# Options for Cost-Effective Treatment of Frack Flowback Water to a Recyclable Quality

**By**

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# Basic Hydraulic Fracturing (Fracking) Process

- Frack fluids are injected into producing formation under high pressure to fracture the reservoir matrix and in so doing increase porosity. Fractures are kept open by simultaneously injecting proppant (frac sand) into fractures to prevent their closure when pressure is reduced.
- For shallow gas wells the volumes vary from hundreds to over 100,000 gallons.
- Volume of water used in single frack of a shale gas well may vary from 1,000,000 gallons to 10,000,000 gallons (100 times or more water than for shallow gas fracturing).
- Frack fluid additives that are used may vary widely depending on characteristics of formation, company, method of fracturing and quality of water used for fracturing operation.
- Ideally water used for fracturing should be very high quality, free of chemicals that might interfere with those used during fracturing process or that might damage the formation being exploited and thoroughly disinfected.

# Substances added to water during fracturing process.

- Proppant (frac sand).
- Friction reducers.
- Foaming agents and antifoaming agents.
- Emulsifiers and de-emulsifiers.
- Gellants and gel breakers.
- Biocides.
- Corrosion inhibitors.
- Oxygen scavengers.
- Scale inhibitors.
- pH adjustment agents.
- Surfactants.
- Viscosifiers.
- Cross linkers.
- Stabilizers.
- Iron control.
- Breakers.

# Common Types of Water Based Fracturing Operations

1. **Gel based systems**
   a. Require the liquid (water) be made very viscous to allow transportation and positioning of the proppant into rock fissures.
   b. Gel ultimately destroyed to allow excess water to be expelled – using gel breakers.
   c. Numerous other chemicals used to perform other functions.
   d. Difficult to treat to recyclable condition.
2. **Slickwater or slick water fracturing**
   a. Chemicals known as friction reducers are added to allow very high velocity of water carrying proppant (keep in suspension during transport).
   b. Numerous other chemicals used to perform other functions.
   c. Much easier to treat to a recyclable condition than gel based systems.
3. **Hybrid systems**
   a. Combination of gel based and slickwater fracturing to overcome danger of proppant being improperly located.
   b. Treatment to recyclable condition may be difficult.

**The exact 'mix' of chemicals used will depend on the formation, nature of the frac being undertaken and the company performing the frack.**

**The mix of chemicals will vary widely.**

**While every service company that provides fracturing services will have their 'preferred' quality of water that is used in their operations - they are capable of using water with a very wide range of quality.**

# Frack Flowback

- **Fluids recovered from water fracks, when the fluid pressure is relieved, is known as frack flowback. It contains all of the chemicals used in the fracturing process, formation water and some of the proppant and other solids (including drilling muds) that have been flushed from the formation.**
- **Volume of flowback varies from approximately 20 to 80 per cent of volume of water injected into formation (40 to 60 per cent is common).**
- **Quality of the frack flowback water varies widely with well condition and location and company performing the fracturing operation (companies use different mixtures of chemicals).**
- **Flowback water is typically very toxic. Historically flowback water is typically separated from the solid fraction and sent to disposal wells. Solids (slurry) are stabilized (e. g. addition of lime) and sent to appropriate land fill.**

# Ultimate fate of frack flowback water today:

- **Deep well disposal.**
- **Storage – waiting for treatment.**
- **Treatment for disposal into environment or reuse/recycle.**

# Deep well disposal

**Advantages:**

- **Safe disposal of hazardous waste.**
- **Well understood.**
- **Costs known and managed within project.**

**Disadvantages:**

- **Can be expensive – trucking and disposal costs.**
- **Roads are required for hauling flowback to disposal wells.**
- **Difficulties associated with defining solid fraction and liquid fraction. Solid fraction is an order of magnitude more expensive to dispose of than liquid fraction.**
- **Loss of water resource.**

# Storage

**Advantages:**

- **Short term solution allowing fracking activity to continue while waiting for long term solution.**
- **Can be constructed in close proximity to fracking operations.**

**Disadvantages:**

- **Construction of secure storage sites.**
- **Temporary solution – ultimately flowback must be either be disposed of , treated such that it can be reused or treated such that it can be disposed of in the environment.**
- **Environmental hazard and potential liability.**
- **Loss of water resource.**

# Treatment for Disposal into Environment

**Advantages:**

- Long term solution for disposal of wastewater with no immediate use.
- No long term storage.

**Disadvantages:**

- Treatment must be sufficient to allow disposal into environment – which might not be allowed under any circumstances or be very expensive to perform.
- Liability risk.
- Loss of water resource.

# Treatment for Reuse/Recycle

**Advantages:**
- Minimal disposal issues (only solid fraction).
- Reduce consumption of fresh water supplies by 30% to 50%.
- Minimal environmental impact.
- Maximum beneficial use of water resource.
- Avoid regulatory issues.

**Disadvantages:**
- Treatment must be sufficient to allow reuse/ recycle for subsequent fracking purposes.
- Treatment may be difficult, expensive or not practical.
- Treated water must be stored until it can be reused.
- Fracking companies must be able to adjust their process to use treated water which may be expensive and incur operational risks.

# Frack Flowback Treatment Objectives for Reuse/Recyle

1. **Treatment must be to a *quality that can be accommodated by service companies performing fracturing operations*.**
2. **Must be able to treat flowback water with *significant variation in quality*.**
3. **Treatment must be *energy efficient*.**
4. **Treatment should *treat all flowback* water while generating *a minimum of waste* (liquid or solid) that must be subsequently disposed of.**
5. **Treatment should use *minimum chemical addition*.**
6. **Treatment should be as *simple and robust* as possible.**
7. **Ideally treatment should be as *rapid as possible* to allow treated water to be available for adjacent fracking operations (for a water supply in fracking of adjacent wells). Treatment systems must be *'scalable'*.**
8. **Treatment facilities should be as *mobile* as possible to allow treatment at several locations with the same equipment.**
9. **Treatment facilities should be *compatible with industry culture*.**
10. ***Capital cost of treatment equipment should be low*.**
11. ***Operating cost of treatment process should be low*.**
12. **Treatment process should be *profitable* to company providing the treatment service.**





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# Frack Flowback Treatment Options

1. Clarification – simple settling in storage facility.
2. Clarification – chemically enhanced (can vary from simple additions of basic coagulants to use of variety of polymers).
3. Clarification followed by filtration.
4. Clarification followed by centrifuge technology.
5. Direct filtration with or without use of coagulants or polymers using Oasis MPSF technology for example.
6. Solids removal using centrifuge technology.
7. Physical/chemical treatment that includes chemical addition followed by clarification processes.
8. Distillation and evaporator technologies.
9. Membrane technologies.

**Several of the *treatment technologies may be used in series* to treat difficult flowback water to a quality suitable for reuse or to produce very pure water using technologies that require careful conditioning before final treatment technology can be used (e. g. membrane systems).**

**Treatment using <u>municipal wastewater treatment facilities</u> is not appropriate because:**

- **Not designed for treatment of frack flowback and may inhibit use of facility for treatment of municipal wastewater.**
- **Typically, only capable of removal of suspended sediments.**
- **May not remove all toxic chemicals limiting disposal opportunities available when only municipal wastewater is treated.**

- Clarification, centrifuge and direct filtration technologies are capable of removing most of the suspended sediment, are scalable, and typically least expensive; but, they may not have a significant impact on dissolved substances that might interfere with reuse.

- Distillation and evaporator technologies can provide very high quality treated water but is limited in application without pre-treatment, can be expensive to operate (though systems often use energy available at well site resulting in zero energy costs), complex and challenging to scale up to treat large quantities.

- Membrane technologies of varying types can be used for basic clarification to removal of all dissolved substances. Very high quality water can be produced. Typically, these will require pre-treatment. These systems can be expensive to operate and face similar challenges to distillation and evaporator technologies.

**Physical/chemical technologies can be used to treat most frack flowback (gel or slickwater) to a recyclable condition depending on the concentration and type of dissolved solids. These systems are very flexible in application, use little energy, use inexpensive readily available chemicals, produce a waste that is readily disposed of, simple to operate, acceptable capital cost and scalable.**

# Physical/Chemical Treatment of Frack Flowback
# Oasis Filter International Ltd. Technology

- **The development of this process was started in 2002 at a time when the Alberta 'Water for Life Program' was just being formulated.**

- **At this time water was just beginning to be considered in short supply, a situation which has significantly worsened.**

- **Development of a process to economically treat frack water to recyclable condition appeared to be an important commercial endeavour.**

# Three Stage Process:

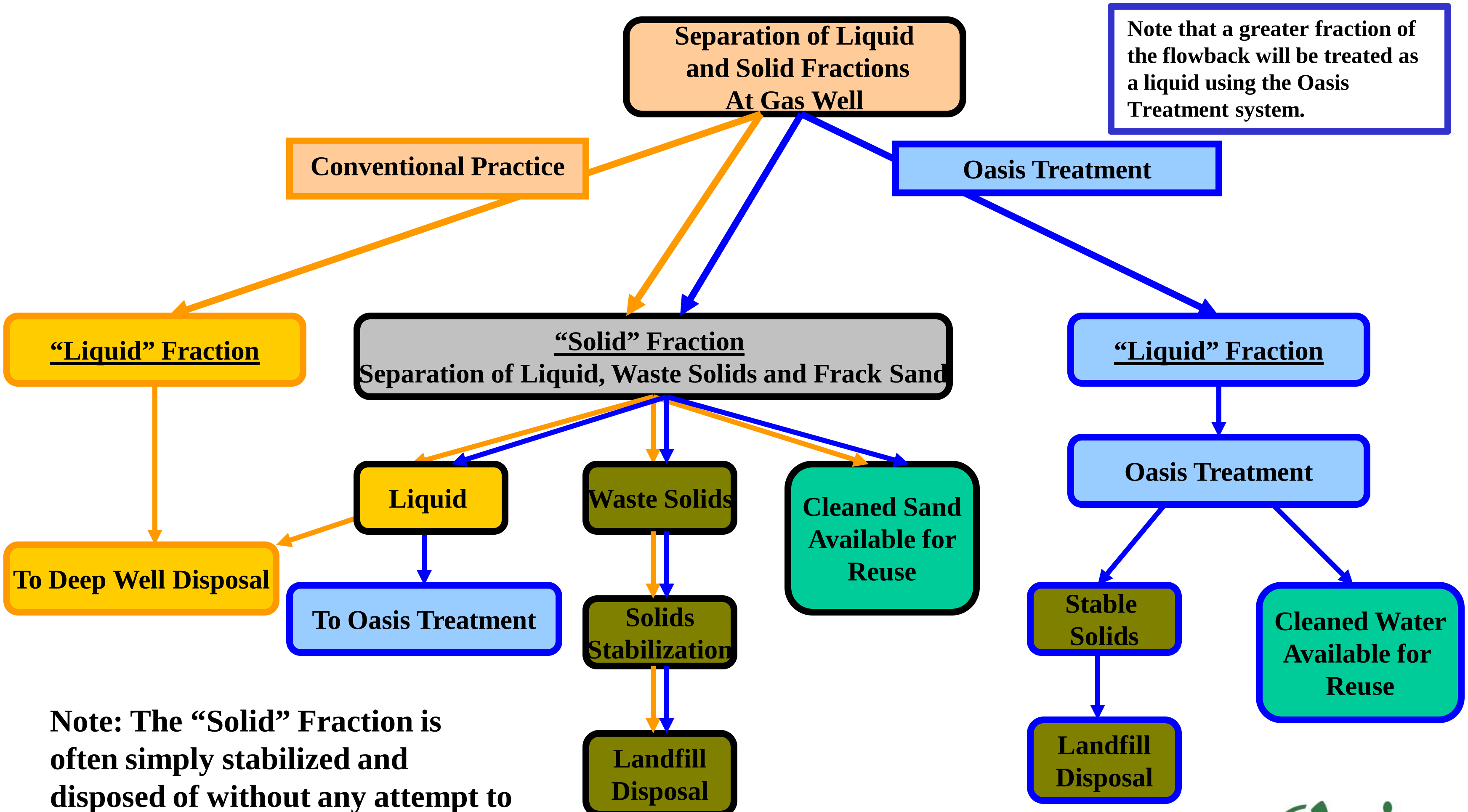
- **Stage One**
  - Breaking complex polymeric suspensions
  - Sedimentation and clarification
- **Stage Two**
  - Breaking mineral complex.
  - Sedimentation and clarification
- **Stage Three**
  - Stabilization and polishing for end use.

**Stage Two or Three water can be further treated to remove dissolved solids using membrane and evaporation technologies (without risk of fouling the processes).**

# Product Water

- 1st stage water is suitable for flushing and cleaning of the frac process equipment.
- 3rd stage water is suitable for recycling in frac process though it may not be practical to treat all flow back water to this degree.
- Bacteria cannot survive in the treatment environment.
- Treated water cannot be returned to the environment.

# Gas Well Frack Flowback Water Treatment




**Note: The "Solid" Fraction is often simply stabilized and disposed of without any attempt to recycle sand.**





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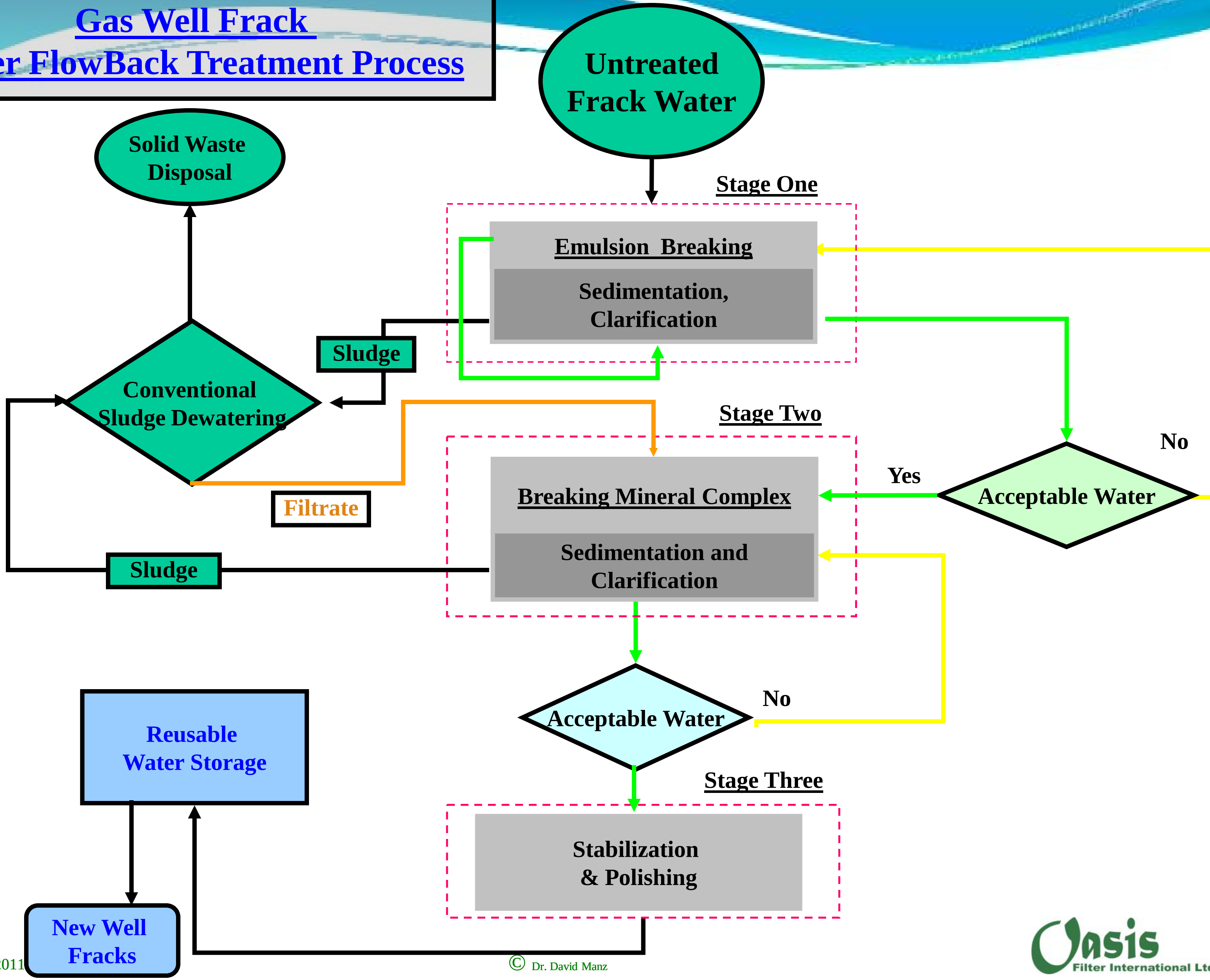
# Gas Well Frack Water FlowBack Treatment Process





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# Bench Scale Testing of Frack FlowBack Water Treatment Procedure

**Before Treatment**

**After Treatment**





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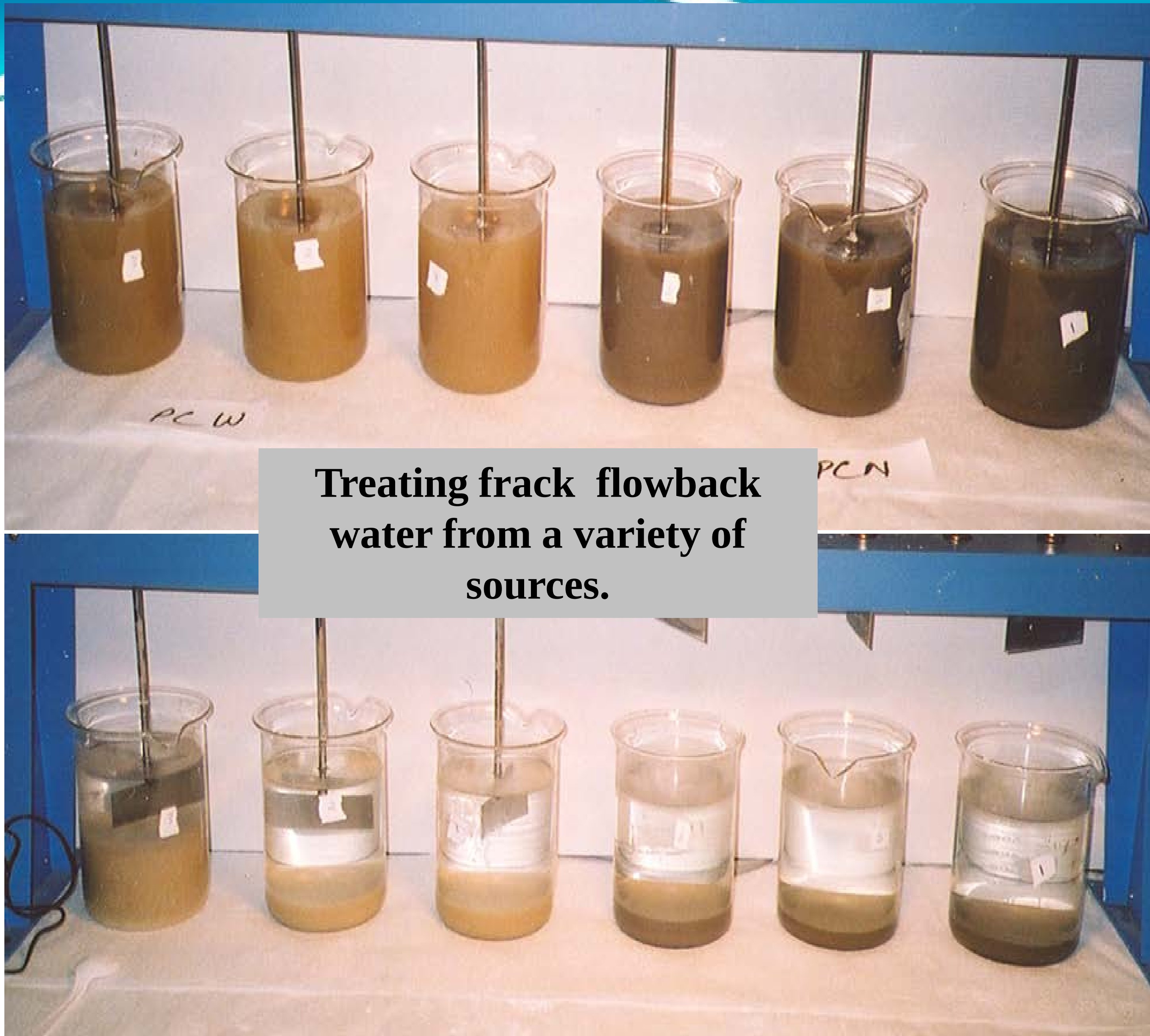
# Treating frack flowback water from a variety of sources.





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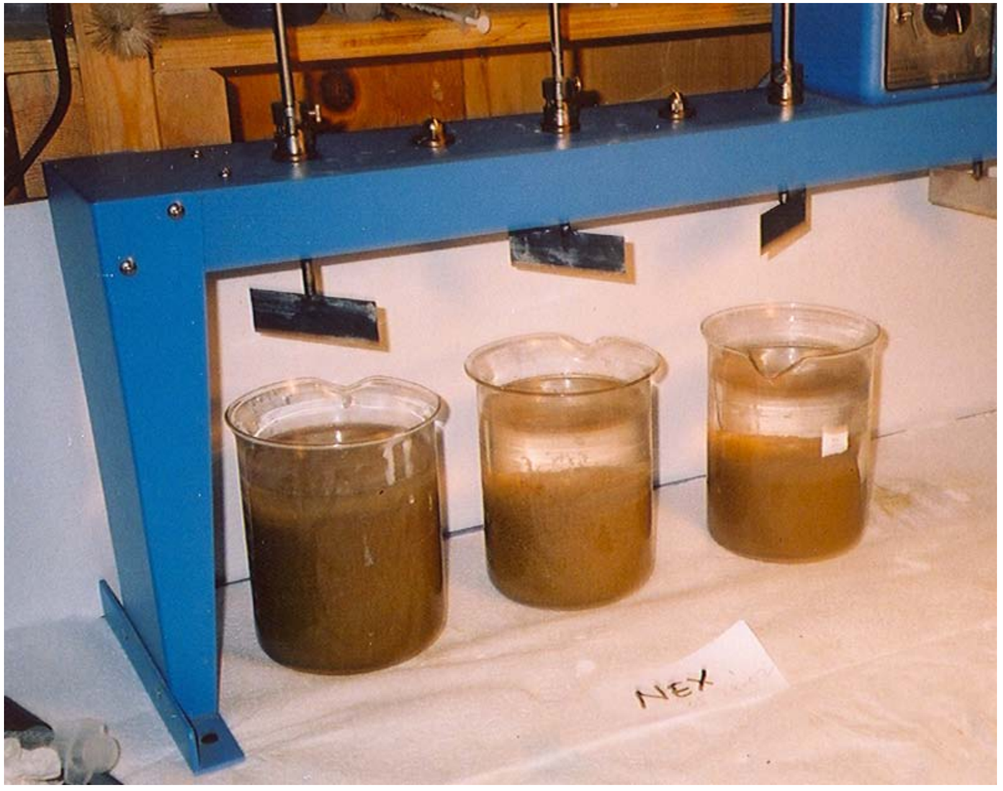
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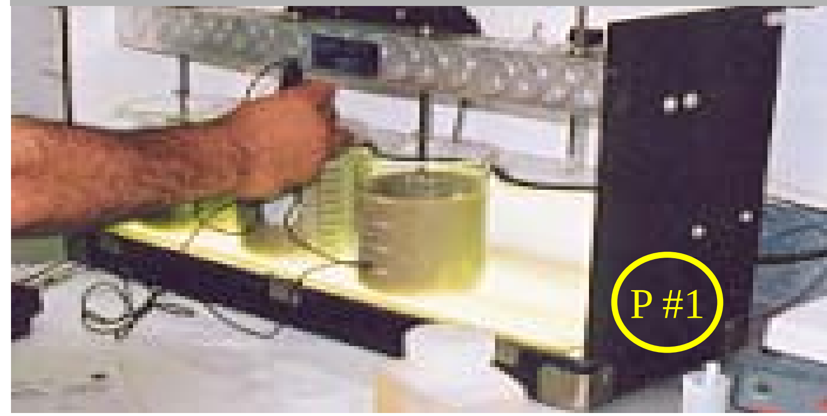
# ***Field*** *Trials*

**Four - 4 cubic meter samples from Haliburton fracks on Suncor (Petro Canada) Wells.**

**Demonstrations performed at Brooks, AB.**

## Jar Tests – to provide guidelines for treatment

- **Establishing Chemical Demand** (P #1)
- **View of Floc Formation (P #2)**
- **Clarified Water (P #3)**







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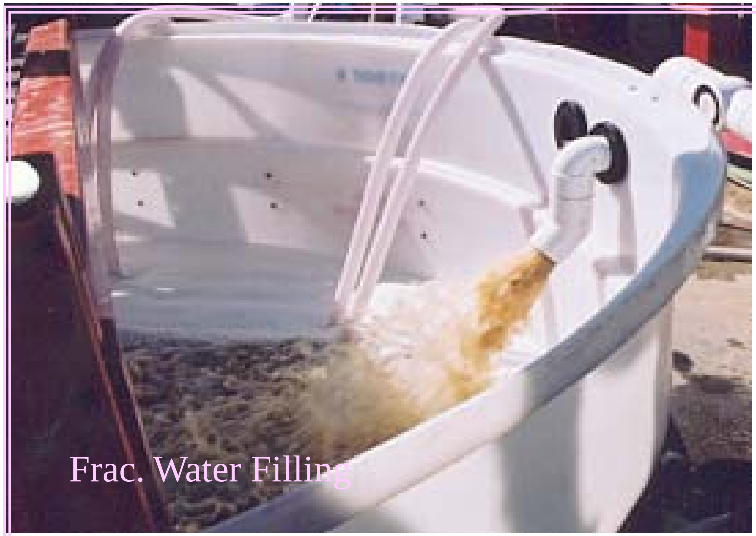
**Setting Up the Batch Treatment Equipment for the Four Cubic Meter Samples at Smithbrook Operation Near Brooks, AB.**

# Field Trials (stage one)

**4 cubic meter samples from Haliburton fracs on Petro Canada Wells.**

**Demonstrations performed at Brooks, AB.**



Frac. Water Filling

Frac. Water Filling

Chemical Addition

Clarification


**Procedure was demonstrated using four 4 cubic meter samples in September 2002.**

**Analysis and testing indicated that the treated water was reusable for future fracturing operations – i.e. no waste.**





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Two products from treatment:

- Reusable water.
- Disposable filter cake.

**Note separation of sludge and water.**

**Amount of sludge will depend on sample.**





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# Summary of Test Results

| | | | Sample Description | Raw Frac. Water | (2nd Stage) Treament |
|---|---|---|---|---|---|
| | | | Sampled Date | 7/16/2004 | 7/14/2004 |
| **Parameter Name** | **Parameter Description** | **Unit** | **Detection Limit** | | |
| Organic Carbon | Total | mg/L | 0.5 | 1650 | 770 |
| Organic Carbon | Dissolved | mg/L | 0.5 | 1220 | Not Analyzed |
| | | | | | |
| Silicon | Dissolved | mg/L | 0.05 | 5.09 | <0.5 |
| Sulphur | Dissolved | mg/L | 0.05 | 30.2 | 84.6 |
| Mercury | Dissolved | mg/L | 0.0001 | <0.001 | <0.0001 |
| Aluminum | Dissolved | mg/L | 0.005 | <0.05 | 0.11 |
| Antimony | Dissolved | mg/L | 0.0002 | <0.002 | <0.002 |
| Arsenic | Dissolved | mg/L | 0.0002 | <0.002 | <0.0020 |
| Barium | Dissolved | mg/L | 0.001 | 1.26 | 0.047 |
| Beryllium | Dissolved | mg/L | 0.0001 | <0.001 | <0.001 |
| Bismuth | Dissolved | mg/L | 0.0005 | <0.005 | <0.005 |
| Boron | Dissolved | mg/L | 0.002 | 2.82 | 1.47 |
| Cadmium | Dissolved | mg/L | 0.00001 | 0.0006 | 0.00027 |
| Chromium | Dissolved | mg/L | 0.0005 | 0.0089 | <0.0050 |
| Cobalt | Dissolved | mg/L | 0.0001 | 0.0141 | 0.0123 |
| Copper | Dissolved | mg/L | 0.001 | 0.165 | 0.516 |
| Lead | Dissolved | mg/L | 0.0001 | 0.0228 | <0.001 |
| Lithium | Dissolved | mg/L | 0.001 | 0.122 | 0.07 |





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| | | | | | |
|---|---|---|---|---|---|
| Nickel | Dissolved | mg/L | 0.0005 | 0.105 | 0.794 |
| Selenium | Dissolved | mg/L | 0.0002 | <0.0020 | <0.0020 |
| Silver | Dissolved | mg/L | 0.0001 | 0.0011 | <0.001 |
| Strontium | Dissolved | mg/L | 0.001 | 1.84 | 1.4 |
| Thallium | Dissolved | mg/L | 0.00005 | <0.0005 | <0.0005 |
| Titanium | Dissolved | mg/L | 0.0005 | 0.047 | <0.0050 |
| Uranium | Dissolved | mg/L | 0.0005 | <0.005 | <0.005 |
| Vanadium | Dissolved | mg/L | 0.0001 | <0.0010 | <0.0010 |
| Zinc | Dissolved | mg/L | 0.001 | 2.59 | 0.419 |
| | | | | | |
| Temp. of observed pH and EC | | °C | | 18.6 | 19.3 |
| Suspended Solids | Total | mg/L | 1 | 85 | Not Analyzed |
| pH | | | | 6.95 | 7.84 |
| Electrical Conductivity | | µS/cm at 25ºC | 1 | 3320 | 6390 |
| | | | | | |
| Calcium | Dissolved | mg/L | 0.2 | 102 | 537 |
| Magnesium | Dissolved | mg/L | 0.1 | 21.2 | 2.6 |
| Sodium | Dissolved | mg/L | 0.4 | 735 | 917 |
| Potassium | Dissolved | mg/L | 0.4 | 9.3 | 20 |
| Iron | Dissolved | mg/L | 0.01 | 3.91 | <0.10 |
| Manganese | Dissolved | mg/L | 0.005 | 0.887 | 1.38 |
| Chloride | Dissolved | mg/L | 0.5 | 460 | 1930 |
| Phosphorus | Dissolved | mg/L | 0.05 | 0.25 | <0.05 |
| Nitrate - N | | mg/L | 0.1 | <0.5 | <1 |
| Nitrite - N | | mg/L | 0.05 | <0.2 | <0.5 |
| Nitrate and Nitrite - N | | mg/L | 0.2 | <0.8 | <2 |
| Sulphate ($SO_4$) | Dissolved | mg/L | 0.2 | 90.7 | 254 |

| | | | | | |
|---|---|---|---|---|---|
| Hydroxide | | mg/L | 5 | <5 | <5 |
| Carbonate | | mg/L | 6 | <6 | <6 |
| Bicarbonate | | mg/L | 5 | 1400 | 431 |
| P-Alkalinity | as $CaCO_3$ | mg/L | 5 | <5 | <5 |
| T-Alkalinity | as $CaCO_3$ | mg/L | 5 | 1150 | 353 |
| Total dissolved solids | Calculated | mg/L | 1 | 2110 | 3870 |
| Hardness | as $CaCO_3$ | mg/L | | 341 | 1350 |
| Ionic Balance | Dissolved | % | | 104 | 101 |

**Samples of treated water were determined to be recyclable for future fracturing operations – without dilution of fresh water.**

# Advantages of Physical/Chemical

# Flowback Treatment Process

1. Recycle 100% of frack water flowback water – with appropriate dilution of fresh water.
2. Reduce consumption of fresh potable water by 30% to 50%.
3. Treatment and recycling competitively priced when compared to currently used disposal methods.
4. Solid waste is stable and readily land filled.
5. Waste water from frack sand cleaning operations can be treated and recycled.
6. Treatment process is simple and robust.
7. Treatment process is readily piloted and may be tailored to suit chemistry of particular site.
8. May be batch or continuous flow.
9. Process facilities may be fixed or portable.
10. Scalable and able to be made portable.

**In 2004 – 2005 there was very little interest in Alberta for treatment technology that would allow reuse of frack flowback and attempts to commercialize were abandoned.**





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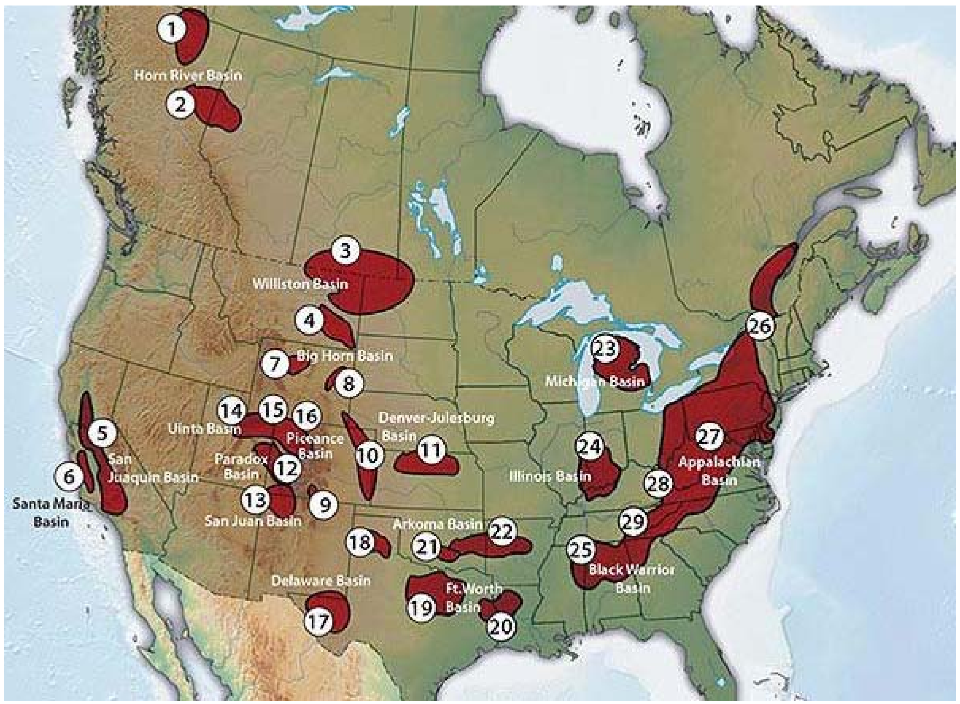
## Probable reasons for lack of interest:

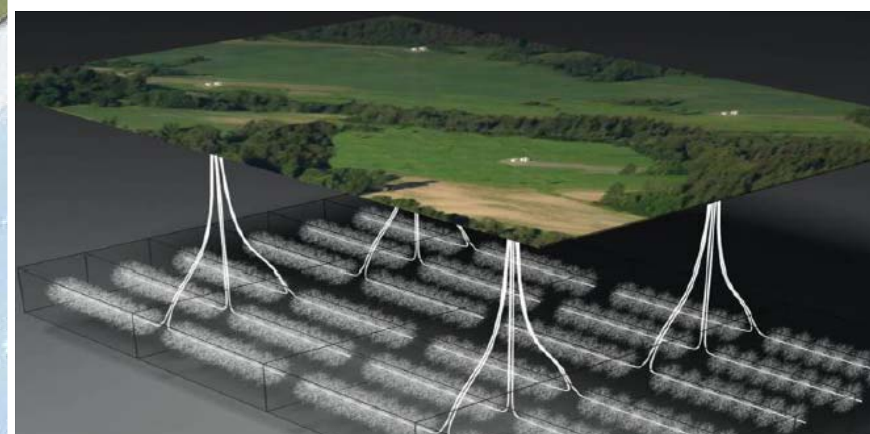
- Fresh water for use in frack operations was available at low cost.
- Volumes of water involved were not considered large.
- Disposal (deep well) was convenient and not very costly considering overall cost of performing fracing operations.
- No regulatory requirement or incentive to reuse frack flowback water.

# Fast forward: 2010

# Shale - Gas

**Economic exploitation requiring extensive fracturing operations.**



*wellbores**Image courtesy Statoil/Hydro***





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## Important differences between shallow gas well fracturing operations and shale gas well fracturing operations:

1. Volume of water used in single frack of a shale gas well may vary from 1,000,000 gallons to 10,000,000 gallons (100 times or more water than for shallow gas fracturing).
2. Disposal using deep wells may not be available or economical (location and cost).
3. Disposal in the environment is not an option.
4. Water for fracturing operations is or will soon become difficult / expensive to obtain.
5. Volumes of frack flowback water are so large that large semi-fixed treatment facilities may be economical.
6. Environmental and regulatory concerns are significant.

**Process and proto-type development of the physical/chemical treatment technology (and most others) need to undertaken carefully considering:**

1. **Specific shale – gas basin,**
2. **Method of fracturing used (volume and quality of water),**
3. **Characteristics of flowback,**
4. **Availability of fresh water for fracturing operations,**
5. **Opportunities for disposal and storage,**
6. **Probable frequency of fracturing and**
7. **Economics.**



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# Summary comments:

1. Treatment technology is available to treat ALL frack flowback water to a condition where it can be reused for subsequent fracking operations. Treatment technologies can be selected based on treatment needs (quality of flowback, treatment objectives, volume of water to be treated, local water management issues, remoteness of location, presence of disposal wells, solids disposal opportunities, availability of fresh water, costs, etc.).

2. Owner/operators must be interested in maximizing the use of water diverted for fracturing operations and instructing service companies providing fracturing on their wells to use recycled water.

3. Water management strategies associated with development of gas fields must include and integrate frack flowback treatment options.





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# Thank You

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