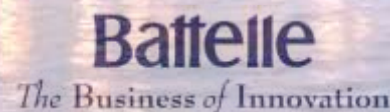


Bioremediation of a Dissolved Ammonia and Nitrate Plume Through In-Situ Denitrification

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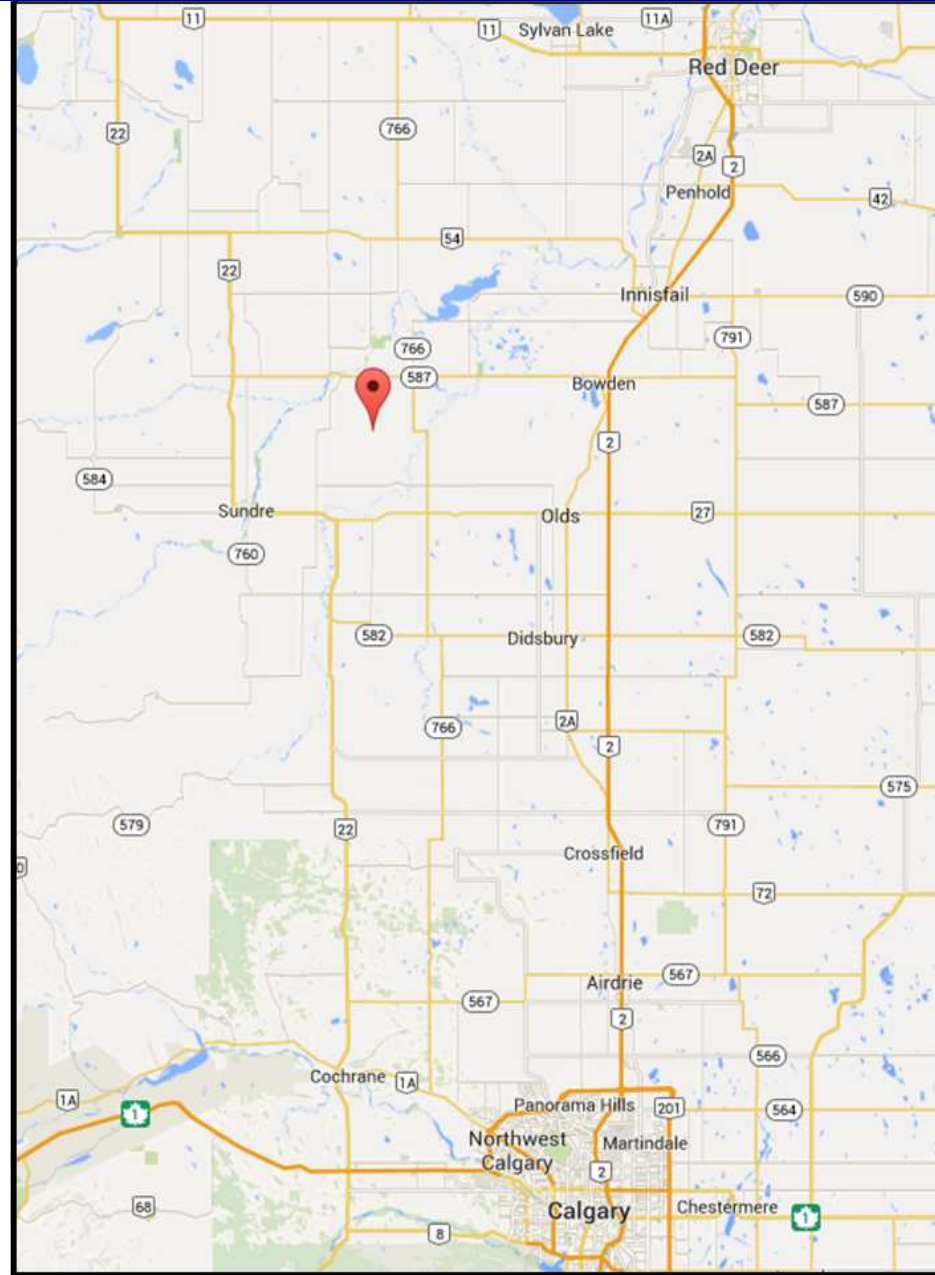
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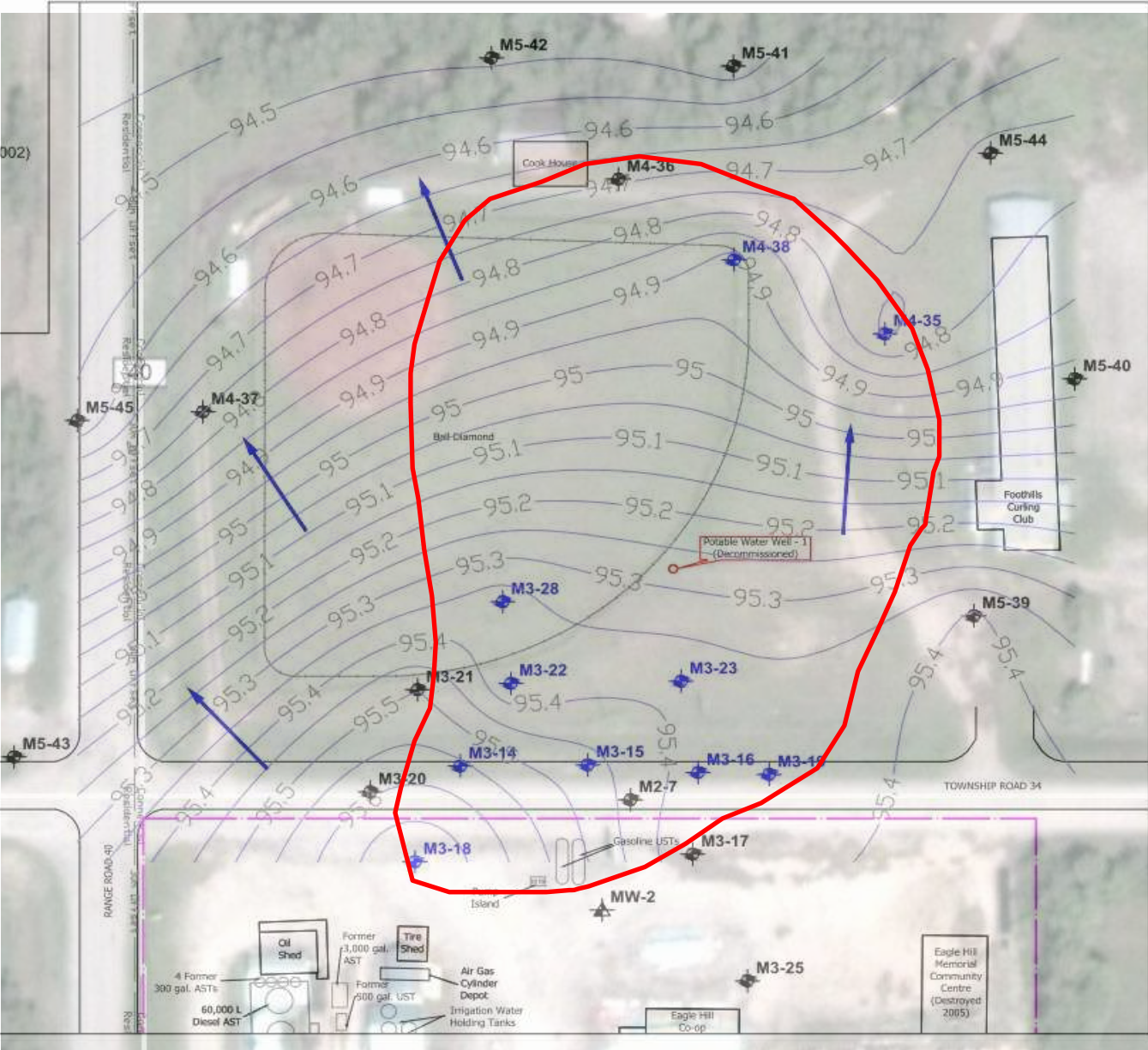
Background

- Small unincorporated community in central Alberta, Canada
- Petroleum facilities including gas bar and bulk fuel facility in operation since the 1930's
- Multiple ESAs since 2001 identifying PHC impacts in soil and groundwater
 - On-site
 - Off-site
- USTs were removed in 2006 and replaced with ASTs



Background

- Legend:**
- M3-14 Monitoring Well
 - M3-15 Monitoring Well (Injected)
 - MW-1 Monitoring Well (Cushman-Ball, 2001)
 - BM2-17 Monitoring Well (Nichols Environmental, 2002)
 - Approximate Property Boundary
 - Building
 - Groundwater Flow Direction
 - 94.5 Groundwater Contour



Water Well

Site Characteristics

Lithology

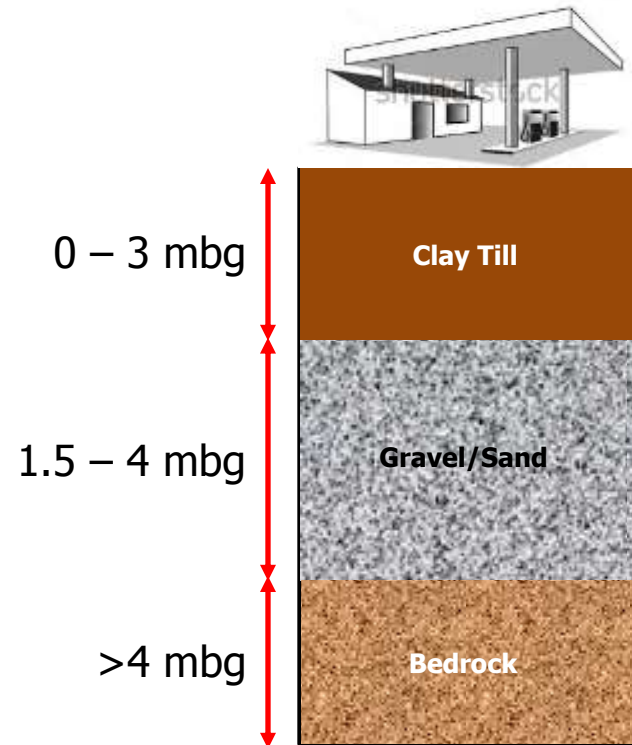
- Soil stratigraphy generally consists of clay till underlain by saturated gravel/sand followed by bedrock

Groundwater

- GW depth approximately 1.5 mbg
- Flow is toward the north

Gradient

- GW gradient 0.0086 m/m



Previous Remedial Efforts

Bio-Stimulation

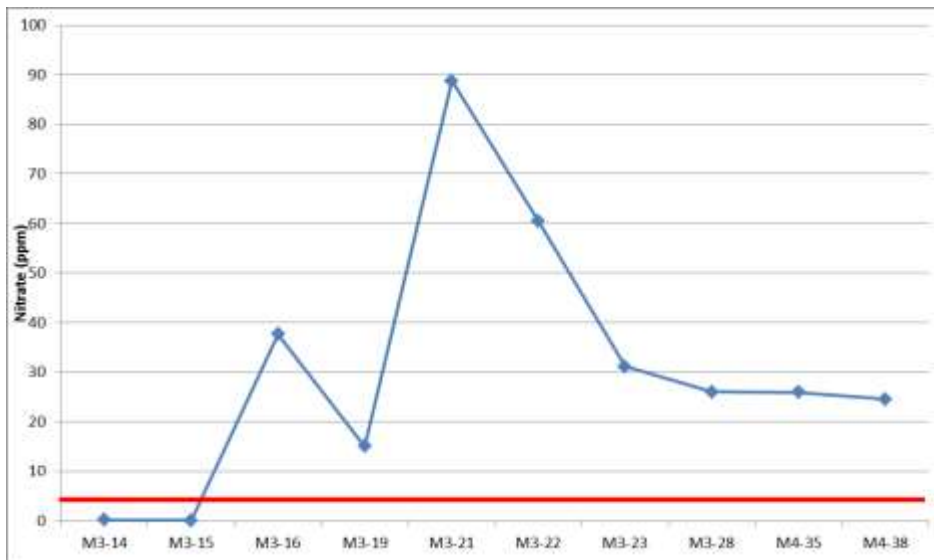
- Addition of nitrogen-based liquid fertilizer into the near-surface GW
- 500-L of 10-34-0 mixed with 500-L of 28-0-0 liquid fertilizer
 - Direct injected into nine monitoring wells and injection header



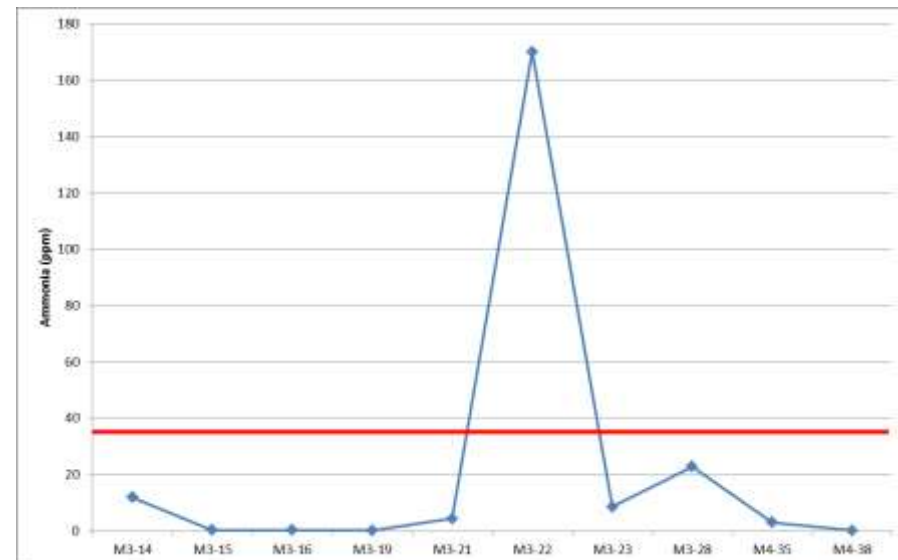
Previous Remedial Efforts

- As a result of limited carbon (low PHC impacts, coarse-grained geology), the added nutrients were not completely consumed
- GW nutrient concentrations (NO_3 , NO_2 , NH_4) exceed applicable regulatory guidelines
- Elevated concentrations of orthophosphate also present

Nitrate (guideline = 3 ppm)

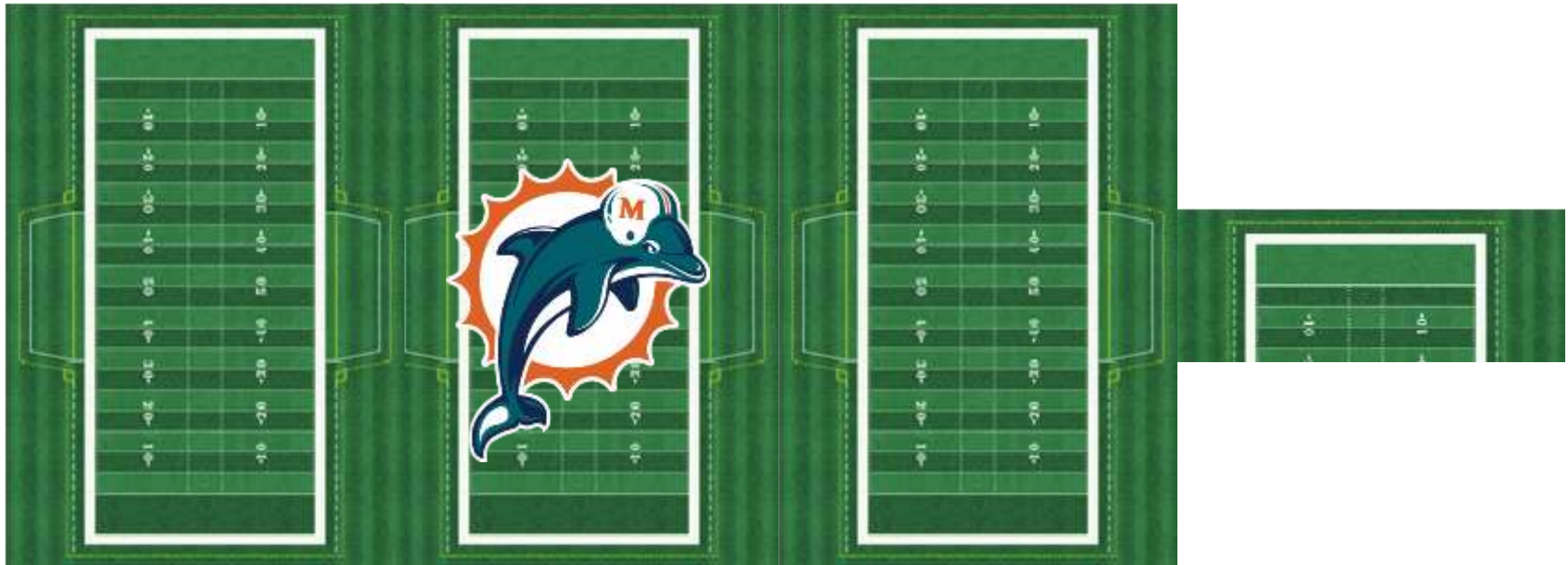


Ammonia (guideline = 34.2 ppm)



Plume Characteristics

- Nutrient impact area estimated to be 16,850 m²



- Thickness of the impacted aquifer is approximately 2.5 m
- Porosity approximately 35%
- Estimated 14,745 m³ of nitrate impacted groundwater requiring treatment

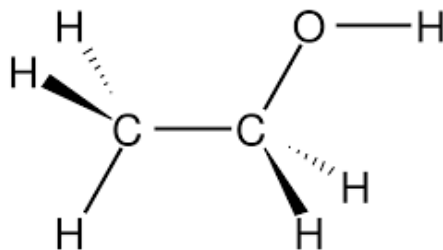
Remedial Approach

- Average nitrate concentration of 27 mg/L
- Average ammonia concentration 10.63 mg/L
- Estimated mass:
 - Nitrate estimated to be 398 kg (880 lbs)
 - Ammonia estimated to be 157 kg (350 lbs)

Remedial Approach

- Site has limited carbon
- Elected to use ethanol
 - Often used as a treatment for fertilizer impacts
 - Environmentally inert
 - Reasonable choice because of low PHC concentrations
- Ethanol is very labile and would have low toxicity

Balanced Stoichiometric Equation



Remedial Approach

- Based on literature review, 1.4 mg of ethanol is required to denitrify 1 mg of nitrate
 - =1,088 kg of ethanol required
- Consideration also given to additional carbon consumption
 - Presence of iron (Fe^{3+})
 - Oxygen
- Recommendation to double the mass
 - =2,175 kg

Injection Summary

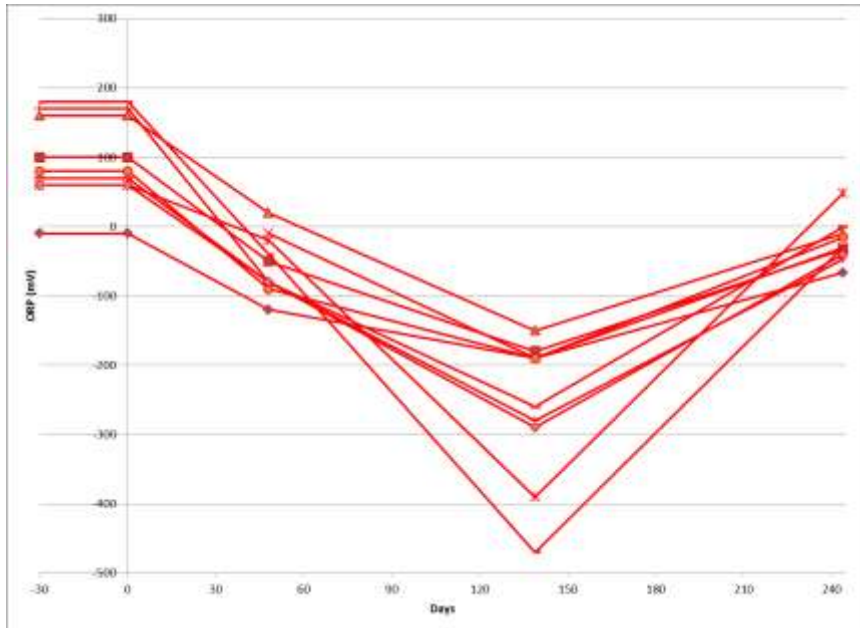
- Ethanol added to the same wells
 - Approximately 20,600 litres of 15% ethanol injected
- GW monitoring and sampling programs completed pre- (-30 days) and post-amendment (48, 139, 244 days)
 - Wells were developed by purging 100L per well



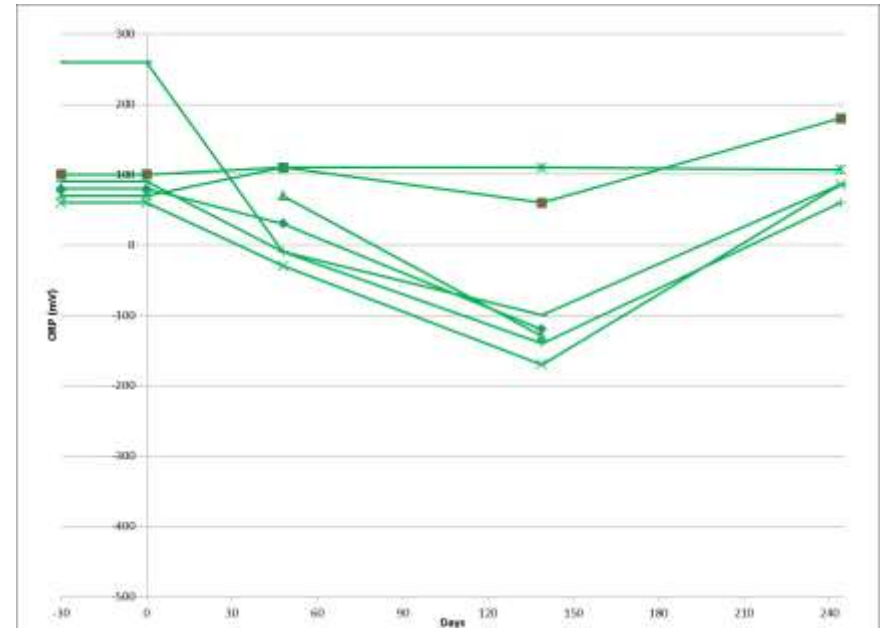
Results

Field Measured Oxidation Reduction Potential

Amended Wells



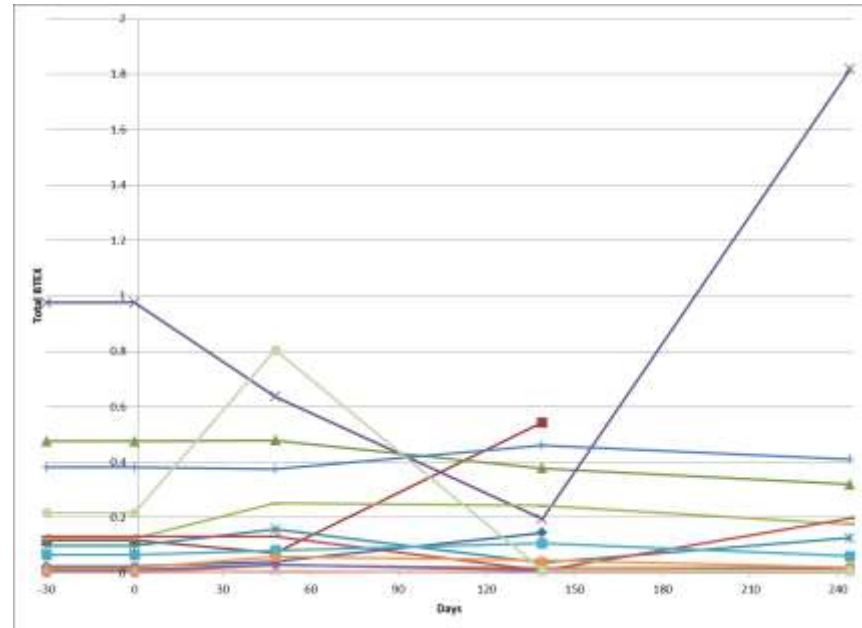
Non-amended Wells



- ORP decreased significantly following amendment
 - Reducing environment, returning close to baseline 240 days post amendment
- Larger decrease noted in wells receiving ethanol amendment versus non-amended wells

Results

Petroleum Hydrocarbons (Total BTEX)

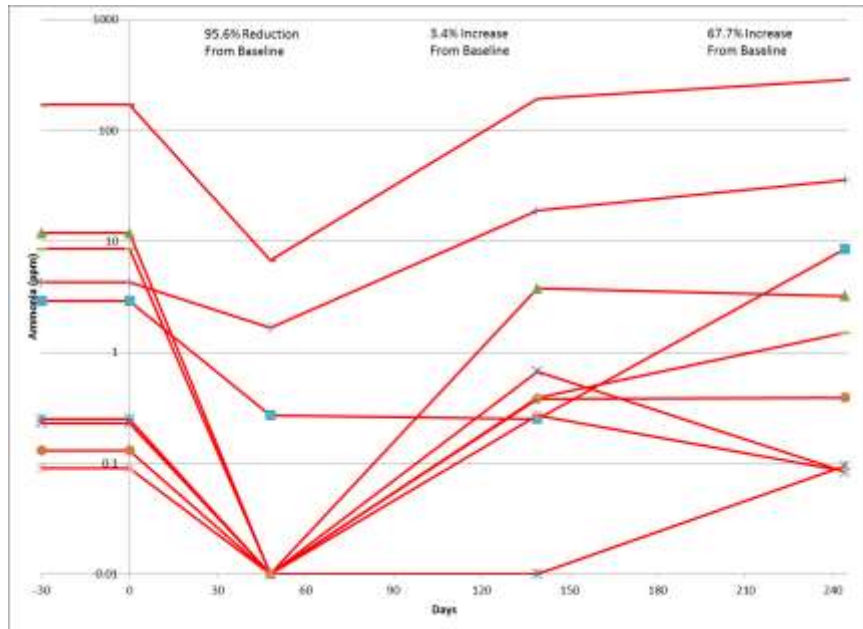


- PHC concentrations remained low between pre- and post-amendment
- EtOH is a simple carbon source, preferential consumption
- TOC (bioavailable carbon) increased

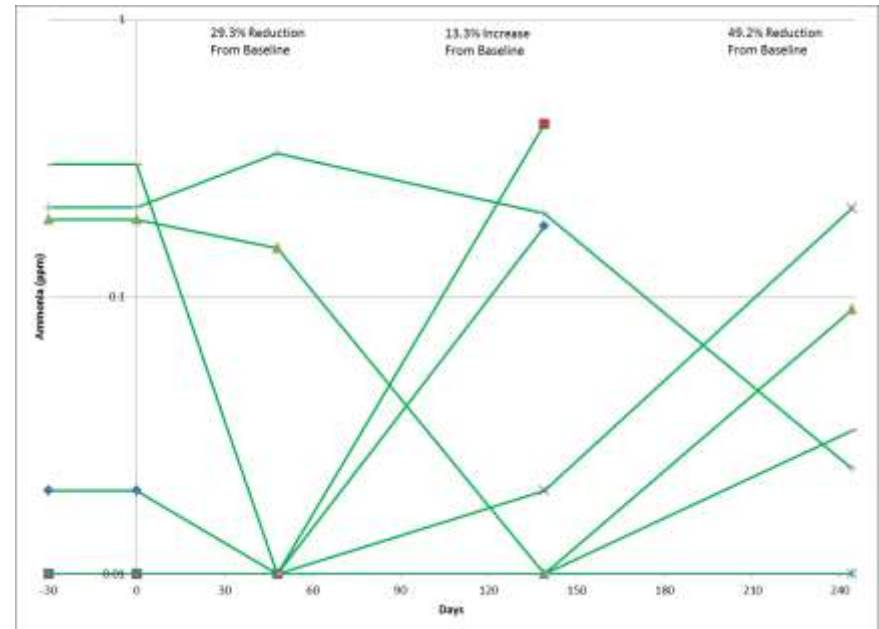
Results

Ammonia

Amended Wells



Non-amended Wells

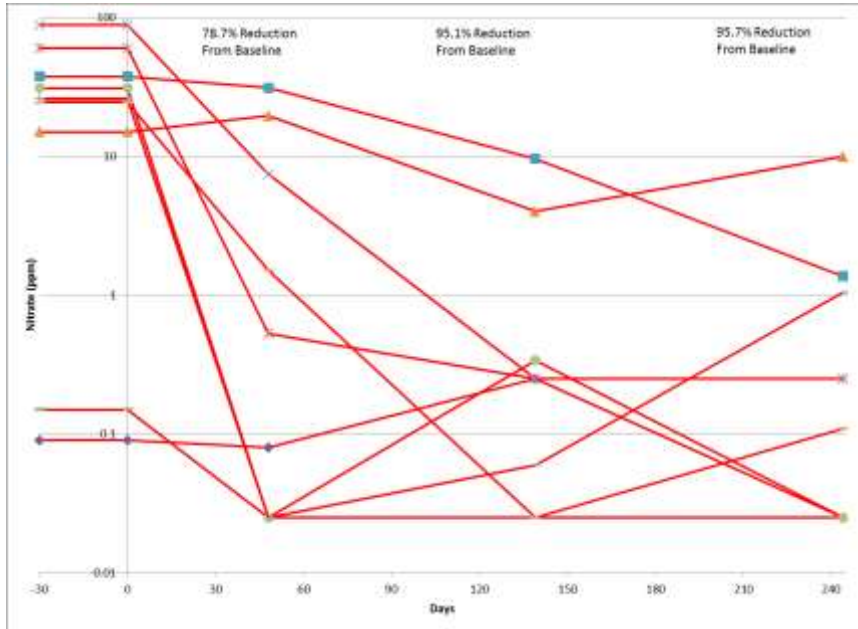


- Ammonia showed initial nitrification after 48 days (96%)
- 68% increase from baseline after 240 days
 - Likely diffused back into the area once carbon source was consumed

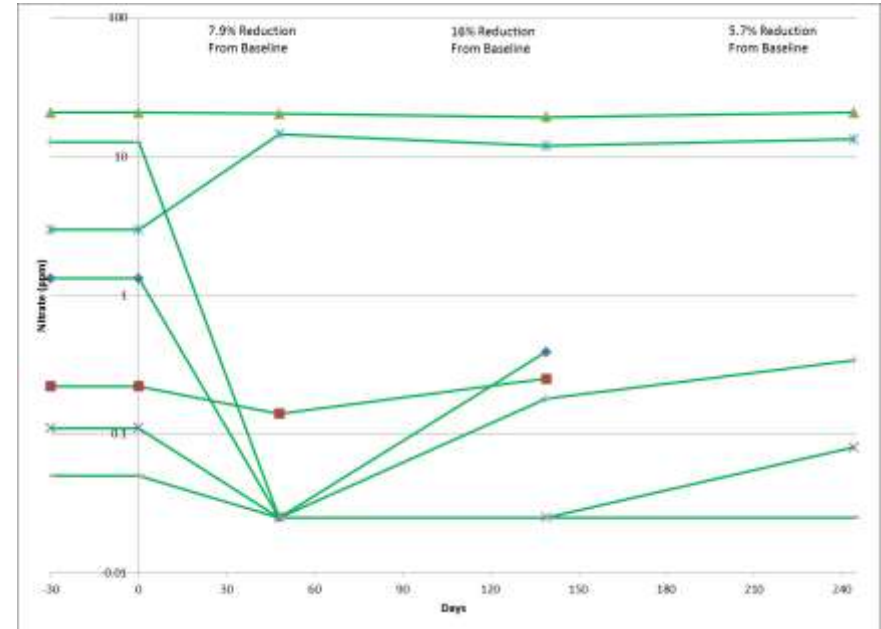
Results

Nitrate

Amended Wells



Non-amended Wells

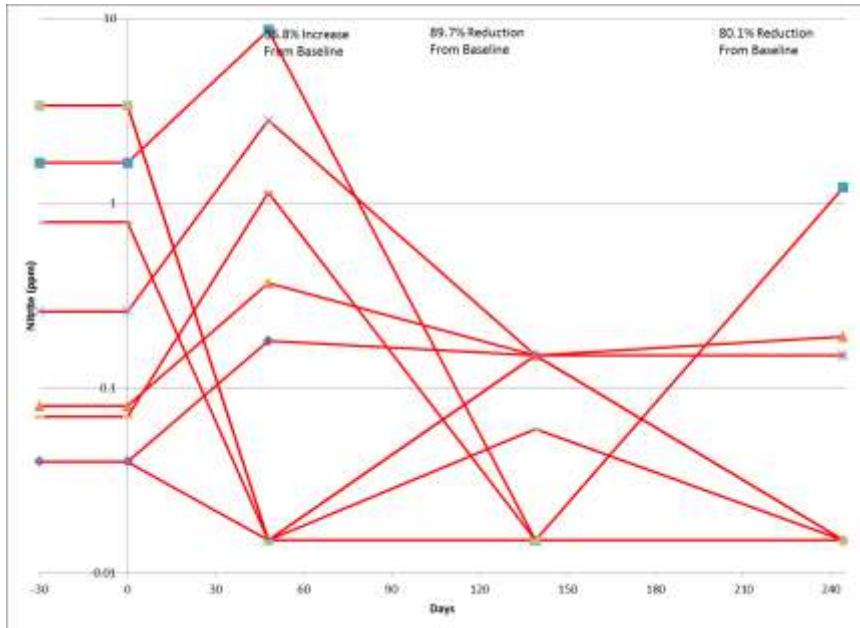


- Stable decreasing trend
 - 96% reduction from baseline to final sampling event

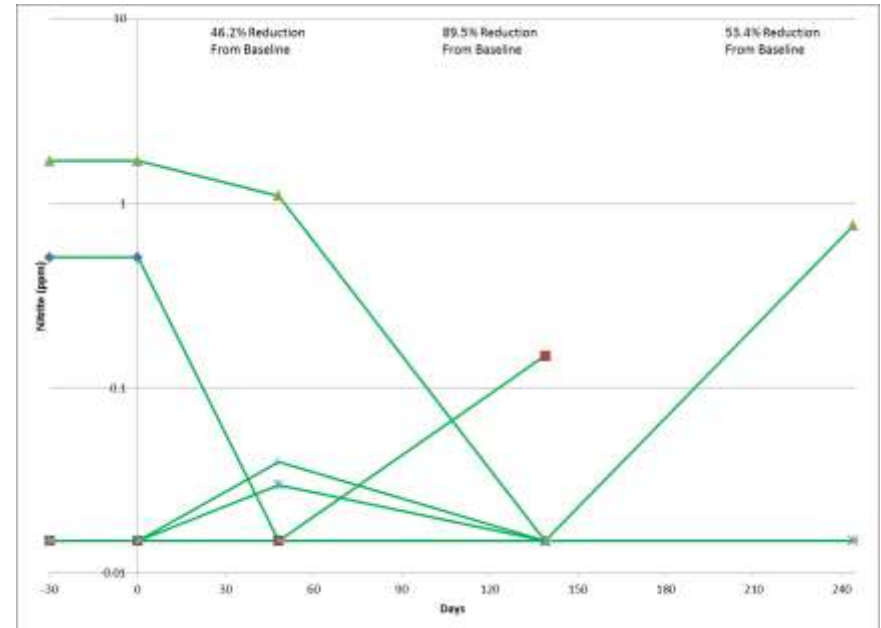
Results

Nitrite

Amended Wells



Non-amended Wells

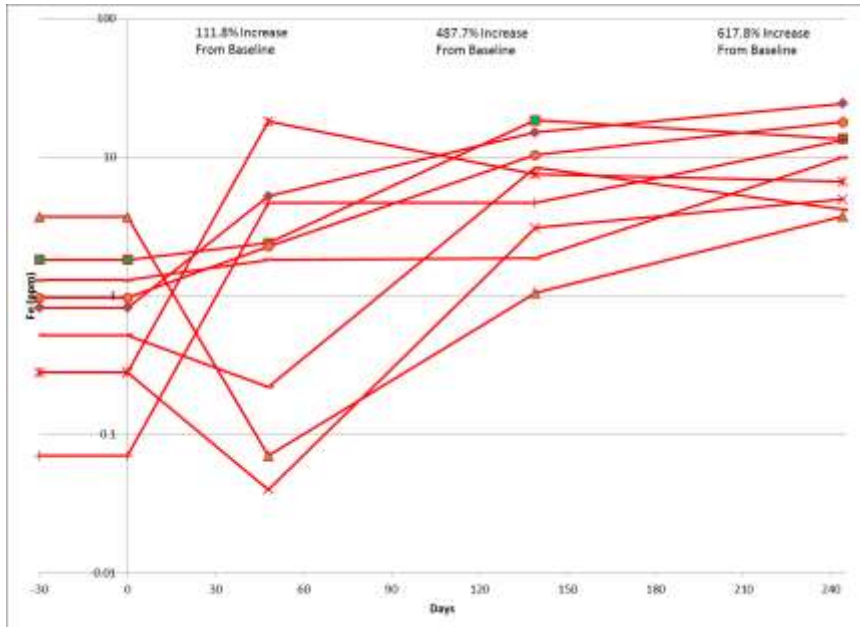


- Initial increase in nitrite concentrations a good indication of ammonia nitrification
- Decreasing concentrations of nitrite may indicate that the rate of nitrification is slowing

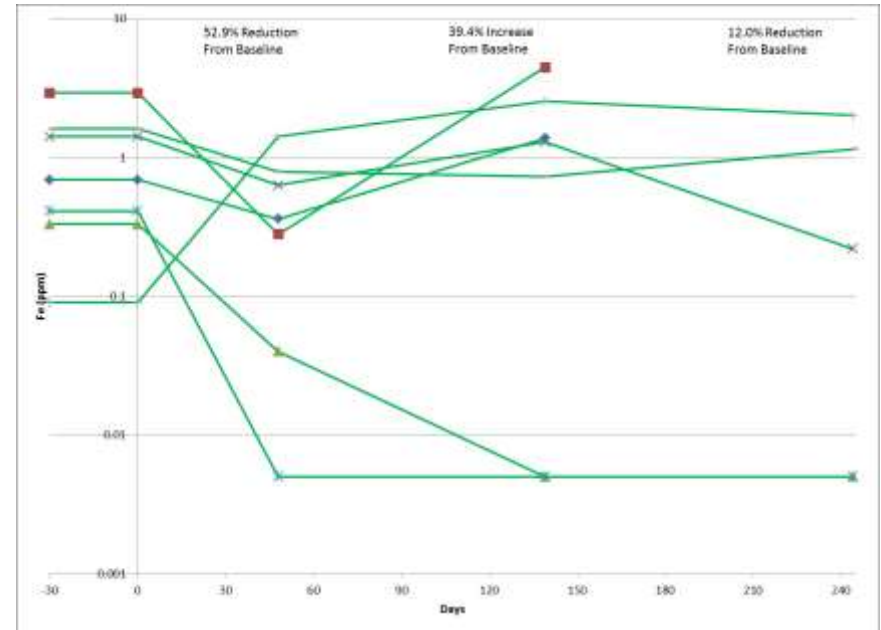
Results

Dissolved Iron

Amended Wells



Non-amended Wells



- Dissolved iron concentrations increased 620% from baseline
- The significant decrease in ORP may have resulted in the mobilization of metals
 - Evaluation of which metals were mobilized is still ongoing

Other Results

- Orthophosphate concentrations were below method detection limits
 - Orthophosphate may act as a rate limiting step in nitrogen compound degradation
- Bacteria concentrations
 - No discernable pattern for bacterial communities (SRB, IR, HA and SF)

Conclusions

- nitrification of ammonia would decrease DO and produce anaerobic conditions
 - Site was near anaerobic to begin. DO concentrations <1 ppm both pre and post amendment
 - Ethanol amendment forced redox negative environment
- denitrifying bacteria would use nitrate as an electron acceptor during anaerobic respiration producing nitrogen gas
 - Nitrogen gas was not measured during investigation
 - Nitrogen gas likely increased based on reduction of nitrate concentrations throughout investigation area

Conclusions

- **Nitrite concentrations would also increase**
 - initial increase in nitrite concentrations was a good indication of ammonia degradation – a 37% increase in nitrite concentration was noted
- **reduction of ammonia and nitrate via anammox process**
 - Ammonia initially reduced, but rebounded as a result of diffusion
 - Average nitrate concentration went from 31 ppm in the baseline event to 1.3 ppm after third post amendment event

Questions?

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