Nitrate Treatability Study (NTS)

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Problem Statement

Source: Google Images – Hallmark Farmhouse

Find a solution to rural nitrate contamination in ground water for drinking in domestic households.

NTS Project

- Modeled raw ground water:
  - Ground water concentration is 20 mg/L NO_3-N and 40 mg/L SO_4
- Goal:
  - Treat modeled ground water at the flow rate of 0.2 gallons per minute to below safe levels as suggested by the Safe Drinking Water Act
  - Max Contaminant Level of 10 mg/L NO_3-N
- Success of design:
  - 80% removal of nitrate
  - Service period of 1 month
  - Low Maintenance
  - Low Cost

Presentation Outline

- Part 1 background and technology selection
- Part 2 laboratory protocol and experiments
- Part 3 scale up calculations
- Part 4 system configuration recommendations

Background

- Target group:
  - Domestic single family properties with well drinking water delivery systems in agriculturally rich areas
  - 20% of shallow aquifer wells violate the Safe Drinking Water Act's Max Contaminant Level for nitrate
- Effected population:
  - Infants
  - Elderly
  - People with weakened immune systems
- Risks due to nitrate:
  - Methaemoglobinemia or Blue Baby Syndrome
  - Shortness of breath

Technology Selection

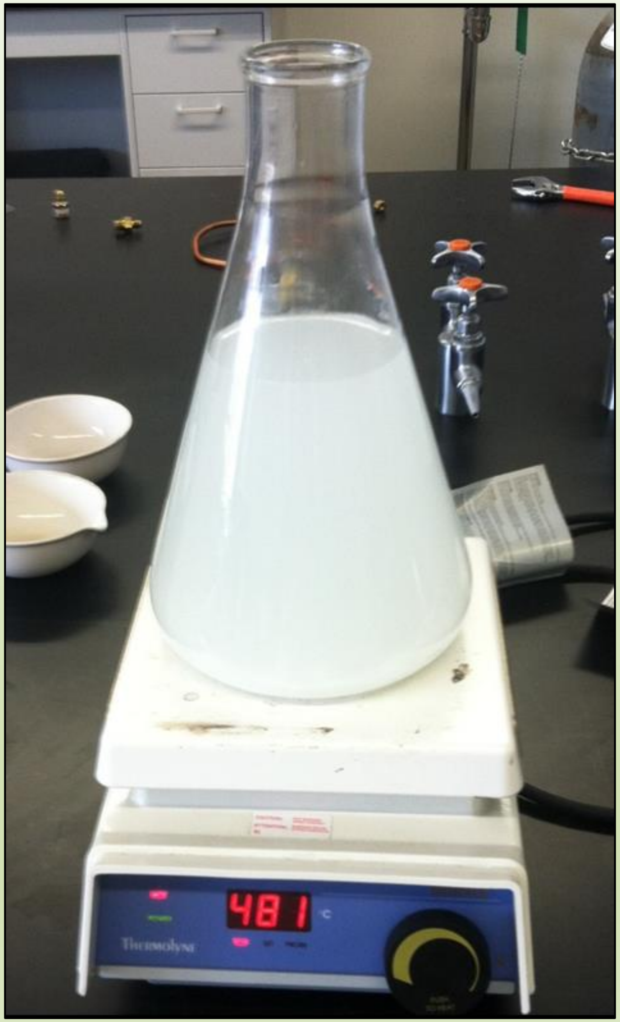
- Nitrate removal technologies:
  - Ion exchange (adsorption)
  - Reverse osmosis (membrane filtration)
  - Electrodialysis (membrane filtration)
  - Biological denitrification
  - Chemical deniftrication
- Selected Technology
  - Strong Base Ion Exchange Resin

Nitrate Selective Resin

- Purolite® A520E
- Exchange capacity:
  - 0.9 meq/mL minimum
- Functional group:
  - Quaternary Ammonium
- Resin size range:
  - 300 um to 1200 um
- Max operating temperature:
  - 212° F
- Operating pH range:
  - 4.5 to 8.5

Synthetic Water for Experiments

- Lake Mary ground water
- Spiked with:
  - $Na\text{-}NO_3$ and $Na_2\text{-}SO_4$
- Final Concentration:
  - 26 mg/L NO_3-N and 40 mg/L SO_4



Synthetic Water Analysis

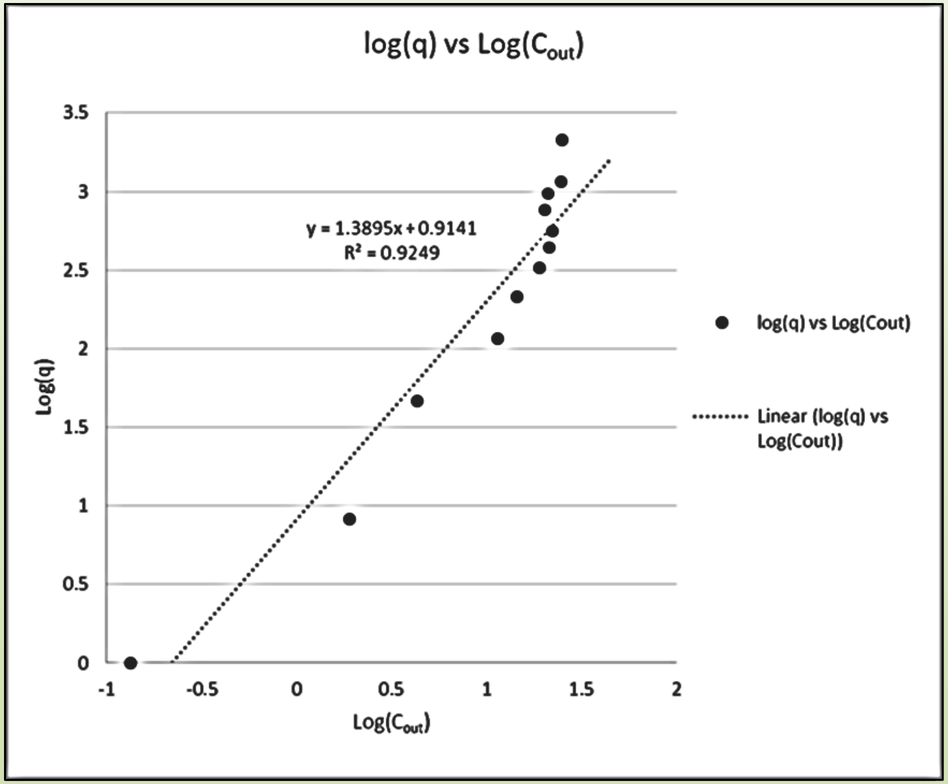
Table 1: Synthetic Water for Experiments 1 and 2							
Anions	mg/L	ppm as $CaCO_3$	meq/L	Cations	mg/L	ppm as $CaCO_3$	meq/L
Nitrate	114.92	93.0852	5.746	Calcium	53		2.65
Sulphate	40		0.833	Magnesium	35		2.916667
Chloride	4		0.113	Sodium	146		6.347826
Bicarbonate	320		5.245902	Potassium	0.2		0.005128
Total Anions			11.938	Total Cations			11.920
TDS=	300	mg/L		LSI=	-0.14		
T=	11.8	C		TH=	320		
P=	0.777	atm		pH=	7		

Laboratory Experiments

- Flow Through Experiment
  - 3 cycles and 33 samples per cycle
  - 10 mL A520E
  - Evaluate Recharge Ability
  - Freundlich Model
- Batch Experiment
  - Batch's 2A and 2B
  - Varied resin mass
  - Freundlich Model

Flow Through Experiment Results

- Parameters:
  - $\frac{1}{n} = 1.39$
  - $K_f = 8.2$
- Results:
  - $q = K_f * C_{out}^{(\frac{1}{n})}$
  - $q = 21.5\, ug\ NO_3 - N\ per\ mg\ Resin$



$Log(q) = \log K_f + (1/n) \log(C_{out})$

Batch Experiment Results

- Experiment 2A
  - o Source of Errors:
    - Old HACH reagents
    - Biological Activity
    - Scratched Cuvettes
- Experiment 2B
  - o Samples await analysis
  - o Need new reagents

Scale Up with Freundlich Parameters

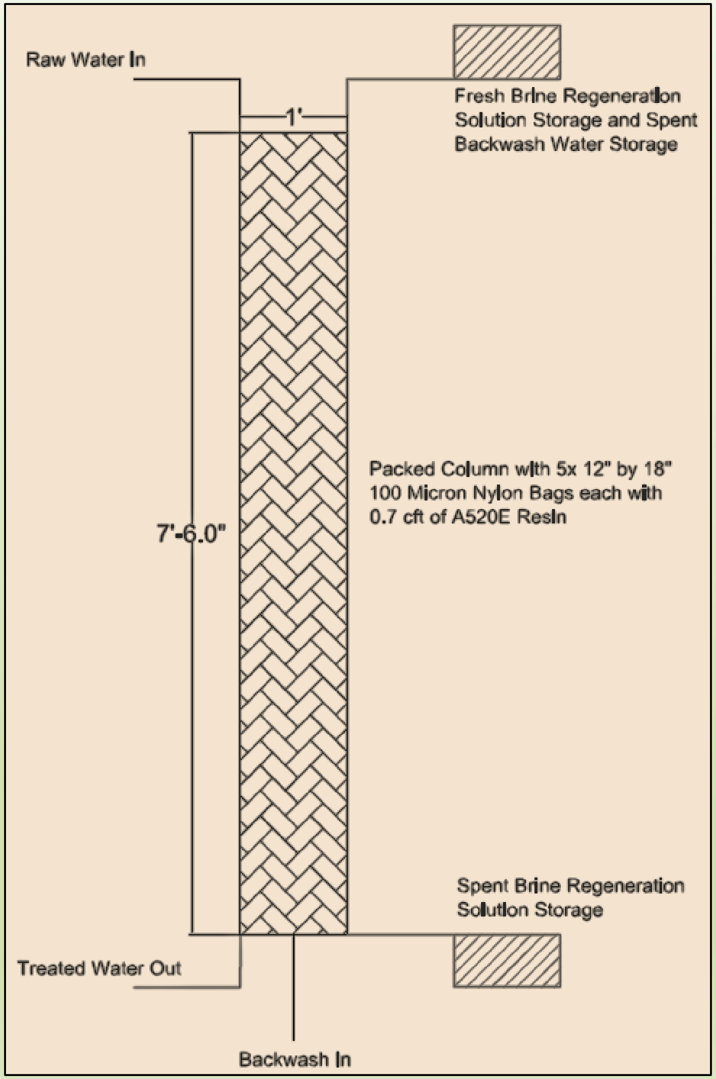
- Scale up Conditions:
  - $C_{in} = 20\frac{mg}{L}NO_3 - N + 40\frac{mg}{L}SO_4$
  - $C_{out} = 2\frac{mg}{L}NO_3 - N + 40\frac{mg}{L}SO_4$
  - $Q = 8640\ gallons/month$
  - $Design\ factor = 0.85$
- Result:
  - $Volume_{resin} = 3.54\ ft^3\ resin$

Scale Up using A520E Documentation

- Scale up Conditions:
  - $C_{in} = 20 \frac{mg}{L} NO_3 - N + 40 \frac{mg}{L} SO_4$
  - $C_{out} = 3.6 \frac{mg}{L} NO_3 - N + 40 \frac{mg}{L} SO_4$
  - $Q = 8640\ gallons/month$
  - $Design\ factor = 0.85$
- Result:
  - $Volume_{resin} = 3.50\ ft^3\ resin$

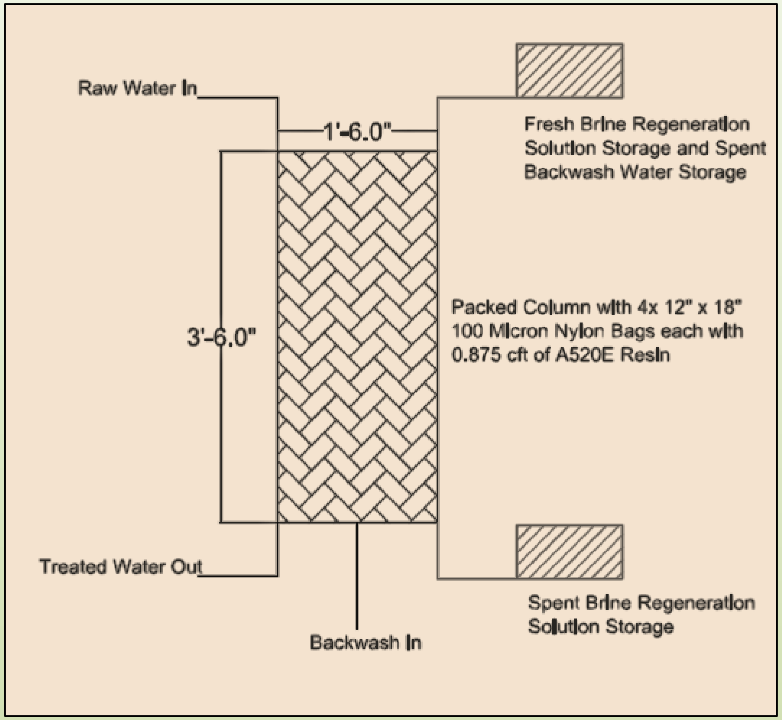
Recommended System Configuration A

- Service Pressure drop:
  - 5.79 to 13.4 PSI
- Backwash flow rate:
  - 2.2 gpm
- Regeneration volume:
  - 105 gallons
- Brine concentration:
  - 8 lb/ft^3
- Temp range:
  - 41°F to 120° F



Recommended System Configuration B

- Service Pressure drop:
  - 1.37 to 3.96 PSI
- Backwash flow rate:
  - 5 gpm
- Regeneration volume:
  - 105 gallons
- Brine concentration:
  - 8 lb/ft^3
- Temp range:
  - 41°F to 120° F



Operating Conditions

Operating Conditions for Recommendations Options A and B				
Operation	Rate	Solution	Time	Amount
Service	0.2 gpm	Influent Water for treatment	30 days	8640 gallons
Backwash	2.2-5 gpm	Influent Water	7-16 minutes	35 gallons
Regneration	1.75 gpm	8lb/ft^3 NaCl	70 minutes	120 gallons
Rinse	4.5 gpm	Influent Water	16 minutes	55 gallons
Design Backwash expansion is 50% to 75% depending on temperature				
128.5 lb NaCl required per 30 day cycle				
Regeneration takes 110 minutes				

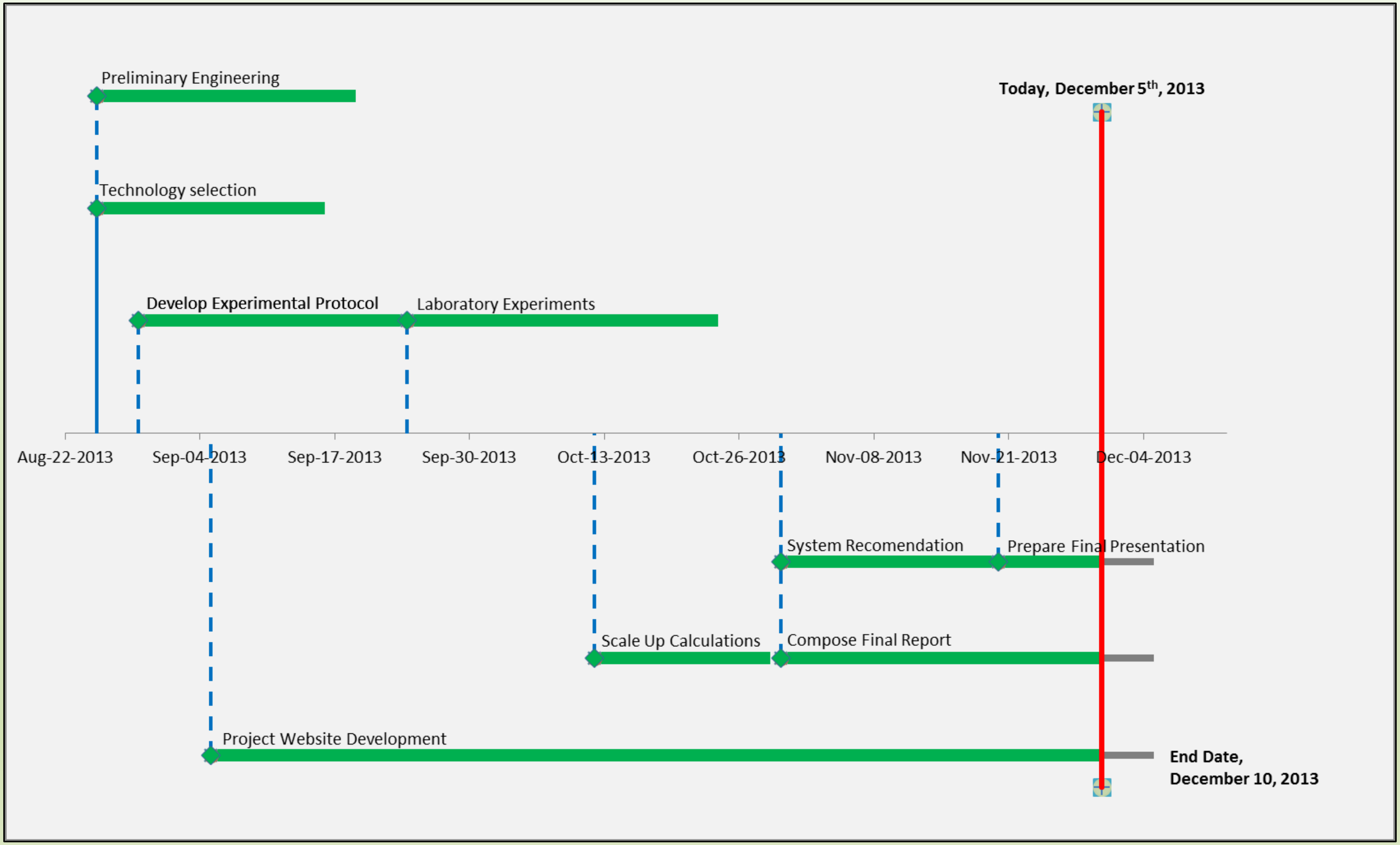
Economic Analysis

- Initial Cost:
  - $2,499.00 ± $200.00 for materials and installation
- Cost Ongoing:
  - $164.00/year for sodium chloride ($NaCl$)
  - $600.00/year in regeneration man hours
- Technician rate:
  - $25.00/hr

Distribution of Hours

Table 2: Distribution of Hours				
Task	Estimated Hours	Actual Hours	Percent of Total	Cost
Preliminary Engineering	50	30	11%	$ 1,350.00
Technology Selection	35	30	11%	$ 1,350.00
Experimental Protocol	25	20	8%	$ 900.00
Project Website	14	20	8%	$ 900.00
Laboratory Experiments	50	50	19%	$ 2,250.00
Scale up Calculations	50	40	15%	$ 1,800.00
System Recommendation	57	25	9%	$ 1,125.00
Final Report	35	30	11%	$ 1,350.00
Final Presentation	10	20	8%	$ 900.00
Totals	326	265	81%	$ 11,925.00

Project Organization



Conclusion

- Project Objectives:
  - o 80% removal of nitrate
  - o Service period of 1 month
  - o Low Maintenance
  - o Low Cost

Questions?