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Harnessing Wind Power For Remediation Via Soil Vapour Extraction In Remote Areas

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Banff, Alberta

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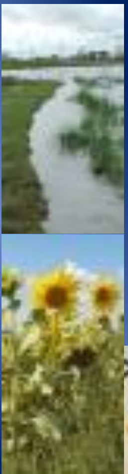
Project Supported by :
Apache



Objective and Outline

- OBJECTIVE:
  - Provide a lower carbon footprint process for extracting vadose zone subsoil volatile organic chemicals in remote areas
- OUTLINE:
  - Site Characteristics
    - Environmental characteristics
    - Nature and distribution of chemical impacts
    - Remediation endpoints
  - Vapour Collection & Treatment System
    - Vapour wells
    - Renewable power subsurface soil air pumps (windmills)
    - Vapour storage and processing
    - Power system and instrumentation
    - Treatment system
    - Year round operation solutions
  - Results and Conclusions
    - Volatile organic chemical mass extraction rates
    - Carbon footprint
    - Estimate time to cleanup

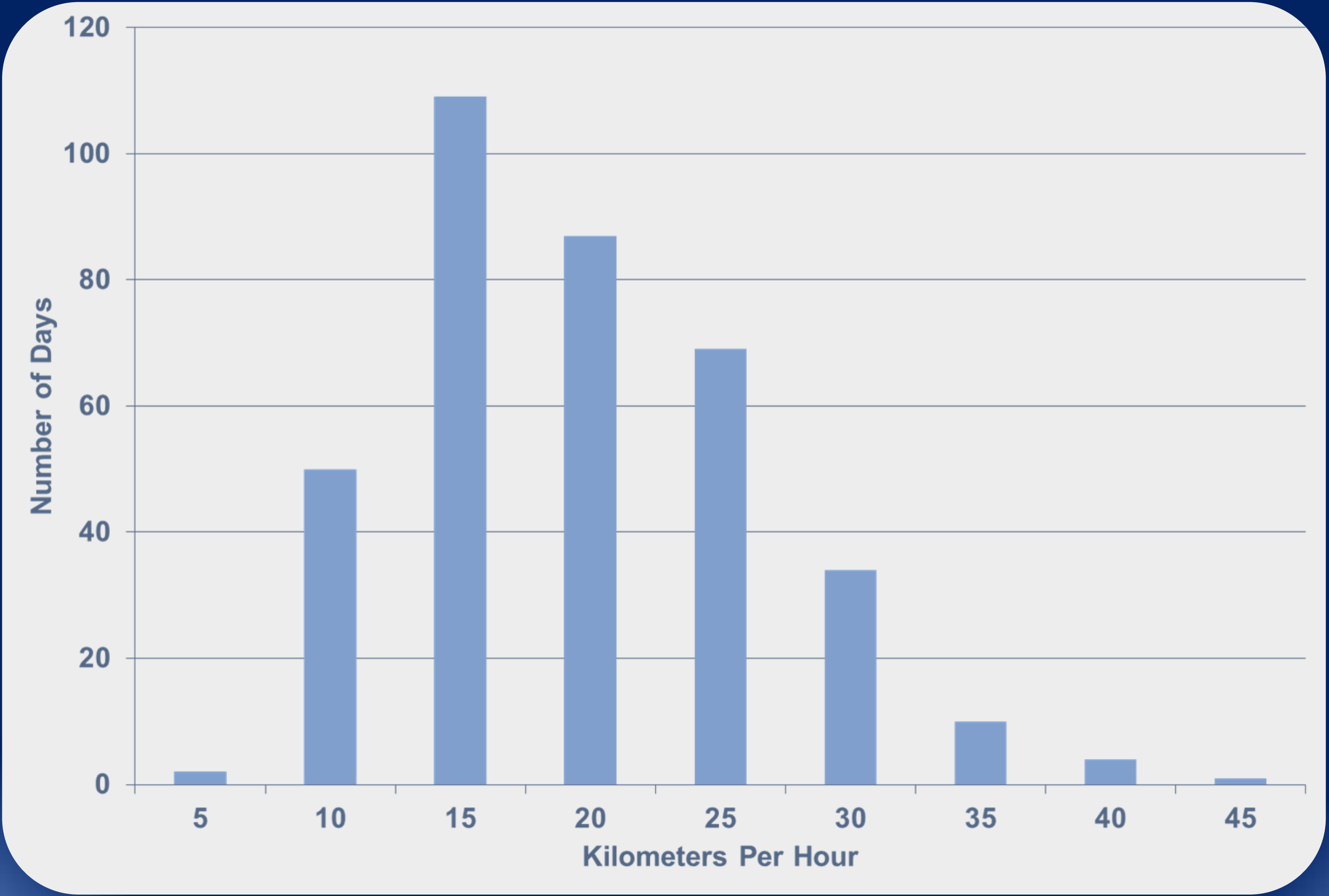
Site Characteristics

Site Characteristics

- LOCATION:
  - Rural area of Alberta
  - Local region being returned to a native pasture ecozone
  - Low impact footprint approaches are preferred
  - No readily available power source – requires remote source

Site Characteristics

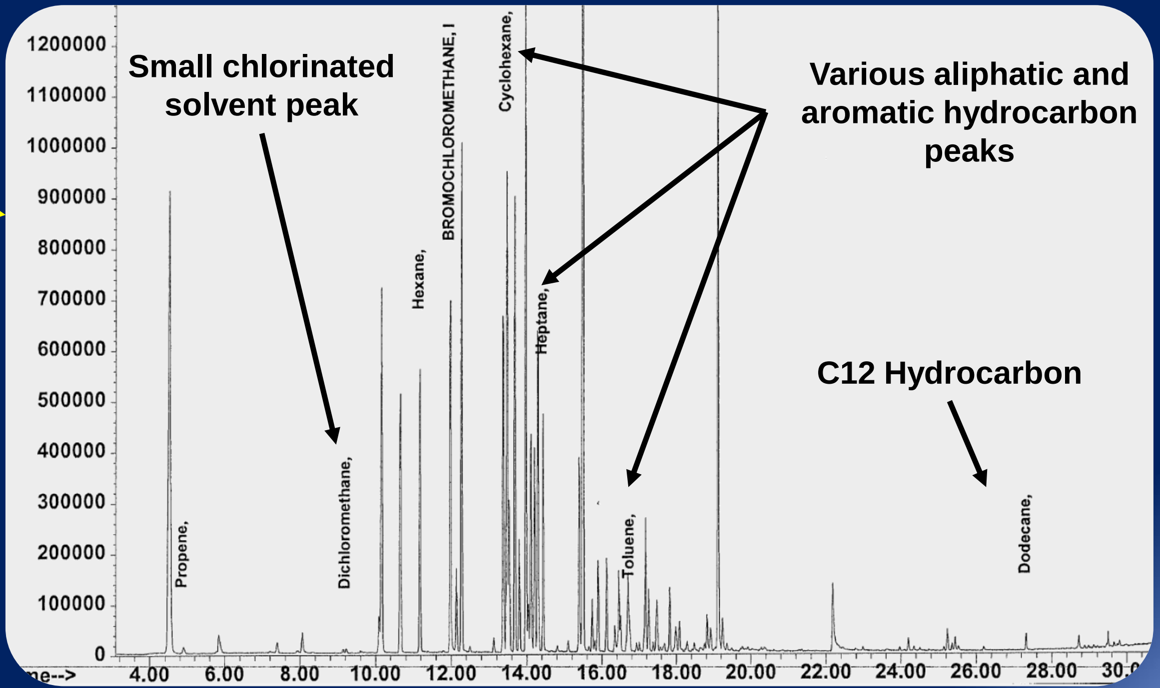
- CLIMATE:
  - Warm summers, cold winters, humidity generally low
  - Temperatures may reach – 30 ºC in winter
  - Decent wind speeds on average



Site Characteristics

- NATURE OF CONTAMINANT IMPACTS:
  - Non-sour gas well and condensate (gasoline range hydrocarbons)
  - Solvent impacts due to cleaning operations
  - Impacts in ground appear related to tank location and pit box
  - Typical volatile organic chemicals (VOCs) in soil air space
    - GC/MS analysis, < C_{14}, aromatic and aliphatic, with chlorinated organics and ketones in some samples
- REMEDIATION ENDPOINT:
  - Site-Specific Risk Assessment (SSRA) Human and Ecological Health Soil Remediation Guidelines

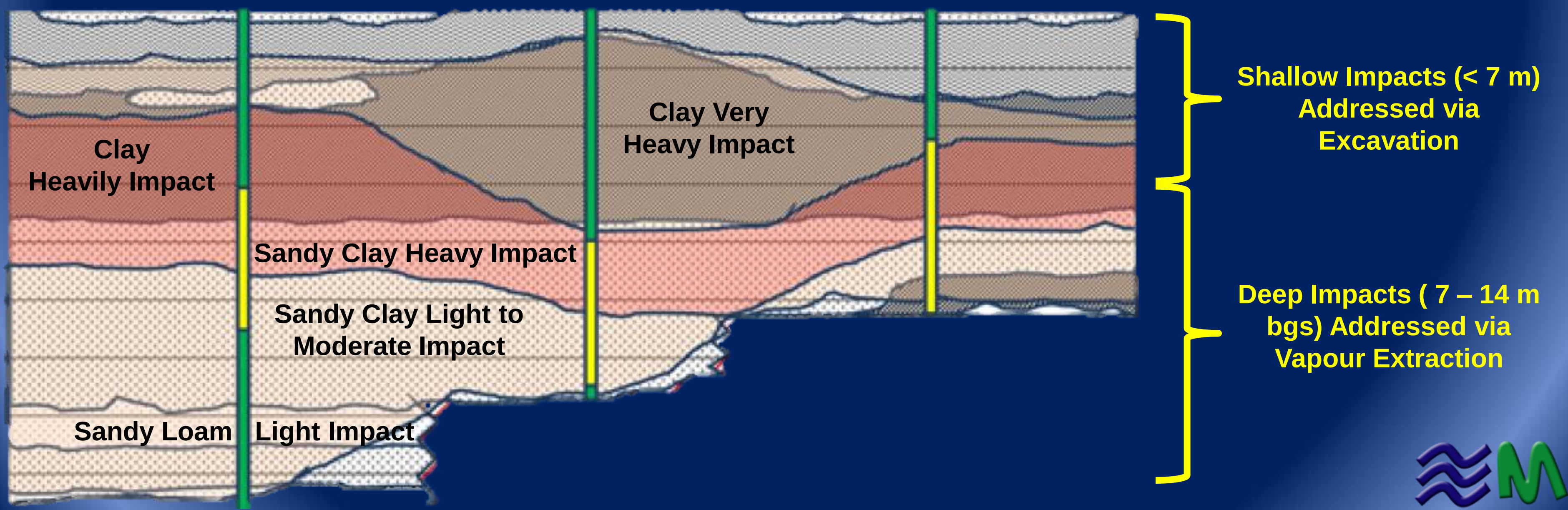
Compounds detected in soil air space



Site Characteristics

- LITHOLOGY:
  - Heterogeneous lenticular distribution of soil layers
  - Unsaturated soils to soil depth 20+ m bgs

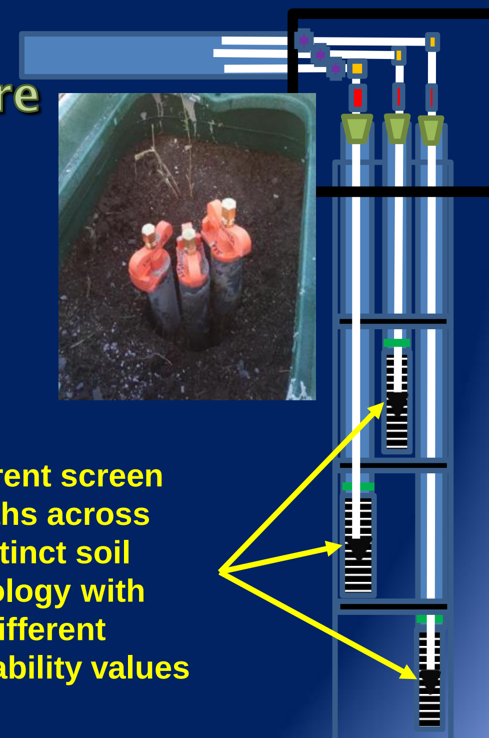
- VERTICAL IMPACT DISTRIBUTION:
  - Heavier molecular weight (MW) chemical impacts primarily in 7 m bgs fine textured soil
  - Lighter MW chemical impacts at 7 to 14 m bgs
  - Lighter MW chemicals broke through to deeper depths – smaller Kd values, less soil adsorption
  - Relatively huge pit would be required if all impacts excavated



Vapour Collection & Treatment System

Vapour Collection System

- VAPOUR WELLS:
  - 24 Single or triple nests (>60 individual wells in total)
  - 10 positive pressure air supply wells surrounding impact
  - 14 negative pressure air extraction wells within impact
  - Pilot test conducted for well spacing – wells spaced at ~5 m lateral offset (well center to center); constrained by structures
  - Nested well screens were required due to distinct lithologies
    - Allowed for optimization of extraction
    - Units that produced minimal vapours could be shut off until they re-bound or are recharged by the positive pressure wells
  - Nested wells were installed within a single 6" diameter auger hole



Red contours identify impact area – approximately 20 m x 15 m

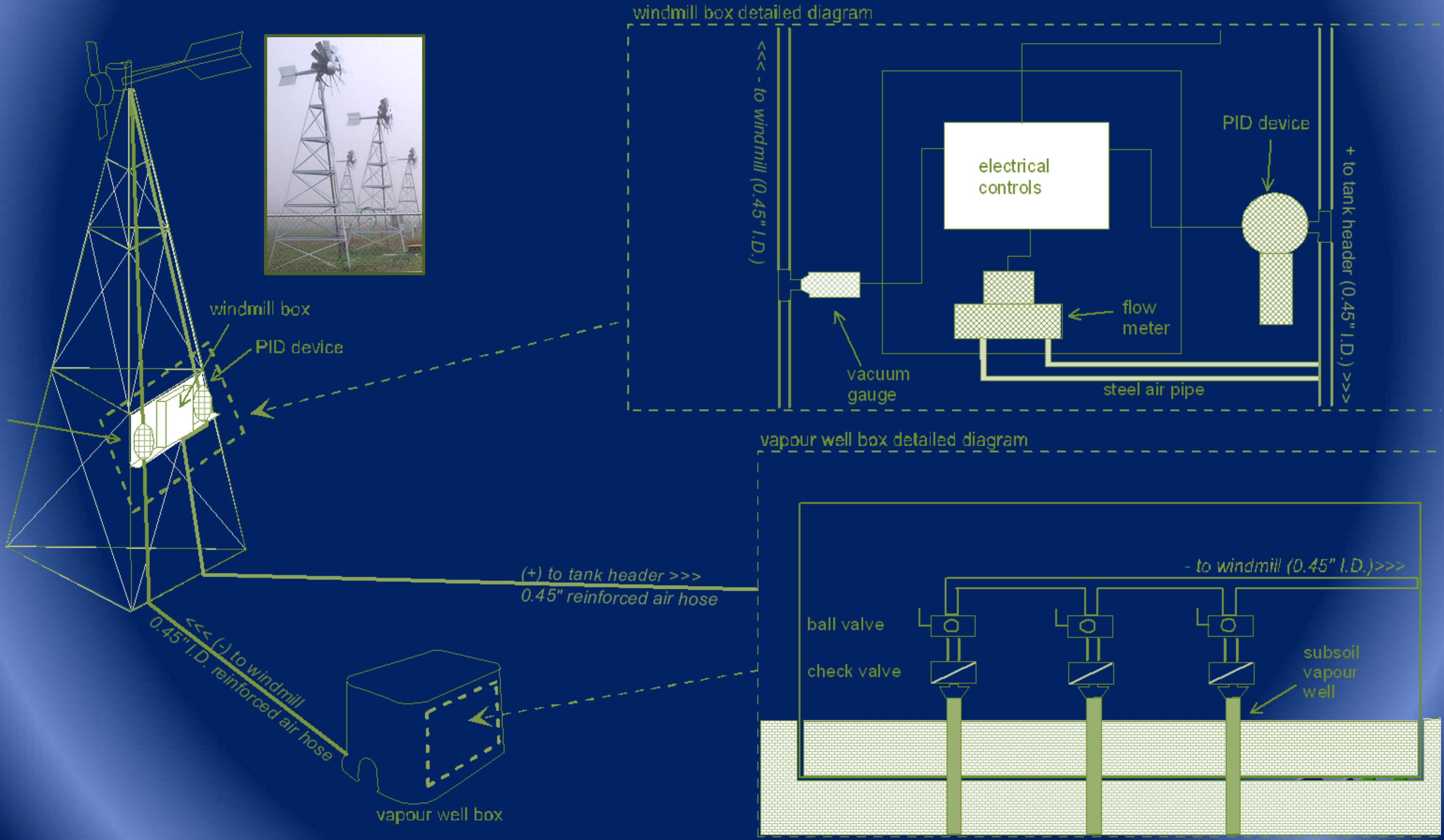
Different screen depths across distinct soil lithology with different permeability values

Vapour Collection System

- WINDMILLS:
  - structures from Koenders Windmills Inc. in Saskatchew
    – Canadian company in operation since 1988
  - Dual diaphragm design, very functional at low & high wind speeds
  - Windmill feet anchored in concrete, easily installed by 3-4 workers
  - Optically pleasant – agricultural style
- Vapour storage vessel with pressure specifications
  - Contains organic vapours before treatment
- Fenced site to prevent human/livestock/wildlife 'interactions' with equipment and vapours

Vapour Collection System

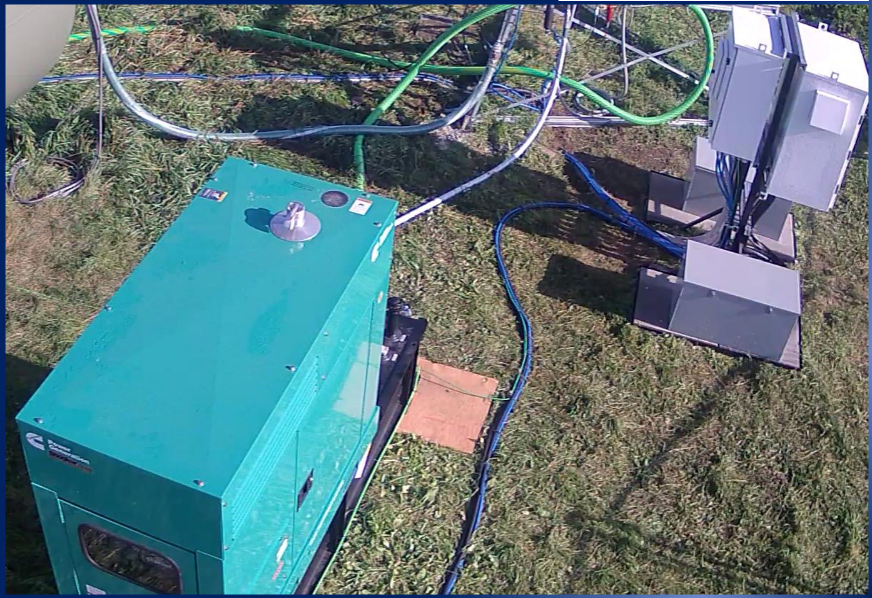
- GENERAL LAYOUT:
  - concentration measurement and air flow for mass calculations
  - Vacuum gauge for *in situ* air mass availability limits



Vapour Collection System

- POWER SYSTEM:
  - Small diesel generator with integrated fuel tank
  - Large bank of rapidly charging batteries
  - Genset run for 1.3 hours per day in summer, spring and fall; average 3.8 hours in winter (cold battery charging)
  - Intermittent operation

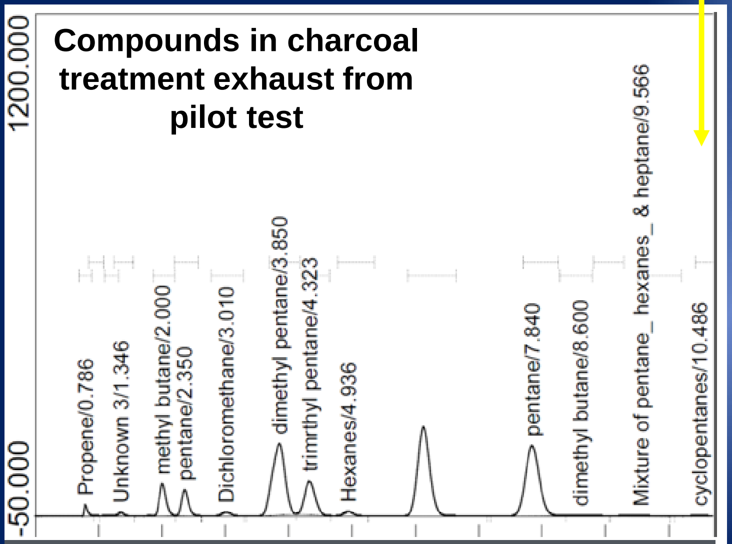
- INSTRUMENTATION:
  - Inline Photo Ionization Detector (PID)
  - Inline flow meter
  - Inline vacuum gauge
  - Dome cameras (infrared - night)
  - Storage tank flow meter
  - Storage tank pressure gauges
  - Genset conditions (temp, etc.)
  - SCADA communication system
    - Cellular (or satellite) network
    - Real time data and photos, pressures, PID, flows
    - Controllable remotely



Treatment System

- TREATMENT OPTIONS:
  - thermal oxidation, catalytic oxidation, condensation, carbon adsorption, resins adsorption, biological degradation
  - Activated charcoal tested, found inadequate – breakthrough in pilot tests (GC analysis of exhaust) - charcoal rapidly saturated

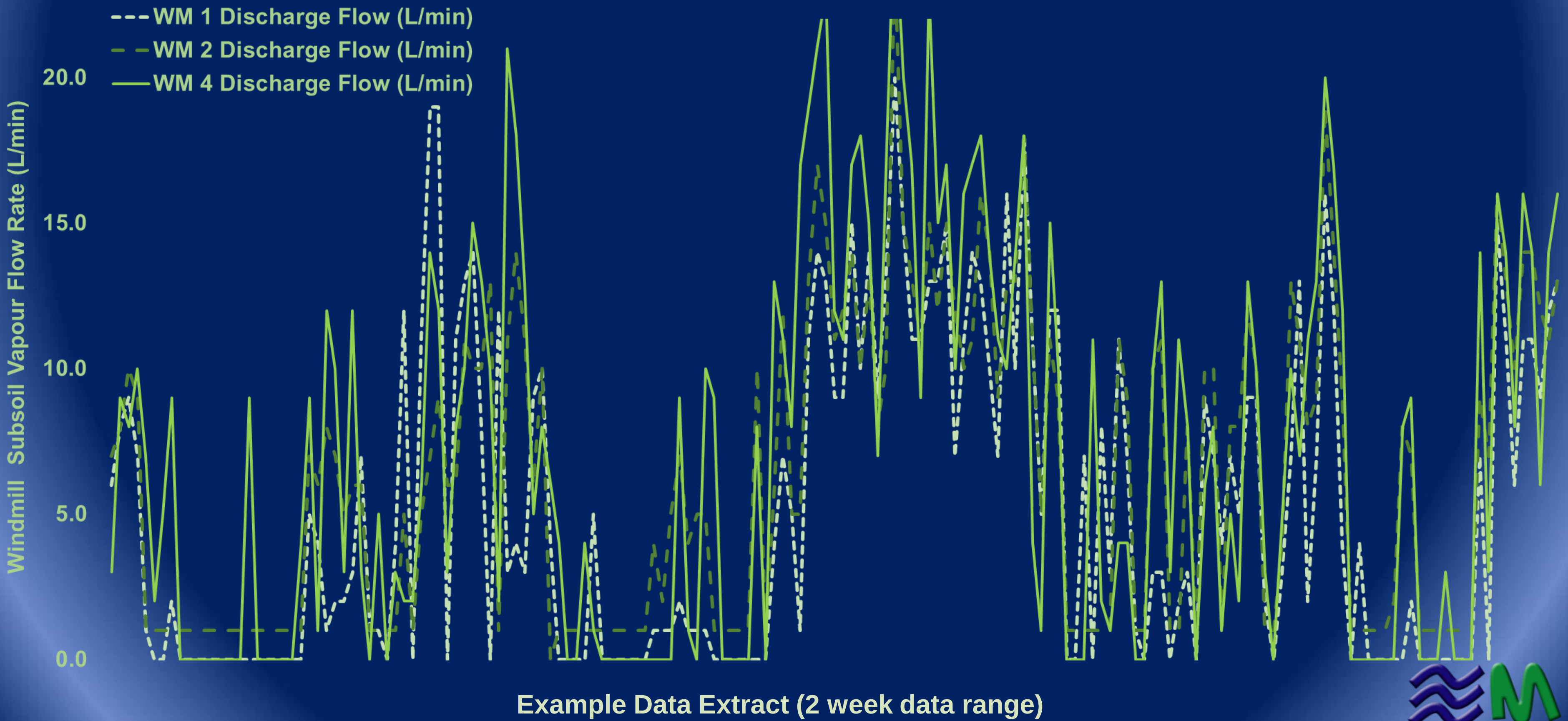
- SELECTED OPTION:
  - Thermal oxidation via co-combustion selected
    - Advantage – already consuming diesel to charge battery bank
    - Lower VOC airstream/engine intake mixing ratio of 1:20 produced negligible emissions; 1:10 ratio more notable emissions
    - VOCs represent approximately 0.38% of the fuel for combustion (mass/mass)
    - Gas powered engine could take advantage of VOC combustion, but would require a concentrating step – minimal net advantage



Results and Conclusions

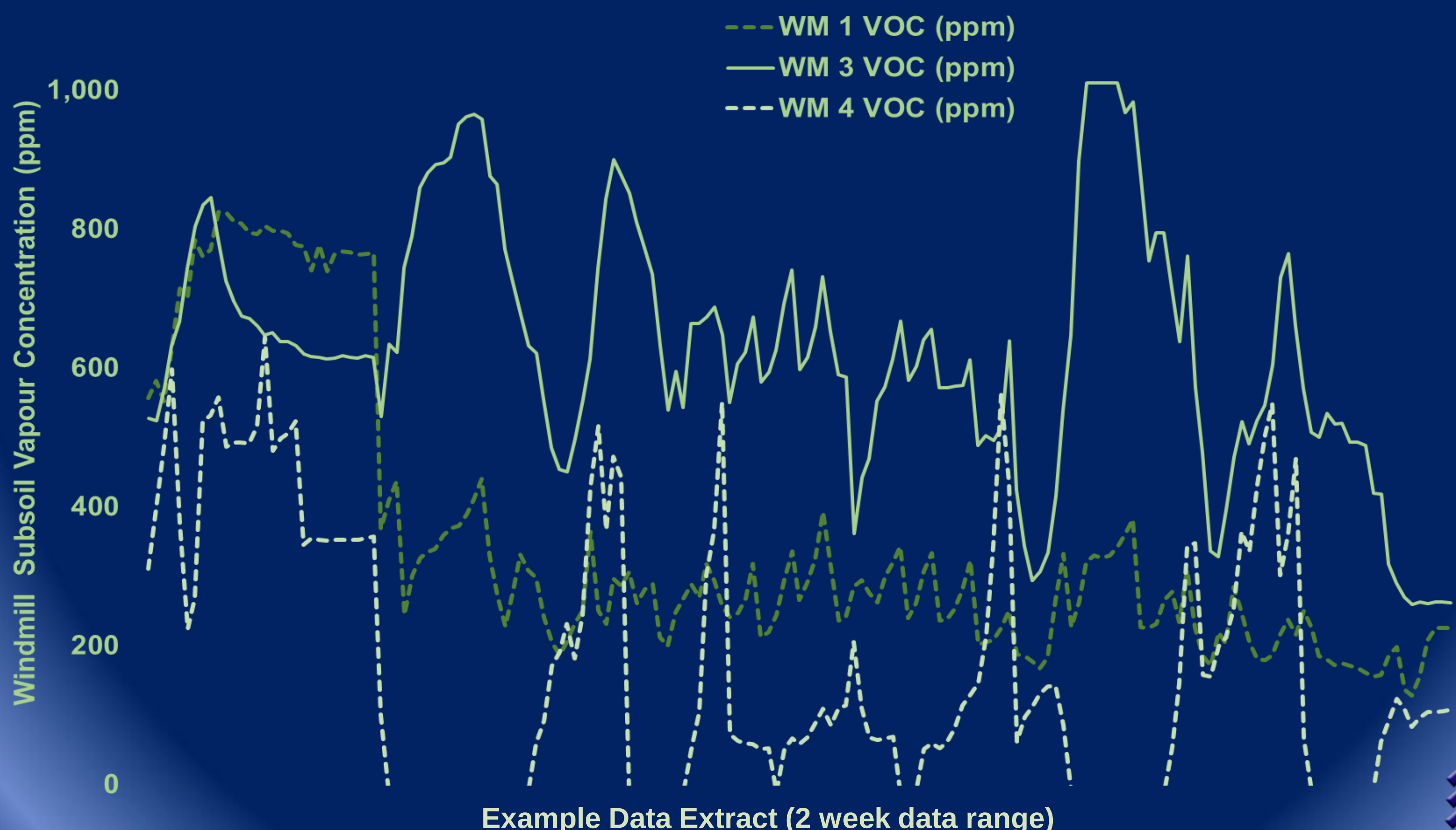
Results

- Windmill pumping rates are time-variable as a function of wind speed and direction
  - SCADA allows early diagnosis of windmill seal leaks or other mechanical issues (flow rate drops relative to other windmills)
  - Typical flow rates were > 15 L/min in high wind; 5 to 15 L/min in moderate wind; and 1 to 5 L/min in low wind (per windmill)
  - Acceptable operation under low wind speed conditions



Results

- Extracted subsoil VOC concentrations were variable over time, wind speed, extraction duration, and between well locations
  - Depletion of subsoil air space occurred in some well screens
  - Intermittent pumping rates of windmills acts as a natural surging system that allows for recovery and rebound of vapours
- Concentrations ranged from 100 to ~1000 ppm



Results

- MASS RECOVERY AND REMEDIATION TIME TO ENDPOINT:
  - Concentration range of 100 to 1,000 ppm
    - PID correction required – chemical specific
    - ppm to mg/m3 correction required – chemical specific
    - Conservative site-specific calculation: 100 ppm = 1,040 mg/m^3 (2.6-fold correction for PID (e.g., n-heptane) and 4.0-fold for ppm to mg/m^3 (e.g. n-heptane)
      - Actual correction factors more complicated and less conservative

  - Approximately 2,520 kg of liquid product equivalent needs to be removed to achieve the SSRA-based remediation guidelines
    - Each windmill extracting approximately 0.1 kg/day
    - For n=5 windmills, extracting 14.5 kg/month of liquid product or ~174 kg/year (or 312 L/year)
    - Time to remediate with 5 windmills = 14.5 years
    - Currently adding 5 more windmills (total of 10) – time to remediate expected to reduce to approximately 7.25 years

Results

- CARBON FOOTPRINT REDUCTION FOR WIND VERSUS ELECTRIC:
  - estimated by comparing power and fuel demand from electrical vacuum pump and generator (gas or diesel) in lieu of windmills
    - 3 CFM electric vacuum pump, 3.4 A @120VAC (~= 5 windmills)
    - Operating 24 hours per day, 365 days per year
    - Equivalent to 404 Watts
    - CO_2 emission reduction of 3,540 kg to 8,370 kg/yr depending on power source (most efficient is diesel genset at low load)

Vapour Pump	Power Source	Average Flow Rate (CFM)	Power Draw (A @120VAC)	Fuel Consumption (L/year)	CO_2 Emission Reduction (kg/year) [(1)]
Windmills (n=5)	Wind	2.9	NA	NA	NA
Electrical Vacuum Pump (3.4 A)	Gas Generator (Powerhouse 500 (450 W rated); 0.41 L/hr)	3	3.4	3573	8370
	Diesel Generator (18 kW Prime; low load; 1.7 L/hr)			1322	3543

(1) – excludes emissions associated with fuel transport

Conclusions

- The use of dual diaphragm pumps mechanically operated via windmills is an effective means of vapour extraction
    - Produced on average approximately 3 cfm, 24 hours per day, all year round, based on 5 windmills, extracting vapours from depths of up to 15 m bgs
- The use of a small genset with a substantive battery bank can be used to maintain operation of SCADA system components (including cameras, heavy instrumentation data feedback, as well as remote control) year round even in cold climates,
    - Genset can serve as a source of vapour treatment when flow rates are optimized
- Use of windmills can notably reduce the carbon footprint of soil vapour extraction systems
    - Between 3,540 and 8,370 kg/year of CO_2 emission reduction can be reasonably achieved (excludes additional emissions due to additional fuel transport requirements)
- Significant vapour extraction can be achieve with even a small scale windmill setup