Optimized Approach for Minimizing Oil and Gas Asset and Remediation and Reclamation Liability Cost

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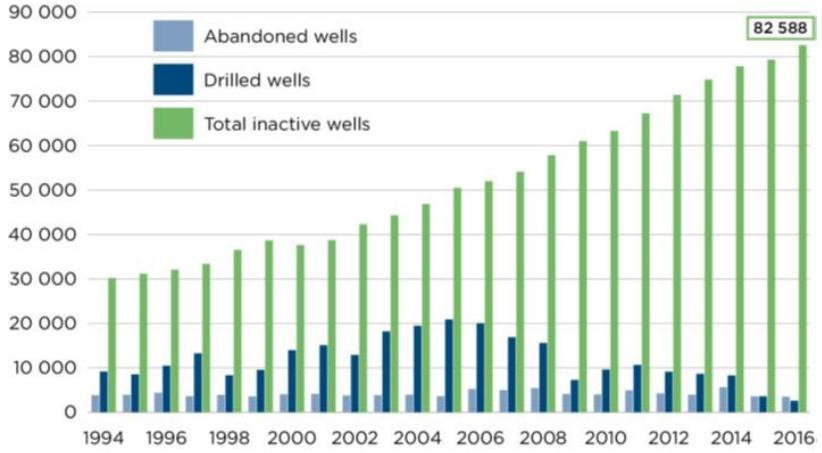
Outline

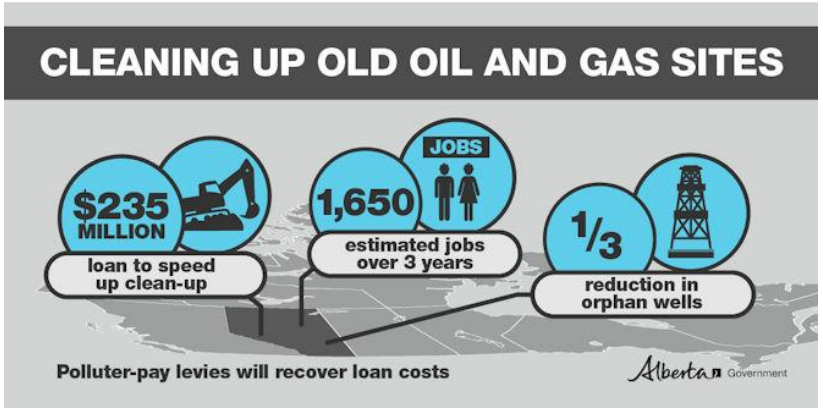
- Alberta inactive wells
- Phase Environmental Site Assessment (ESA) and reclamation liability costs: challenges and opportunities
- Procedure of site remediation and reclamation
- Integration of Life cycle assessment and biogeochemical processes
- Life cycle assessment for comparison of site remediation technologies
- Process-based models for phytoremediation/ reclamations
- Lessons and future work

Inactive wells liability

- 155,000 Alberta inactive wells
- More than 3,600 pipeline segments
- An average costs of $304,448 to reclaim a well
- $58.7 billion liability costs in future reclamations



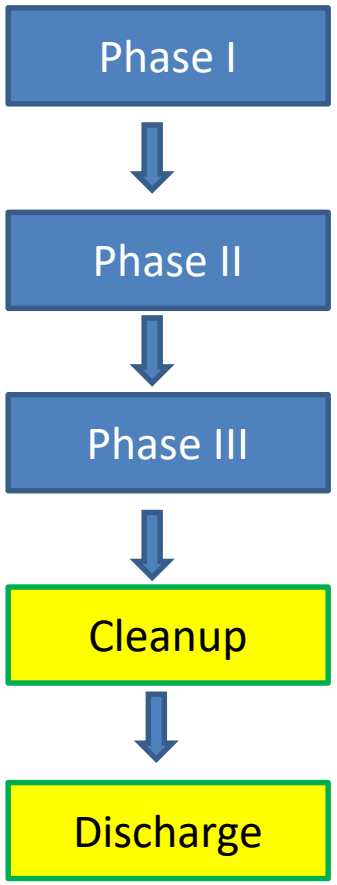
Alberta's inactive wells: 1994–2016 (AER)



Oil - Alberta Energy - Government of Alberta

Phase environmental site assessment

- ESA Phase I: Well site inspection and documents
- ESA Phase II: Sampling and contaminant assessment
- ESA Phase III: Soil and groundwater remediation plan and Feasibility/Risk Studies
- Cleanup, remediation and reclamation
- Certificate and Liability discharge



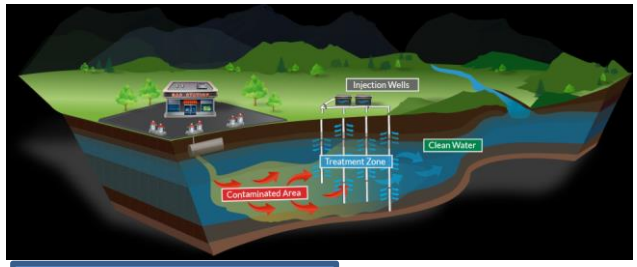
Procedure of well site reclamation

Phase III (Tier 2)
Plans

Phase II (Tier 1)
Contaminates

Phase I (Tier 1)
Inspection

Implementation



Remediation

Reclamation
(Phytoremediation or
Natural attenuation)

Restoration to human health
and ecological protection

Questions:

Cost and feasibility in site-specific conditions during ESA?

Challenges and opportunities

- The costs and technology limitation and uncertainties of the remediation to achieve human health and ecological protection endpoints.
    - Groundwater to drinking water standard to require a long-term operations (often decades to centuries) to pump-and-treat ground water systems, and then either reinject them to the subsurface or disposed of.
    - Soil restoration in site-specific conditions
- Difficulties for cost and feasibility assessment due to different site conditions
- Discourages for many responsible parties from cleaning up sites.

Challenges and Opportunities

- Any other approaches compared to expending huge sums of money on soil and groundwater remedial technologies?
- Or what changes in site management strategies and policies?

Any low cost Reclamation?

Any Changes in well site reclamation

Phase III (Tier 2)
Plans
Phase II (Tier 1)
Contaminates
Phase I (Tier 1)
Inspection

Implementation

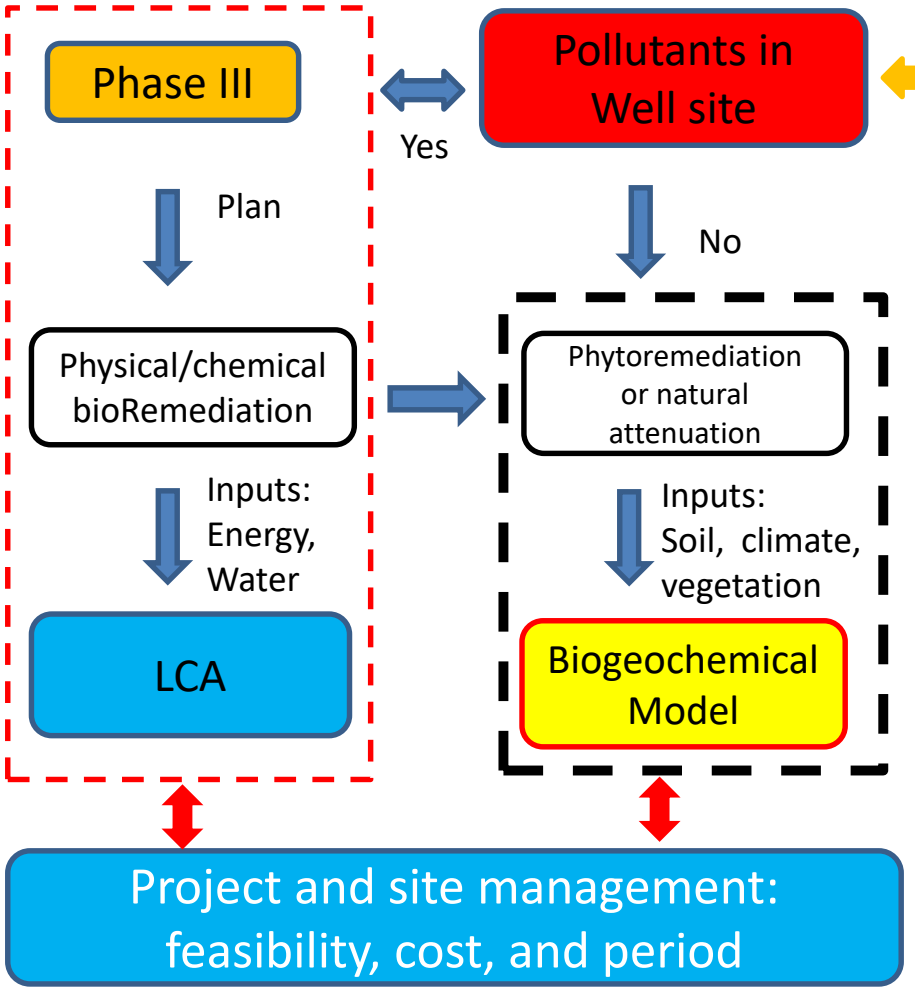
Remediation

Reclamation
(Phytoremediation or
Natural attenuation)

Restoration to nature

- Lower cost of phytoremediation compared to higher cost of physical, chemical, and bioremediation.
- More fraction for lower cost phytoremediation or natural attenuation?
- Increased cost for long-term monitoring and longer exposure to contamination during a long-term operation.

Integrated model of life cycle assessment (LCA) and biogeochemical process



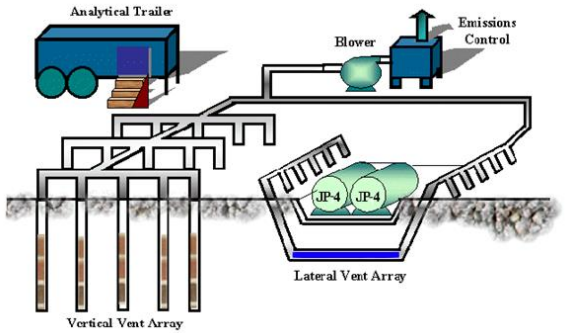
Questions:

1) What concentration of contaminant could be left for natural degradation or phytoremediation with exposure control?

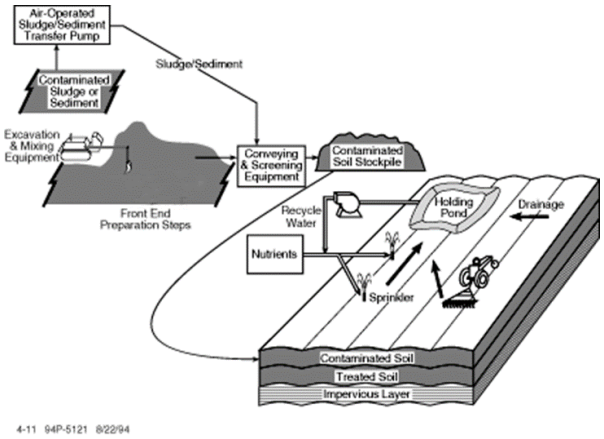
2) How long will a natural attenuation or phytoremediation of pollutants be taken in site-specific conditions (i.e., soil, vegetation, climate)?

3) Could we optimize Oil and Gas Asset and total Liability Cost?

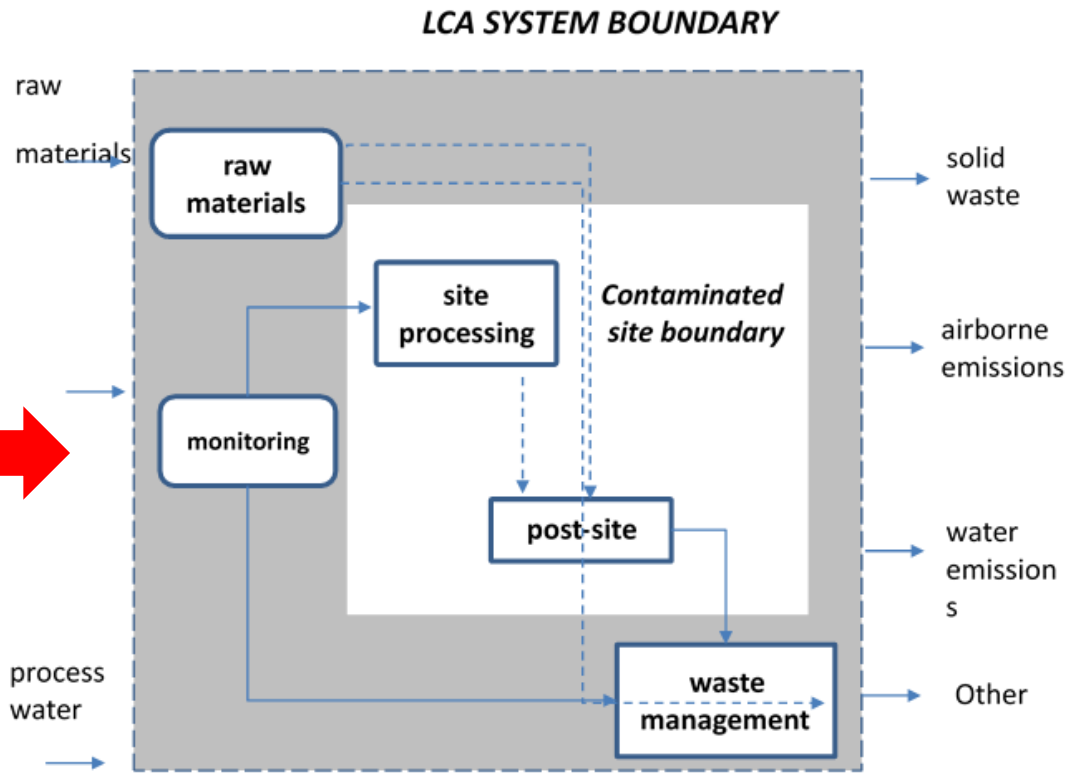
Life cycle assessment for physical, chemical and biological remediation



Typical Bioventing System



Typical Biopile for Solid Phase Bioremediation



LCA analysis for cost, emissions and standard

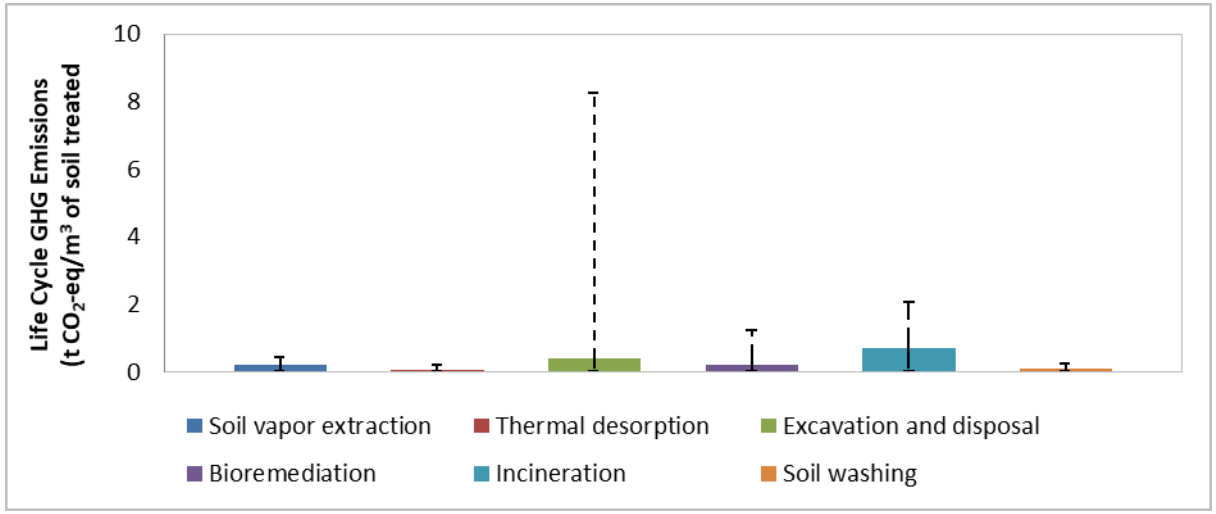
N.Y. Amponsah, et al. / Journal of Environmental Accounting and Management 5(2) (2017) 113-128

Input inventory

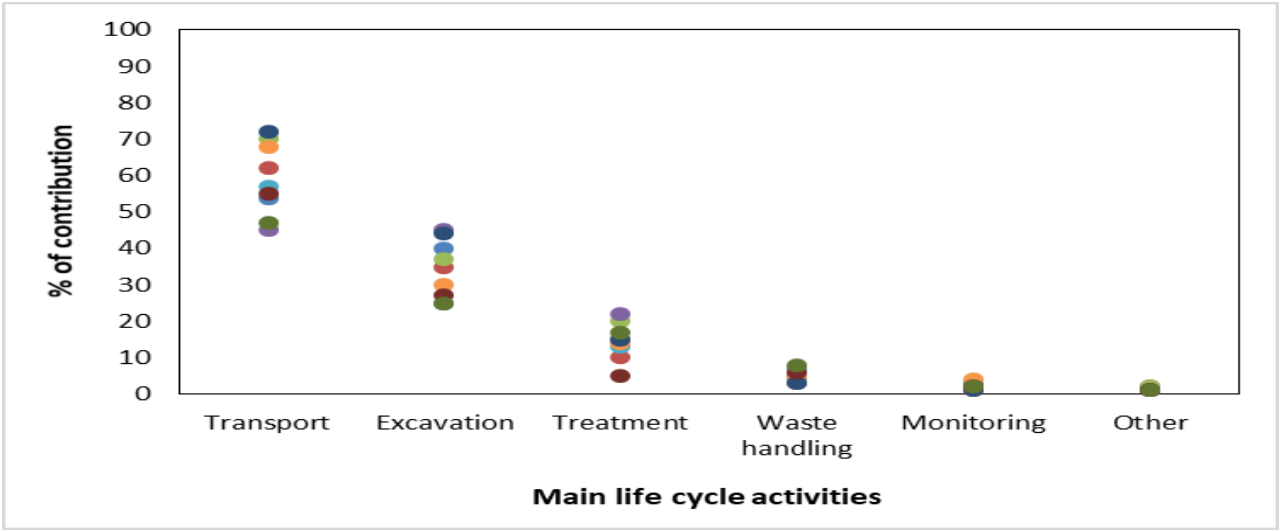
- Materials and energy input inventory: diesel, cement, bentonite, sand, steel, electricity, clean soil, wood chips, urea, PVC, etc. (using Ecoinvent database)
- Outputs: CO_2, chloride, COD, solid waste, dissolved solid, cost, etc.

Greenhouse gas emissions (GHGs) from different remediation technologies

Life cycle GHGs



Maximum life cycle GHGs of different stages

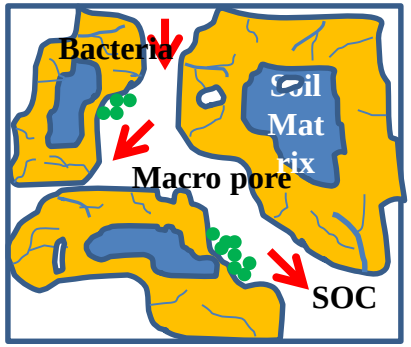


N.Y. Amponsah et al. / Journal of Cleaner Production 186 (2018) 514-525

Biogeochemical for phytoremediation /natural attenuation

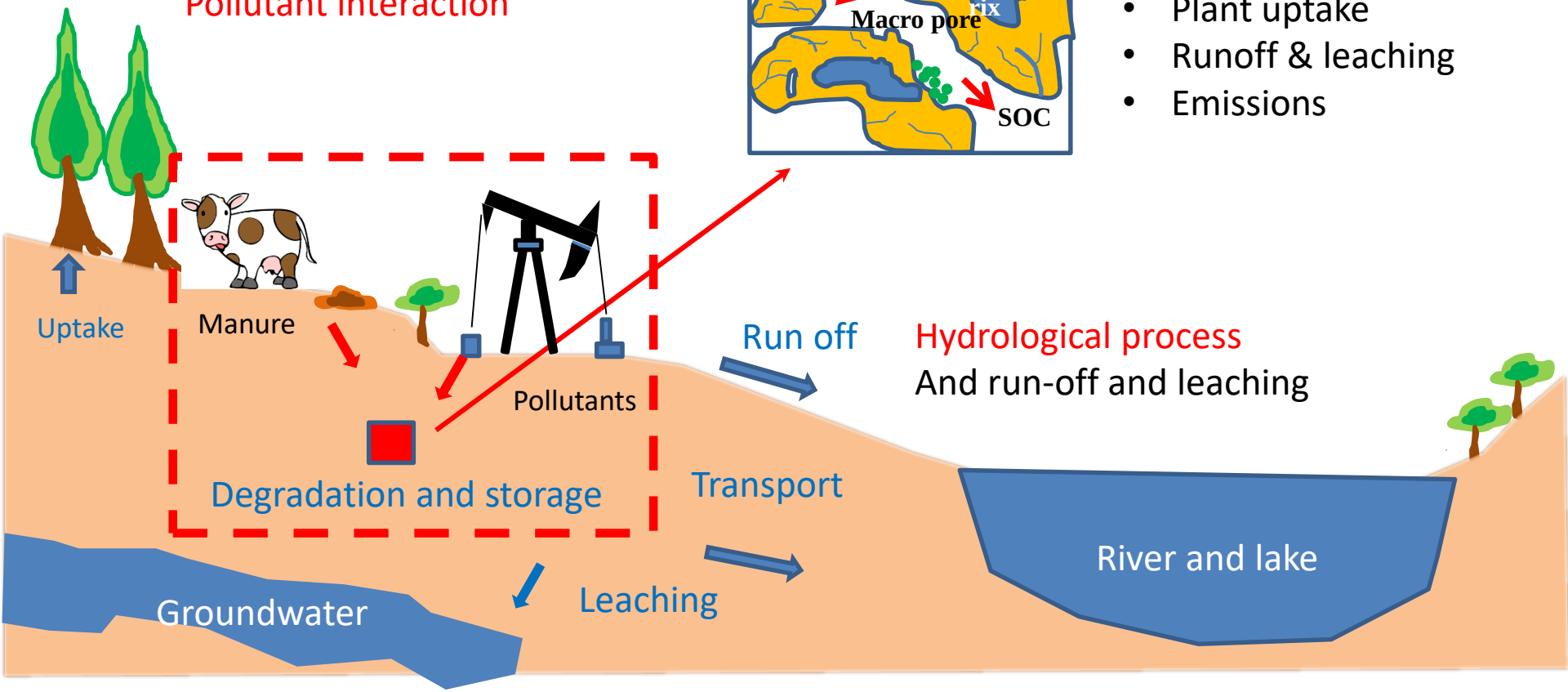
Site-Specific Assessment

Soil, water, vegetation,
Climate, nutrient and
Pollutant interaction



Partitioning pathway

- Soil storage
- Degradation by microbes
- Plant uptake
- Runoff & leaching
- Emissions



Hydrological process
And run-off and leaching

Biogeochemical modelling: DNDC model

- DeNitrification and DeComposition (DNDC)
- Four interactive sub-models: thermal hydraulic, Plant growth, Decomposition, and DeNitrification
- Linkage of soils, crops, weather and agro practice
- Agricultural practice: fertilisation, tillage, grazing, flooding and irrigation

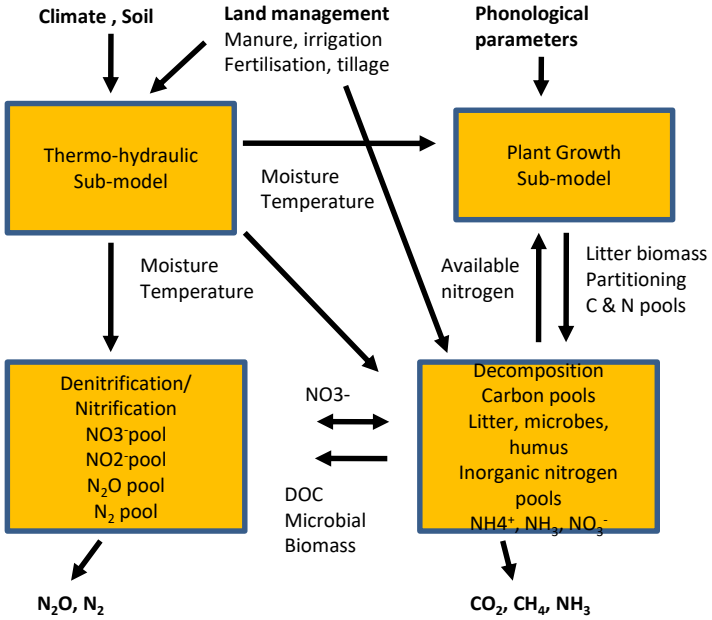
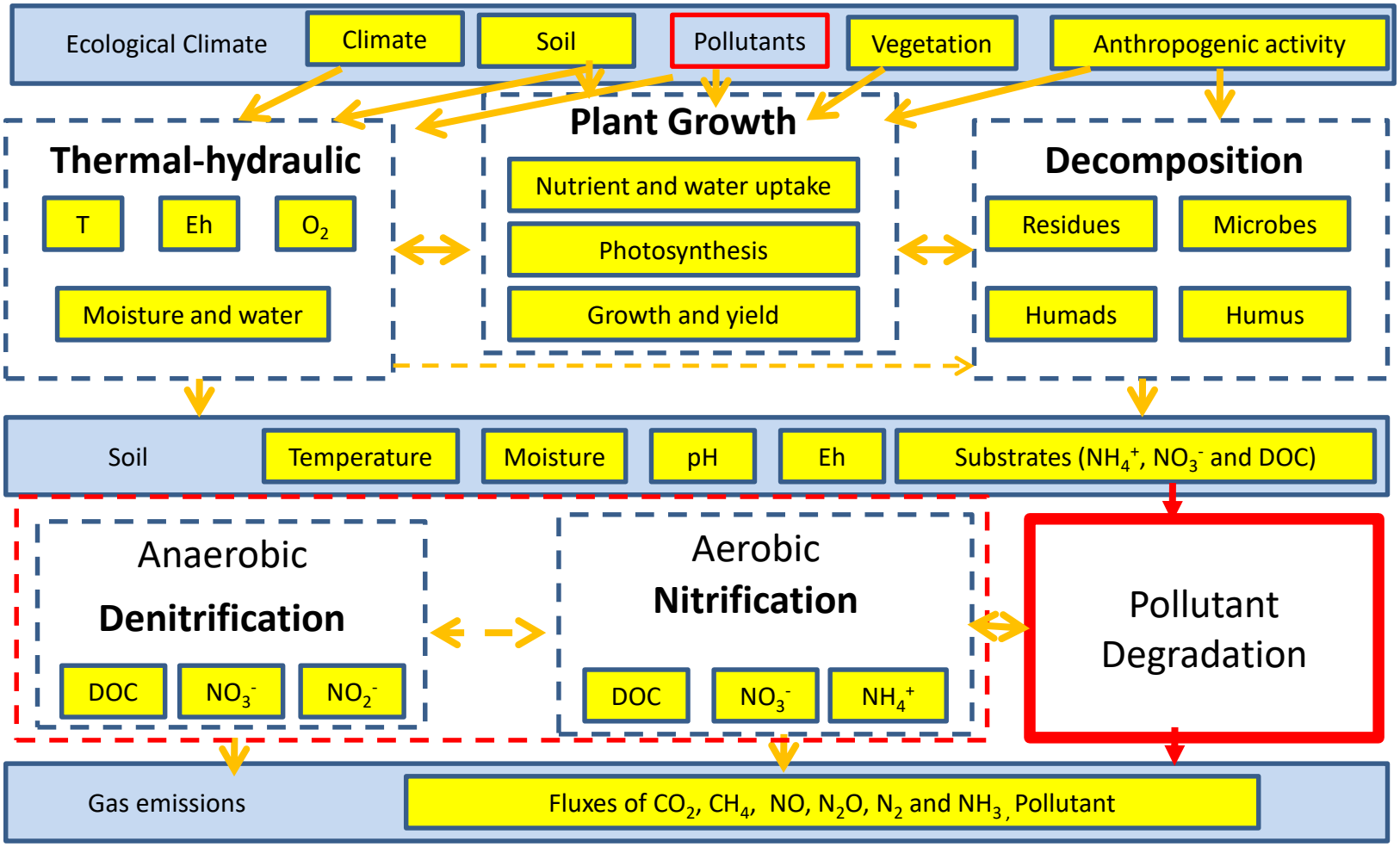


Fig. 1. Water and nutrient cycling in the DNDC Model

Site-specific conditions:
Soils, vegetation, Weather, Agro practice

DNDC framework for pollutants



Input data of site-specific conditions

- Site: Latitude, Atmospheric background (NH_3, $\mu gN/m^3$ and CO_2, ppm).
- Soils: texture and clay fraction, bulk density (g/cm^3), pH, Wilting point, initial NO_3^- (mg N/kg), initial NH_4^+ (mg N/kg), initial fraction of litter and humus, initial soil temperature and moisture, pollutants
- Weather: daily Tmax, Tmin, precipitation, solar radiation (MJ/day), and wind speed
- Vegetation: Planting month/date, harvest month/date, optimum yield (kg dry matter/ha), water/N demand and uptake, yield and littler production.
- Management: irrigation/ fertilisation/manure/composts times, applied date and amount (kgN/ha) for each application

PAHs degradation at three sites in Alberta

PAHs degradation in soil

$$\frac{Ci}{C_{0i}} = e^{-k_i t}$$

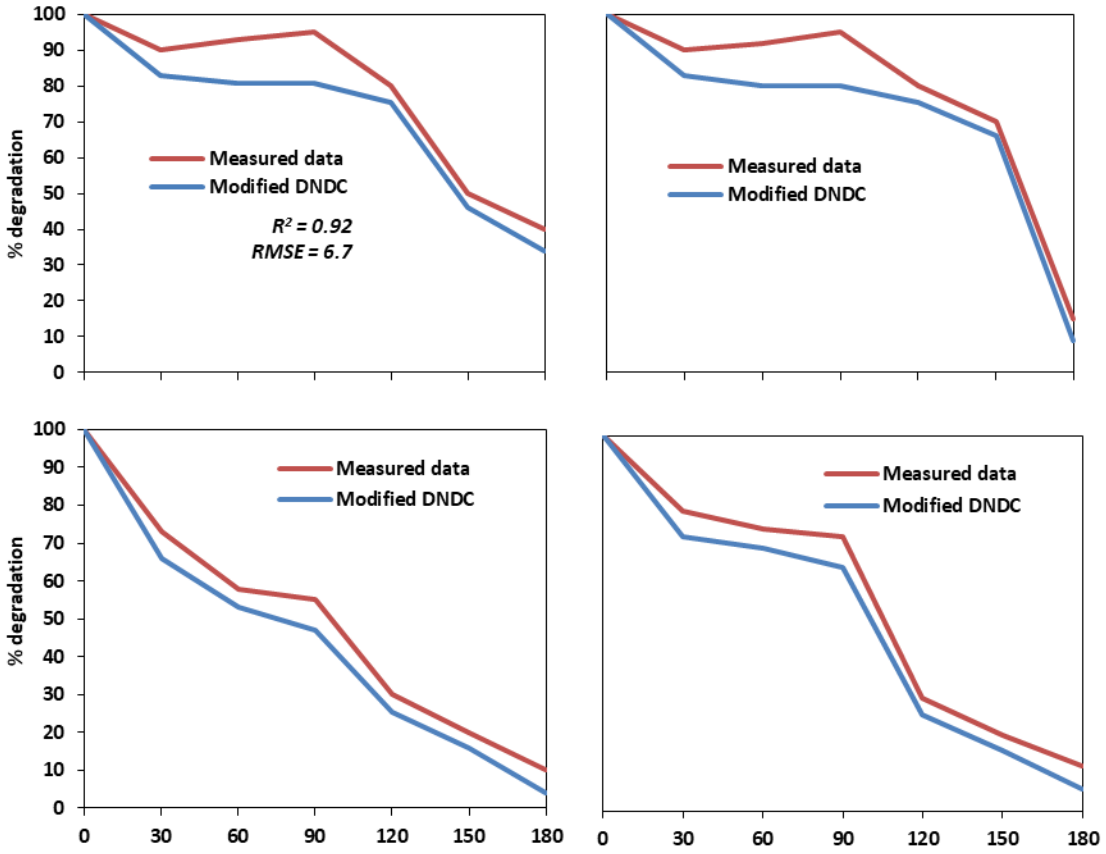
ki = *ki_ref*(-1.0/((*avgSoil_T* + 273) * 0.008314))+ b × (*avgSoil_wfp* - *refSoil_wfp*)

Tests using data from three well sites:
Ft. McMurray (W-01), Edmonton (W-02) and Red Deer (W-03) (AEP, 2016)

N.Y. Amponsah, et al. /Soil Science Society of American Journal , in press

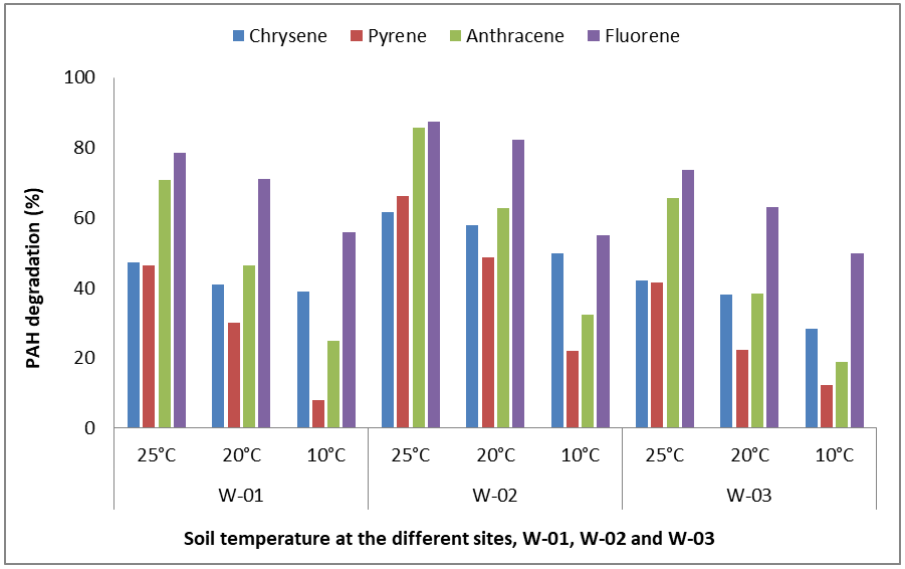
PAHs degradation

- The simulated results agree well with the observed data
- The modified DNDC model can simulate PAHs degradation at site-specific conditions

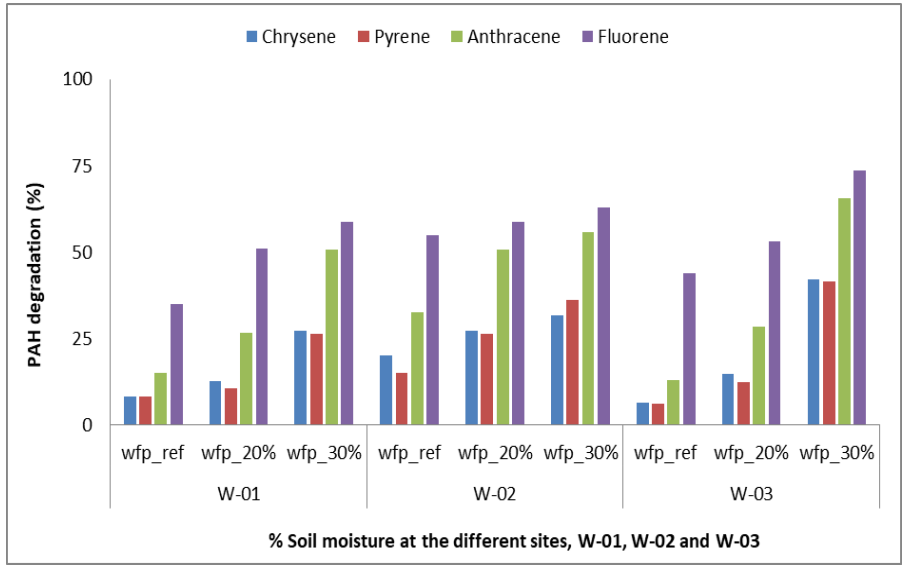


Ft. McMurray (W-01)

Impacts of environmental factors

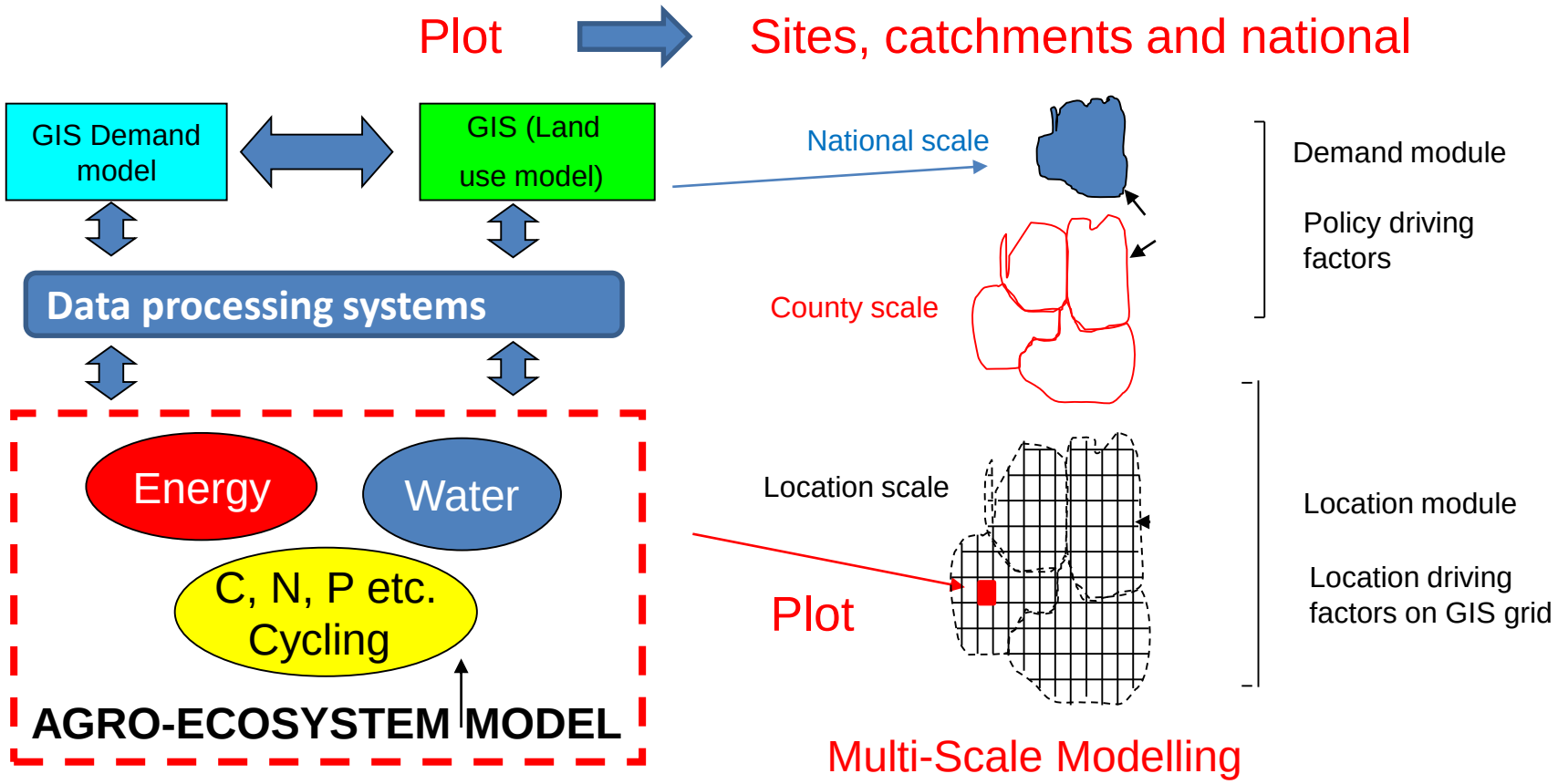


Effect of soil temperature on soil PAH degradation

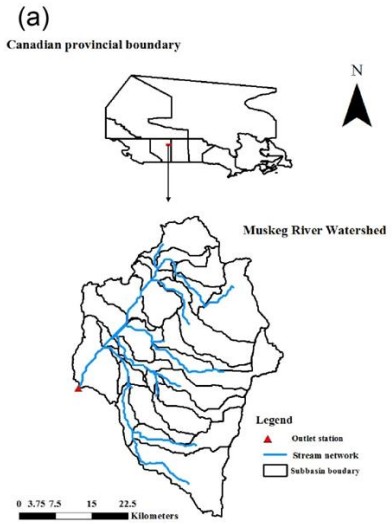


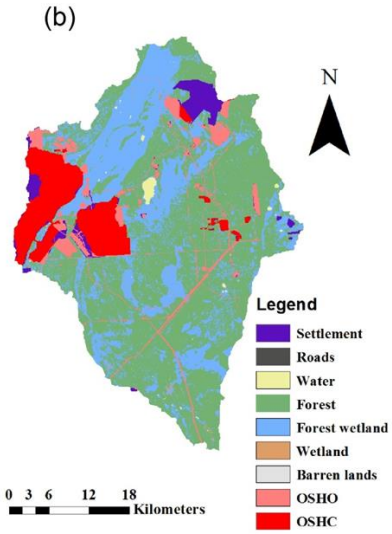
Effect of soil moisture on soil PAH degradation

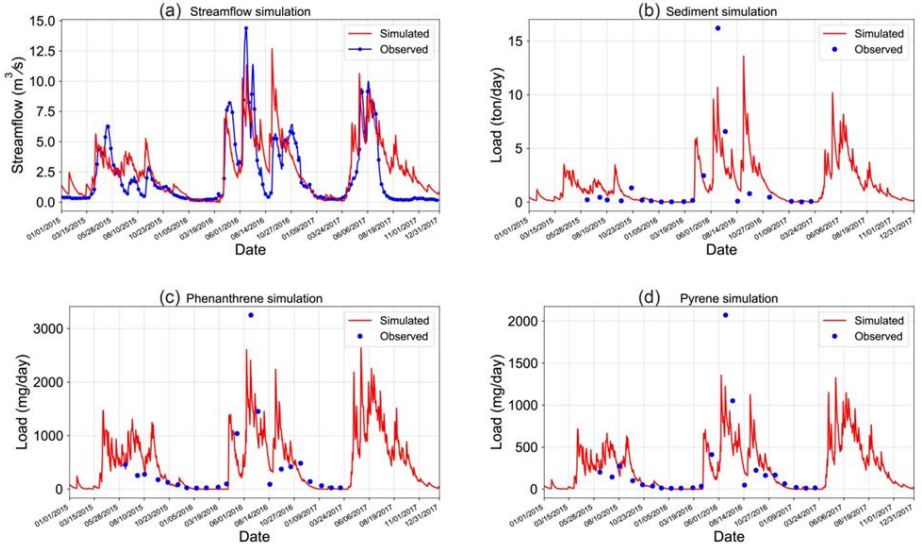
Model Upscaling



Fate and transport of PAHs in Muskeg river watershed







Muskeg River Watershed

Comparisons of simulated and observed daily flow (a), sediment load (b) and PAHs loads (c and d).

Du et al., Environmental Modelling and Software 111 (2019) 432–443

What can we learn from the framework?

- Help identify key factors and processes for site-specific assessment
- Improve understanding of hybrid reclamation processes and system
- Compare different scenarios and assess different remediation technologies
- Help design and implement monitoring systems
- Propose/adjust measures for adaptive management of reclamation and decision making

Future work

- LCA costs of different remediation
- More calibration and validation for process-based models
- Integration of LCA and biogeochemical models for assessment of the hybrid remediation
- Further work to be done

References

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- N Amponsah et al. 2017. Environmental Profile of Two Soil Remediation Options – A Case Study in Northern Alberta, Journal of Environmental Accounting and Management, 5(2): 113-128
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Thank you very much for your attention!