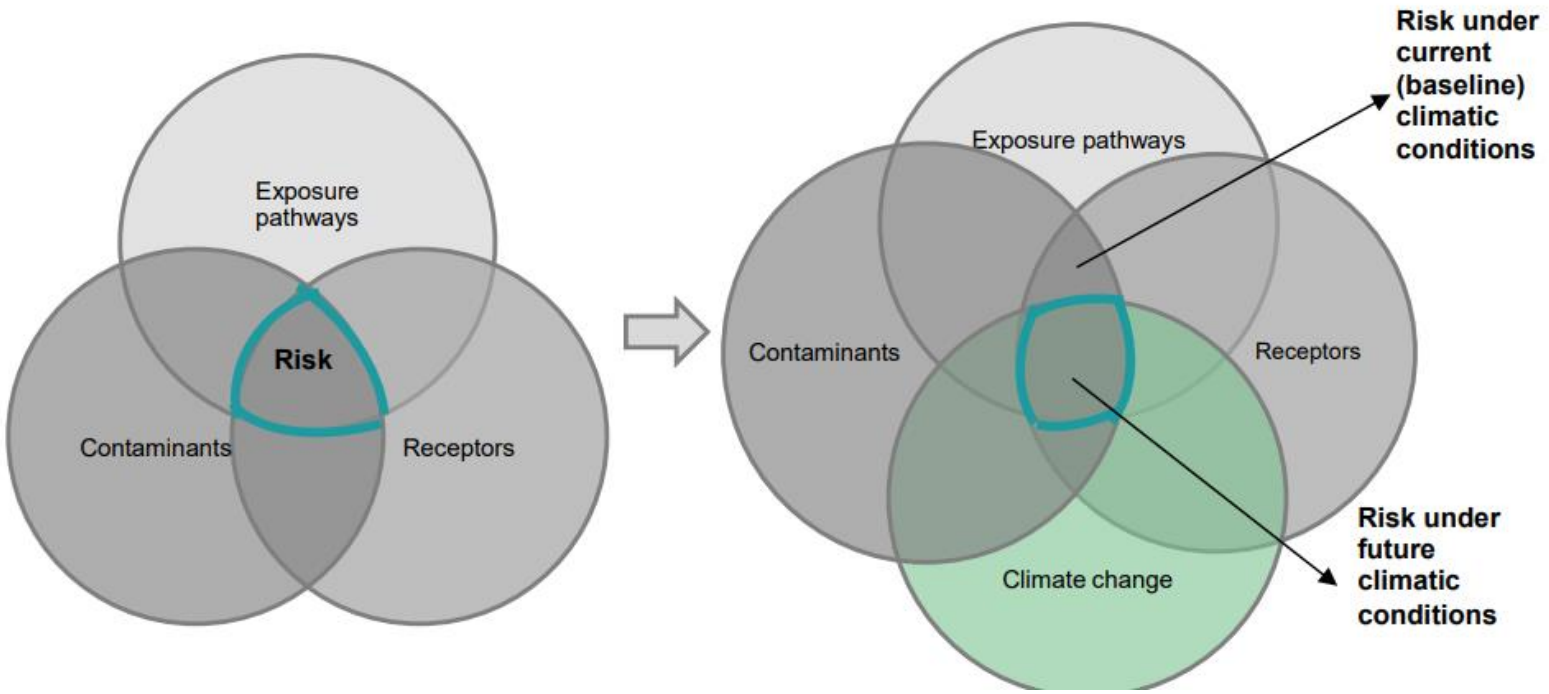


Expanding the view of design thinking



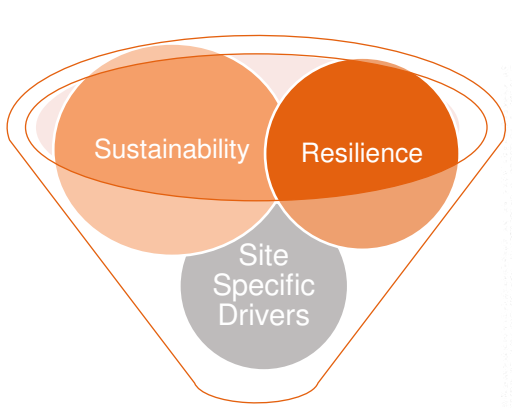
Key Concepts: • **Systems Thinking** • **Resource Efficiency** • **Innovation** • **Engagement**

Integrating Climate Change Considerations into CSM



https://publications.gc.ca/collections/collection_2022/eccc/En14-487-2022-eng.pdf

Integrating Sustainability | Site Evaluation and Remediation - CSM



Development of CSM Integrating Sustainability and Resilience

Is Adaptive Site Management Warranted Due to Site Challenges

Yes

No

Refine Conceptual Site Model

Set or Revisit Site Objectives

Develop Interim Objectives and Adaptive Remedial Strategy

Develop Long-Term Management Plan

Design and Implement Remedy

Monitor and Evaluate Performance

Are Interim Objectives Met?

Are Site Objectives Met?

Initiate Closure Process

is a Contingency Remedy Specified?

Can Remedy be Optimized?

is Progress Acceptable?

Re-Evaluate Remedy Basis

Yes

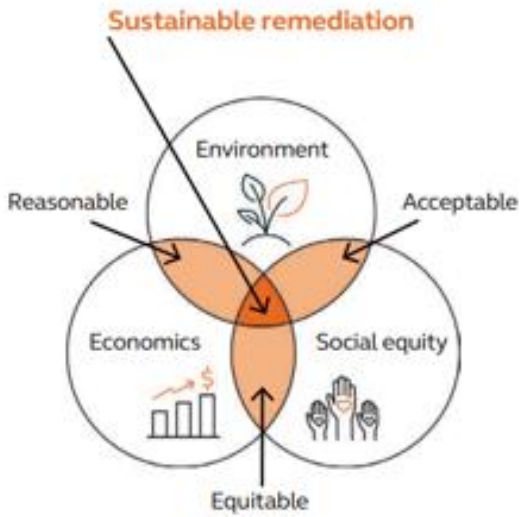
No

Figure 6-4. SRR CSM.

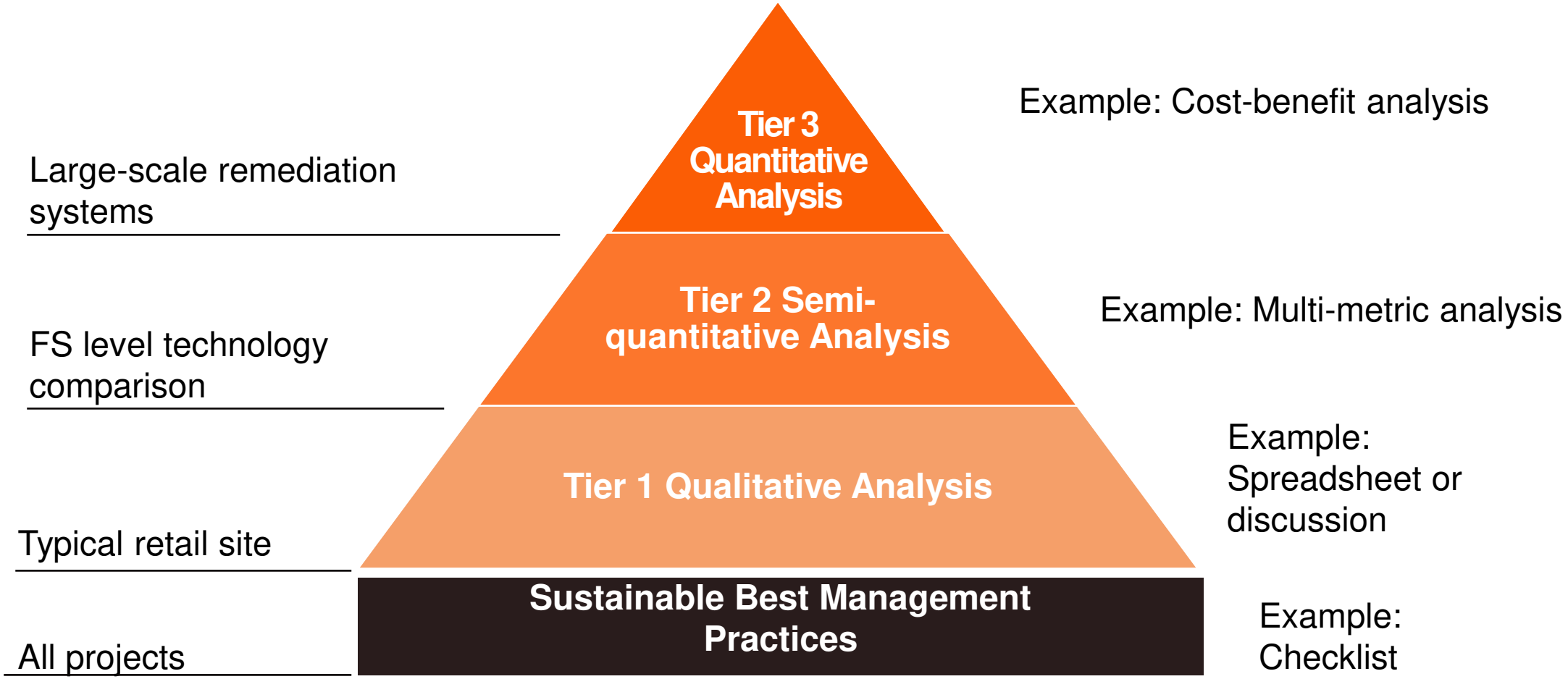
Source: Adapted from ITRC (2017) [93].

Benefits of SRR

- Environmental Benefits
  - Reduced emissions
  - Lower energy/water consumption
  - Reduced waste
  - Sustainability metrics
- Social and Economic Benefits
  - Indigenous engagement and Arcadis' Inuit Benefit Plan
  - Stakeholder collaboration
  - Economic vitality
  - Community benefits



SRR Implementation | Tiered Analysis Approach



Arcadis SBMP Tool

Creating measurable outcomes from qualitative gains

Innovative Monitoring and Remediation Technologies

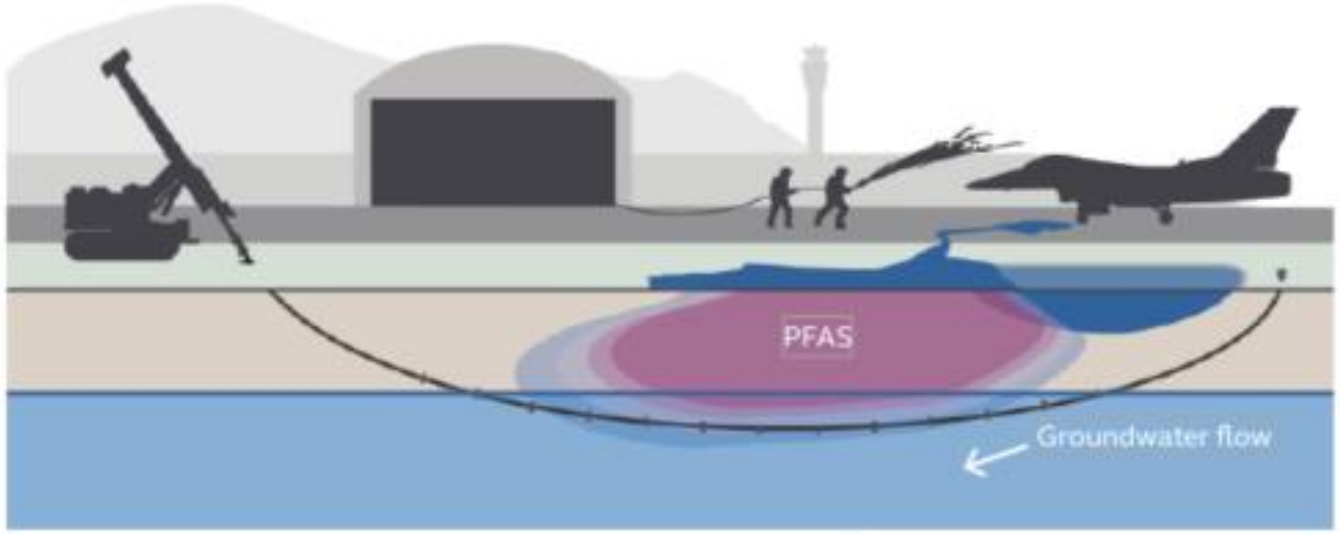


Figure 11: Conceptual depiction of the Vertebrae™ segmented wall.

Innovative horizontal well applications for monitoring and remediation achieve site goals as well as traditional installation of multiple wells and offer a solution that results in:

- smaller land disturbance footprints,
- reduced wastes and materials and
- reduced emissions

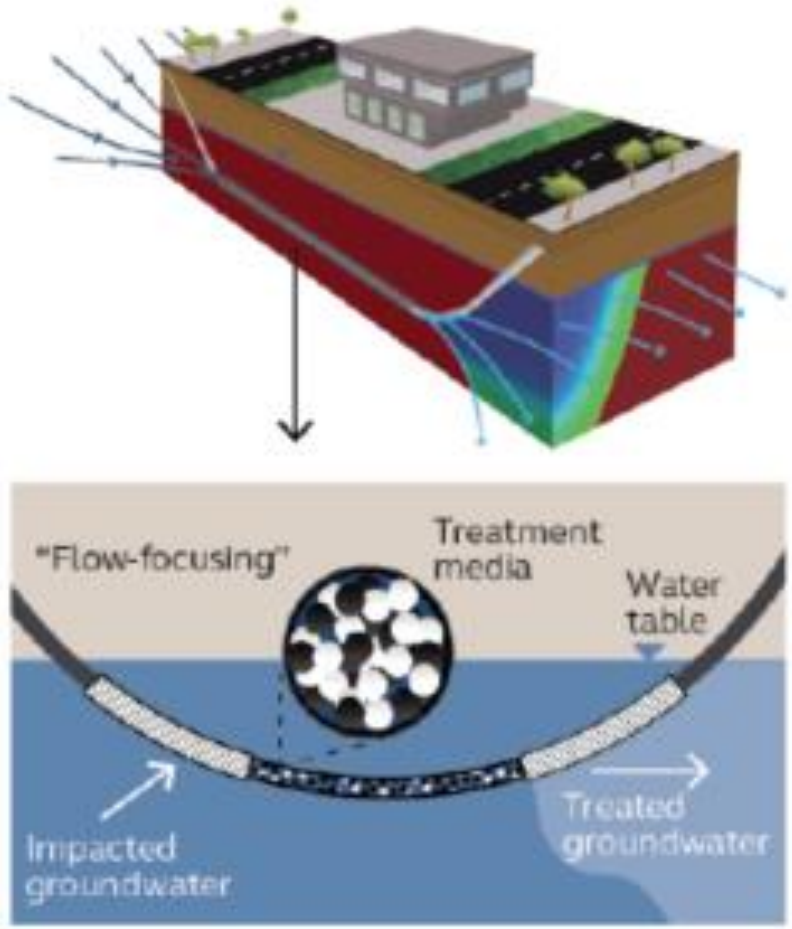


Figure 10: Conceptual depiction of HRX well treatment process

Innovative Remediation Technologies

Thermal in-situ remediation (TISR™) is a practical method for modest heating of contaminant treatment zones utilizing a sustainable heat source, closed loop fluid circulation system, and borehole heat exchangers (BHEs) (GWMR 2018).

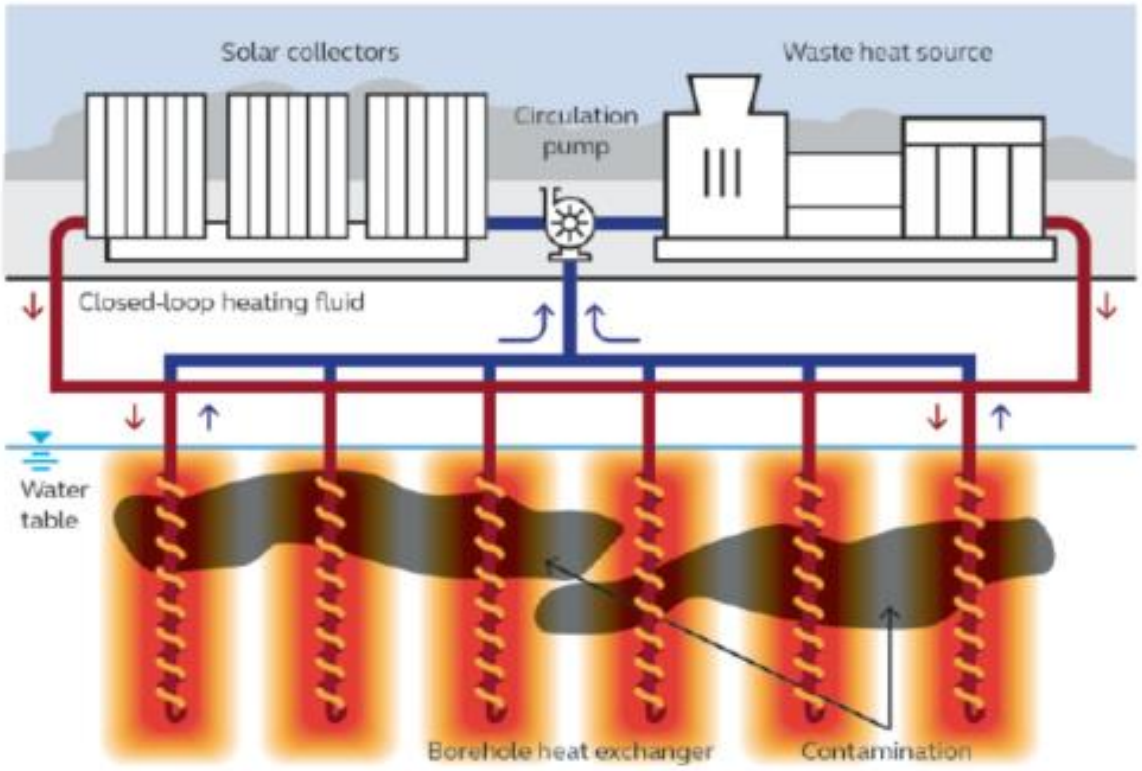
- Solar energy
- Waste heat
- Reduce raw materials by leveraging existing infrastructure

Example site: Bolt on to existing system

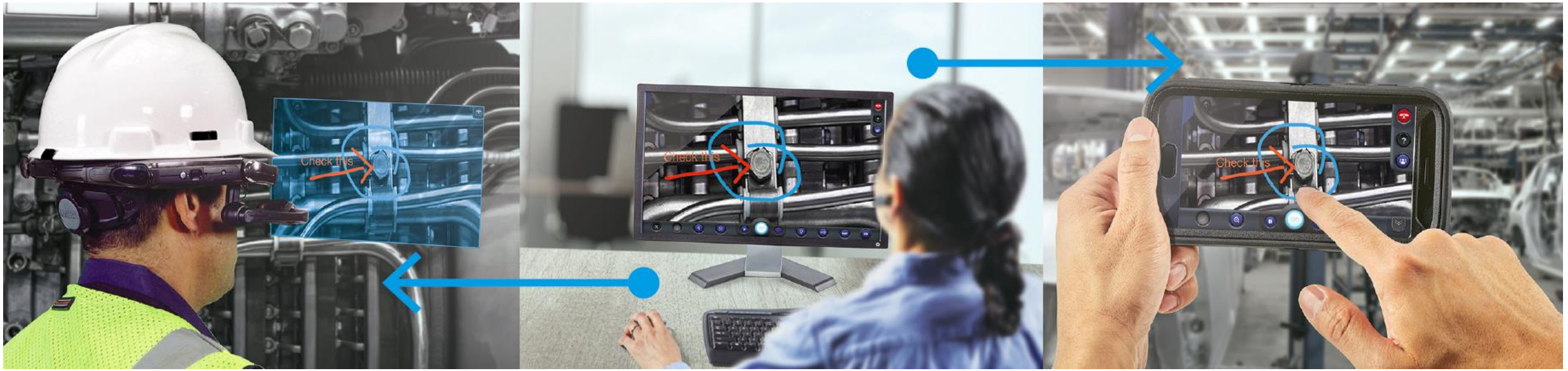
Electrical savings: $75,000

GHG Emission Reduction: 240,000 pounds

Reusable equipment



Innovative Digital Tools and Virtual/Remote Monitoring

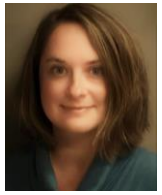


Innovations in Sensors and the Internet of Things, Digital Twins, and Immersive Technologies allow digital reinvention in the environmental remediation industry. These innovations result in carbon avoidance from reduced travel and continued innovation through increased global communication.

Sumon Chatterjee P. Eng., PE, PMP

Project Manager, Arcadis Canada

Sumon.chatterjee@arcadis.com



Jessica Gattenby

SRR SME, Arcadis US.

Jessica.gattenby@arcadis.com

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