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NRC INDUSTRIAL RESEARCH ASSISTANCE PROGRAM – FINAL REPORT

FRACTURE STIMULATION / FLOWBACK WATER TREATMENT PROJECT – PHASE 1

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FUNDY Engineering

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SAINT JOHN CHARLOTTETOWN HALIFAX

The Fundy Engineering and Consulting Research Team

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Purpose of IRAP Project

Extraction of natural gas from deep shale beds is a relatively new industry that is heavily focused in North America, but continues to expand globally as new shale beds are discovered and developed and extraction technology improves. Shale gas extraction is more widely known by the method used to accomplish the gas extraction; hydraulic fracturing, or more often slangily referred to as fracking. In New Brunswick, the Frederick Brook Shale has all the right ingredients to become a world-class shale play because it is over-thickened with a gross pay thickness of 1 km, it is estimated to have gas reserves in excess of 65 Tcf, it has higher than normal formation pressures, and it has open fractures present throughout. Thus, the shale gas industry in New Brunswick is looking to expand and capitalize on this natural resource. While there is great fiscal potential for New Brunswick in the exploration, development, and production of natural gas from the Frederick Brook Shale, it must not come at any environmental cost.

Historically, one of the most important concerns with the shale gas industry revolves around the use of water and the subsequent potential water pollution resulting from hydro-fracking (i.e., fracking using water as the fracking medium). This is the fundamental concern of many New Brunswick residents. The purpose of this project is twofold: (1) to understand the New Brunswick shale gas hydro-fracturing water cycle, including the current New Brunswick government's regulations concerning water sourcing and disposal, the water quality at all points in the shale gas hydro-fracking process, and the regional and worldwide waste disposal methods employed by this industry; and (2) to review the wastewater treatment and shale gas literature and provide a review of technologies, both treatment technologies and existing mobile water treatment solutions, which could be used to create a Fundy Engineering mobile wastewater treatment plant.

Development of a mobile treatment plant would lead to a reduced water footprint by New Brunswick's shale gas industry. Treating flowback or production water would make it suitable for re-use as a fracking fluid, thus limiting the amount of freshwater needed in the hydro-fracking process and reducing the amount of water requiring disposal after fracking is complete. Mobile, or centralized, treatment plants are used primarily in arid regions of the world. For example, it is essential that water use is minimized in Texas. As the treatment procedure of these mobile treatment plants has to be specifically designed for the quality of flowback and production water of each shale play, the development of a New Brunswick specific mobile water treatment will depend on: (1) the deep aquifer water in the region; (2) the fracking chemicals used (which would be specifically designed for a shale formation); (3) the flowback and production water encountered; and (4) the quality/composition of the treated water needed by the industry for re-use in fracking.

Summary of Project Findings

New Brunswick Hydro-Fracking Water Cycle

At the project outset, we developed a New Brunswick specific hydro-fracking water cycle diagram to guide us throughout this project (Figure 1). Within this water cycle we outlined each of the steps in the shale gas hydro-fracking process, what changes are made to the water at each step, and the treatment/disposal options of the water once fracking is complete. As we are interested in creating a mobile water treatment plant, which would recycle water for reuse in future fracture stimulation events, we outlined the water cycle that would be observed if this technology was introduced in New Brunswick; as a comparison to the current New Brunswick water cycle (Figure 1).

In both the conventional and sustainable water flow paths, the starting location is the same; clean freshwater needs to be sourced for use in the hydro-fracturing process. The province of New Brunswick, in their *Rules for Industry* (2013), outline the preferred sources of this water. The most preferred source is treated water from shale gas hydro-fracturing flowback water or other industrial water, and the least preferred is potable groundwater.

The next step in the water cycle is the mixing of fracture fluid, through the addition of a proppant, usually sand, and a mixture of chemicals to aid in the fracture stimulation process. These chemicals compose on average 0.5 – 1% of the total fracture fluid, and the chemical composition of the fracture fluid must be disclosed to the New Brunswick government (*Rules for Industry*, 2013). The recipe is posted online at fracfocus.ca, which is publically accessible.

The fracture fluid is then injected into the well under high pressure in order to create fissures and cracks in the shale; creating paths between the trapped gas and the wellbore, allowing the gas to flow to the surface once the pressure is reduced. The sand in the fracture fluid moves into these cracks during the fracture stimulation process and when the pressure is reduced they remain in place, holding open the newly formed cracks and fissures. If proppant was not included in the frack fluid, the fissure and cracks would form during fracture stimulation, but then close again once the pressure was reduced, thereby re-trapping the gas.

The final step of the fracture stimulation process is the release of water pressure, which allows the gas to begin to flow up the well to be captured. Along with the shale gas, three types of water migrate out of the well: Drilling fluid, fracking fluid, and formation water. The formation water in New Brunswick has a similar composition to seawater, and thus is also a threat to groundwater due to its saltiness. All of these types of water must be captured and stored on-site and then trucked away for treatment and disposal elsewhere.

(On next page)

Figure 1: A summary of the conventional and water recycling water use flow paths for the hydro-fracturing industry in New Brunswick. A selection of reuse and final treatment options are outlined, as well as a comparison of water use between a recycling and non-recycling fracture stimulation treatment.

TOWARDS A MORE SUSTAINABLE USE OF WATER RESOURCES FOR NATURAL GAS DEVELOPMENT - A NEW BRUNSWICK SOLUTION

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Fundy Engineering is researching the opportunities for the New Brunswick natural gas industry to responsibly treat and reuse water used for hydraulically fracturing gas wells and water produced from those wells. Requiring flowback and produced water recycling and reuse will reduce the demand for clean, freshwater resources and will reduce the total volume of wastewater requiring final disposal.

REUSE TREATMENT OPTIONS

Advanced wastewater treatment is critical to reducing the volumes of clean, freshwater used for producing fracture fluid. Various options are available to the New Brunswick oil and gas industry for treating flowback and produced water for use in the generation of fracture fluid. Fundy Engineering envisions modular equipment that can be moved from well pad to well pad or that can be setup in a centralized location for treating water from many wells at once. This will also yield several spinoff benefits, such as reduced truck traffic.

THERMAL DESALINATION

Desalination, although highly energy intensive, produces demineralized water and a highly concentrated solute from the wastewater.

REVERSE OSMOSIS

Flowback and produced water can be treated using reverse osmosis whereby pressure is applied to force water through a semi-permeable membrane leaving behind a highly concentrated solution containing many types of molecules and ions.

FORWARD OSMOSIS

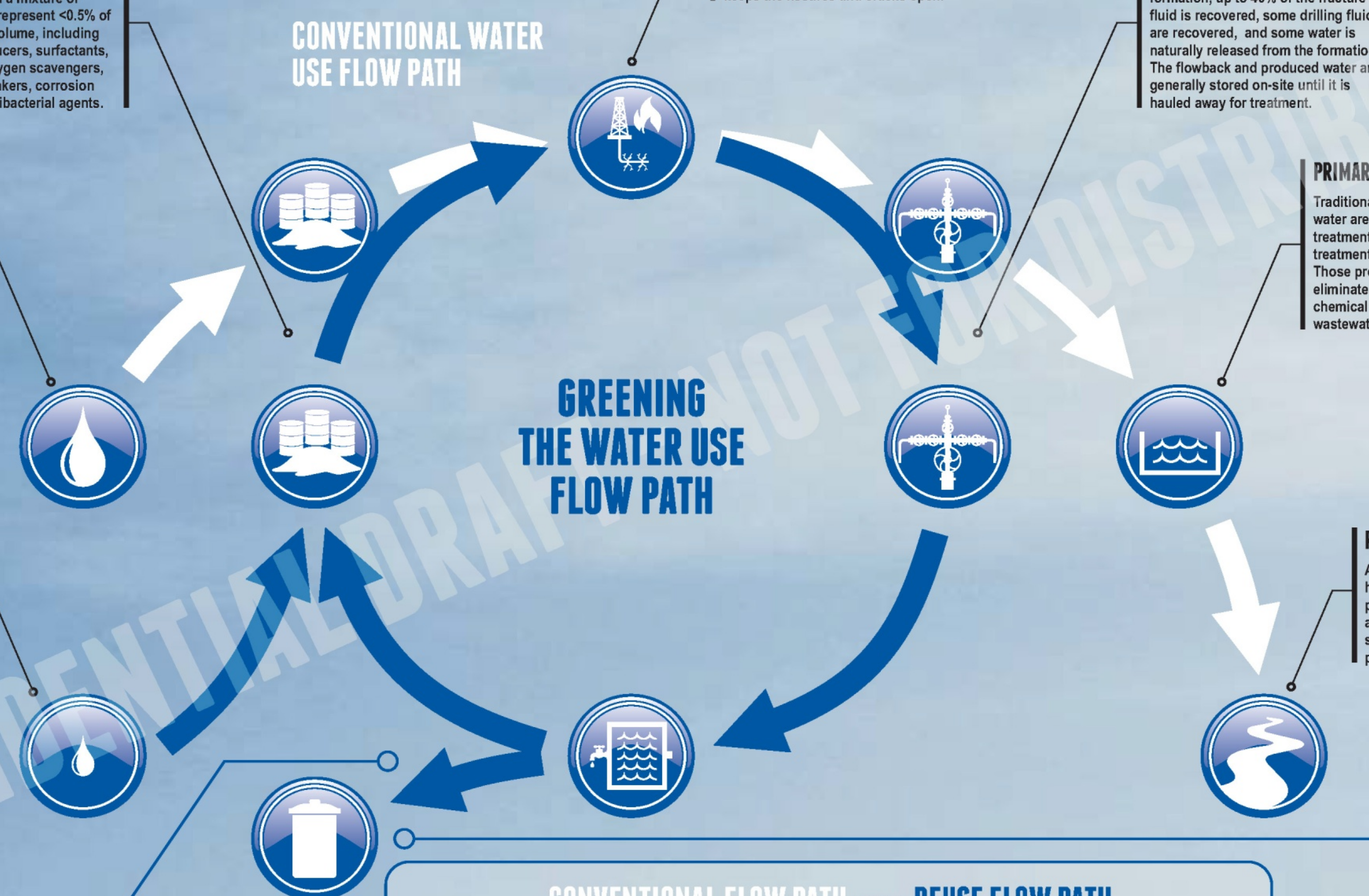
Flowback and produced water can be treated using forward osmosis whereby a highly concentrated solution is used to draw water through a semi-permeable membrane producing a highly concentrated solution containing many types of molecules and ions.

ELECTROCOAGULATION

An electrical charge is used to destabilize suspended, emulsified, or dissolved contaminants in a wastewater that are impossible to remove by filtration and chemical treatment processes.

ACTIVATED CARBON

Carbon, which has been activated with oxygen to improve its porosity, is often used in conjunction with other filter media to remove pollutants from water. The extremely high surface area of activated carbon has the ability to adsorb large quantities of pollutants.



FRACTURE FLUID

Added to the water is a proppant, typically sand, and a mixture of chemicals, which represent <0.5% of the total fluid by volume, including acids, friction reducers, surfactants, gelling agents, oxygen scavengers, breakers, cross-linkers, corrosion inhibitors, and antibacterial agents.

CLEAN WATER

Hydraulically fracturing an unconventional gas well generally requires millions of litres of water, which can be obtained from surface water sources, groundwater sources, municipal water systems, and surface water runoff collection ponds.

CLEAN MAKE-UP WATER

During the wastewater treatment process, there will be some loss of water. Clean, freshwater will likely be used for sourcing make-up water.

FRACTURE STIMULATION

The fracture fluid is injected into the well under high pressure in order to generate fissures and cracks within the geological formation. The chemical additives help the fluid move into the formation and the sand in the mixture keeps the fissures and cracks open.

FLOWBACK & PRODUCED WATER

As gas is released from the geological formation, up to 40% of the fracture fluid is recovered, some drilling fluids are recovered, and some water is naturally released from the formation. The flowback and produced water are generally stored on-site until it is hauled away for treatment.

PRIMARY TREATMENT

Traditionally, flowback and produced water are sent to a primary wastewater treatment plant for biological treatment, solids settling, and dilution. Those processes do very little to eliminate the potential threat of chemical species contained within the wastewater.

RECEIVING WATER BODY

After the flowback and produced water has been treated through primary processes, it is typically discharged to a natural receiving water body, such as streams where additional dilution and possibly treatment occur.

CONVENTIONAL FLOW PATH VERSUS REUSE FLOW PATH

CONSIDER THE FOLLOWING SCENARIO...

The following values are considered average values obtained from a broad spectrum of other jurisdictions.

- **2 MILLION LITRES** per frack
- **10 FRACKS** per well
- **25% RECOVERY** total flowback & production
- **40% TREATABILITY** total flowback & production

HOW DO THE TWO PATHS COMPARE PER WELL?

- **20 MILLION LITRES** (2 million litres x 10 fracks)
- **18.2 MILLION LITRES** (2 million litres for first frack + 1.8 million litres per each 9 subsequent fracks)
- **5 MILLION LITRES** (2 million litres x 10 fracks x 25% recovery)
- **3.2 MILLION LITRES** (0.3 million litres x 9 fracks + 0.5 million litres for final frack)

The total volume of freshwater required remains large because of the modest recovery treatability rates assumed based on average values obtained from a broad spectrum of other jurisdictions.

FINAL WASTE DISPOSAL OPTIONS

Regardless of the process selected for treating flowback and produced water, there will be a disposal requirement. Materials for disposal may include filtered sediments, concentrated hazardous chemicals, spent filter media and cartridges, *etc.* There are various disposal methods used in other jurisdictions that may be applicable to the New Brunswick industry. Also, New Brunswick's geographical location lends itself to some unique alternative disposal methods.

DEEP WELL INJECTION

In other jurisdictions, flowback and production water are often injected deep underground. The wastewater is injected between impermeable geological layers to avoid contaminant migration to other layers. Sometimes, spent gas wells are used as deep injection wells.

LANDFILL

Flowback water has been applied to landfills where it is allowed to flow through the landfill. As the water migrates through the landfill, it is partially treated and is collected in the landfill leachate. Also, sediments collected through the treatment process are sometimes disposed of at landfills.

BRINE OCEAN DISPOSAL

New Brunswick is partially surrounded by saltwater. Through a dilution process, there may be an opportunity to introduce produced water to the Bay of Fundy or other saltwater bodies for final disposal.

ANTI-ICING SALT BRINE

Salt brines are sometimes applied to New Brunswick's highways in the winter to serve as an anti-icing product. There may be opportunities to use produced water as a salt brine for winter highway maintenance.

Treatment and disposal of the flowback water is the final step in the fracture stimulation water cycle. New Brunswick historically has sent its fracture stimulation water to Nova Scotia for treatment and disposal, but this is currently not an option due to the moratorium in place in Nova Scotia on all shale gas industries. The water was treated in a specialized water treatment plant, with the solids being sent to a landfill and the clean water being disposed of in a waterway. It is unknown at this time where the final treatment of the water from the New Brunswick shale gas industry would occur today, and this is a serious issue which would need to be resolved before the shale gas industry could begin fracking with water again.

An intermediate treatment step in the shale gas hydro-fracking water cycle would allow for flowback water to be partially cleaned, as it would not need to be pure water if it will only be made into fracking fluid. This would both reduce the overall amount of water needed for subsequent fracture stimulation cycles, as there is always more than one fracture stimulation event at each well, and reduce the amount of water which arrives at the final treatment and disposal stage of the water cycle after fracture stimulation is complete. There would be other beneficial spinoffs as well, as the number of trucks hauling water to and from the well pad site would be greatly reduced. One concern is that the partially cleaned water would need to be stored on-site between fracture stimulation events, which if a spill were to occur this contaminated water would still impact surface and groundwater.

<u>What Technologies Exist for Treating Shale Gas Flowback/Production Water for Recycling?</u>

A number of treatment technologies are available for treating water and one of the main focuses of this research project was to review each of them for their suitability for treating hydro-fracturing flowback and production water. The treatment technologies that we reviewed in detail include:

- Chemical Coagulation /Precipitation,
- Electrocoagulation,
- Thermal Evaporation / Distillation / Desalination,
- Reverse Osmosis,
- Forward Osmosis,
- Gravity Clarifier,
- Air Flocculation / Dissolved Air Flocculation,
- Electro-Flotation, and
- A number of Physical Filtering Technologies such as carbon and sand filtration.

<u>What Commercial Mobile Treatment Solutions are available in North America?</u>

One of the questions we had while doing research for this project was ‘what mobile treatment solutions are already commercially available, and could these be used or modified for use in New Brunswick?’ As the treatment of water for reuse as fracking fluid is an important question in arid regions such as Texas, many solutions have been developed. A comprehensive review was completed, looking at what treatment solutions have been created, what types of treatment technology they employ in their treatment process, and what type of input and output water can they be used for. This exercise allowed us to see what types of treatment technologies are being used for different water types, how this could be applied to our New Brunswick solution and if any ‘turn-key’ solutions may already exist which could be used in New Brunswick if hydro-fracking expands.

Alternatives to Hydro-Fracking

Prior to 2009, Corridor Resources, the major player in the shale gas industry in New Brunswick, used water as the fracture stimulation fluid in their shale gas wells. That year, fracture stimulations using gelled propane were performed by GasFrac in an attempt to improve fracture characteristics and flowback. Gelled liquid propane is still currently being used successfully by Corridor Resources in partnership with GasFrac in New Brunswick as it has been shown to improve well performance, and has resulted in savings due to the elimination of water handling processes. As water is not used at all when using gelled propane there is no sourcing clean water, no storing flowback and production water, no chance of spills, and no treatment and disposal of the contaminated water necessary.

The gelled liquid propane has many advantages over water, but of course with some disadvantages as well. Two of the main advantages liquid propane has over water are: (1) that if spilled liquid propane will evaporate, whereas water will seep into the soil, which could lead to polluted groundwater if the water is contaminated, and (2) rather than returning as contaminated flowback water needing treatment and disposal, propane can be separated from the natural gas and sold back to the propane distributors. The main disadvantages are the hydraulic fracturing industries' problem, rather than the general public's, as it is more expensive to work with propane than water, and increases the fire/explosion risk on the fracking site.

Conclusion

If the hydro-fracking industry does move ahead in New Brunswick, results of this research project will allow Fundy Engineering to quickly move into Phase II whereby bench testing treatment technologies for a mobile treatment plant would be completed. Bench testing would have to be completed with a shale gas industry partner who could provide both untreated water for us to use, as well as some guidelines for us to achieve with our treatment process. We feel that this partnership would be easily drawn up as, through this project, we have reached out and our ideas have been well received by both Corridor Resources and SWN Resources who would be the major industry players if the shale gas industry moves forward in New Brunswick. We currently have signed confidentiality agreements with both two companies.

We feel that after doing research for this project that this type of mobile treatment technology will benefit the New Brunswick environment, will be viewed as a positive technology by the residents of New Brunswick, and would be a worthwhile further R & D investment for Fundy Engineering if fracking using water as the fracture stimulation medium expands in New Brunswick.

That being said, using gelled propane as the fracture stimulation fluid is a proven alternative solution for New Brunswick. An interesting follow-up project would be to complete an in-depth comparison on the use of water and gelled propane in terms of overall cost to the company, the safety to the on-site workers, the risk to the environment, and the long term sustainability of both methods in New Brunswick.