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2019 Bioremediation Symposium | April 15-18 | Baltimore, Maryland

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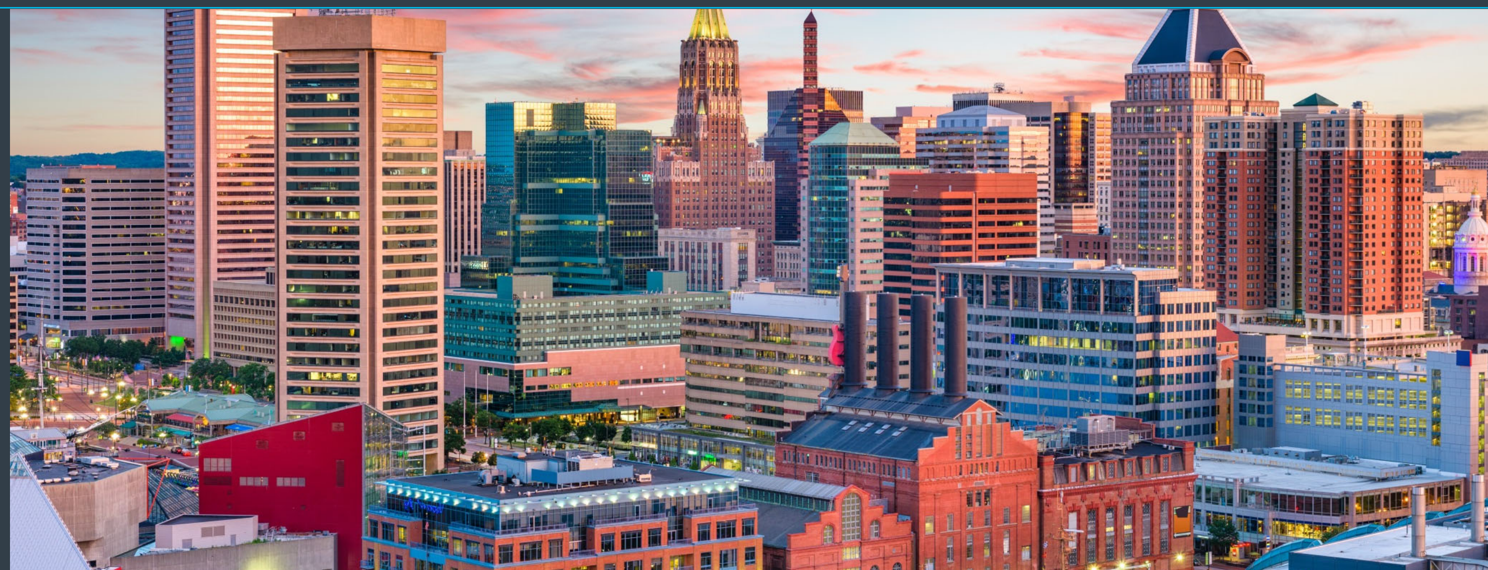
SURF SUSTAINABLE REMEDIATION FORUM



Comparing Microbial to Physical Chemical Remediation Technologies and Associated Water Chemistry Amendments in GSR Assessments

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April 18, 2019

Site Description

- Chemical manufacturing facility – Pennsylvania
  - Ammonium sulfate waste stream was discharged to soil surface in mid 1900s.
  - High density ionic plume, migrated down to saprolite/bedrock surface

- Turned into two large, dilute plume areas migrating towards a river
  - South plume: ammonia (~200 mg/L), sulfate (<100mg/L)
  - East plume: ammonia (~100 mg/L), sulfate (500 mg/L)

- Corrective action objectives:
  - Control human exposure to hazardous groundwater
  - Ensure that groundwater migration does not contaminate adjacent river above applicable SWQSs.

Regulatory Context: RCRA Corrective Action Program

– EPA Statement of Basis - plumes technically impracticable to remediate
  - Remedy costs and timeframe exceeded $25M and 100+ years
  - 2D mass-flux assessment showed dilute plume discharge to river was below standards
  - Long term monitoring natural attenuation remedy granted, with requirement to monitor point of compliance boundary for exceedances.
  - Contingency plan to implement remedial action if needed.

– GSR Assessment of Contingency Options:
  - Engineered Bioreactor
  - Physical-Chemical Treatment

GSR Metrics

– **Green**
  - Greenhouse Gas
  - Criteria Air Pollutants
  - Energy
  - Landfilled Waste

– **Sustainable**
  - **Environmental**
    - GHG Emissions
    - Other Air Emissions (including Ammonia)
    - Landfilled Waste
    - Preserve Ecosystem/Habitat
  - **Social**
    - Valuing Nature
    - Human Health and Safety
  - **Economic**
    - Cost
    - Lifespan and Flexibility

GSR Assessment Toolbox

- **SiteWise:**
  - Publically available excel based environmental footprint tool
  - Includes all remedial activities, i.e.
    - Material consumption, transportation, on-site construction, labor, waste handling
  - Uses life cycle based factors to quantify common environmental metrics for on site and off site activities, i.e.
    - GHG emissions, energy use, water use, waste production, worker safety

- **AECOM Qualitative Sustainable Remediation Tool (AqSRT):**
  - Excel based proprietary tool built by AECOM based on SuRF-UK sustainable remediation indicators
  - Can be customized to look at site specific themes or sustainability indicators
    - Environmental
    - Social
    - Economic

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Ex Situ Bioreactor

- Multi acre mulch bed bioreactor system to nitrify and denitrify groundwater to convert ammonia to nitrogen gas and sulfate to sulfide followed by sulfide precipitation.
- Caustic amendment to neutralize the acidic conditions produced by nitrification
- Microbial production of sulfide required the use of zero-valent iron (ZVI) that precipitated iron sulfide.
- Discharge to infiltration bed

Ex Situ Physical-Chemical Treatment System

- Air stripping system to volatilize ammonia and precipitation of sulfate with barium.
- Caustic amendment to remove ammonia by air stripping, acid neutralization following stripping to return the treated water to a neutral pH.
- Barium chloride added to precipitate barium sulfate.
- Discharge to infiltration bed

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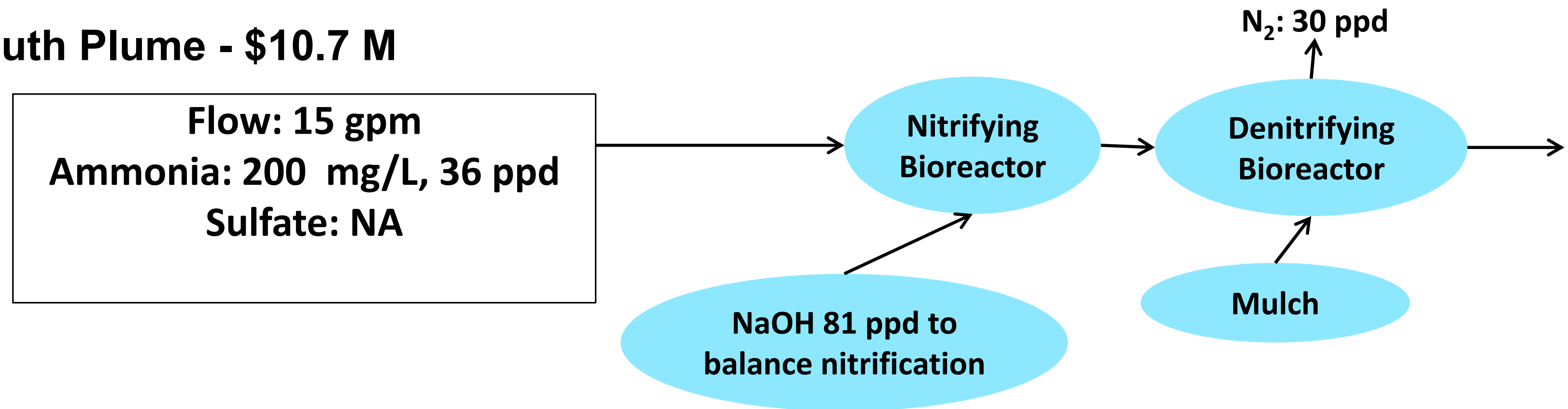
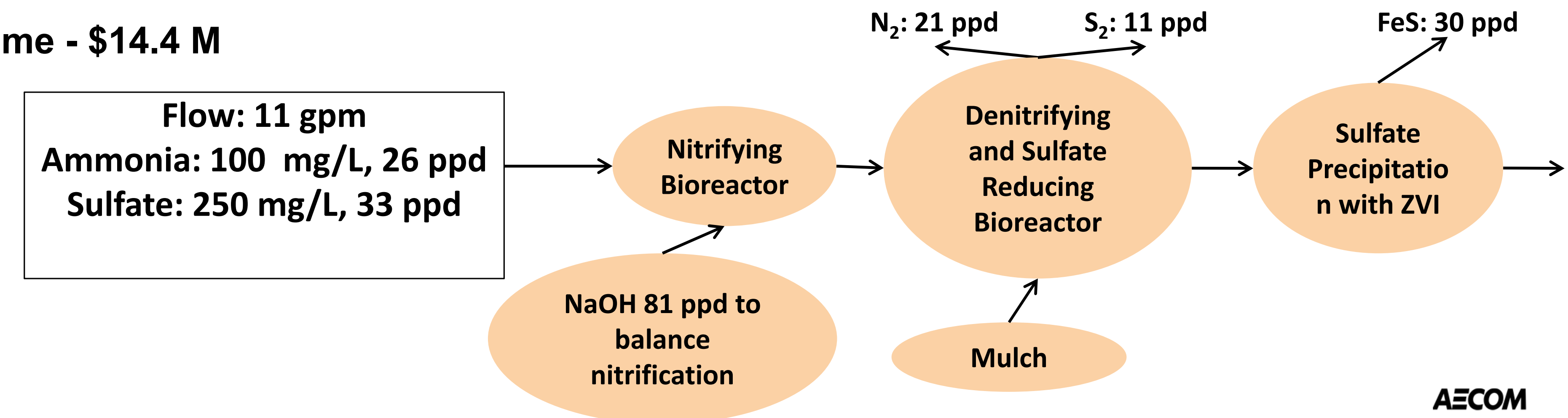
Process Flow Diagram – Bioreactor

- **South Plume - $10.7 M**



- **East Plume - $14.4 M**



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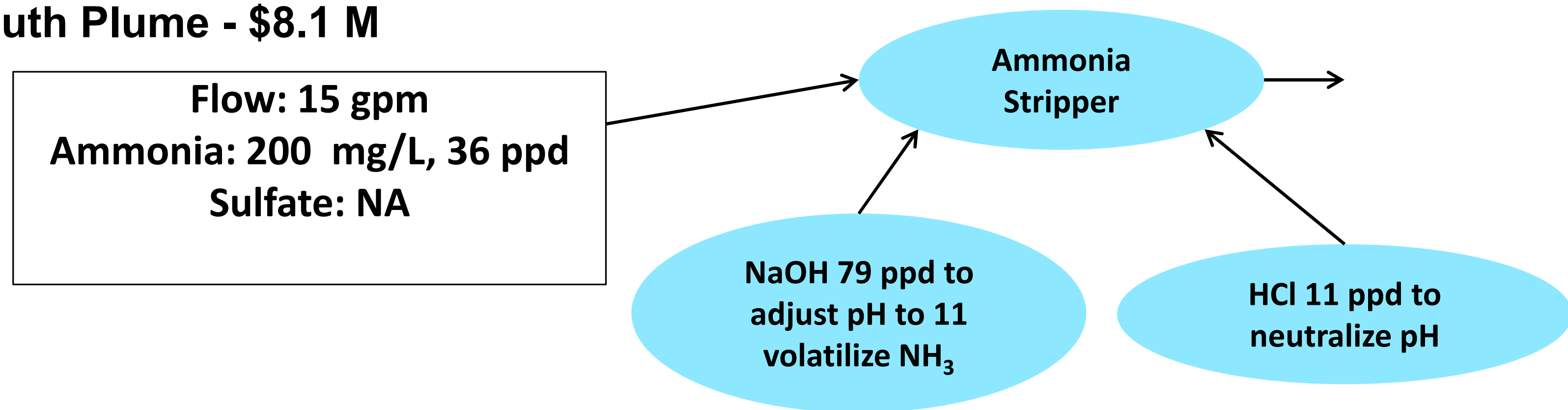
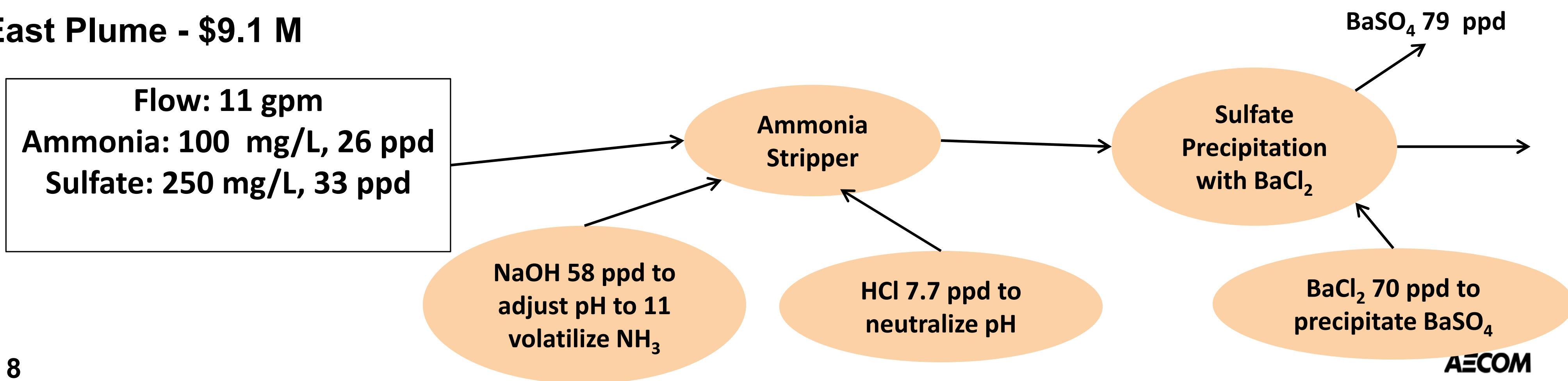
Process Flow Diagram – Phys/Chem Treatment

– **South Plume - $8.1 M**



– **East Plume - $9.1 M**



SiteWise Assessment Approach

1. Develop remedial option scope and material balance for the three remedial alternatives by reviewing the CMS document, standard practices, technical experience, and client feedback for each alternative.
2. Determine specific inputs (quantities, utilization, etc.) by reviewing the CMS-TI conceptual designs, cost estimates, and standard practices for each alternative.
3. Input the quantities into the SiteWise tool, peer review the calculations and basis. Utilize SimmaPro material impacts where needed.

– Key Step: Defining the scope of each remedial alternative to be able to quantify inputs.
  - Set analysis boundary
  - Clearly state all assumptions

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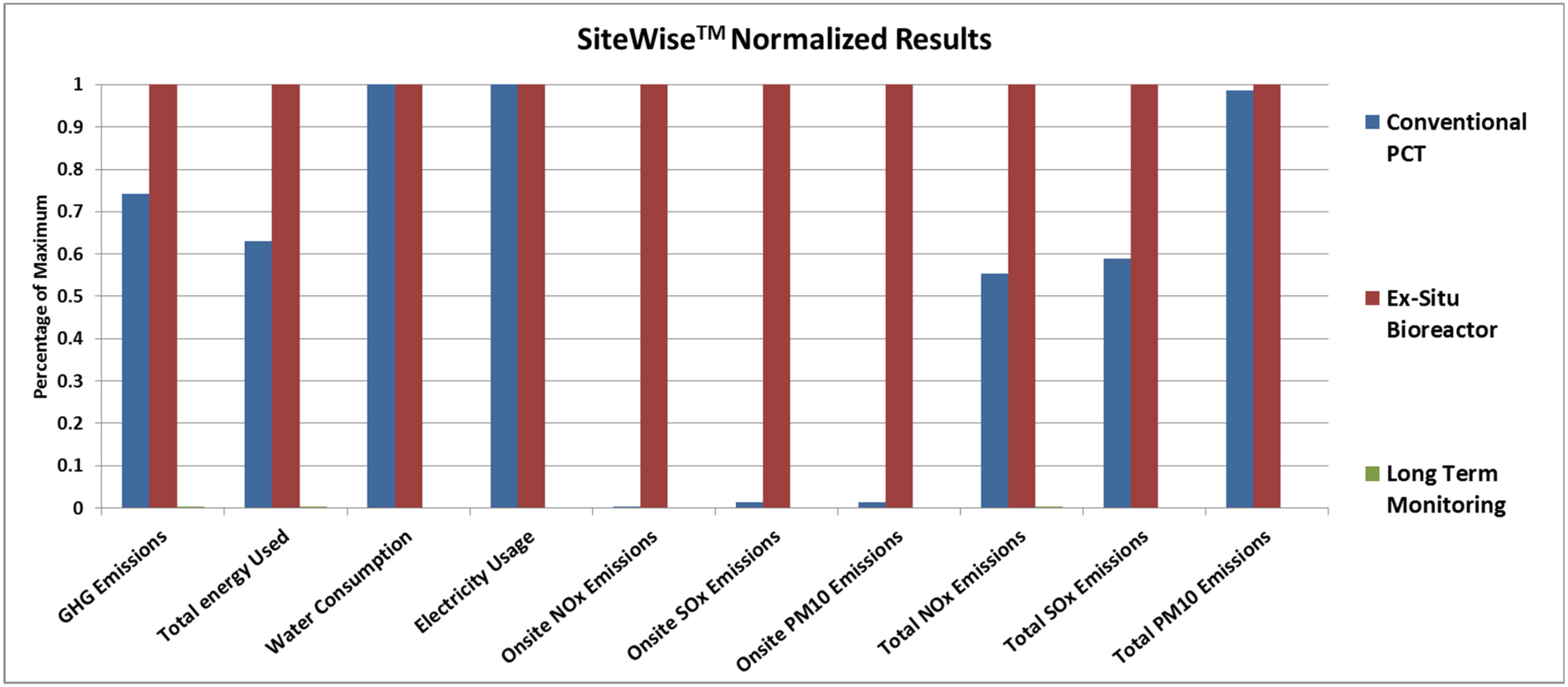
SiteWise Results

Remedial Alternatives	GHG Emissions	Total Energy Used	Water Consumption	Electricity Usage	Total Conventional Air Emissions	Ammonia Emissions	Non-Hazardous Waste Landfill Space
	metric ton	MMBTU	gallons	MWH	metric ton	metric ton	tons
Physical/Chemical TTX	1777	17686	249862	490	12.12	427	433
Bioreactor	2395	28082	249862	490	19.58	0	224
Long Term Monitoring	6.19	85.75	0	0	0.04	0	0

Remedial Alternatives	GHG Emissions	Total Energy Used	Water Consumption	Electricity Usage	Total Conventional Air Emissions	Ammonia Emissions	Non-Hazardous Waste Landfill Space
Physical/Chemical TTX	Medium	Medium	High	High	Medium	High	High
Bioreactor	High	High	High	High	High	Low	Medium
Long Term Monitoring	Low	Low	Low	Low	Low	Low	Low

SiteWise Results



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An unexpected finding…

– Biological/natural based remedies often thought to be more sustainable than other technologies

– This assessment showed the footprint of the microbial bioreactor option to be on par with the physical-chemical treatment option. Must consider all remedy aspects:

- pH control for nitrification
- Mulch for bed material

= ↑ **Environmental Footprint**

- Some greener alternatives?
  - Consider use off limestone filtration bed for pH control instead of liquid caustic additives
  - Consider securing beneficial reuse mulch material e.g. tree maintenance waste

AqSRT Assessment Approach

1. Define assessment criteria based on client sustainability priorities and built in sustainability categories.

2. Assign a weighting value (1 to 5) to each assessment criteria based on environmental metrics results from the SiteWise tool, discussions of criteria importance to client, and inferred stakeholder values for the community.

3. Rate each remedial option (1 to 5) against each of the assessment criteria, i.e., the relative degree to which the option addresses each sustainability criteria.

The tool aggregates the resulting scores and provides equal weighting of sustainability themes to the overall score

AqSRT Inputs

Assessment Criteria		Weight	Remediation Option			Justify your scores for each of the assessment criteria
			LTM	BR	PCT	
Economic	Cost to Build and Operate	5	5	1	2	Conceptual level cost estimates
	Project Lifespan and Flexibility	3	5	3	1	BR more flexible than PCT
		TOTAL	10	4	3	
Environmental	GHG Emissions	5	5	1	1	BR and PCT same order of magnitude
	Ammonia and Conventional AP Emissions	4	5	5	1	Conventional air pollutant emissions quite low compared to Ammonia
	Impacts to Ecosystems / Habitats	4	5	1	3	Physical footprint, chemical handling needs
	Energy	2	5	1	1	Estimated energy for by-product mulch in SiteWise are allocated from lumber
	Landfilled Waste	3	5	2	1	Based on SiteWise results
		TOTAL	25	10	7	
Social	Impacts on Human Health and Safety	4	5	2	1	Chemical handling, complexity of operations
	Valuing Nature - Community Access	5	5	1	4	Smaller footprint (multiple acres for bioreactor vs PCT), preserve open space.
	Process Safety - Chemical Exposure	4	5	2	1	Caustic, HCl, BaCl for PCT
	Beneficial Reuse of Materials	1	1	5	1	Bioreactor uses mulch and ZVI. Others none
		TOTAL	16	10	7	

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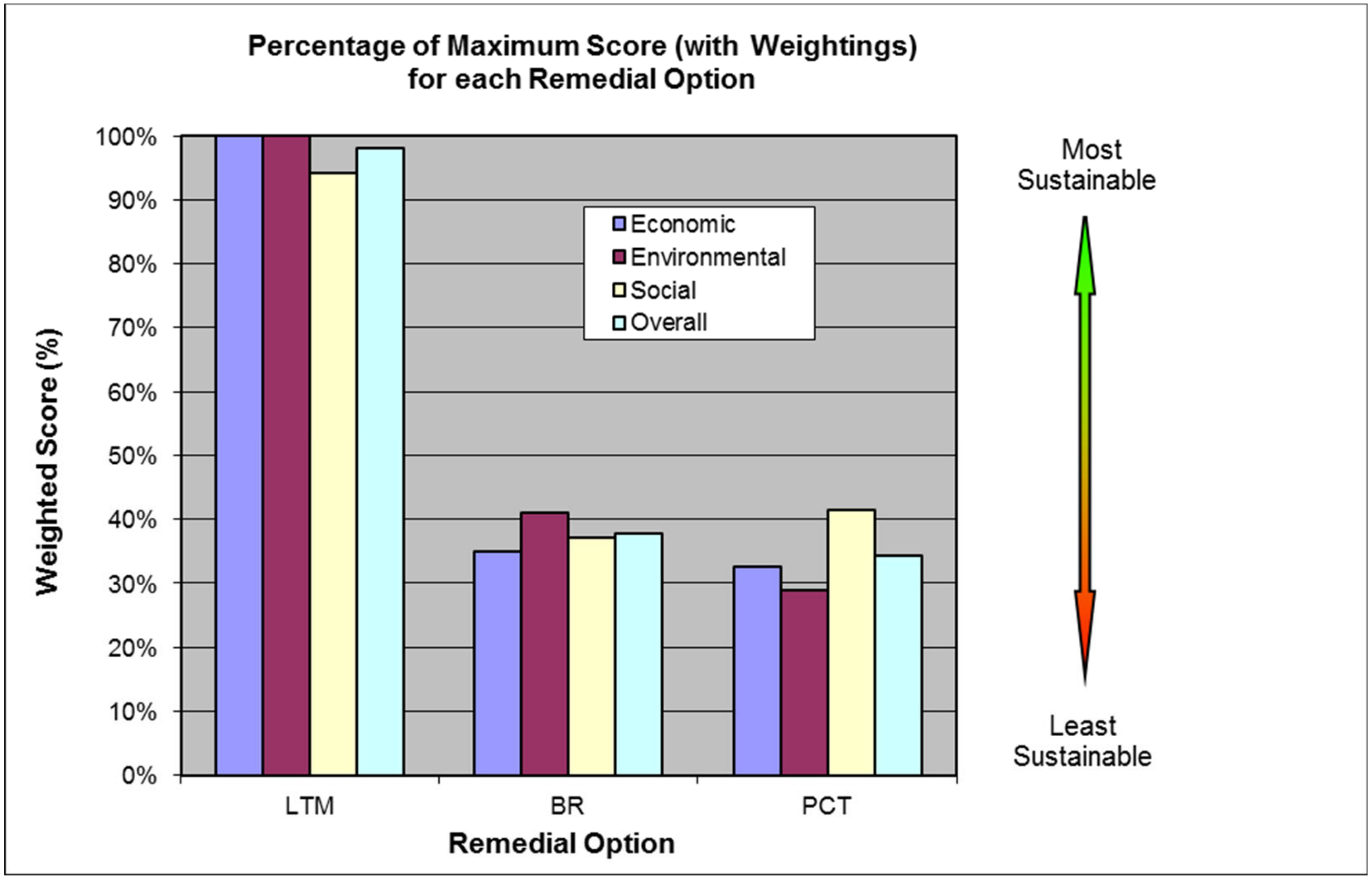
AqSRT Results



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Overall Conclusions

- Many benefits to conducting sustainable remediation assessment early on in the remediation process:
  - Identify and incorporate footprint reduction opportunities into the design
  - Better transparency, engagement and understanding of sustainability tradeoffs (Environmental, Social, Economic)
- Different tools can show different results.
  - AqSRT identified PCT as the highest environmental impact (lowest scoring), while SiteWise identified PCT with generally lower environmental impact.
  - Differences in compared criteria & considerations (ammonia, valuing nature).
- The unexpected SiteWise results showing comparable footprints for the two remedies enabled identification of high-impact materials and project components.
  - Don’t make assumptions about which technologies are sustainable!

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Thank You!

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