Potential Implications of the Proposed South Heart Lignite Mine on the Tongue River Aquifer

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Outline

» Introduction

» Methodology

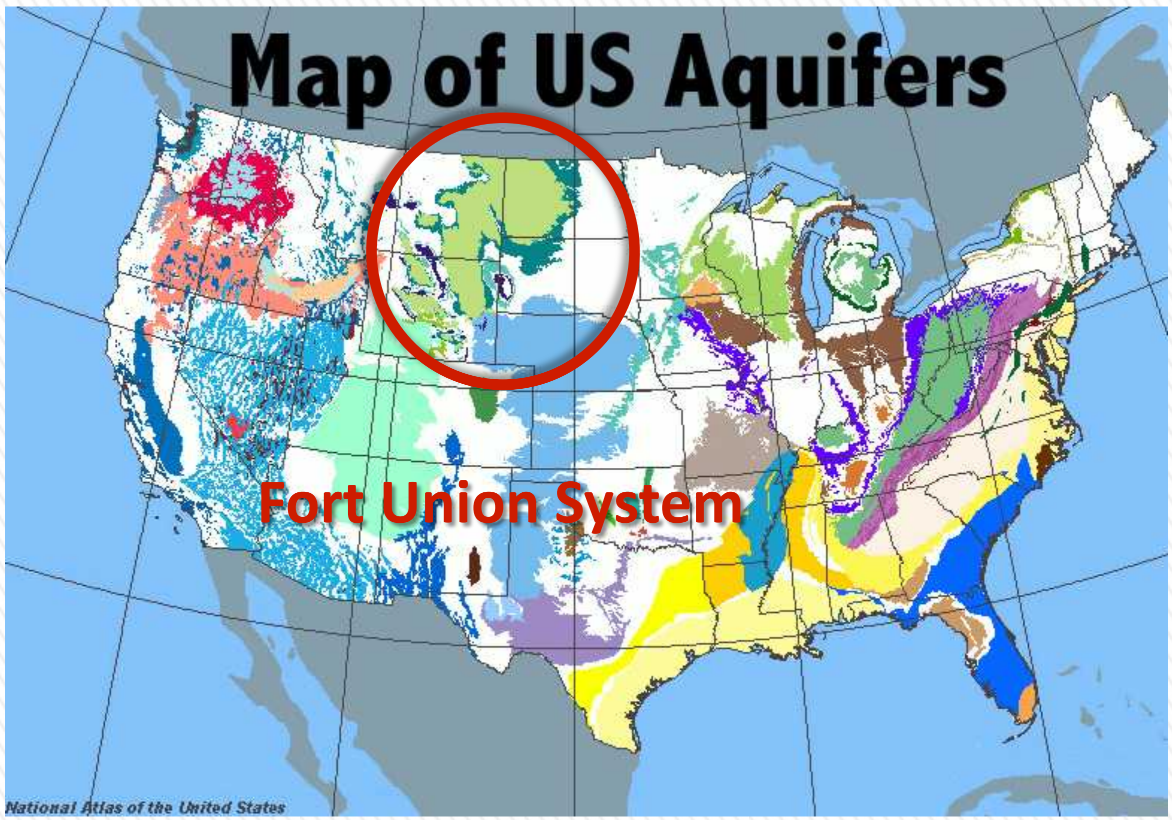
» Results

» Conclusions

» Questions

Objective

» To determine how the proposed South Heart Lignite Mine (SHLM) will impact the Tongue River Aquifer using PHREEQC



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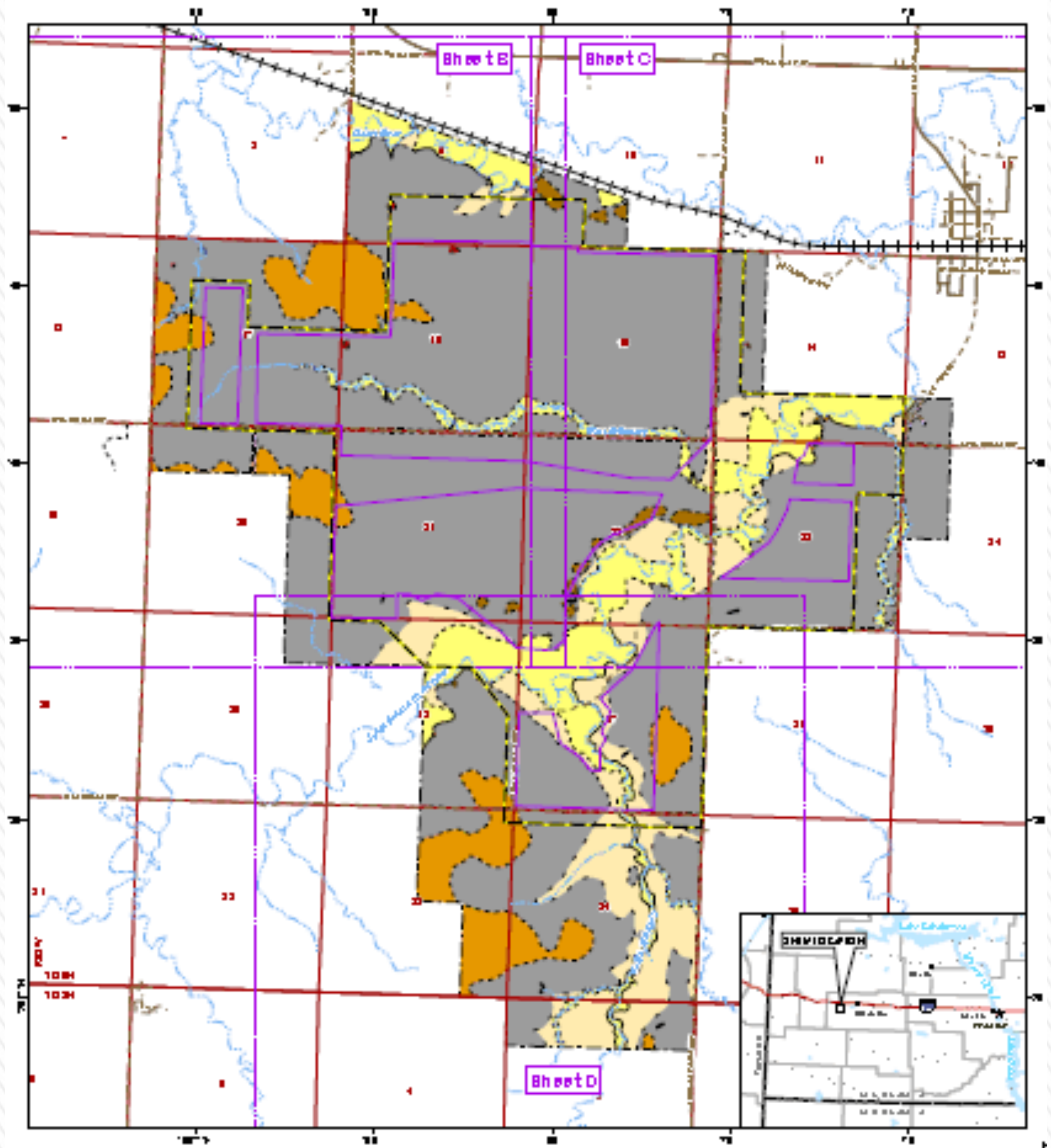
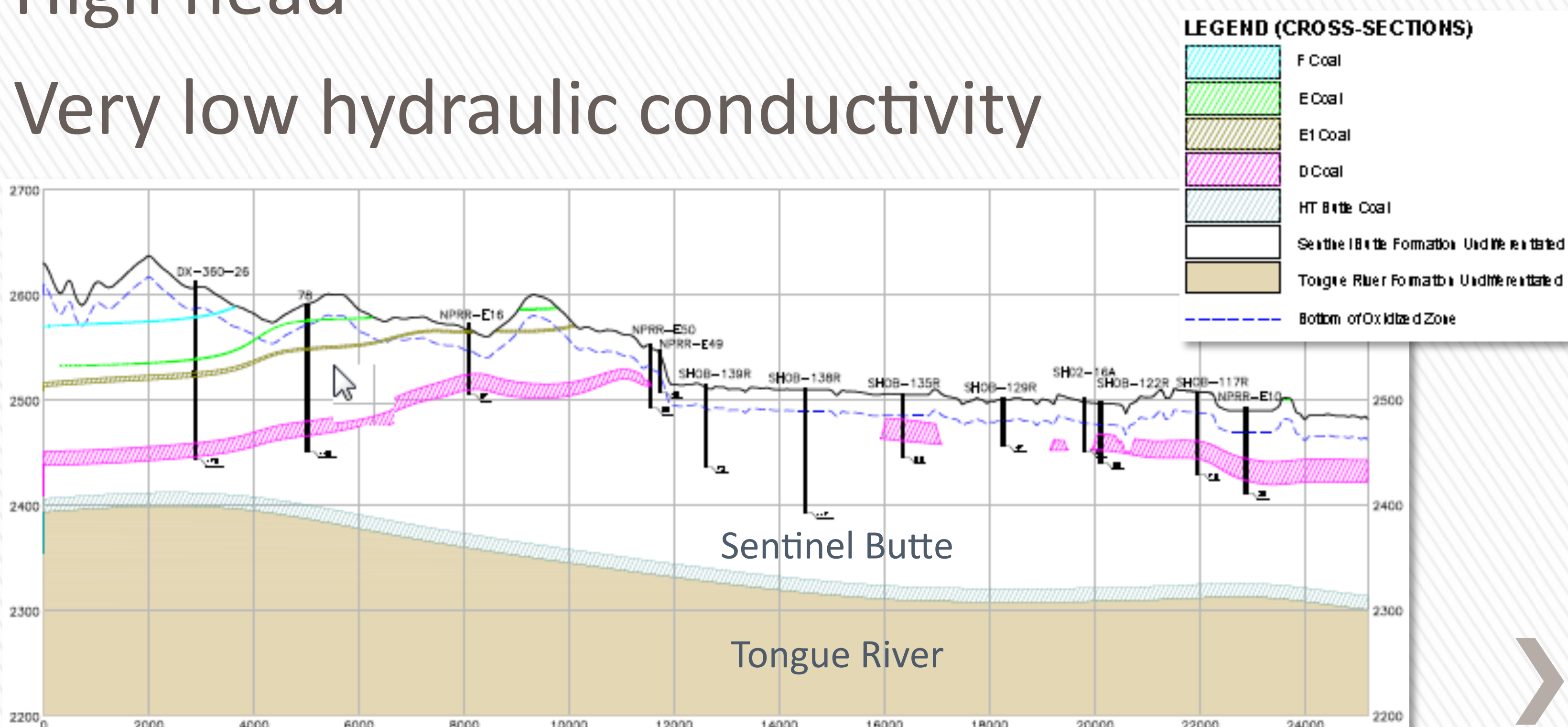
SHLM

Proposed mining area and relative location in ND



Tongue River Aquifer

- Unconfined aquifer
- Recharged directly by precipitation
- High head
- Very low hydraulic conductivity



SHLM area cross-section

Tongue River Aquifer

- Mineralogy
  - Quartz
  - K-Feldspar
  - Calcite
  - Dolomite
  - Kaolinite
  - Illite
  - Gypsum
  - Apatite
- Percent composition varied with depth

Methodology

» Used borehole records and well logs from inside the mine permit area

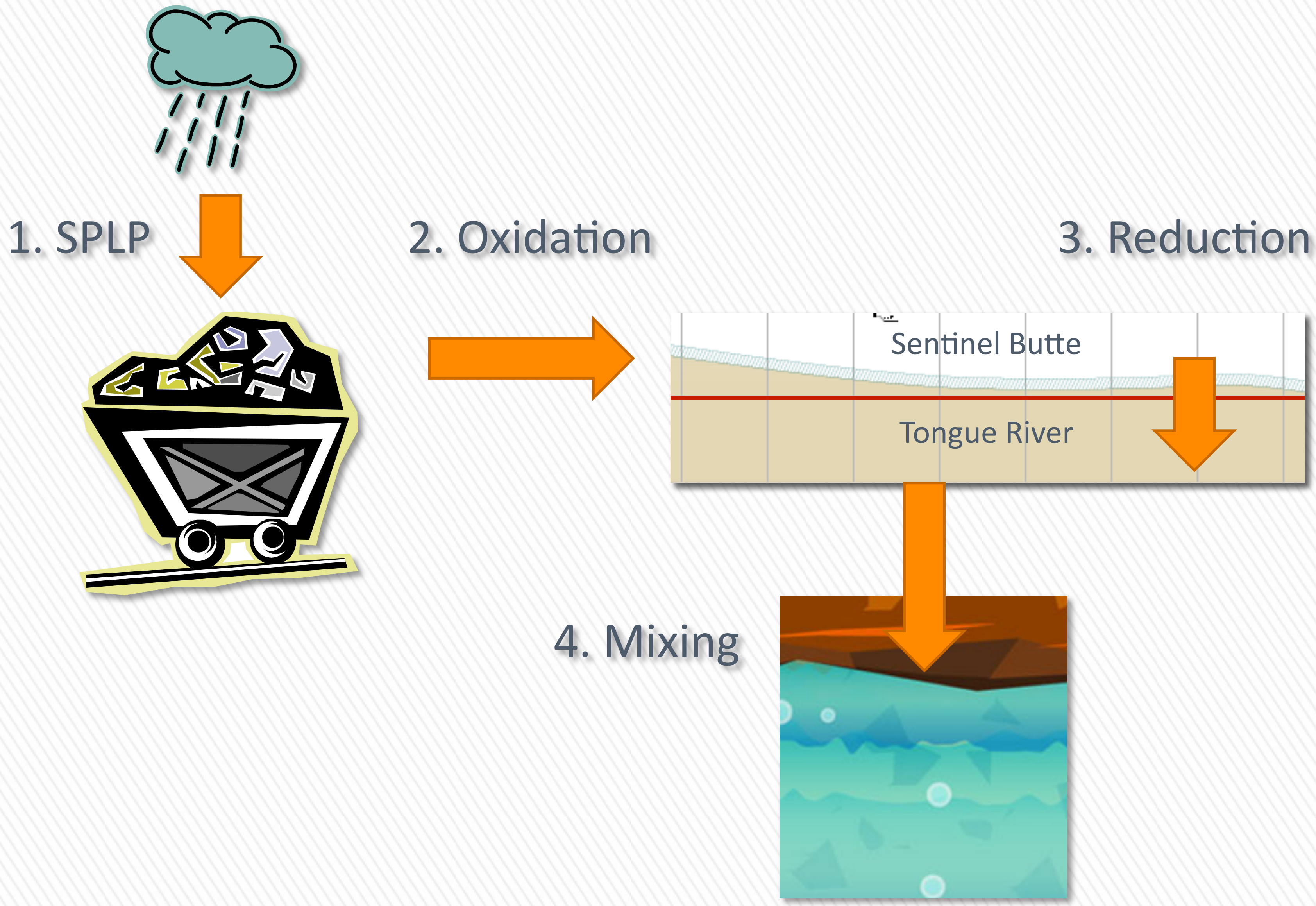
» SPLP data used as initial solution

» Assumed solid/solution equilibrium

» Part oxidation, part reduction in soil profile

» Utilized equilibrium, ion exchange, surface tools and mixing to complete modeling

Methodology



Model Inputs

```
SOLUTION 1-2 SPLP
    temp        15
    pH          7.444
    pe          10
    redox       pe
    units       mg/l
    density     1
    Al          0.664
    As          0.042
    Ba          0.271
    B           0.311
    Cd          0
    Ca          20.678
    Cl          1.333
    Cu          0.007
    F           0.434
    Fe          1.748
    Mg          6.022
    Mn          0.023
    Na          57.911
    K           2.311
    Pb          0.002
    Ni          0.01
    Se          0.009
    U           0.001
    Zn          0.098
    -water      1 # kg
```

Simulation 1
- SOLUTION 1-2 SPLP
- END

Simulation 2
- USE solution 2
- EQUILIBRIUM_PHASES 1
- SAVE solution 2
- END

Simulation 3
- EXCHANGE 1 Upper Soil
- SURFACE 1 Upper Soil
- SAVE solution 2
- END

Simulation 4
- USE solution 2
- EQUILIBRIUM_PHASES 2
- SAVE solution 2
- END

Simulation 5
- EXCHANGE 2 Lower Soil
- SURFACE 2 Lower Soil
- SAVE solution 2
- END

Simulation 6
- SOLUTION 3
- MIX 1
- END

```
SOLUTION 3
    temp        10
    pH          7.068
    pe          -4
    redox       pe
    units       mg/l
    density     1
    Al          0.075
    As          0.025
    Ba          0.041
    B           1.034
    Cd          0
    Ca          41.175
    Cl          5.444
    Cu          0.009
    F           0.256
    Fe          15.633
    Mg          0
    Mn          0.327
    Na          583.5
    K           6.463
    Pb          0
    Ni          0.023
    Se          0.001
    U           0.001
    Zn          0.004
    N(5)        0.057
    N(3)        0.019
    S(6)        1087.094
    -water      1 # kg
```

Results

After Oxidation

Elements	Molality	Moles
Al	2.461e-005	2.461e-005
As	5.606e-007	5.606e-007
B	2.877e-005	2.877e-005
Ba	1.973e-006	1.973e-006
Ca	5.160e-004	5.160e-004
Cl	3.760e-005	3.760e-005
Cu	1.102e-007	1.102e-007
F	2.285e-005	2.285e-005
Fe	3.130e-005	3.130e-005
K	5.911e-005	5.911e-005
Mg	2.477e-004	2.477e-004
Mn	4.187e-007	4.187e-007
Na	2.519e-003	2.519e-003
Ni	1.703e-007	1.703e-007
Pb	9.654e-009	9.654e-009
Se	1.140e-007	1.140e-007
U	4.202e-009	4.202e-009
Zn	1.499e-006	1.499e-006

After Reduction

Elements	Molality	Moles
Al	4.182e-005	4.186e-005
As	5.602e-007	5.606e-007
B	2.875e-005	2.877e-005
Ba	1.972e-006	1.973e-006
C	1.091e-005	1.092e-005
Ca	1.342e-002	1.343e-002
Cl	3.757e-005	3.760e-005
Cu	1.101e-007	1.102e-007
F	2.283e-005	2.285e-005
Fe	3.128e-005	3.130e-005
K	5.816e-006	5.821e-006
Mg	1.401e-002	1.403e-002
Mn	4.183e-007	4.187e-007
Na	2.517e-003	2.519e-003
Ni	1.702e-007	1.703e-007
P	8.786e-009	8.793e-009
Pb	9.646e-009	9.654e-009
S	2.552e-002	2.554e-002
Se	1.139e-007	1.140e-007
Si	9.515e-004	9.523e-004
U	4.198e-009	4.202e-009
Zn	1.498e-006	1.499e-006

After Mixing

Elements	Molality	Moles
Al	2.231e-005	4.464e-005
As	4.473e-007	8.949e-007
B	6.227e-005	1.246e-004
Ba	1.136e-006	2.272e-006
C	5.458e-006	1.092e-005
Ca	7.227e-003	1.446e-002
Cl	9.567e-005	1.914e-004
Cu	1.260e-007	2.520e-007
F	1.817e-005	3.635e-005
Fe	1.558e-004	3.117e-004
K	8.566e-005	1.714e-004
Mg	7.010e-003	1.403e-002
Mn	3.189e-006	6.381e-006
N	2.717e-006	5.435e-006
Na	1.397e-002	2.794e-002
Ni	2.813e-007	5.628e-007
P	4.395e-009	8.793e-009
Pb	4.825e-009	9.654e-009
S	1.843e-002	3.688e-002
Se	6.331e-008	1.267e-007
Si	4.760e-004	9.523e-004
U	4.203e-009	8.410e-009
Zn	7.800e-007	1.561e-006

Results

EPA Primary Drinking Water Regulations	Before Mine Drainage	MCL (mg/L)	After Mine Drainage
As	0.025	0.01	0.030
Ba	0.041	2	0.156
Cd	0	0.005	0.000
Cr	0.001	0.1	0.000
Cu	0.009	1.3	0.009
F	0.256	4	0.345
Pb	0	0.015	0.001
Hg	0	0.002	0.000
Se	0.001	0.05	0.005
U	0.001	0.03	0.001

EPA Secondary Drinking Water Standards	Before Mine Drainage	MCL (mg/L)	After Mine Drainage
Al	0.075	0.05 - 0.2	0.602
Cl	5.444	250	3.428
Cu	0.009	1	0.009
F	0.256	2	0.345
Fe	15.633	0.3	17.402
Mn	0.327	0.05	0.000
pH	7.068	6.5 - 8.5	10.734
Sulfate	1087.094	250	1769.280
Zn	0.004	5	0.051

Conclusions

- Nearly all species were undersaturated
  - Cu metals and Fe oxides supersaturated
- pH does not fit typical lignite mines
- Metals concentrations fairly low
- Overall, negative impact on groundwater quality

Future Work

» Implement advection and transport modeling

» Model calibration

» Verification of waste rock composition

References

» Trapp, Henry, and M. G. Croft. *Geology and Ground-water Resources of Hettinger and Stark Counties, North Dakota*. Bismarck: North Dakota State Water Commission, 1975.

» ND Public Service Commission. Reclamation Division. *South Hearth Lignite Mine Permit Application*. Bismark: n.p., 2010.

» Chidambaram, S., M. V. Prasanna, and AL. Ramanathan. "Hydrogeochemical Modelling for Groundwater in Neyveli Aquifer Using PHREEQC: A Case Study." *Natural Resources Research* 21.3 (2012): 311-24.

Questions