Methane Farming Through Use of Indigenous Microbes

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Wyodak Coal Seam
70 Feet Thick
Basin Map

Luca/Patriot Pilot and Field Projects in PRB

Tongue River: analog

South Kitty (Wyodak-Anderson) Unit: present application

Pronghorn, and remainder of Kitty: other pilot-phase restorations

Docket # 202-2011
Pilot-stage restorations: nutrient emplacement

Surface

Nutrient Delivery System

Proprietary mixture of nutrients gravity fed into coal seam

Gas Sold

500 Corporate Circle, Suite C, Golden, CO 80401 303.534.4344 Proprietary & Confidential

Docket # 202-2011

I-4a: Push Pull Schematic
Pilot-stage restorations: fluid recovery and gas production

Water, microbes and gas produced to surface

Surface

Gas
Sold

Gas
Sold

Water
Discharged
on
Surface

Nutrient
Methane

Microbes living in coal

Coal Seam
Methane Farming

Surface

Water and amendments injected in coal seam

Gas and water produced to surface, water recycled

Gas Sold

Methane

Microbes living in coal

Docket # 202-2011
Vitamins and Minerals

- Calcium (as calcium chloride)
  - Milk
- Magnesium (as magnesium chloride)
  - Vegetables, cereal
- Phosphate (as magnesium phosphate, phosphoric acid, calcium phosphate, sodium phosphate, potassium phosphate, or sodium tripolyphosphate)
  - Milk, cheese, meats
- Potassium (as potassium chloride)
  - Milk, fruits, vegetables
- Vitamin B-12, Niacin, Thiamin, Riboflavin, Biotin, Pantothenic Acid, Folate
  - Many foods, human vitamin supplements
Multi-nutrients

• Casein hydrolyzates
  – Special dietary foods as a protein source
• Yeast extract, Brewer’s yeast, Soy protein, Peptones
  – Food flavorings
Cell Vitality Enhancers

• Glycerol
  – Many prepared foods
• Weak Organic Acids (and sodium, potassium, calcium, and magnesium forms)
  – Formic: Fruits, honey
  – Acetic: Vinegar
  – Propionic: Butter, cheese
  – Butyric: Butter, cheese
  – Lactic: Yogurt, cottage cheese
  – Decanoic: Added to coat fruits and vegetables
• Glyceryl Triacetate
  – Food additive
• Ethyl lactate
  – Wine, fruits, chicken
• Polyoxyethylene
  – Sweeteners
Tracers

- Potassium iodide
  - Most foods, especially seafood
- Sodium chloride
  - Table salt
- Potassium chloride
  - Substitute for table salt
- Sodium bromide
  - Ionic salt
- Potassium bromide
  - Ionic salt
### Injection Water Quality

**Docket # 202-2011**

<table>
<thead>
<tr>
<th></th>
<th>TDS (mg/L)</th>
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<tbody>
<tr>
<td>Untreated Reservoir Water</td>
<td></td>
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<tr>
<td>Treated Water, Pre Reservoir Dilution</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>239</td>
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<tr>
<td>Average</td>
<td>912</td>
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<tr>
<td>Median</td>
<td>830</td>
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<tr>
<td>Outliers</td>
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<tr>
<td>Count</td>
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<tr>
<td>Average</td>
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<tr>
<td>Median</td>
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<td>Outliers</td>
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</table>

One outlier at 11,538 mg/L

Class II Standard

Class III Standard
Restored vs Unrestored Outfall Data in Eastern PRB (WYPDES Data, 170 Outfalls, 4938 Samples)

Number of Samples

Concentration

Analyte

Docket # 202-2011

G-13: Restoration Treatment Effects on Individual Parameters
Stiff Diagram
South Kitty (Wyodak-Anderson) Unit
Pre-Treatment Samples

* Carbonate not included in analysis
Stiff Diagram
South Kitty (Wyodak-Anderson) Unit
Post-Treatment Samples

* Carbonate not included in analysis
<table>
<thead>
<tr>
<th>Coal</th>
<th>Bicarbonate (mg/L)</th>
<th>Calcium (mg/L)</th>
<th>Chloride (mg/L)</th>
<th>Magnesium (mg/L)</th>
<th>Potassium (mg/L)</th>
<th>Sodium (mg/L)</th>
<th>Sulfate (mg/L)</th>
<th>Specific Conductance (μmhos/cm)</th>
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<tr>
<td>Smith</td>
<td>708</td>
<td>19.0</td>
<td>14.3</td>
<td>7.9</td>
<td>5.3</td>
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<td>1.0</td>
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<td>Wyodak</td>
<td>1,004</td>
<td>33.8</td>
<td>7.3</td>
<td>20.9</td>
<td>11.2</td>
<td>287</td>
<td>1.8</td>
<td>1,415</td>
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</tbody>
</table>
Exhibit WE-3

Powder River Basin - Campbell Co, WY
South Kitty (Wyodak-Anderson) Unit

Domestic-use Water Wells

to be Monitored

WELL SYMBOLS
- Abandoned Well
- Abandoned Gas Well
- Dry Hole
- Gas Well
- Location
- Monitor Well
- Oil Well
- Plugged & Abandoned
- Shut In Gas Well
- Water Well

Docket # 202-2011
• Class V (5F2) UIC area permit #10-498
• Authorization to inject water only into 32 wells in the unit area
• Valid for five years
• Field-wide limit of 3,570 barrels of water per day (BWPD)
• Individual well limits of 500 – 1,000 BWPD
• Sampling and monitoring required
  – Baseline and semi-annual water samples of CBM wells that are capable of water production
  – Offer to, and monitoring of, WSEO-permitted wells within ½ mile of a dual-purpose well at baseline and semi-annually
  – Quarterly grab samples of injection water
  – Samples analyzed by a 3rd party lab
Exhibit WE-4
Monitoring and Sampling - Conclusions

• DEQ Class V UIC Permit # 10-498
  – Permit requires substantial and regular; 1) sampling, 2) independent laboratory testing, 3) monitoring and 4) reporting of water quality and quantity parameters for the protection of the coal seam and related water aquifers across the entire proposed unit during the 5 year term of the Permit.
  – This is an comprehensive and adequate set of requirements to monitor the aquifer and water rights.

• Domestic Use water wells
  – Every one of the 31 domestic use wells, with 32 water rights permitted by State Engineers Office, within the shaded area shown on Exhibit WE-3 map, will be monitored and reported as a part of the DEQ Permit # 10-498. This area is larger than the conservative Area of Review determination submitted and approved by DEQ.
  – Only 1 of these domestic wells is completed in the Wyodak coal seam formation; most are in sands located either above or beneath the Wyodak coal.
Tongue River Project
Production & Restoration Response of All Wells
Averaged to Compare Primary Production to Enhanced-Recovery Responses

- Cum: 96.1 MMCF/Well
- Rem: 14.5 MMCF/Well
- Total: 110.6 MMCF/Well

- Primary Production (260 wells throughout)
- Predicted Average Future Production
- Actual Production including Adjacent Area Response, Averaged to 58 successful restorations

+37.4 MMCF/Well vs baseline trend

Baselined trend

33 mcfpd
Benefits to local stakeholders

• Groundwater is re-injected, and conserved
• Prior surface disturbances (wells; roads; rights-of-way) continue to provide economic benefit
• The methane farming footprint on the ground is very light
• Mineral owners can look forward to a modest but steady income stream for a long time
Economic benefits

• Reliable production of clean energy
• Minimal new disturbances
• NO MARKET INTERVENTIONS NEEDED
• Long-term sustainability of supply