Environmental Impacts of Unconventional O&G

An introduction to environmental impacts of shale gas and tight oil development.

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Yukon Select Committee on Hydraulic Fracturing January 31, 2014

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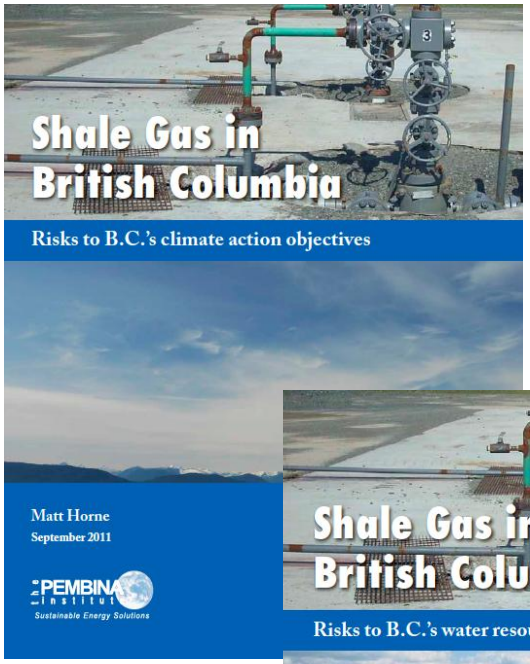

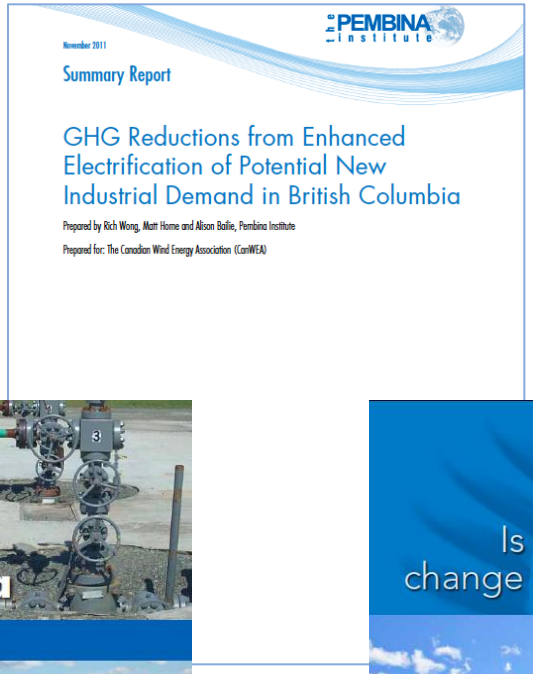

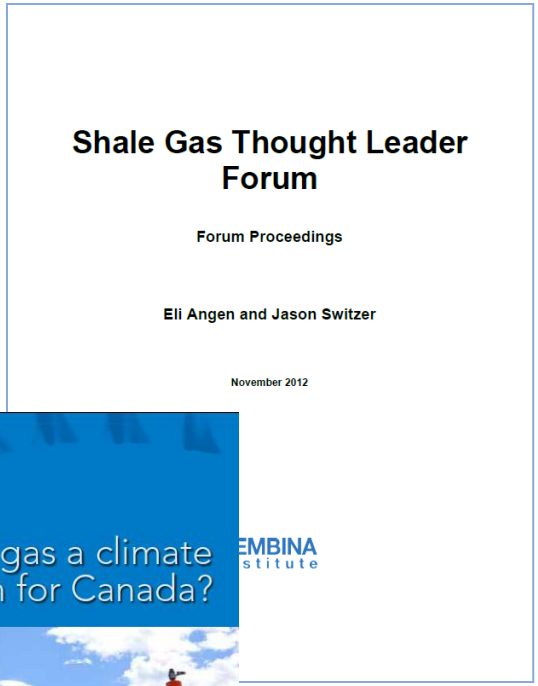

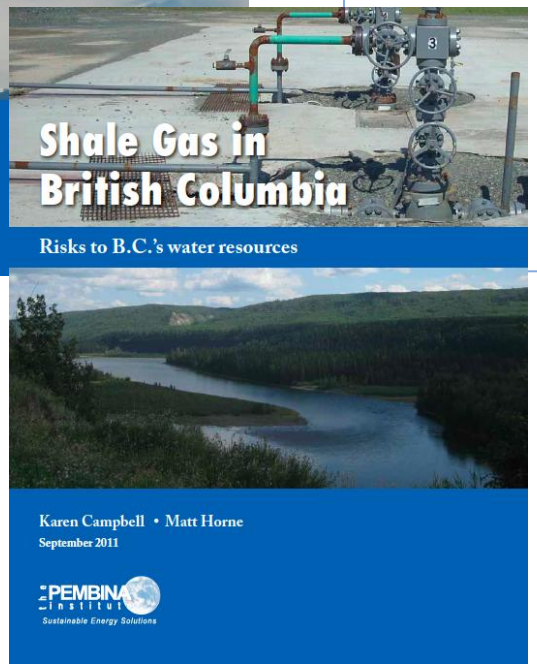

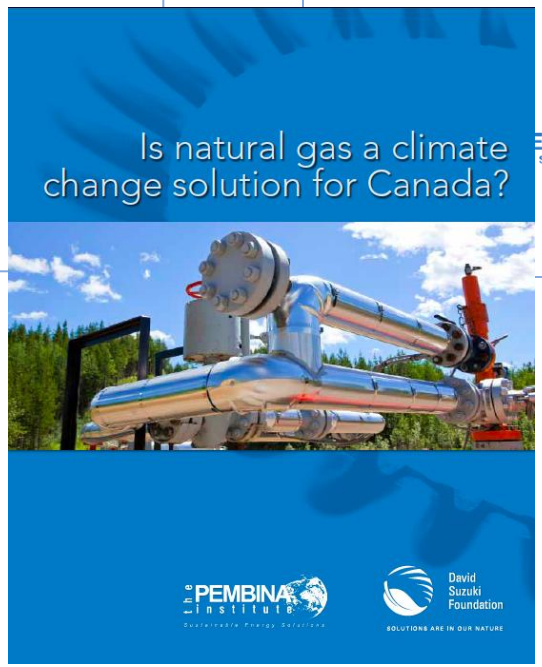

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Headlines & Recommendations

Robust regulation is challenging:

- Rapid technology change, gaps in knowledge
- Important to have regional planning and land use strategies in place prior to approving significant development

Key elements:

- Should be adaptable to changing understanding & evolving pace and scale of development
- Cumulative impacts for water and land:
  - need thresholds and limits, proactive regional water sourcing, waste management and land use planning
- GHGs/Venting & Flaring: Need limits and continuous improvement
- Need data transparency to enable benchmarking and performance monitoring
- Legacy: need mechanisms for management of long term liability - orphan wells etc.

Definitions

Ecological Thresholds:

- Can be described as the point at which a relatively small change in external conditions causes a rapid change in an ecosystem. When an ecological threshold has been passed, the ecosystem may no longer be able to return to its state.

Cumulative Effects:

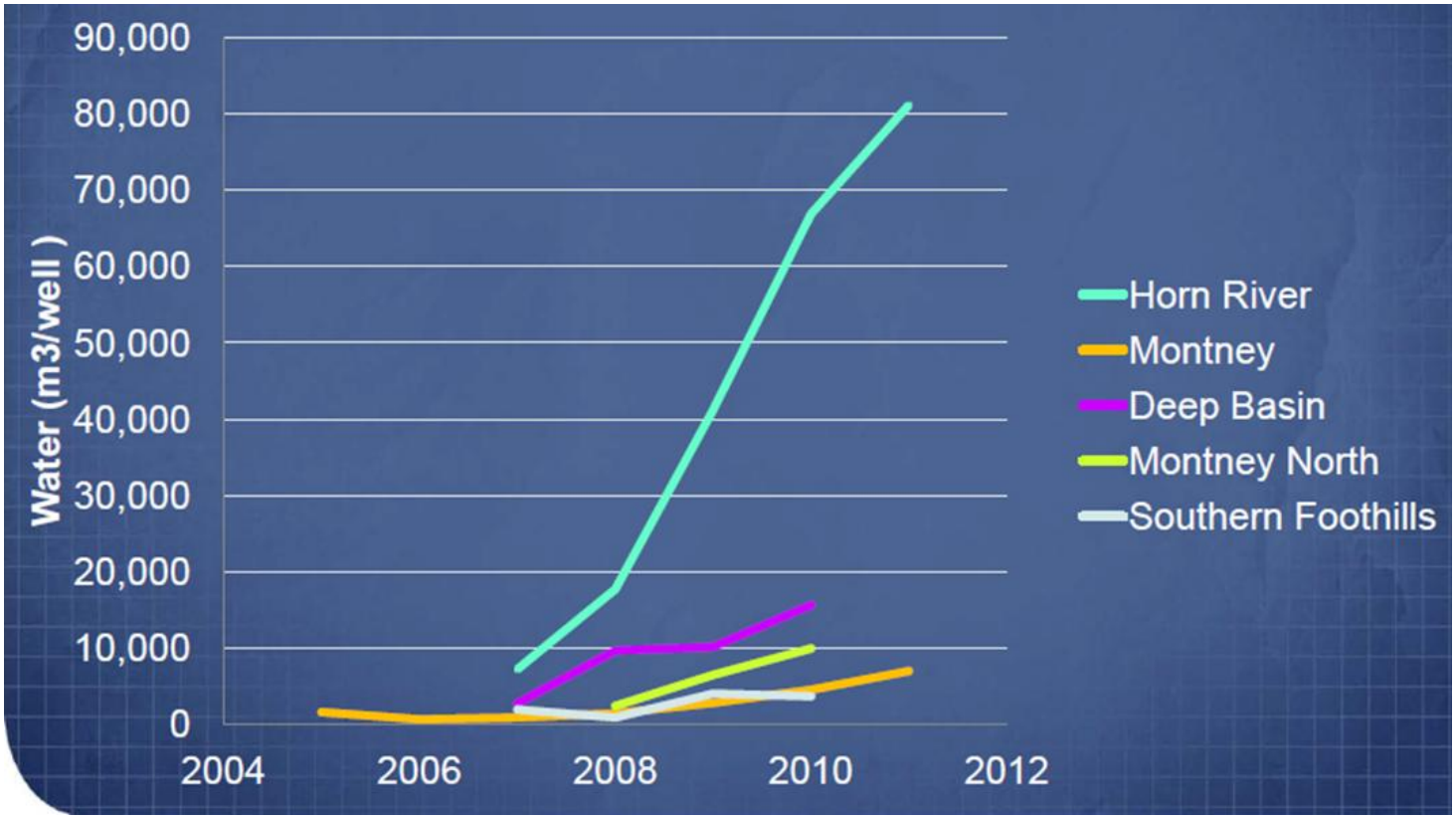
- The state in which a series of repeated actions have an effect greater than the sum of their individual effects

Outline of Environmental Impacts

- Water Use
- Water Contamination
- Waste Disposal
- Air Emissions
- Greenhouse Gases
- Surface Land /Habitat Disturbance
- Legacy Issues
- Cumulative Effects

Water Use

- Fresh water is easiest and cheapest source
- Amount of fresh water removed from water cycle has been increasing over time with longer drill length, more fractures per well
- Withdrawals are from both surface and groundwater sources.



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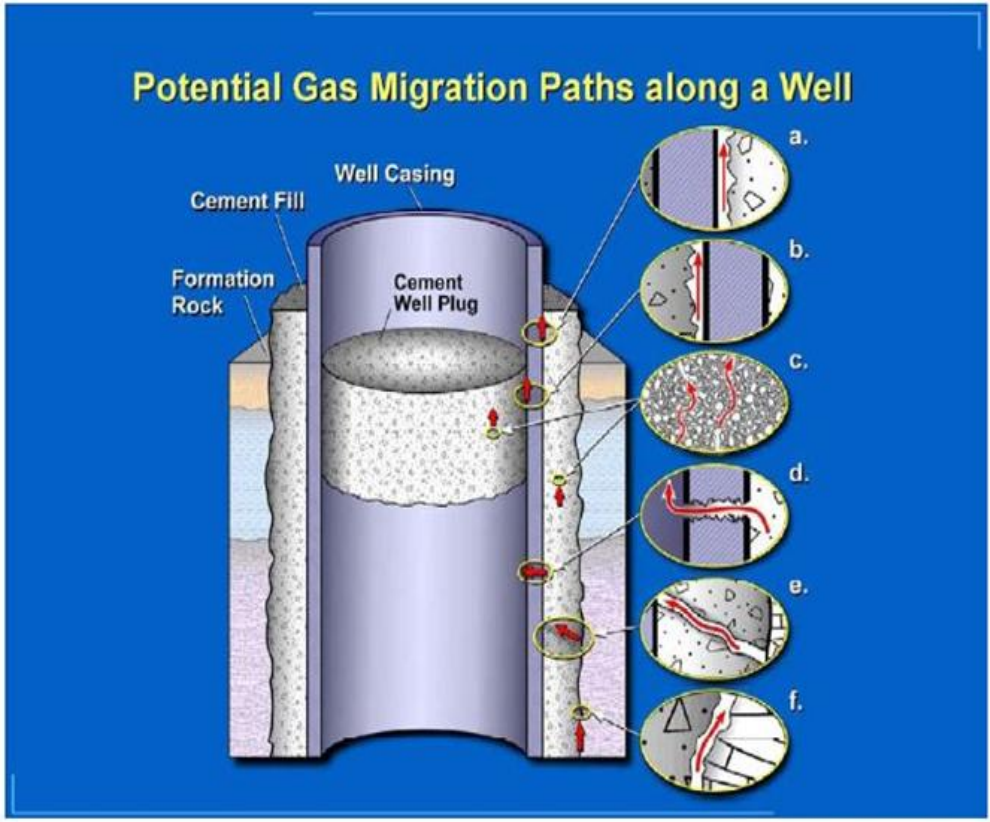
Contamination Risks

- Improper casing and cementing can create pathways for fluid to migrate to underground aquifers adjacent to wellbores.
- Improper fluid handling at surface can result in impacts on local aquifers
- NORMS (Naturally occurring radioactive material) require specialized handling and disposal



Source: Alberta Energy Utilities Boa

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Fracture Fluid Additives

- Risk is greatest when undiluted and accidents/spills cause release into environment.
- Contamination occurs through surface spills, poor handling of flowback water, and potential migration of fluids that remain underground
- Non-toxic additives may reduce risk: *Alberta requires use of non-toxic additives in the groundwater zone.*
- Disclosure and transparency good step but still need clarity on proprietary chemicals and toxicity. (Fracfocus.ca BC, AB, NEB)

Fracture Fluid Additives

Hydraulic fracturing fluids or additive	Recommended Disposal
Foaming Agent F104 Corrosion Inhibitor A186 Organic Acid L36 Chelating Agent Liquid Breaker Aid J318 Breaker J218 Biocide B69 PSG Polymer Slurry J877	Hazardous waste disposal facility.
Water Gelling Agent J424	Hazardous waste landfill, incineration, or sanitary landfills in some jurisdictions.
Potassium Chloride M117	Hazardous waste landfill. Material may be acceptable in some sanitary landfills.
Coalbed Methane Additive J473	Incineration, disposal well injection or other acceptable methods according to local regulations.
Borate Crosslinker J532	Inject in disposal well. Small amounts may be acceptable in sanitary sewer.
Gelling Agent U28	Neutralized material is generally acceptable in sanitary sewers.

Source: Schlumberger MSDS

Waste Disposal

- Deep well disposal may be best if: radioactive materials are present, if there are low seismic risks, and fluid are not expected to migrate – strict monitoring
- However - capacity is not limitless and pressure must be closely regulated – linked to induced seismic events
- Other options: Mobile treatment facilities, permanent treatment facilities, shipping waste elsewhere
- Municipal treatment plants not equipped to deal with industrial waste – eg. (NORMS)

Waste management options should be carefully assessed and safest option chosen.

Water Conservation and Protection

- Water reuse and recycling is becoming the norm. Operators in Marcellus are reusing 96% of produced water.
- Saline groundwater use is possible but requires consideration to prevent release into freshwater systems
- Casing and cementing integrity should be continuously monitored and production halted if leakage is occurring. For production and disposal wells
- Strict prevention and monitoring of surface spills.

Regional Water Management

- Baseline water quality/quantity and ongoing monitoring essential to inform regional water planning
- Important where competing water uses exist and seasonal water levels fluctuate
- Ensure disclosure of activity/performance data and use to inform strategy

Need to understand hydrology prior to development and manage water resources to maintain quality and quantity in order to support other uses and healthy ecosystems.

Air Emissions

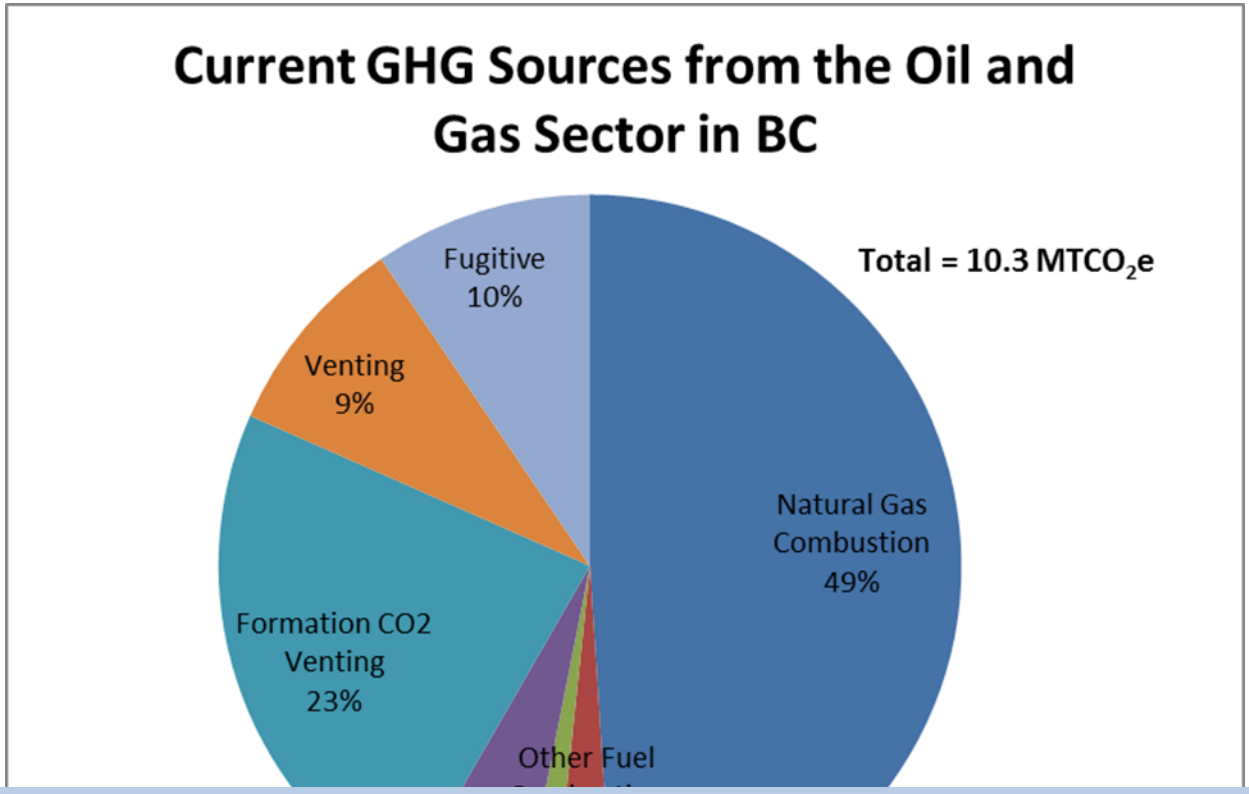
- Includes particulate matter, NOx, SOx, methane, VOC and some carcinogens (e.g. benzene)
- Can have health impacts if near a local community

Air shed quality must be continuously monitored and regulated. Continuous improvement should be encouraged.

Greenhouse Gases

- Natural gas/diesel combustion to power facilities is a large source of GHGs. Electrification with renewables and clean grid is an option to reduce
- Formation CO2 (e.g. Horn River is 12% CO2) – removed during processing and vented to atmosphere - formation specific
- Methane Venting
  - Greater global warming potential than pure CO2.
  - Uncertainty in exact volumes – Field measurements vs. modeled estimates across supply chain.
- Flaring has been on the rise in Alberta/US due to unconventional development.

Greenhouse Gases



Need to consider lifecycle emissions - including flaring/venting, formation CO2, transportation distance and energy source being displaced and work to reduce and limit emissions across the supply chain.

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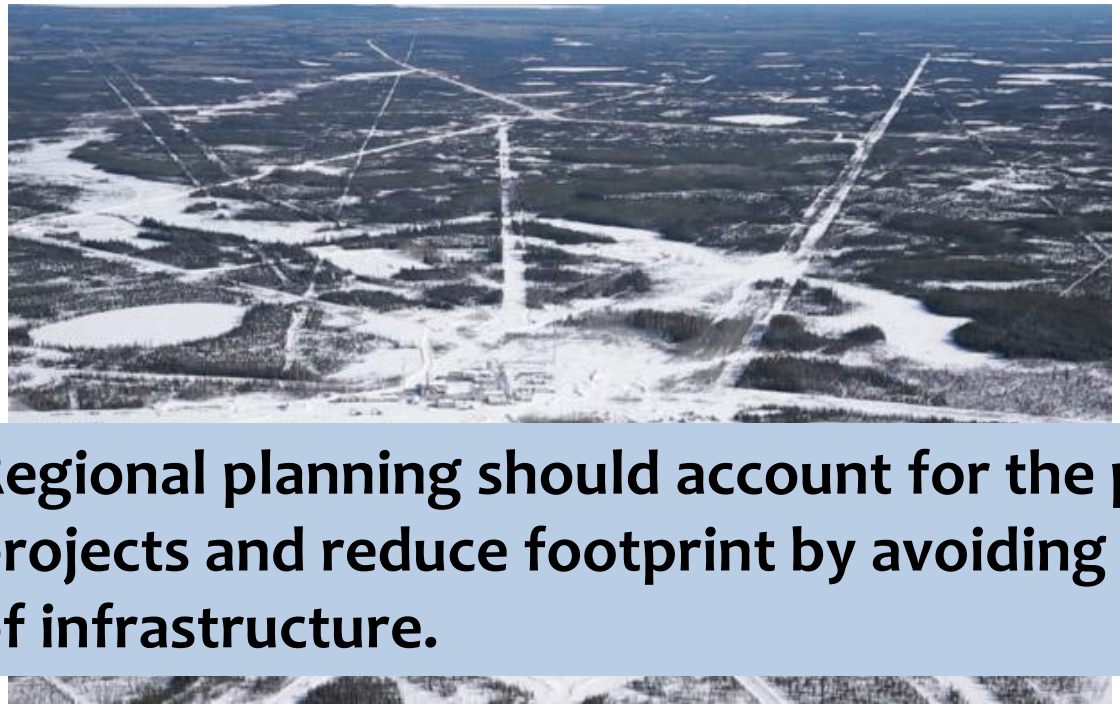
Surface & Land Disturbance

- Roads, pipelines, seismic, well pads and camps all add to surface footprint
- Overlapping infrastructure causes habitat fragmentation and leads to exceeding ecological thresholds



Regional planning should account for the plans of all projects and reduce footprint by avoiding duplication of infrastructure.

Source: Fracking operations in BC's Horn River Basin (Two Island Films).

Seismic

- Used to evaluate sub-surface geology
- Impacts predator-prey relationships
- Soil compaction and erosion
- Damage to riparian areas
- Direct and indirect wildlife impacts

Low impact hand cut line, 2m wide

Mechanically cut high impact line 6m wide

Site Preparation

- Clearing of Land/Construction of roads, well pads, pipelines, other infrastructure.
- Off /On-road vehicle activity
- Pipelines usually follow once production is proven

Nexen's Dilly Creek site in the Horn River Basin of northeastern BC.

Drilling and Completion

- Most active time at well pad.
- Large scale requires lots of equipment

Activity should be planned in order to reduce impacts on wildlife (calving/rutting season) and consider local community impacts and limitations.

Hydraulic Frac ,Horn River B.C. Source: bctwa.org

Operation and Production

- Requires wells, processing plants, pipelines and associated infrastructure.

Need data transparency to enable benchmarking and performance monitoring and drive continuous improvement

Spectra Gas Plant near Fort Nelson B.C. Source: bctwa.org

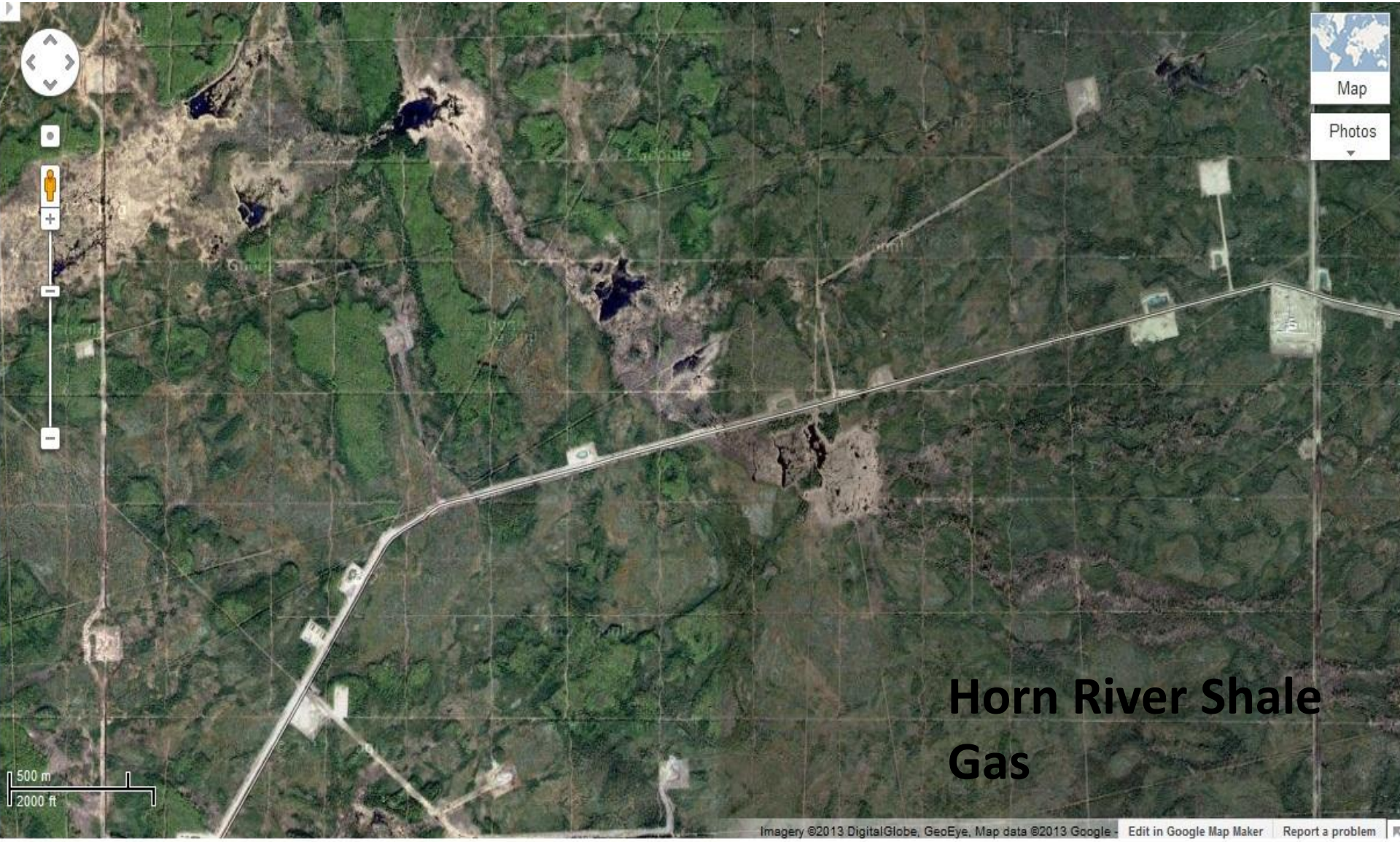
Reclamation

- Return disturbed land to a pre-disturbed condition or for a specified end land use
  - Major challenges trying to replicate pre-development wetland / muskeg conditions.
  - Current practice is to reclaim muskeg to upland conditions of aspen, spruce, and mixed wood forest.
- Only proceeds if remediation is complete and testing confirms that regulations are met.
- Long lag times before sites/roads are reclaimed

Legacy Issues

- Lifespan of activities: Exploration to abandonment → 60+ years
- Abandonment, remediation and reclamation regulations should be established and comprehensive
- Need mechanisms for management of long term liability - orphan wells, long term monitoring etc.
- Ensuring long-term wellbore integrity?
- Increased long term access from roads to sensitive areas creates long term disturbance

Cumulative Effects



Cumulative Effects

- Monitoring
  - Establishing baseline assessment for parameters is essential.
  - Continuous monitoring
- Setting science/TK based thresholds/targets
- Establishing no-go protected areas for sensitive habitat or areas of cultural significance
- Must occur at a regional level. Not project level
- Incorporates all industries and stressors into long range planning

Cumulative effects

- Pace and scale of development should allow for ecosystem integrity and local economic benefit
- Regional Planning and Cumulative effects management are essential to minimize impacts of unconventional development on both communities and the environment
- Requires adequate enforcement and support from all stakeholders to be effective

Conclusions

- Unconventional oil / gas has large-scale implications; requires large-scale planning and monitoring.
- Technologies and practices exist to reduce some impacts but not all.
- Communities should have access to independent information and have a meaningful role in baseline and project-specific monitoring as well as decision-making.

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