FGD as a Soil Amendment for Mine Reclamation

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FGD Properties of Value for Mineland Reclamation

- $CaCO_3$ equivalency
- Presence of plant nutrients
- Particle size
- Presence of gypsum*
- Presence of calcium sulfite

FGD Properties That Reduce Their Value for Mineland Reclamation

- Material handling properties
- Boron and heavy metals
- Salt concentrations
- Easily eroded after application
- Variability of material
- Bulky nature of material
- Regulatory issues

History of Gypsum as a Soil Amendment

- Early Greek and Roman times
- Fertilizer value discovered in Europe in last half of 18^{th} century
  - Germany (1768) – Reverend A. Meyer
  - France (date?) – Men working with alabaster (plaster of paris) noted better grass growth in areas they shook dust from clothing
- Extensive use in Europe in 18^{th} century

History of Gypsum as a Soil Amendment

- Widespread use in America (Pennsylvania region) in late 1700's
  - Benjamin Franklin demonstration – "This land has been plastered"
  - Richard Peters book – gypsum came from Nova Scotia

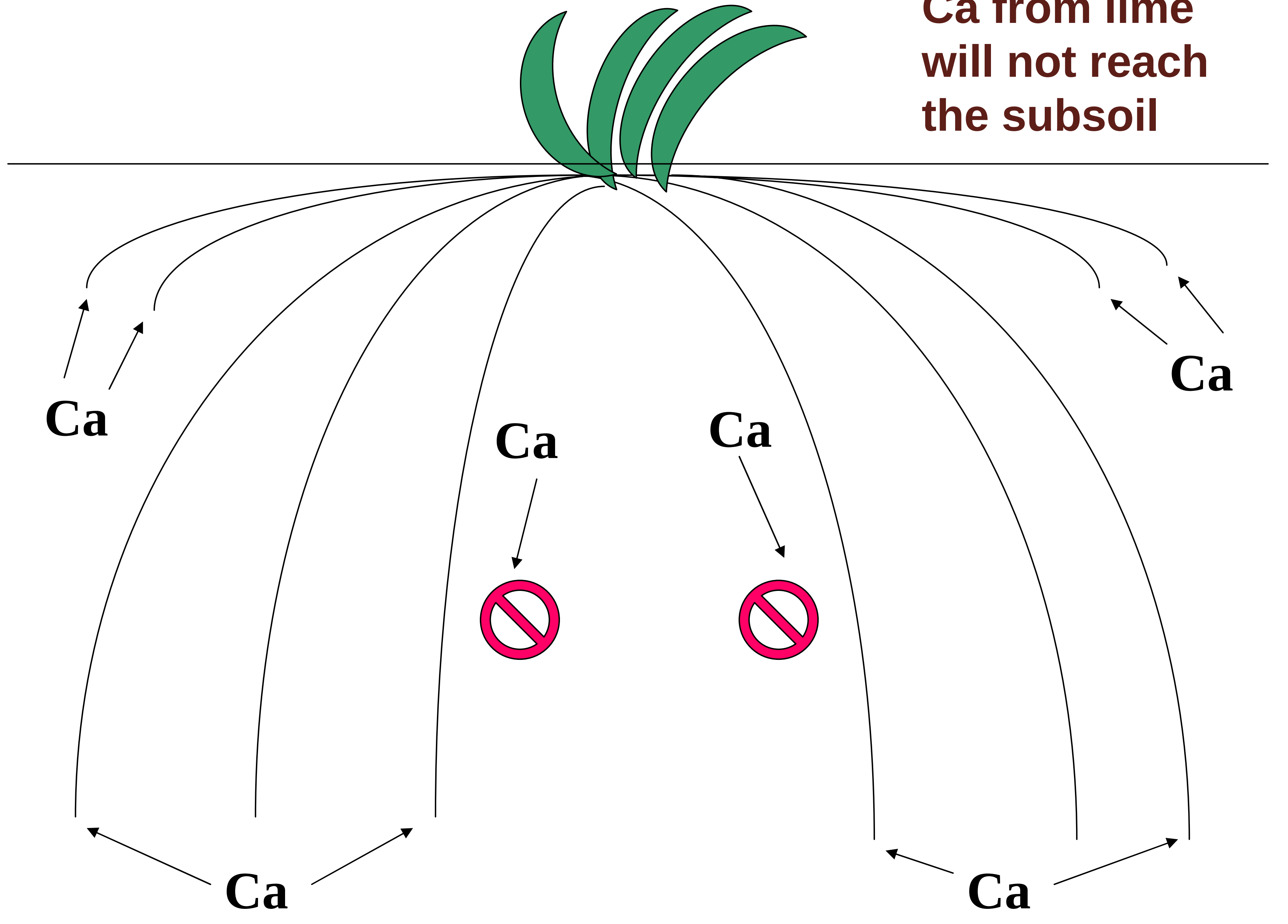
Summary of Gypsum Benefits for Mineland Reclamation

- Ca and S source for plant nutrition
- Source of exchangeable Ca

  Ameliorate subsoil acidity and Al^{3+} toxicity

  Reclaim sodic soils
- Flocculate clays to improve soil structure
- Solubility
  - 2.5 g/L or 15 mM (approximately 200 times moer than ag lime)

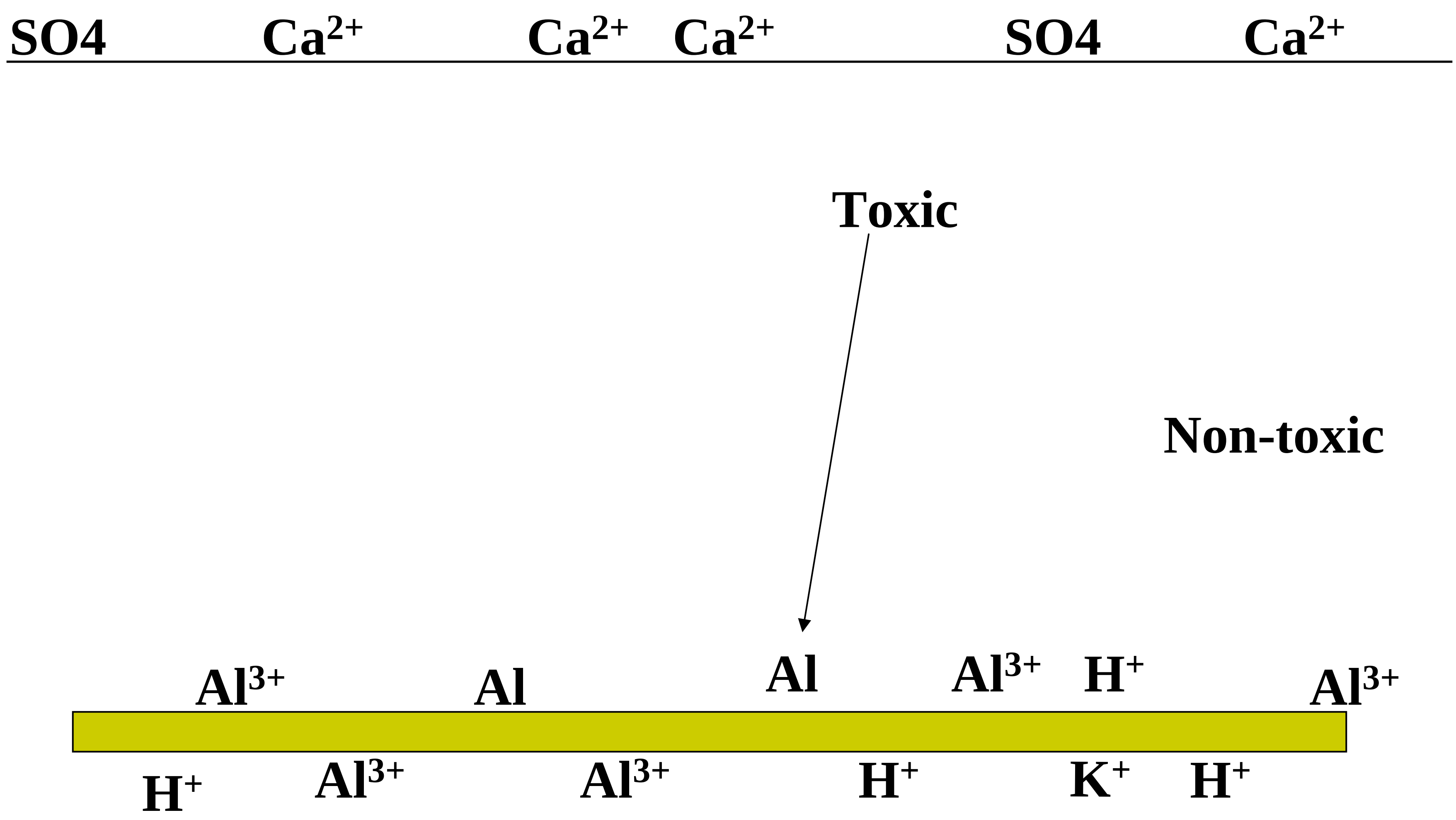
Ca from lime will not reach the subsoil



Amelioration of Subsoil Acidity and Al^{3+} Toxicity

- Surface-applied gypsum leaches down to subsoil
- Ca^{2+} exchanges with Al^{3+}
- SO_4^{2-} forms complex ion $AlSO_4^{+}$ with Al^{3+}
- $AlSO_4^{+}$ is not toxic to plant roots
- Results in increased root growth in the subsoil

Gypsum applied to surface of soil with acidic subsoil



Clay platelet in subsoil

Increased Root Growth into Subsoil

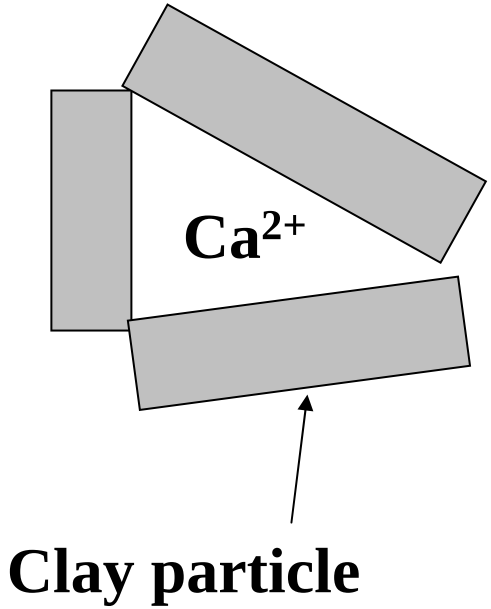
- Increased water absorption
- Increased recovery of nutrients from subsoil
  - Demonstrated in Ohio and Brazilian soils
  - Improved N-use efficiency

Gypsum and Clay Flocculation

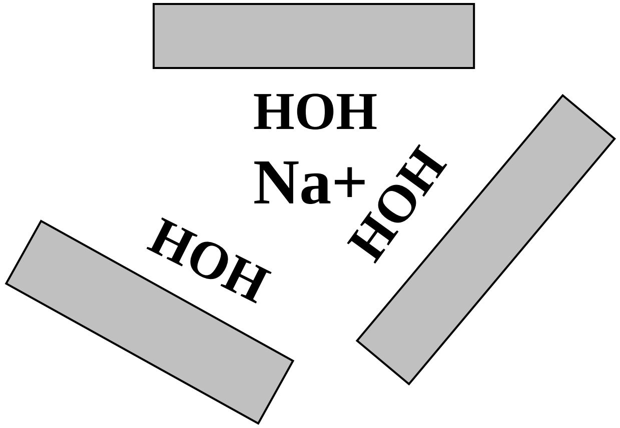
- Reduces soil crusting
- Improves water infiltration
- Improves water transmission (conductivity)

Flocculation and Dispersion

Flocculated clay



Dispersed clay



Gypsum applied to surface of sodic soil

SO4 Ca^{2+} Ca^{2+} Ca^{2+} SO4 Ca^{2+}

Mg^{2+} K^{+}

Na^{+} Na^{+} H^{+} Na^{+} Al^{3+}

Clay platelet in sodic soil

Fleming AML Site (east central Ohio)

1. Located within the Pottsville and Allegheny system of Pennsylvanian-age sedimentary rocks of eastern Ohio.
2. The Lower Kittanning (No. 5) coal was mined from the site by surface operations over a 20-year period approximately corresponding to 1950 through 1970.
3. The mine site was abandoned after depletion of the coal and clay reserves in the early 1970s. Soon thereafter, local residents lodged complaints regarding flooding and sedimentation along a nearby road. Springs were discharging AMD with pH less than 4 and high concentrations of dissolved solids, including iron and sulfate.

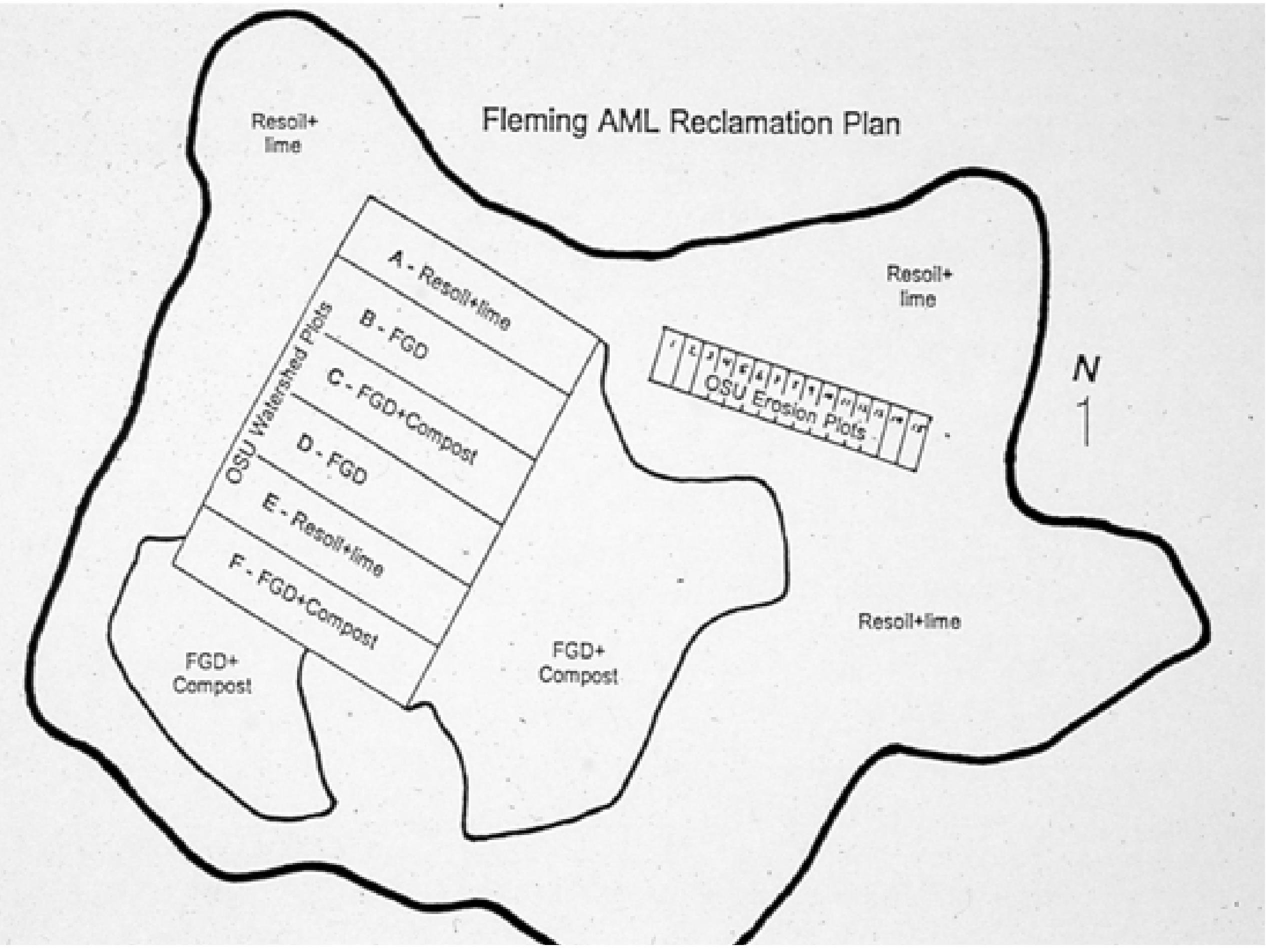
Fleming AML Site (east central Ohio)

- Highly eroded underclay (25 acres)
- Unreclaimed spoil (45 acres)
- Coal refuse (5 acres)

Fleming Site (Prereclamation)

Fleming Site (Prereclamation)

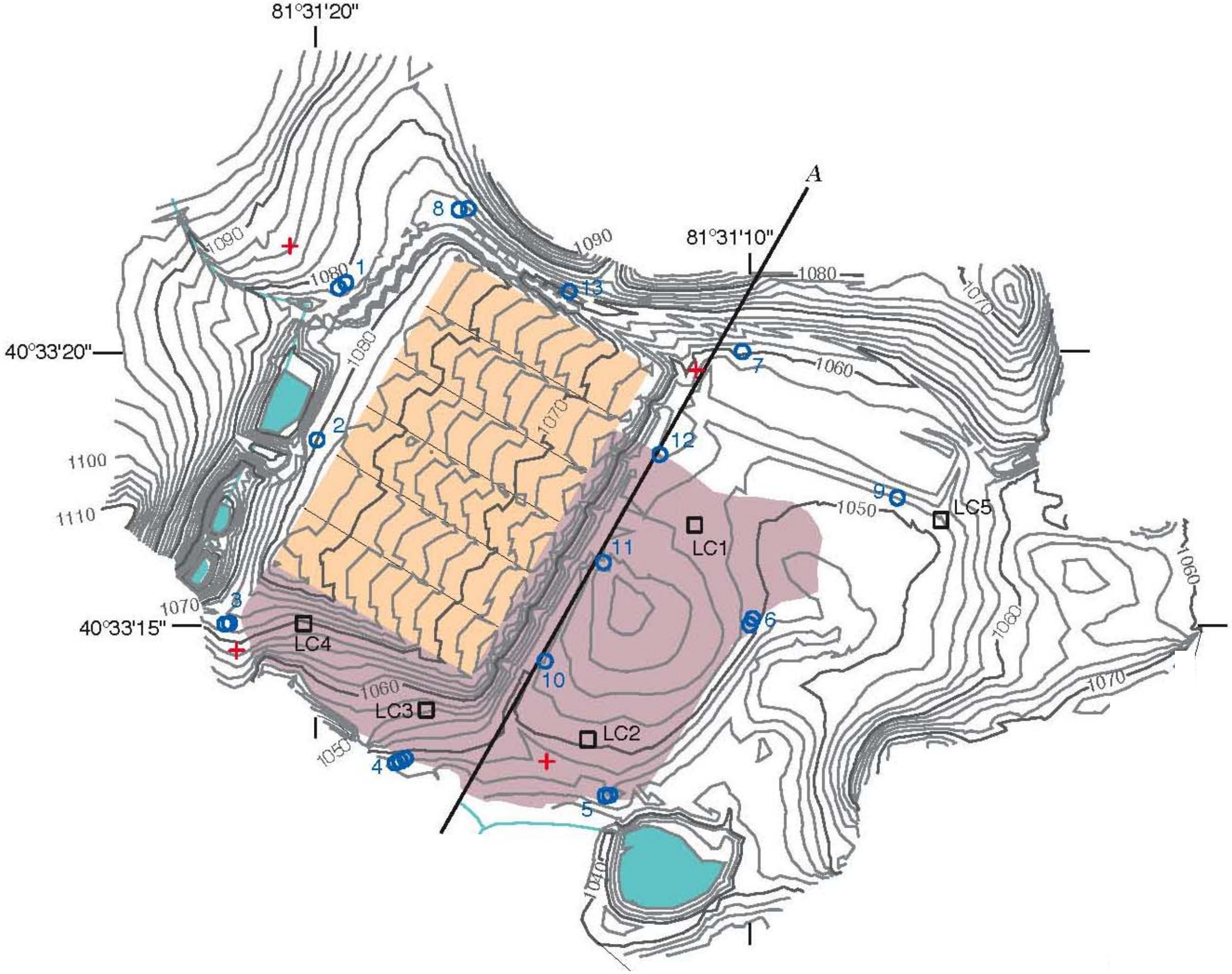
Fleming Site (Reclamation Plan)



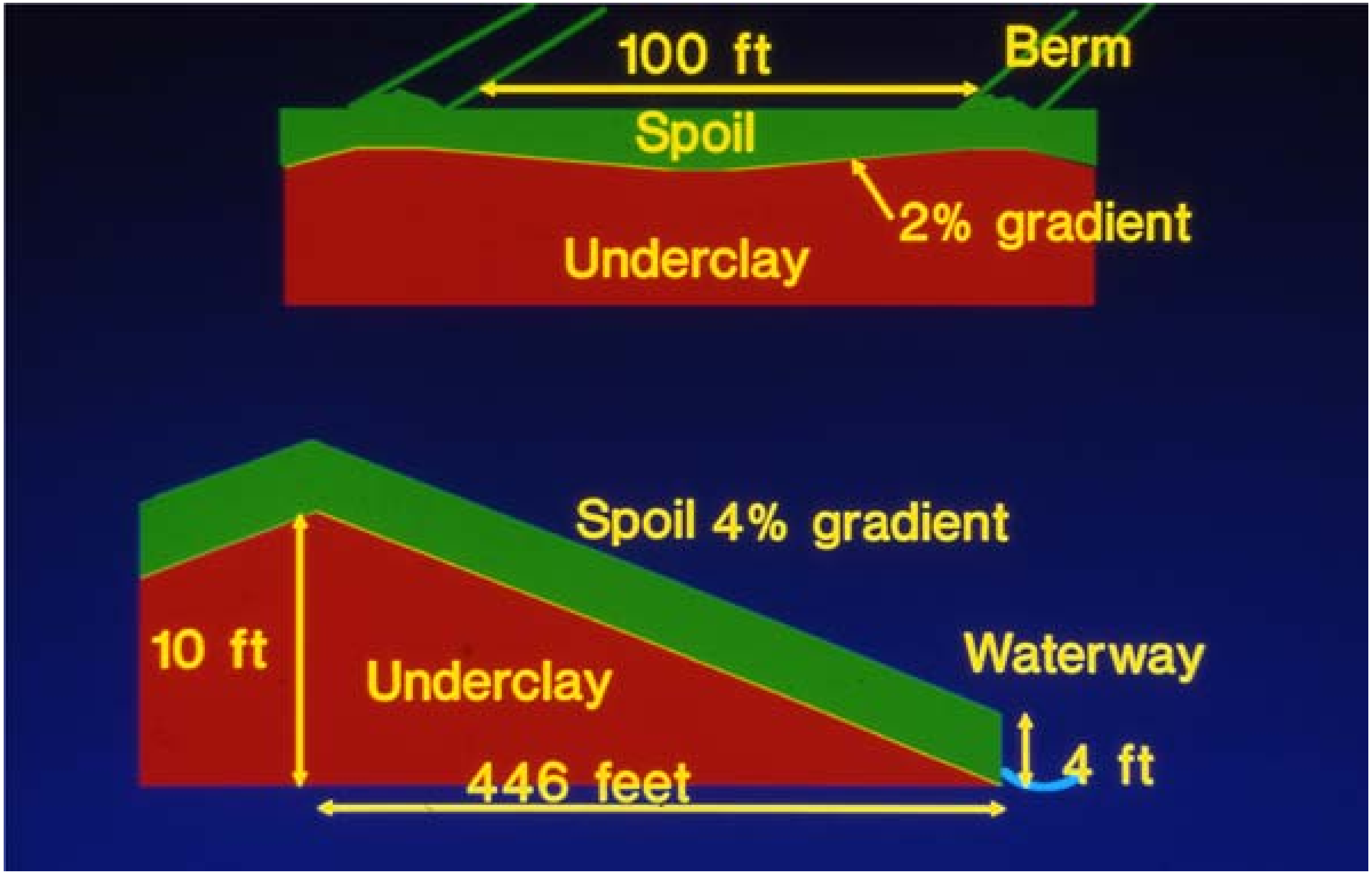
Fleming Site (Reclamation Plan) Treatments Applied in 1994

1. 125 dry tons/acre of FGD product
2. 125 dry tons/acre of FGD product plus 50 dry tons/acre of yard waste compost
3. 50 dry tons/acre of limestone plus 8 inches of resoil treated with an additional 20 tons/acre of limestone

Fleming Site (Reclamation Plan)



Fleming Site (Reclamation Plan)



Fleming Site (Reclamation Activities)

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Constituent	FGD Product	Yard-Waste Compost
	Major Elements (weight percent)	
Aluminum	3.3	3.8
Calcium	18	3.6
Iron	4.4	3.3
Potassium	0.59	1.5
Magnesium	9.5	0.93
Manganese	0.01	2.1
Sodium	0.10	0.52
Sulfate-S	4.9	<0.05
Total Carbon	4.5	13
Organic Carbon	0.73	13
Calcium Carbonate Equivalency (CCE)	38.3	3.5

Fleming Site (Reclamation Activities)

Constituent	FGD Product	Yard-Waste Compost	Maximum Concentration in Spoil and Aquifer Material
	Trace Elements (parts per million)		
Arsenic	75	11	91
Boron	190	92	120
Beryllium	3	1	9
Barium	150	400	730
Cadmium	<2	<2	<2
Chromium	37	290	210
Nickel	23	37	100
Lead	15	110	110
Selenium	1.3	6	21.5
Strontium	160	130	720

Fleming Site (Reclamation Activities) Metals Concentrations

Trace Element Concentrations of Reclamation Materials (Fleming Site)

Element	FGD	Compost	Mix	Resoil	503 Ceiling
	Concentration (mg kg^{-1})				
As	76.9	11.47	58.3	5.5	75
Cd	1.5	0.2	1.1	3.3	80
Cr	46.8	284	114.4	95.6	3000
Cu	44.3	69	51.3	62.8	4300
Pb	21.8	26	23.0	15.9	840
Mo	5.9	27.8	12.1	0.2	75
Ni	74.0	383	162	44.8	420
Se	4.2	0.25	3.0	0.7	100
Zn	71.5	108	81.9	137.8	7500

Fleming Site (Reclamation Activities) Metals Loading

Loading Rates of Reclamation Materials (Fleming Site)

Element	Proposed Loading Rate (lbs acre^{-1})			
	FGD	Mix	Resoil	503 Limit
As	19.2	20.4	14.3	37
Cd	0.4	0.4	8.6	35
Cr	11.7	40.0	248.6	2680
Cu	11.1	18.0	163.3	140
Pb	5.4	8.0	41.3	267
Mo	1.5	4.2	0.5	16
Ni	18.5	56.7	116.5	375
Se	1.0	1.1	1.8	89
Zn	17.9	28.7	358.3	2500

Fleming Site (Reclamation Activities) Dioxin Concentrations

DIOXIN CONCENTRATIONS (TTE'S)

SAMPLE	CONCENTRATION (ppt)
PFBC / Compost Mix	2.83
AFBC / Compost Mix	3.08
PFBC Ash	0.53
AFBC Ash	0.48
Compost	4.33
Minespoil	0.57

Fleming Site (Reclamation Activities)

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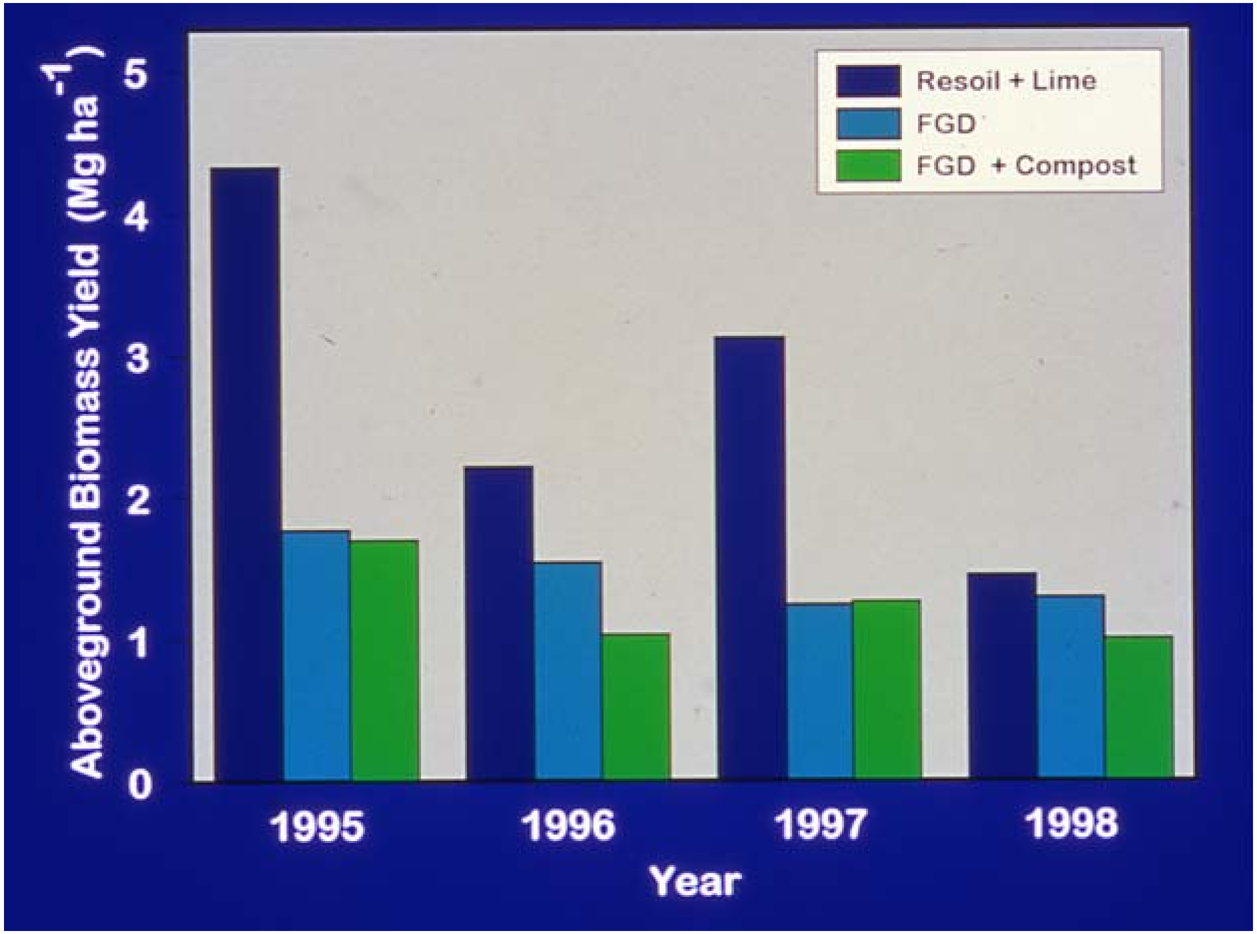
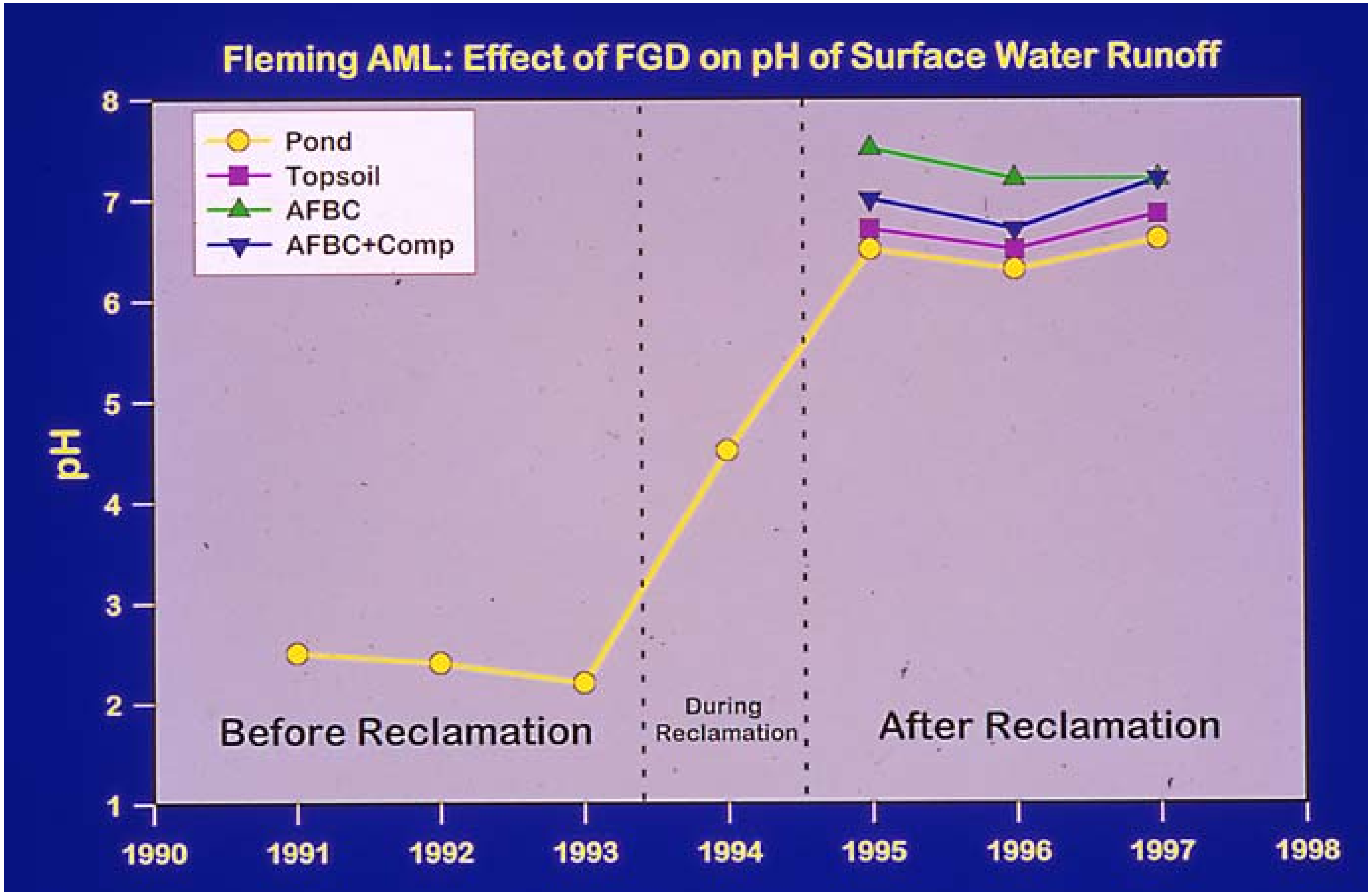
Fleming Site (Reclamation Results) Biomass Production



Fleming Site (Reclamation Results) Surface Water Data



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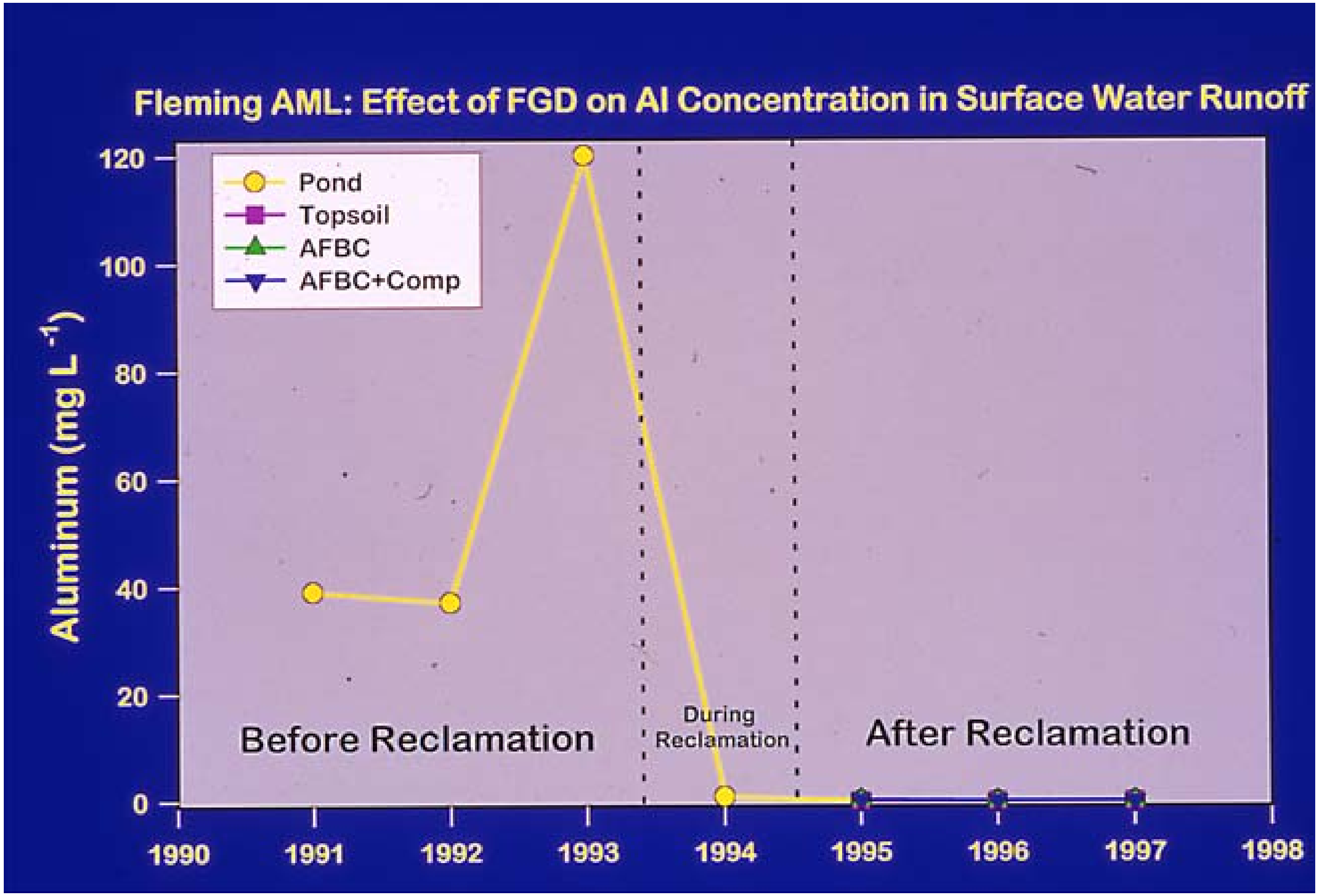

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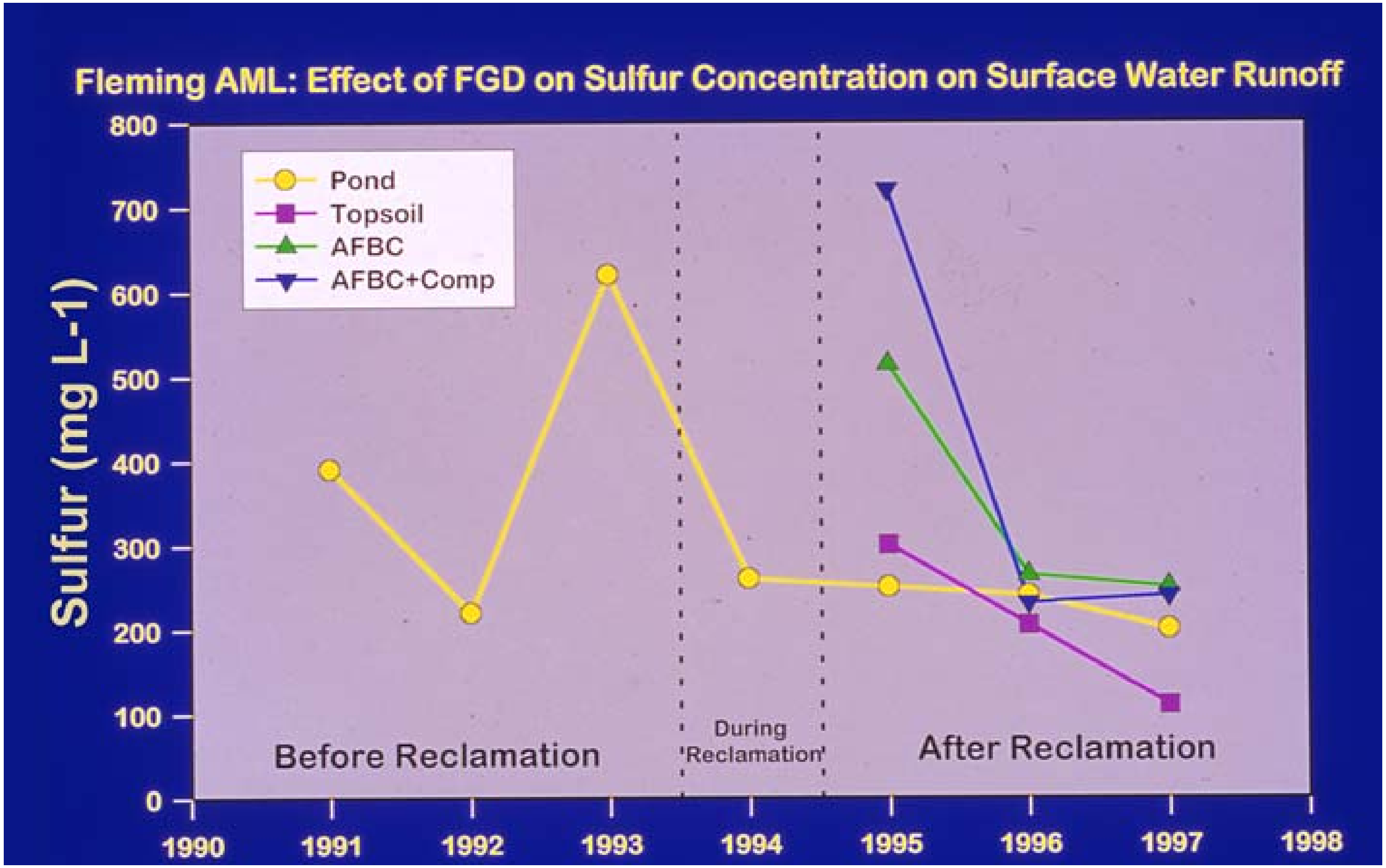

Fleming Site (Reclamation Results) Ground Water Data

Constituent	Maximum Contaminant Level (mg/L)	Detection Limit (mg/L)	Total Number of Samples	Number of Detections Above Detection Limit	Number of Samples Exceeding MCL	Maximum Value (mg/L)
			National Primary Drinking Water Regulations			
Antimony	0.006	0.106	160	8 (5)[a]	Unknown	0.16
Arsenic	0.05	0.001-0.002	185	37 (20)	0 (0)[a]	0.010
Barium	2	0.001	160	160 (100)	0 (0)	0.075
Beryllium	0.004	0.0001-0.002	160	79 (49)	30 (19)	0.037
Cadmium	0.005	0.001-0.08	206	90 (44)	61 (30)	0.17
Chromium	0.1	0.002-0.1	206	118 (57)	0 (0)	0.026
Coppper	1.3	0.002-0.05	206	66 (32)	0 (0)	0.31
Fluoride	4.0	0.1-1.0	216	105 (49)	36 (17)	15.0
Lead	0.015	0.001-0.01	196	9 (5)	1 (<1)	0.058
Mercury	0.002	0.0001	61	0 (0)	0 (0)	na
Nitrate	10	0.01-0.05	163	34 (21)	0 (0)	4.4
Selenium	0.05	0.001-0.005	178	38 (21)	0 (0)	0.006

[a]Percent of samples is given in parentheses.

Fleming Site (Reclamation Results) Ground Water Data

Constituent	Maximum Contaminant Level (mg/L)	Detection Limit (mg/L)	Total Number of Samples	Number of Detections Above Detection Limit	Number of Samples Exceeding MCL	Maximum Value (mg/L)
			National Secondary Drinking Water Regulations			
Aluminum	0.2	0.015-0.045	206	188 (91)[a]	104 (50)[a]	29.6
Chloride	250	0.1-1.0	216	188 (87)	1 (<1)	261
Copper	1.0	0.002-0.05	206	73 (35)	0 (0)	0.31
Fluoride	2.0	0.1-1.0	216	124 (57)	0 (0)	0.015
Iron	0.3	0.010	228	219 (96)	164 72	920
Manganese	0.05	0.0016	228	228 (100)	224 (98)	150
pH	6.8-8.5	na	267	na	192 (72)	3.2 (min) 7.9 (max)
Silver	0.10	0.003-0.046	206	183 (89)	0 (0)	0.063
Sulfate	250	0.11	216	216 (100)	212 (98)	13,500
TDS	500	computed	164	na	157 (96)	20,850
Zinc	5	0.001-0.06	206	188 (91)	0 (0)	3.8

[a]Percent of samples is given in parentheses.

Fleming Site (Reclamation Results) Ground Water Quality Hypotheses

Why was there such a minor influence of the FGD product on water quality?

1. The sampling schedule missed the highest concentrations of PFBC by-product leachate.
2. The mass of FGD product applied was so small that dilution by rainwater and the overwhelming influence of AMD obscured detection of changes.
3. Elements derived from the FGD product leachate have precipitated as secondary minerals in the unsaturated zone.

Fleming Site (2006)

Fleming Site (2006)

Conclusions

Reclamation at the Fleming AML site using FGD product was successful

1. Vegetation was reestablished and erosion was reduced.
2. Water quality showed a raised pH, which was maintained throughout the 7-year period after reclamation.
3. Surface water and ground water quality improved compared to the levels found prior to reclamation.

Conclusions

Reclamation at the Fleming AML site using FGD product was successful

4. Because of low application rates and sorption onto iron and aluminum hydroxides, it is believed none of the toxic elements of concern (arsenic, lead, or selenium) will cause water quality problems at these application rates.
5. Seven years later, however, ground-water quality remained poor and showed no signs of improvement.