Climate Resilient Brownfield Remediation

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Climate Resilience

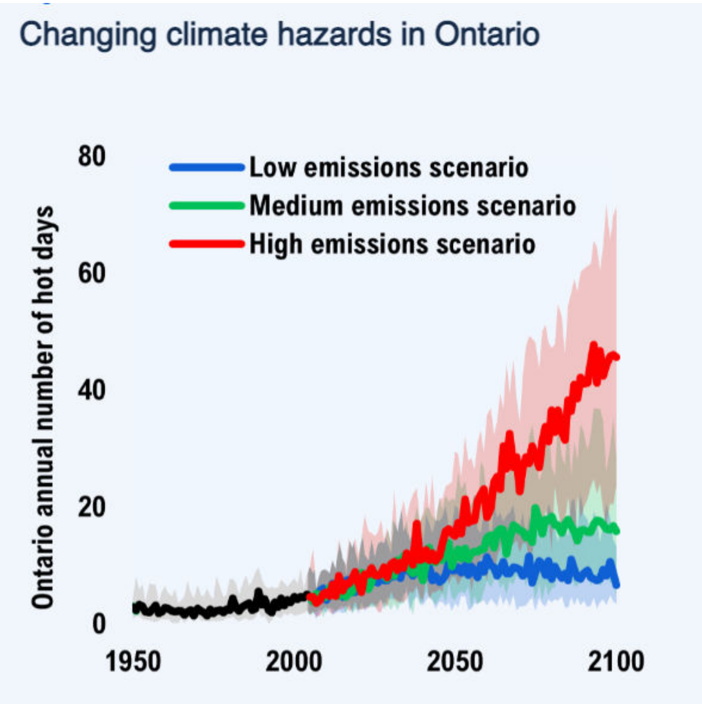
The ability of a site to perform in accordance with its original design intent under the potential stresses of climate variability, weather extremes, and related impacts associated with future climate conditions.

Climate Considerations

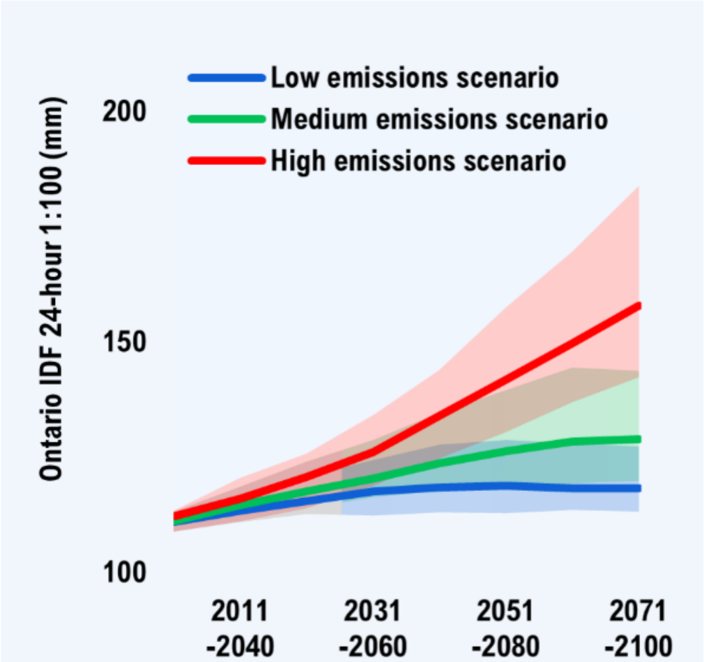
Potential Hazards:

- Riverine Flooding
- Coastal Flooding
- Local Precipitation (Flooding)
- Temperature
- Drought
- Groundwater
- Wind

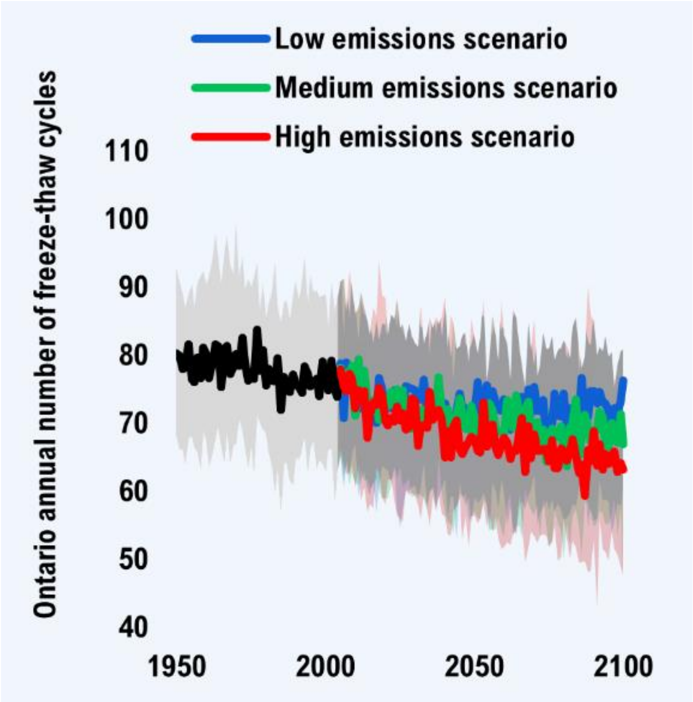
Changing Climate in Ontario



# of hot days >30C



1 in 100 year rainfall



# of days when temp crosses 0C

Climate Risk Assessment Approach

- Hazard Screening
- Hazard Confirmation
- Vulnerability Assessment
- Develop Resilience Measures

Hazard Screening

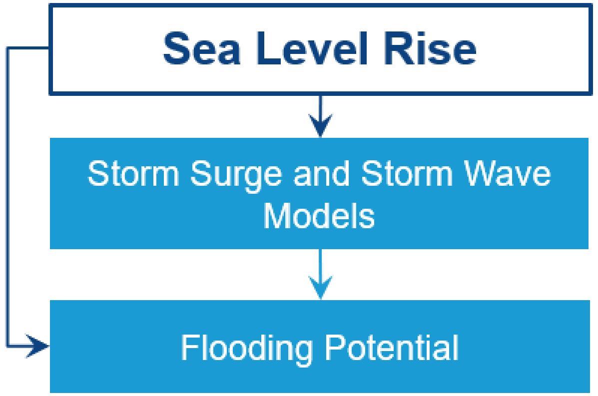
- Regional Models to complete hazard screening for site

Extreme Heat	2030	2040	2050
RCP 4.5	Moderate	High	High
RCP 8.5	Low	High	High

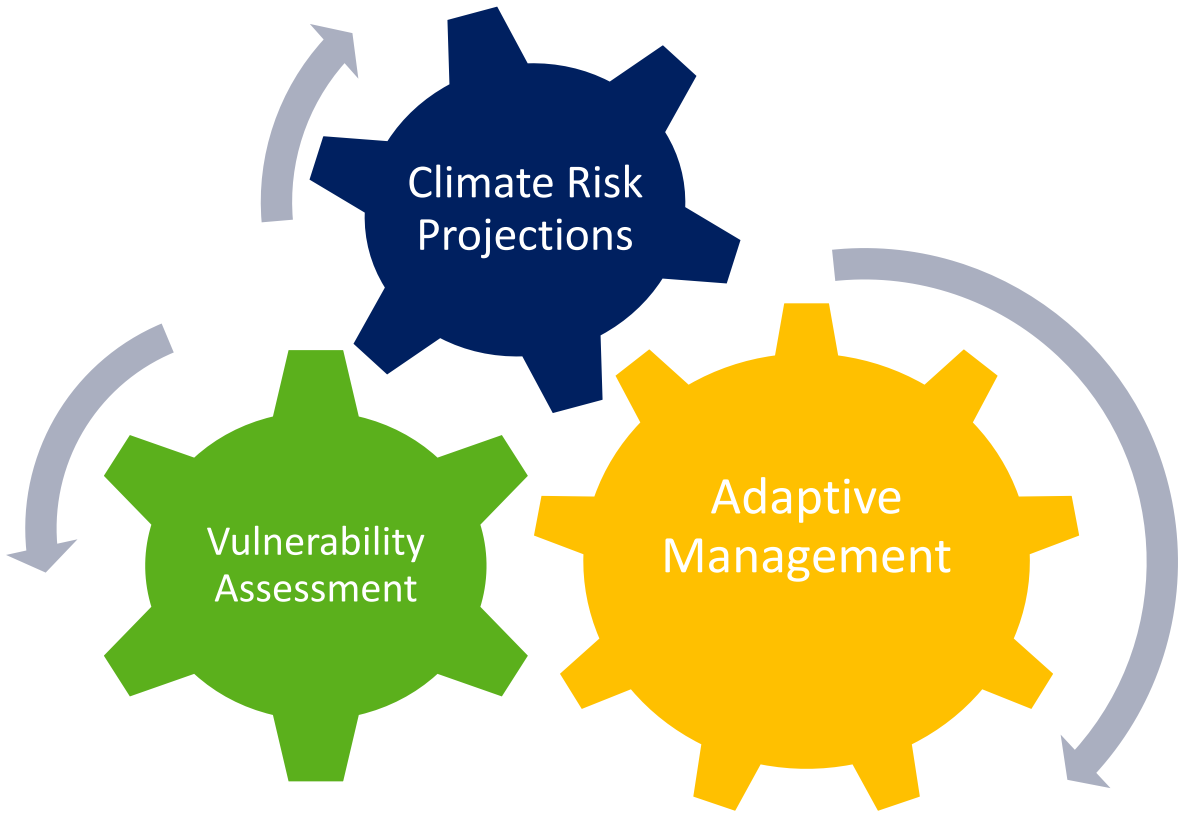
Extreme Rainfall	2030	2040	2050
RCP 4.5	Moderate	Low	Moderate
RCP 8.5	Low	Low	Moderate

Hazard Confirmation & Vulnerability Assessment

- On-site inspection
- Modeling of specific hazards and consequences
- Identification of existing control measures (e.g., stormwater management infrastructure)
- Climate Change Sensitivity Assessment (Likelihood for the climate change hazards of concern to reduce effectiveness of a remediation)



Adaptive Management Strategy



Guidance

USEPA

- *United States Environmental Protection Agency Climate Change Adaptation Plan* (USEPA, June 2014)
  - Plan concludes that changing climatic conditions and rising sea level could compromise the protectiveness of hazardous waste site remedies
  - Vulnerability analyses and adaptation plans must be incorporated throughout the cleanup process, including feasibility studies, remedial designs, and remedy performance reviews
  - Due to wide variability in climate conditions, the process is most effective through use of a site-specific strategy

USEPA

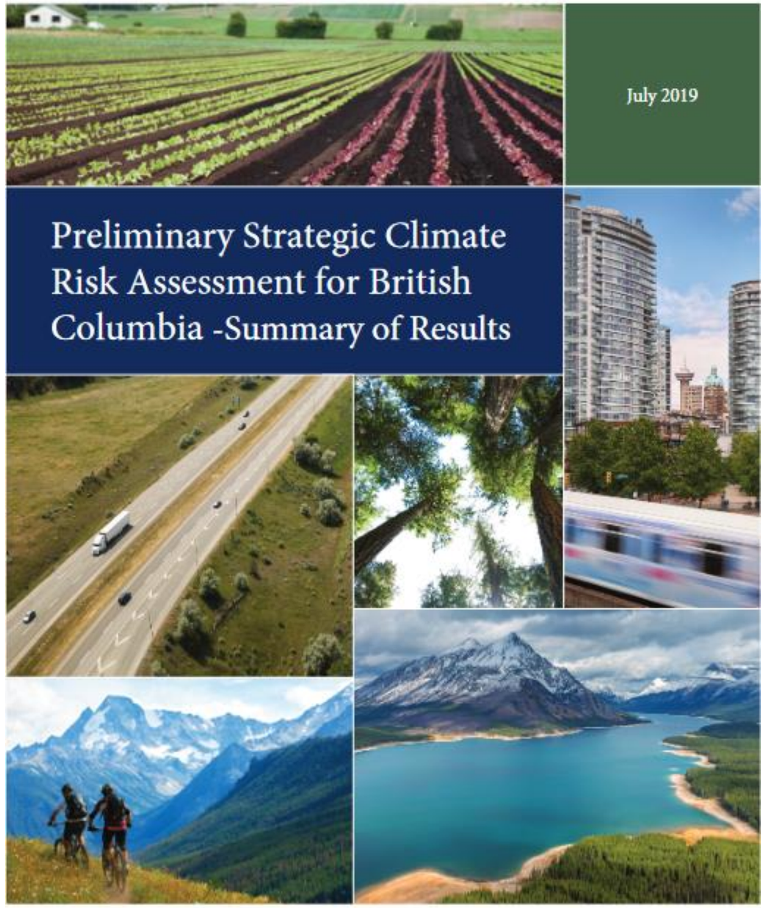
- *United States Environmental Protection Executive Order* (USEPA, June 2021)
  - Remedies at contaminated sites may be vulnerable to the impacts of climate change and extreme weather events.
  - Raise awareness of climate change and extreme weather event vulnerabilities
  - Apply climate change and weather science as standard practice
  - Recommends periodic screening of Superfund remedy vulnerabilities
  - Adapt and identify measure for climate resilience

Washington State Toxics Cleanup Program

- Sustainable Remediation: Climate Change Resiliency and Green Remediation
- Detailed processes to:
  - Identify climate change impacts that have the greatest potential to adversely affect cleanup sites
  - Understand the scope of vulnerabilities for sites
  - Learning the types of vulnerable cleanup sites and where they are located
  - Determining which specific types of remedies have high potential to be affected by climate change impacts, and what those vulnerabilities may be.
  - Develop a process for cleanup project managers to conduct a more detailed and site-specific vulnerability assessment
  - Inform the development of an adaptation strategy to increase resilience of cleanup remedies

BC Climate Risk Policy

- Including climate change adaptation and sustainability into provincial site remediation requirements
- Strengthening remediation requirements to protect groundwater quality
- Goal is new Policy in spring 2024



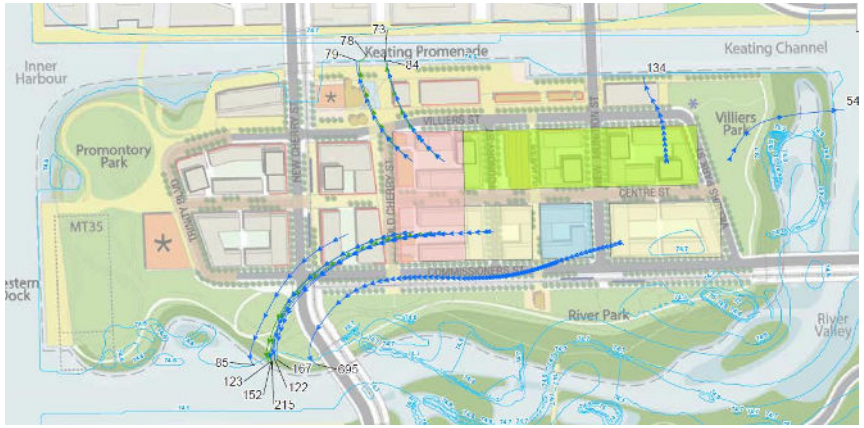
Resilient Design

Climate Considerations in RA

- Ingestion of GW. Groundwater elevation change. Increase or decrease may change ingestion of potable GW pathway assumptions.
- Inhalation of IA. Groundwater elevation change. May change vapour intrusion assumptions, may affect attenuation factor.
- Protection of Aquatic Life. Surface Water Dilution. Assumption of 10 times mixing may not be applicable. Distance to groundwater may change. Decrease in soil moisture content may change.
- RA Framework. May be prudent to complete sensitivity analysis for selection and conceptual design of RMMs.

Case Study: Climate Based Design changes

Pre-River Construction



Post-River Construction

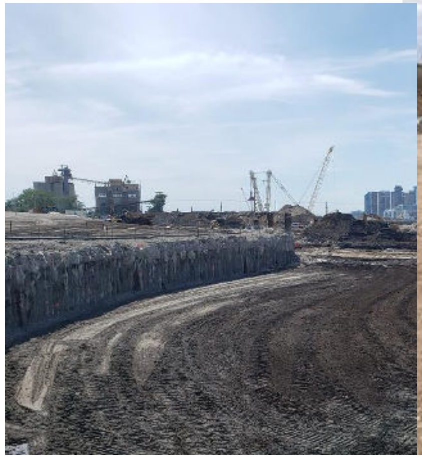
- Before and after groundwater conditions using a site wide groundwater model to demonstrate efficacy of the environmental controls
- Groundwater model demonstrated containment of groundwater and lengthening the flow paths

Barrier Walls

Barrier Walls: Depth seated in competent bedrock; concrete overlapping piles with alternating steel reinforcing beams

1 m wide, 20 to 40 m deep






Design Re-evaluation due to Extreme Event

Climate Risk:

- **Record high Lake Ontario levels in 2017 and 2019 caused extensive flooding and beach erosion**
- **Lake Level Design Criteria was 75.8 masl; updated by 0.4m after completion of detailed design**

Vulnerability Assessment:

- Ran hydrogeological model at multiple high lake levels
  - Toronto 2017 record lake levels
  - Toronto 2019 record lake levels
- Assessed sensitivity of model to changing recharge conditions due to Port Lands redevelopment
- Assess interaction of groundwater with vertical cut off walls

Criteria	Lake Level (masl)
Original Lake Level Design Criteria	75.8
May 2019 Design Change	76.05
November 2019 Design change	76.2

Design Change

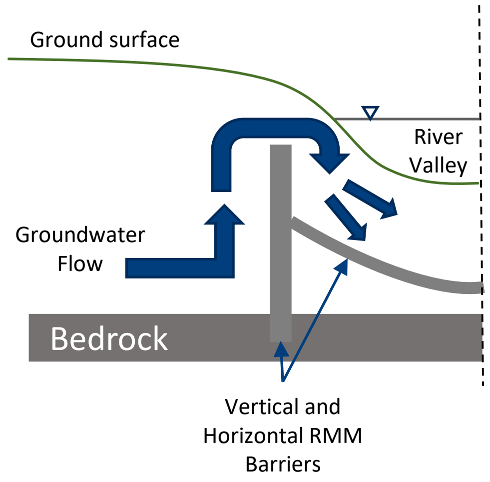
<u>Model Results:</u>

- Mounding and potential overtopping under high groundwater scenario at two locations

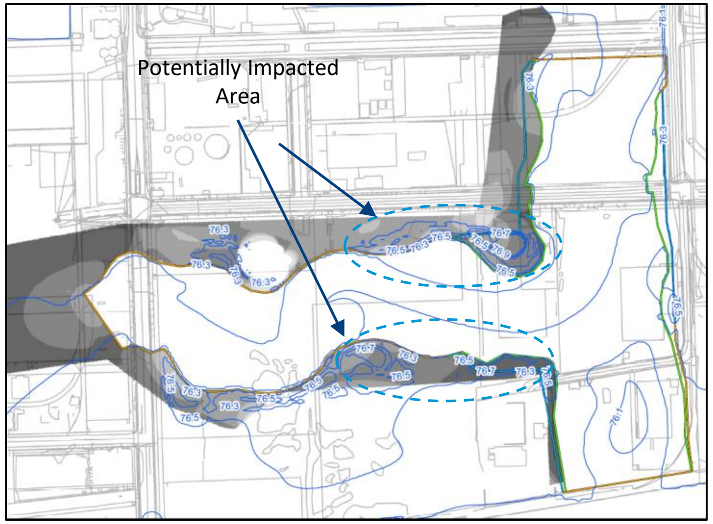
<u>Design Change:</u>

- Final elevation of barrier wall kept at higher elevation
- No modeled flow over Vertical Walls
- Inspection process added to long term monitoring program

Mounding Can Result in Flow Over the Vertical cut off walls



Areas Potentially Impacted by Groundwater Mounding Behind Vertical cutoff walls

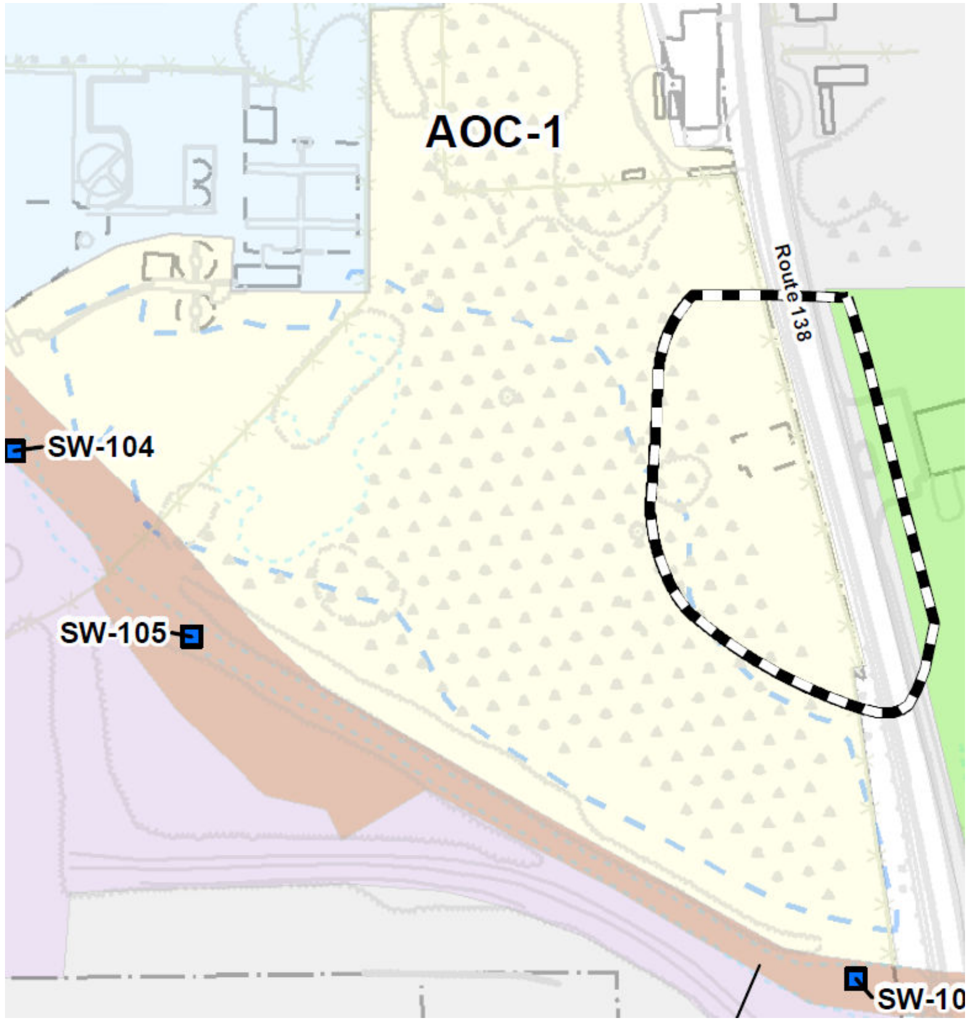


Case Study – Former Gas Station

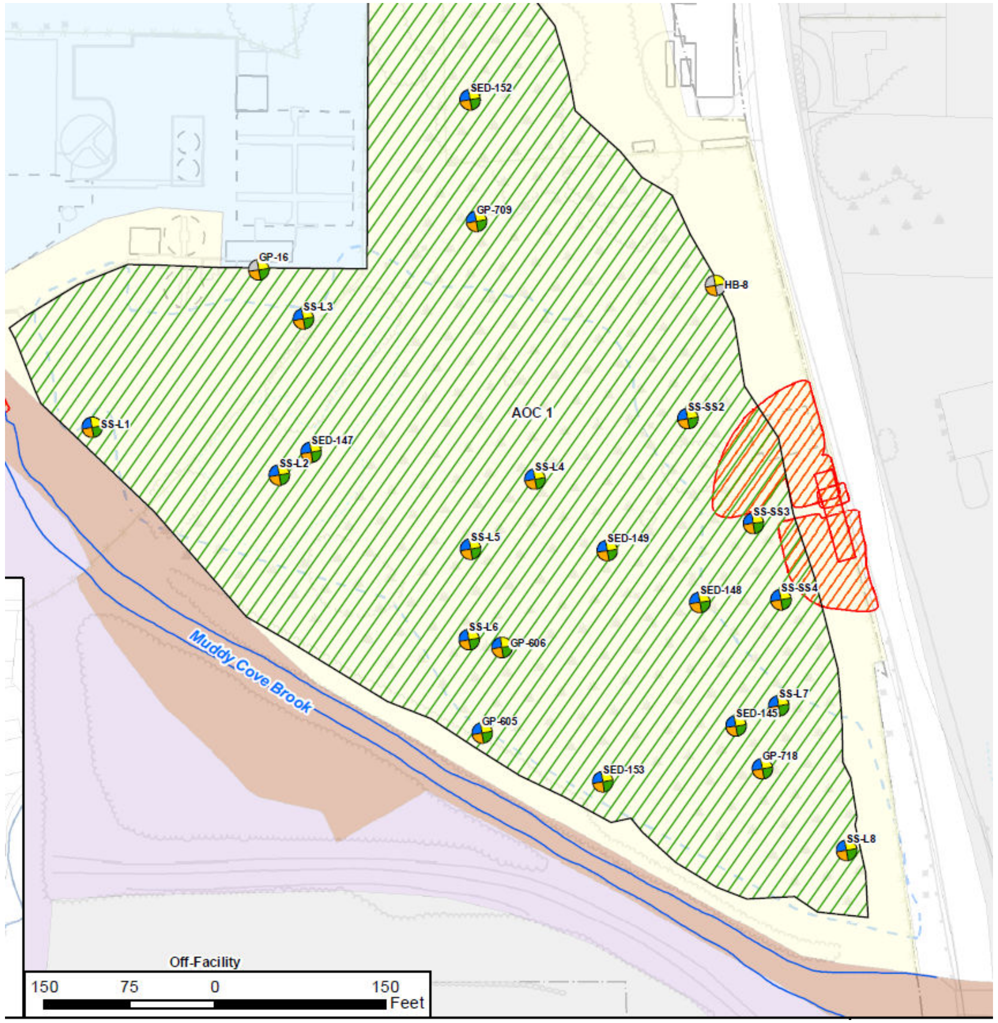
- Team assessed risks on property with wetland
- Noted that wetland boundary was changing over time → prompted re-survey of wetland boundary (affected assessed risks in this area)
- Adapting remedial design to incorporate revised wetland boundary

Larger Wetland = sensitive site

2018 Interpretation



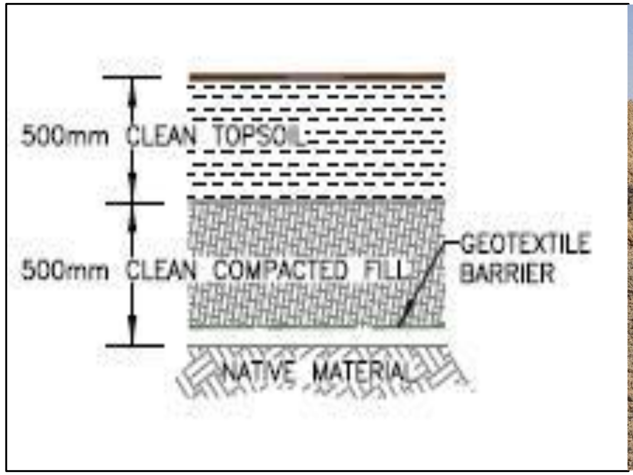
2022 Interpretation



Climate Considerations for Cap Risk Management Measures

Potential Climate Risks

- Erosion. Erosion and overland runoff due to changes in water movement (high intensity rain, flooding, high lake levels)
- Contaminant Release. To sensitive area
- Long-term performance sensitive to low ambient temperatures
- Soil or waste below the cap may settle due to freeze/thaw conditions



Case Study: Cap Erosion

- 100mm of rain in a span of two hours
- Cap failure, water cascaded over slope, eroding cap and geotextile barrier
- Public safety concerns, insurance claims
- Need for resilient design
- $300k repair and long delay

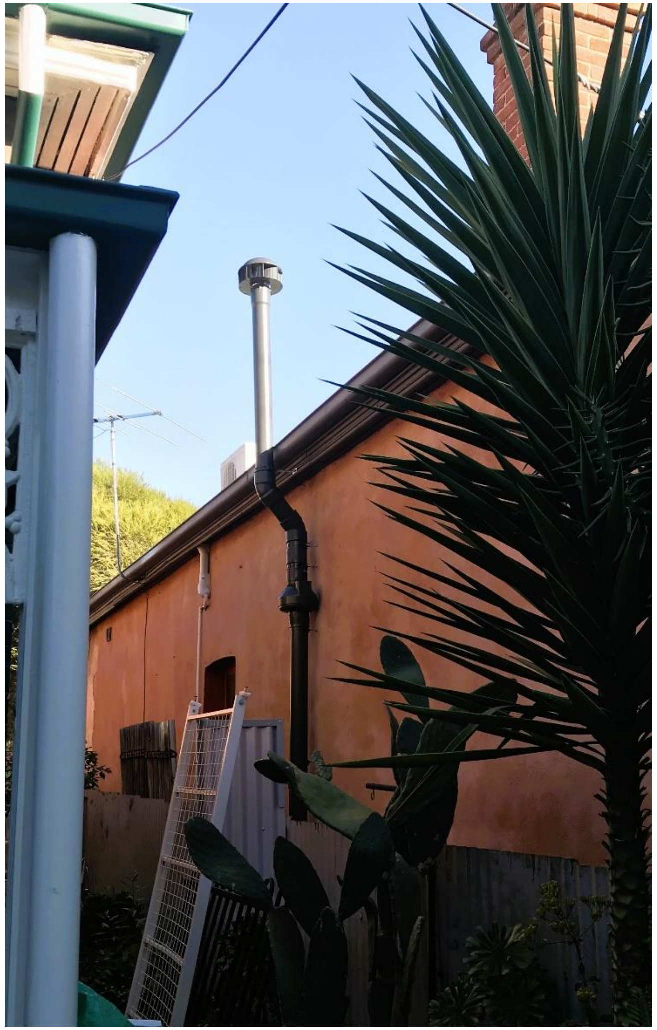
Climate Considerations for VI Risk Management Measures

Potential Climate Risks

- rising groundwater table. design the vapour barrier for waterproofing and mitigating diffusive transfer from a saturated zone. Composite barrier selection.
- Storms and pressure gradients. These could impact the pressure gradient in buildings, increasing VI and may have an impact on mitigation systems, especially passive systems.
- Permafrost melting releases methane and radon that was once trapped, increasing the risk of vapour intrusion into homes that have never had to consider these impacts before
- Power outage. Potentially greater impact on methane mitigation systems
- Freeze-Thaw Cycles. Impact on equipment

Case Study: VI Resilient Design

- VI system in area at risk to power outages
- Active extraction coupled with passive wind turbine for continuous operation in power outages



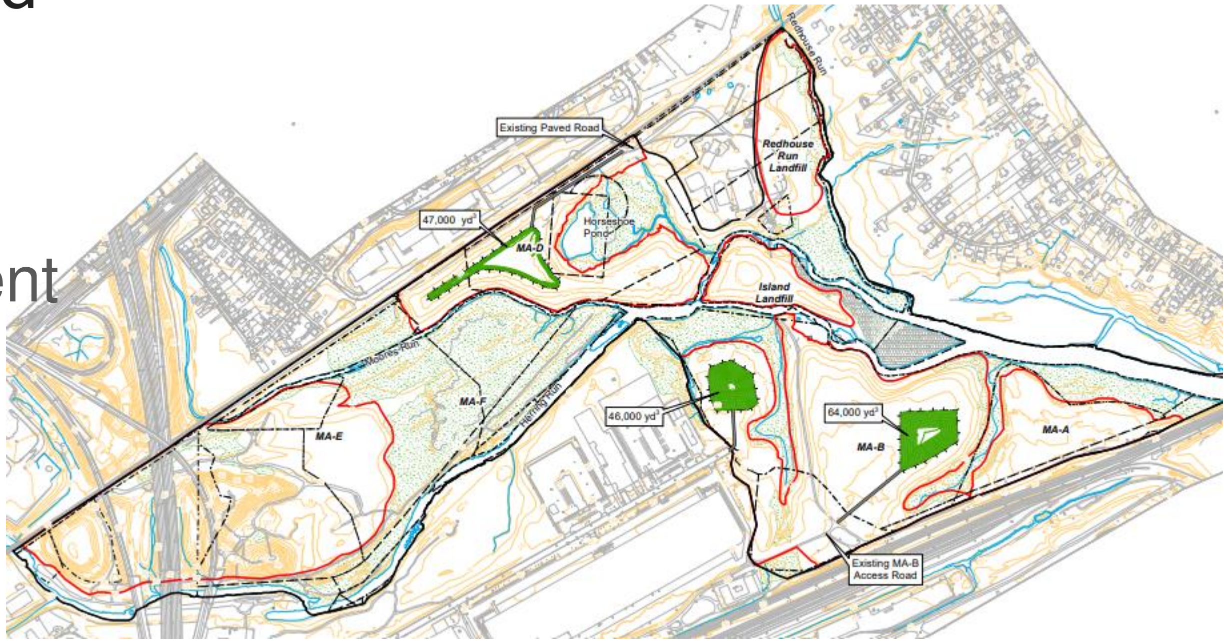
Climate Considerations for Remediation

Potential Climate Risks

- Historical Data vs Future Projections (e.g., maximum/minimum water table levels)
- Long-term change. Performance may be affected by change groundwater depth, flow direction, vadose zone changes, clay desiccation, etc.
- Drought and rewetting. may release stored metal contaminants
- Power outage/downtime. Inundated equipment may fail; power outages; system downtime

Case Study: Climate Based Design changes

- Potential Energy Transition Site
- Former 100 hectare landfill site with potential reuse for recreational and the construction of a solar facility
- Remediation/RMM includes:
  - Leachate and groundwater treatment
  - Capping
  - Permeable Reactive Barriers
  - Enhanced wetlands



Vulnerability Assessment

- Physical Damage
- Water Damage
- Power Interruption
- Reduced Access

Projected Hurricane Storm Surge

Remediation Adaptation

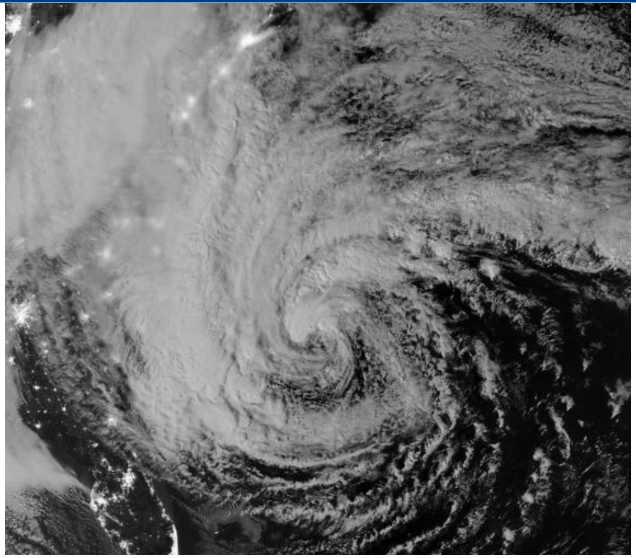
Remediation Component	Climate Risk Issue	Resiliency Design Impact
Capping	Erosion from heavier precipitation	Drainage and max 3:1 slopes Hardened and vegetative stabilization for 100-year storm event at surface water edges (imbricated walls or riprap and/or vegetative stabilization measures)
Leachate and Groundwater	Pump equipment located in floodplain	Elevate pump service panels Add redundancy into system
Enhanced Wetlands	Vegetation affected by increased flooding	Select adaptable plant species
Permeable Reactive Barrier	No Issue	No change

Case Study: Soil Excavation

- Restoration of creek and adjacent parkland to remove creosote contaminated soil
- Redirected creek, excavated sediment, placement of impermeable barrier, groundwater interceptor, creek habit restored
- Creek redirection designed at 1 in 5 year event
- Unanticipated high intensity storm during two-week excavation and excavation soil eroded from banks
- No adverse effect was identified, and creek successfully restored, and habitat rejuvenated

Case Study: In-situ Soil Remediation

- In-situ remediation of 400,000 tonnes of coal tar impacted soil
- Site inundated during hurricane
- Downtime and equipment damage
- Operation resumed and cleanup completed
- 400,000 m^3 of soil imported to flood protect site

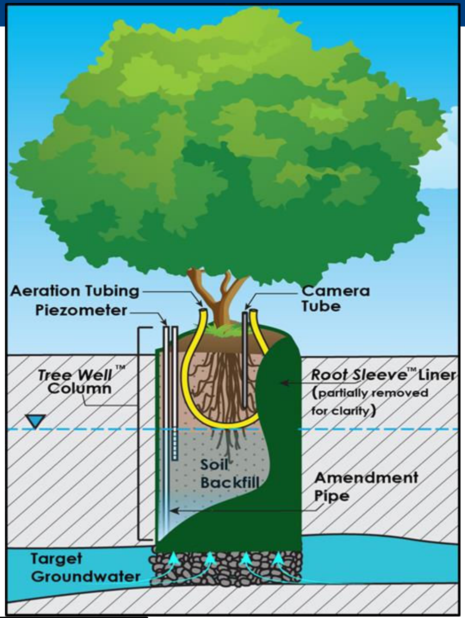


Climate Considerations for Phytoremediation

Potential Climate Risks

- Temperature extremes (*not just high temps!*)
- Droughts
- More frequent and/or stronger storm events
- Sea level rise
- Groundwater Salination

Case Study: Phytoremediation



- Engineered phytoremediation to treat contaminated groundwater
- Site in area often inundated from storms
- Salt tolerant, ***native species***
- Trees thriving in raised, culvert system



Lessons Learned

- Climate projections have a wide range of values
- Climate projections need to be validated by local conditions
- Vulnerability assessments should consider higher probability events and reasonable occurrences
- Build in resiliency into brownfield sites and re-evaluate on periodic basis
- Design with adaptation and resiliency in mind

Discussion?

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