PASSIVE AND NATURE-ASSISTED REMEDIAL TECHNOLOGIES FOR REMOTE SITES

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Introduction & Context

- **Remote Site Challenges**
  - Power
  - Services
  - Access
  - Manpower
- **Remote Site Opportunities**
  - Time
  - Passive, Nature-Assisted Remediation Programs

Balance between:

Capital Investment vs Speed of Clean-up

The Desert Island Analogy

- **Remote Site ~ Desert Island**
  - No available remedial technologies, equipment, services, utilities, manpower or site access
- **Abundant Natural Resources**
- **Abundant Naturally Occurring Processes**
- **Opportunity to Harness and Enhance for Remedial Intervention**

The Toolkit

- Wind, Solar & Hydro Power
- Photo-Chemical Reactions
- Hydraulic Transport
- Wetlands
- Natural Attenuation
- Phyto-Remediation
- Phyto-Transformation
- Soil Amendment

Wind, Solar & Hydro Power

- **Wind power →** capture and conversion of wind energy into mechanical energy or electricity, using wind turbines
- **Solar power →** conversion of sunlight into heat, chemical reactions, electricity and mechanical power via photovoltaic cells
- **Hydro Power →** transmission of moving water into mechanical energy and electricity
- **Run of River →** natural stream/river flow transfer to hydroelectric power

Photo-Chemical Reactions

- *Photo-chemical energy (UV light) stimulates chemical destruction reactions in controlled environments*
  - **Ponds**
  - **Wetlands**
  - **Engineered Environments**

Wetlands

- Naturally occurring or constructed on-site
- Leverages
  - Reactions via micro-organisms in water and plant root zones
  - Direct solar reactions from the sunlight

Hydraulic Transport Mechanisms

- Dissolved and Separate Phase Fluid Flow
- Hydraulic Gradient Control
- Pipe and Channel Flow

Natural Attenuation

- Chemical, Physical and Biological Processes
  - **Sorption**
  - **Volatilisation**
  - **Biodegradation**
  - **Dispersion**
  - **Dilution**

Phyto-Remediation

- Chemical Extraction via transpiration
- Contaminant uptake via plant root systems
- Storage in roots, stems and leave biomass
- heavy metals, some organics and salt

Phyto-Transformation

- Plant metabolism of contaminants
- Micro-organisms in plant root systems metabolism of contaminants in soil/water
- some organic pollutants, hydrocarbons, pesticides, explosives and solvents

Soil Amendment

- Bioremediation enhancement with available vegetation
- Application to bio-piles and landfarms
- Reduction of fertilizer needs

Project Case Study 1

- **Geology**
  - Sand and Silty Sand unit containing shallow groundwater at 2.5m
  - Sand underlain by Clay unit with sand lenses
  - Chlorinated solvent plume in shallow groundwater
  - Primary contaminant is Vinyl Chloride
- **Design Challenges**
  - Control of off-site migration
  - Restoration of on-site soil and groundwater quality
  - Reasonable timelines
  - Cost effective remedial strategy

Project Case Study 1

- **Phyto-Barrier Boundary Control**
- **Nutrient Testing**
- **Hydrogeological Evaluation (1m/yr)**
- **Hybrid Poplar/Willows**
  - Root Zone Structures (2m)
  - Max Transpiration after 3-4 years
- **Theis Draw-Down Model**
  - 150m^3/yr, 1-2m drawdown radius (yrs 1-3), increasing yrs 4+
- **Winter Conditions**
  - Dormant Growth vs Groundwater Flow
- **Installation**
  - 2m between trees, 3m between rows, 2m bgs
  - Soil Amendments – nutrients and vegetation
  - Lateral perforated PVC pipes in trenches – aeration/nutrients

Case Study 1	*Excavating trench to plant hybrid poplar trees*

Project Case Study 1

- **Results**
  - Initial height –> 1m; 1st Spring –> 2m
  - 6 months –> 3-4m; 2years –> 15-20 m
  - Remedial Activity
    - Combined transpiration and microbial activity in root zones
  - 3400 ug/L VC up-gradient
  - < 1 ug/L VC down-gradient
  - >99% Reduction across phyto-barrier
  - < Regulatory Criteria

Case Study 1	Tree growth after several months. Smaller trees in front row

Case Study 1	Tree growth one year after planting

Case Study 1:	*Tree growth after 1-year.*

Project Case Study 2

- **Petroleum hydrocarbon (gasoline) plume**
- **Migration towards the site boundary**
- **Silts and sands underlain by Clay**
- **Shallow groundwater at 3m**
- **Primary design requirements**
  - Low cost solution – site not generating revenue
  - Boundary Control
  - Minimal O&M as site unused
  - No time constraints

Project Case Study 2

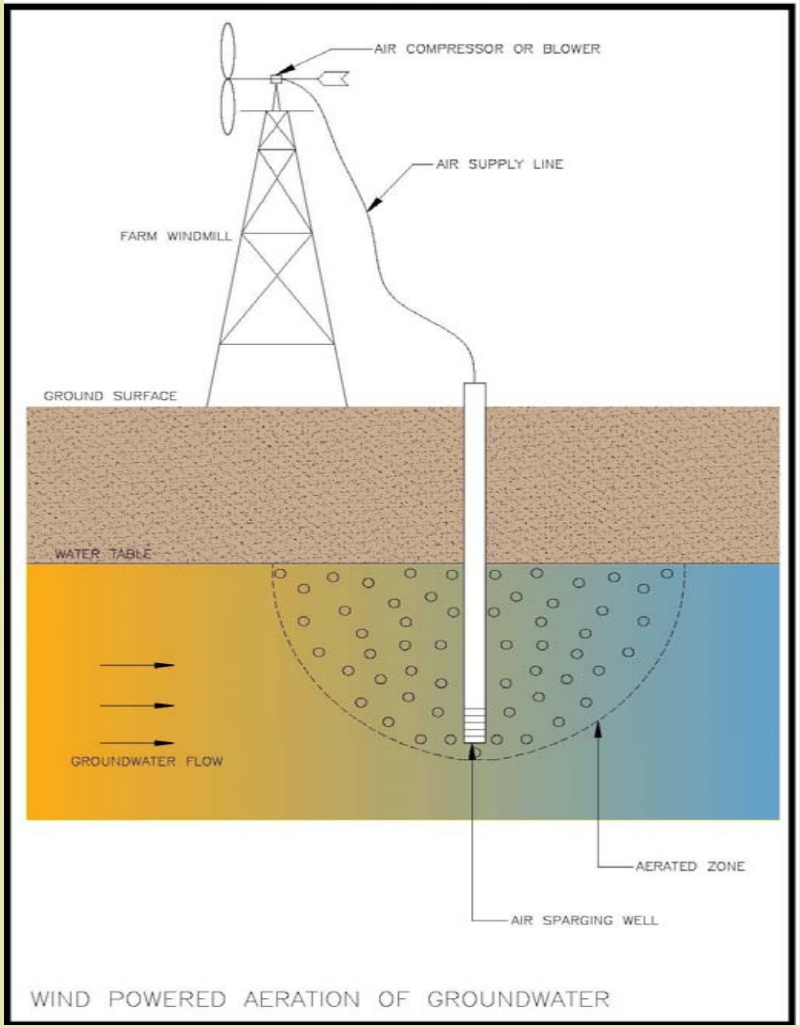
- **Perimeter Control**
  - Phyto-barrier
  - Hybrid Poplar/Willows
  - 2-row Boundary Control System
- **Source and Central Plume Area**
  - Wind-Powered Bio-sparging System
  - Windmill Shaft connect to Diaphragm Pump
  - Variable flows up to 30 psi
  - 3 x Sparge wells
  - Aeration to Accelerate Bioremediation and NA
  - Passive Operation – no O&M

Case Study 2:	***Planting hybrid poplar trees along site boundary***

Case Study 2: ***Windmill and Air-Sparge system installation.***

Designing with Wind Power

- **Direct drive air pump**
- **Pressures up to 30psi**
- **Air accumulation in in-situ pulse tanks**
- **Pulse control with solar control panels or pressure release valves**

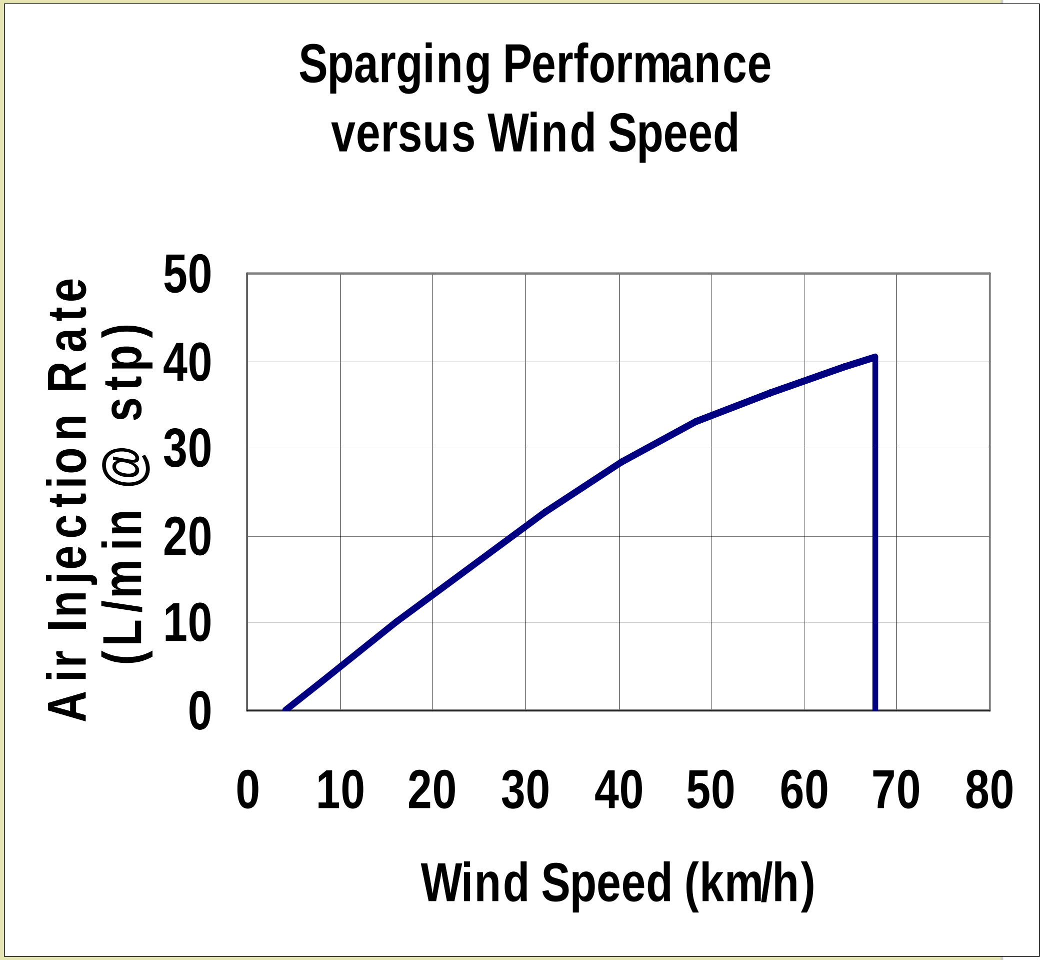


Designing with Wind Power

- **Flow Rates dependant on:**
  - Windmill Design
  - Back Pressure on Air Line
- **Back pressure calculated from water column being sparged**
- **1 psi = 2.3 ft of water column + approx. 1 psi for break-out**
- **Average 3-6 Sparge Wells per Windmill**

Designing with Wind Power

- Alberta Renewable Energy Test Site - Back-pressure of 1.5m of water
- Variable wind speeds using a 20-inch diameter windmill
- Range of air-injection flow-rates at STP
- Average Wind Speeds of 10-30 km/h → 5-20 L/min (or 0.2-0.7 CFM)
- Maximum Winds Speeds > 40km/hr → 30-50 L/min (or 1-2 CFM)



Project Case Study 2

- Perimeter Results
  - 90% Concentration Drop across Phyto-Barrier in 1-year
  - 5% Tree loss – physical damage
- Central Plume Results
  - 75% Concentration Reduction Across Source Area in 1-year

Summary

- **Remote Site Challenges & Opportunities**
- **The Desert Island Analogy**
- **Nature Assisted Remediation: The Toolkit**
- **Case Study 1:**
  - 99% Reduction over Phyto Boundary (2-years)
- **Case Study 2:**
  - 90% Reduction at Perimeter over Phyto Boundary (1-year)
  - 75% Reduction in Source Area from Wind-powered Bio-Sparging

Summary

- Successful remediation design balances the capital investment required and the speed of cleanup.
- For remote sites, it is often most economical to evaluate passive systems over longer time periods.
- Passive, Nature-Assisted Remedial Technologies also applicable to non-remote sites where remedial timelines are not limited.
- Discussion paper to promote information sharing and further application Nature-Assisted Remediation Technologies.