Remediation of Brine Spills: Lessons Learned

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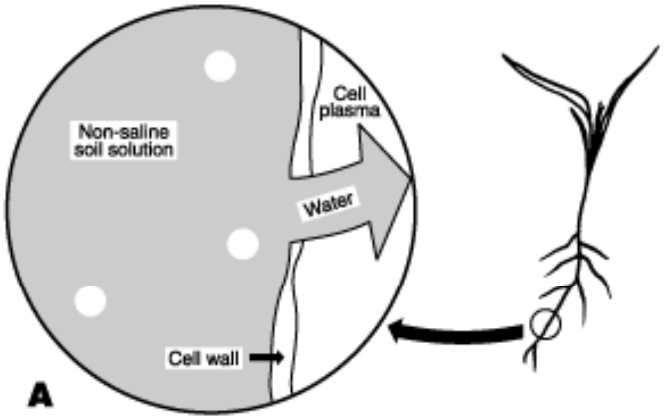
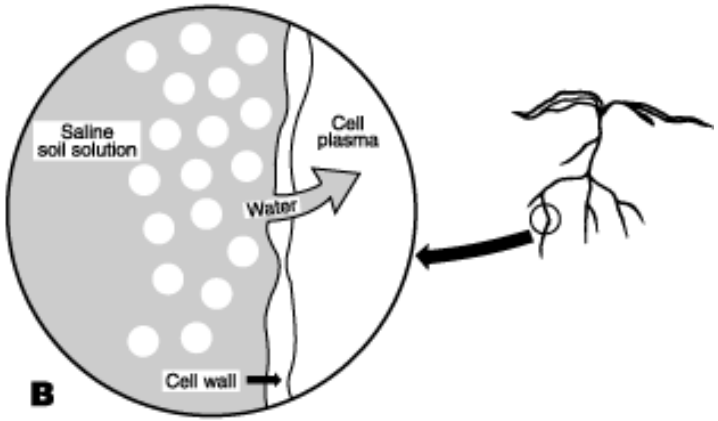
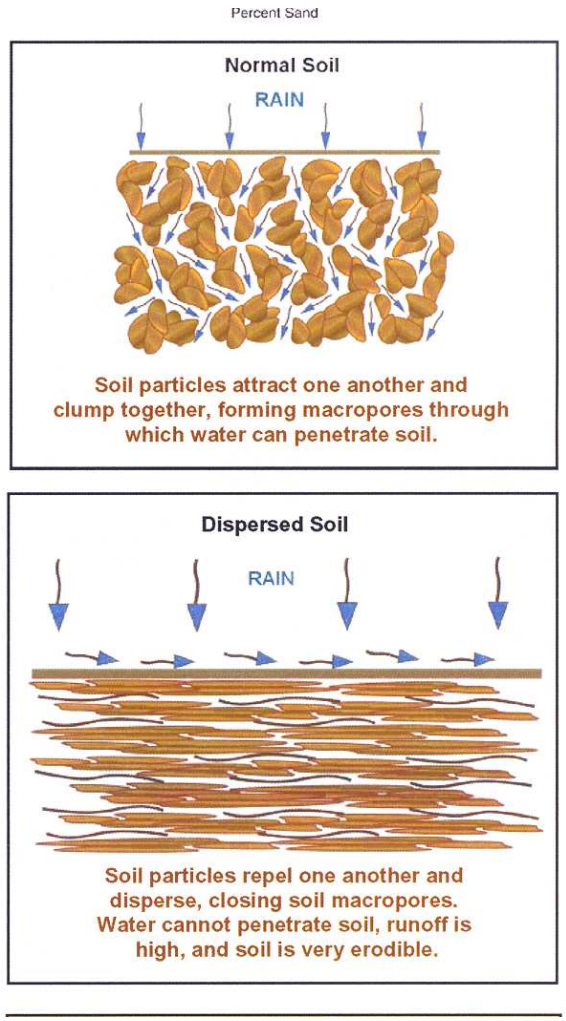
Spills of produced water or brine on soil result in two types of damage:





- Excess salinity
  - Creates an osmotic imbalance that reduces water uptake by plant roots. Plants can go into drought stress even though there is plenty of water in the soil.

Spills of produced water or brine on soil result in two types of damage:



- Excess sodicity (an excess of sodium)
  - Destroys soil structure by dispersing clays
  - Produces a hardpan that will not transmit water
  - Erosion

Both salinity and sodicity must be addressed in any successful remediation of a brine impacted site

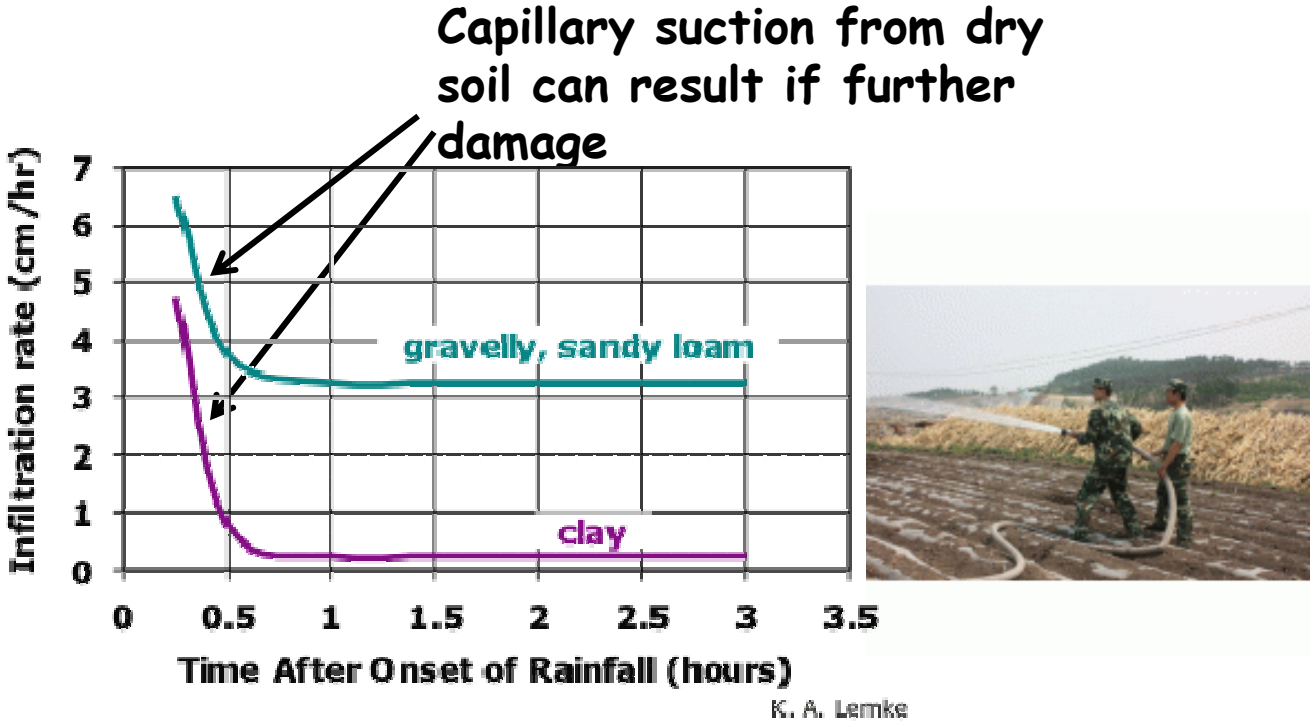
Remediation of a Brine Spill In Brief

- First response
  - Flushing and containment
- Reducing salinity
  - Breaking open the soil
  - Bulking agents
  - Fresh water
  - Drainage
- Reducing salinity
  - Soluble calcium ion to reverse sodic reaction with clays
- Revegetation
  - Taking advantage of plant root systems

There are many ways for this process to go wrong

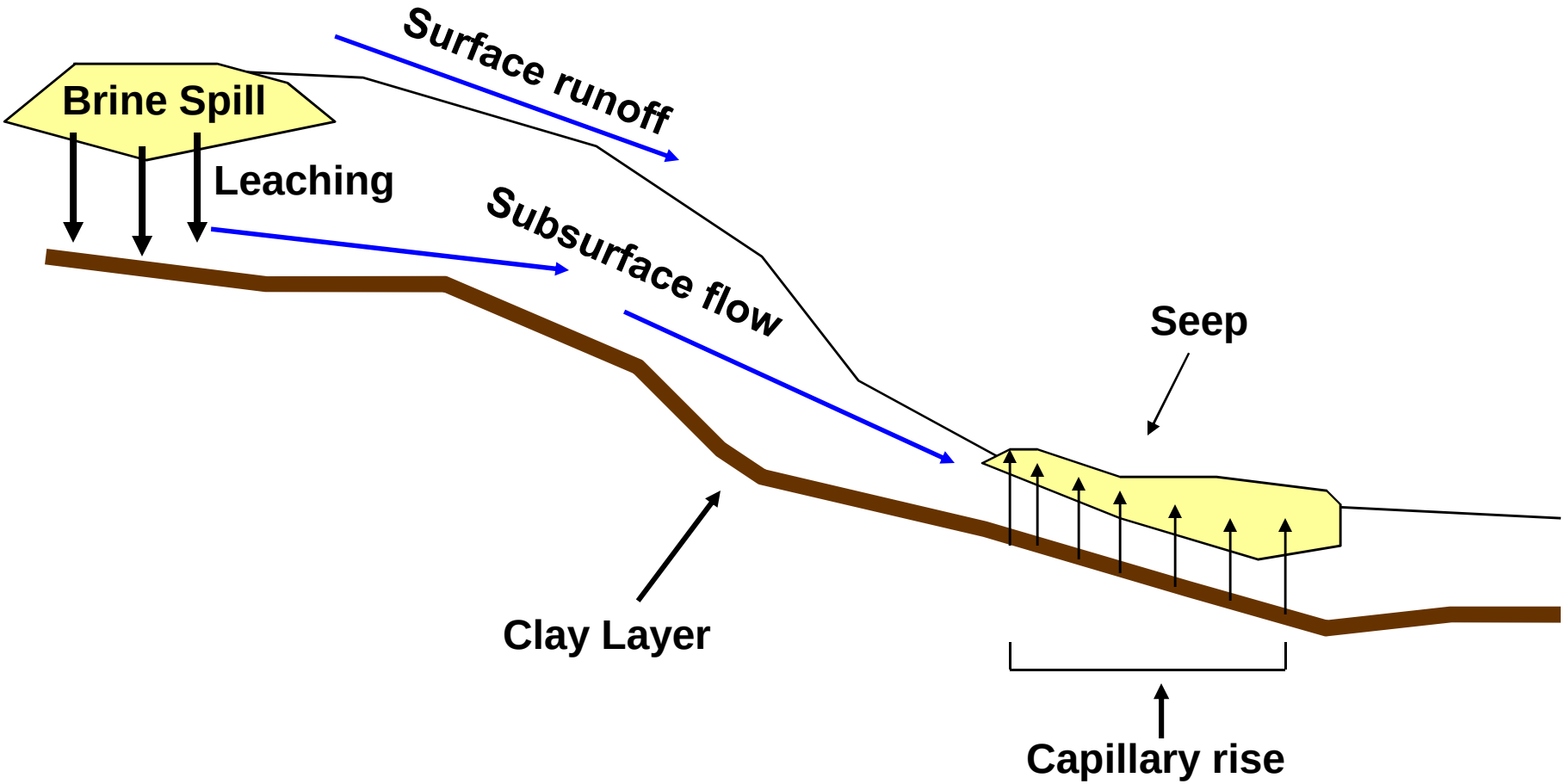
First response to a brine spill

- Flushing with fresh water into a receiving body followed by disposal of salty water
  - Soak the area between the spill and the receiving body with fresh water **before** flushing



Expect things to go from bad to worst if you don't do anything or don't do enough

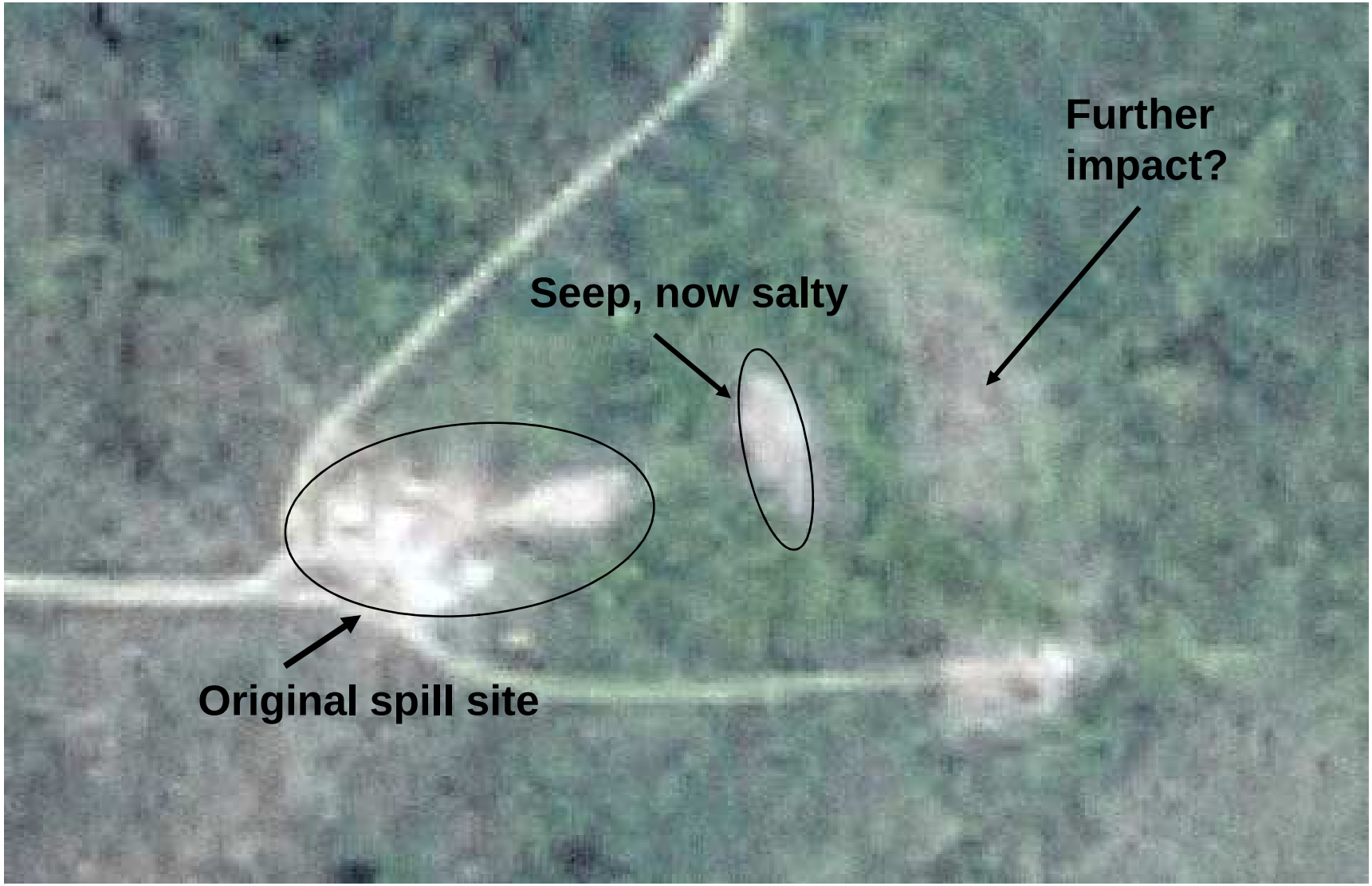
Site topography was an issue

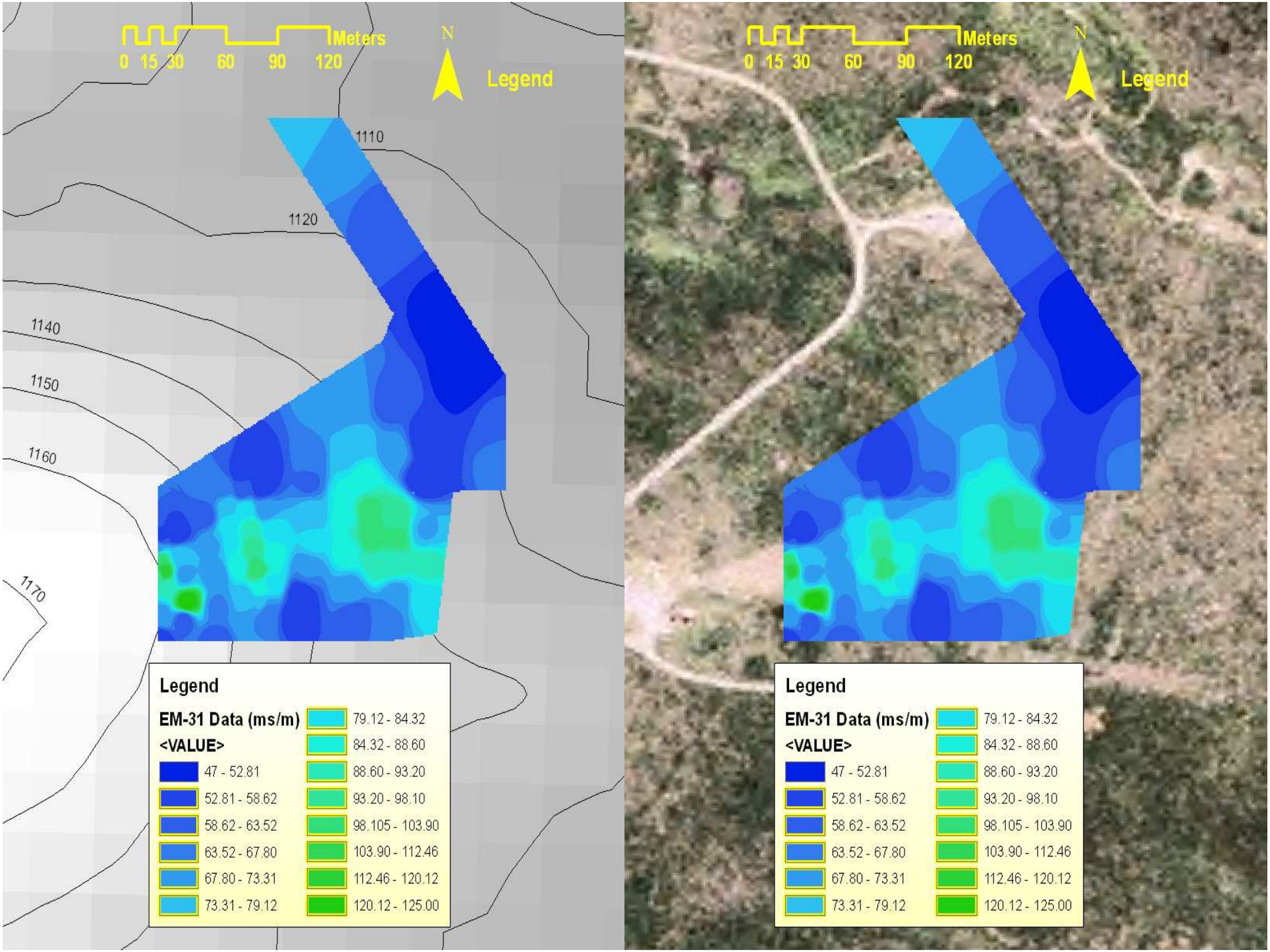


Recommended remediation method

- Ripping, tilling with hay and fertilizer application, calcium source
- Subsurface drain at the bottom of the spill
  - Predicted that the salt was going to continue down slope and pool
- Only hay and fertilizer application with tilling was done (once); no artificial drainage used, no calcium source

Google Earth 2004

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63.52 - 67.80
67.80 - 73.31
73.31 - 79.12
79.12 - 84.32
84.32 - 88.60
88.60 - 93.20
93.20 - 98.10
98.105 - 103.90
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112.46 - 120.12
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93.20 - 98.10
98.105 - 103.90
103.90 - 112.46
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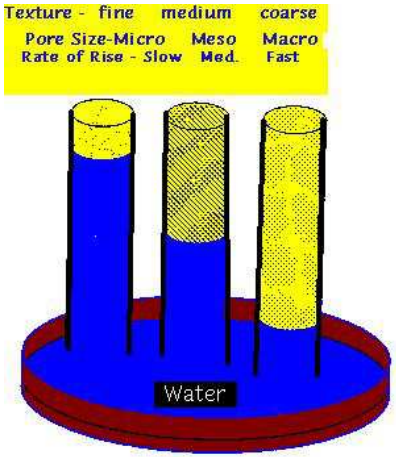
120.12 - 125.00

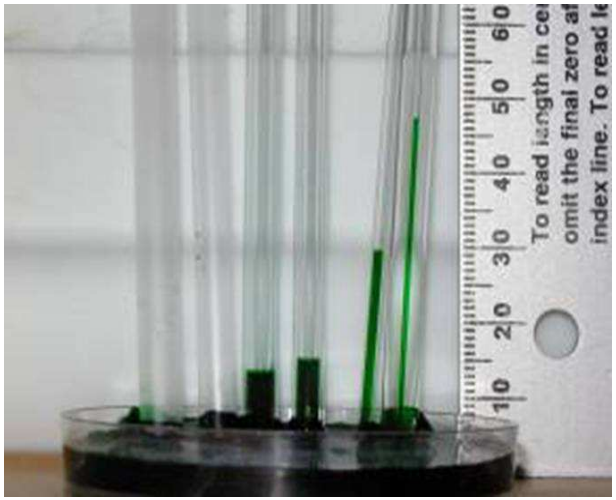
Water

- Soluble salts are transported by water – **No water no movement**
- How much water? A unit depth of water will remove about 80% of the salts from the same depth of contaminated soil.
- Example: a 24-inch layer of brine contaminated soil with an EC of 40 mS/cm. 24 inches of water passing through this soil will reduce the EC to 8 about mS/cm. Normal soil will have an EC < 4 mS/cm.
- Lots of water is required which means lots of time if you don't irrigate.
- Lots of organic matter in the soil improves permeability to water. A thick layer of mulch retains moisture and reduces evaporation.

Capillary Migration?

- Capillarity can be described as the migration of soil moisture against the forces of gravity
  - Occurs in unsaturated soil environments
- Three contributing factors of capillary action
  - Pore size in the soil matrix
  - Surface tension of soil water
  - Wettability of soil mineral particles





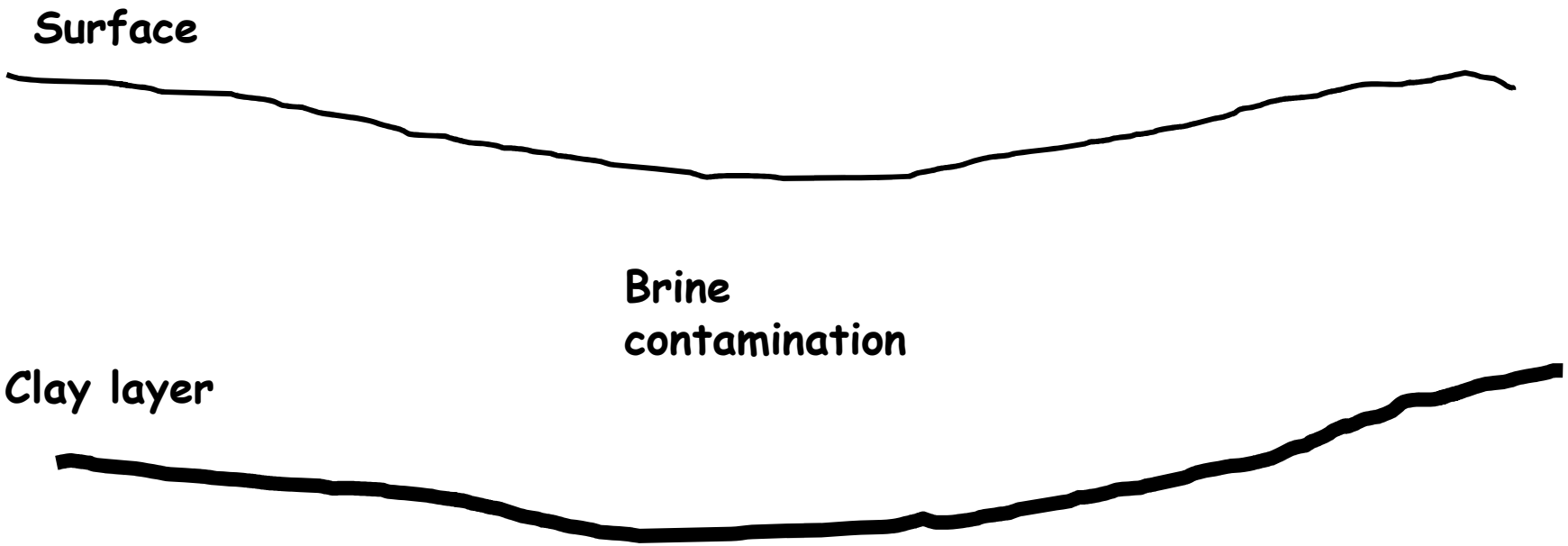
Capillary Migration

- Capillary action causes the unexpected migration of brine within the soil
  - Has proven to negate remediation efforts
  - The same forces causing the vertical migration of brine also cause the LATERAL migration of brine
- Helps explain the persistence and growth of brine scars
- Brine components must be driven well beyond the plant root zone in the long term to allow revegetation

Drainage the salt has to have somewhere to go

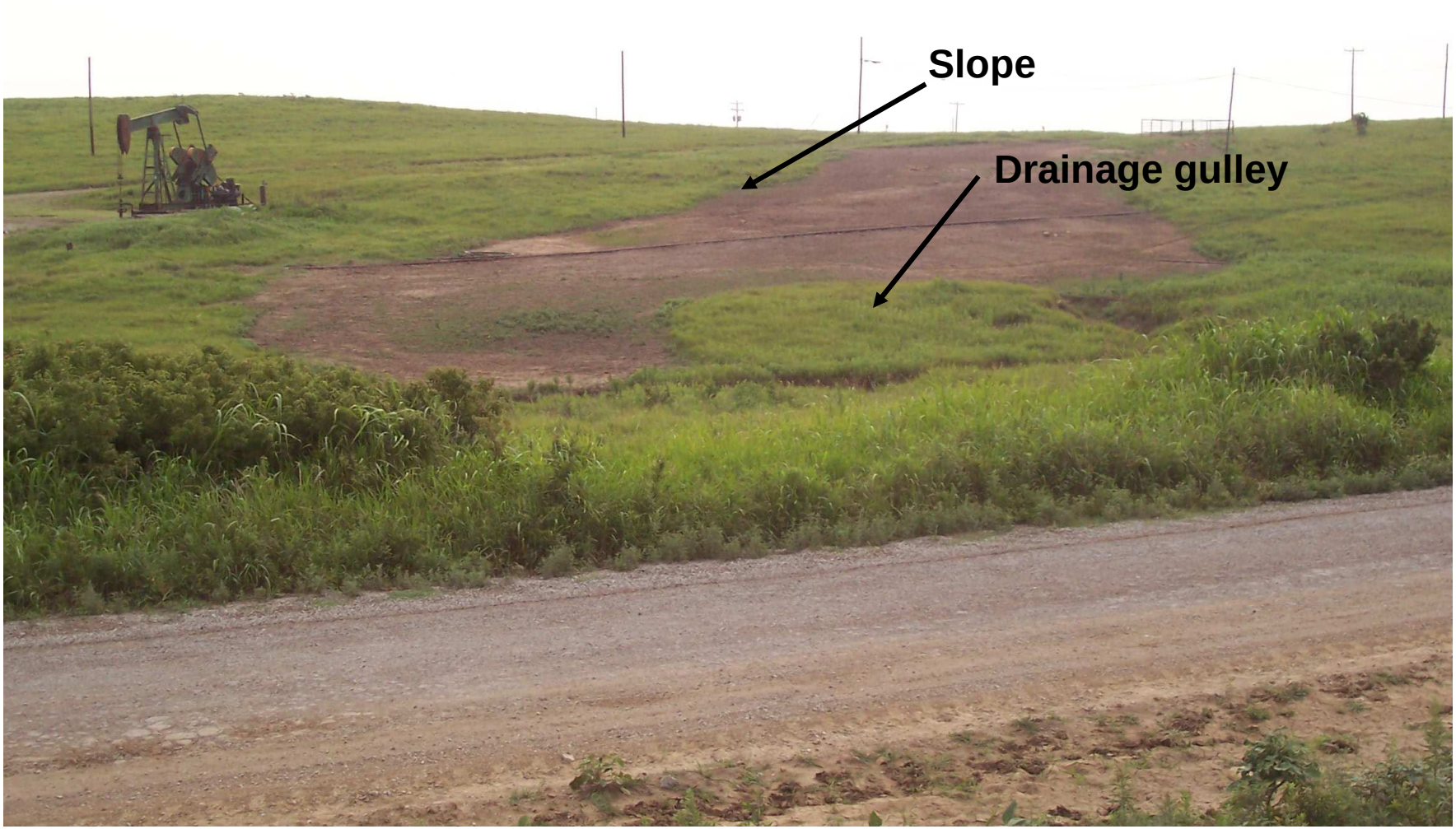
- What are the options?
  - Vertical drainage
    - Will it go deep enough? How deep is deep enough?
    - Will it impact groundwater?
  - Lateral drainage
    - Will it cause additional damage?
    - Can I protect environmental receptors?

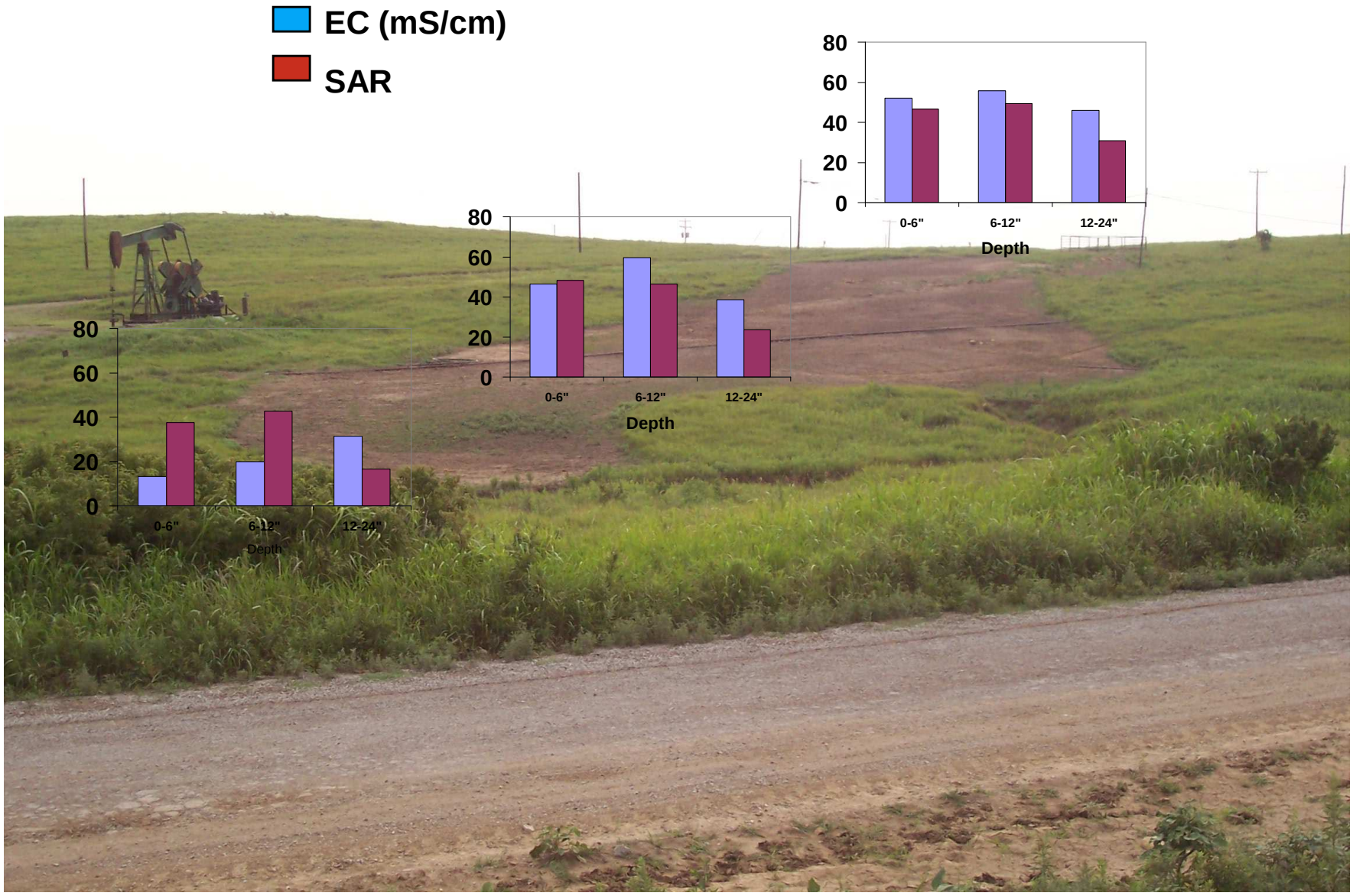
Where will the salt go?

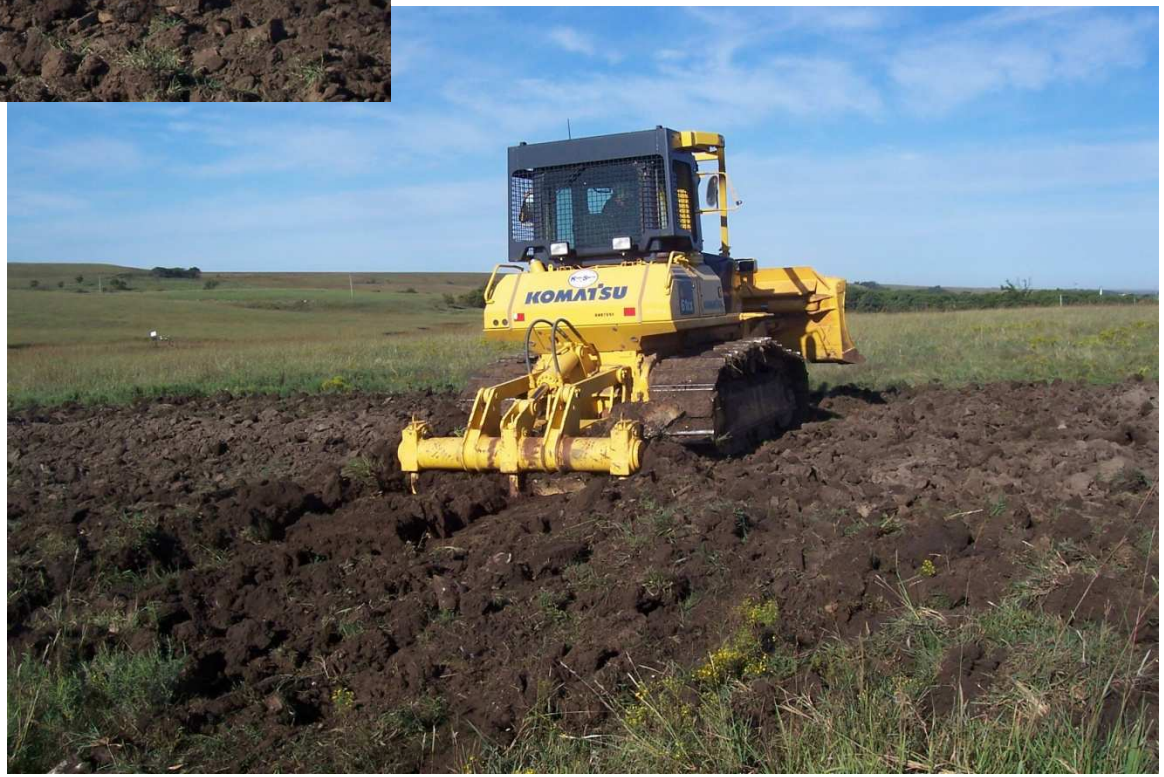


Four-year old brine spill twice "remediated" (tilling with gypsum)

Great drainage possibilities




EC (mS/cm)
SAR
80
60
40
20
0
0-6"
6-12"
12-24"
Depth
80
60
40
20
0
0-6"
6-12"
12-24"
Depth
80
60
40
20
0
0-6"
6-12"
12-24"
Depth



Initial ripping of brine impacted soil

Incorporating hay

Adding organic acid remediation amendment

Tilling in remediation amendment and hay

Surface application of clay swelling agent

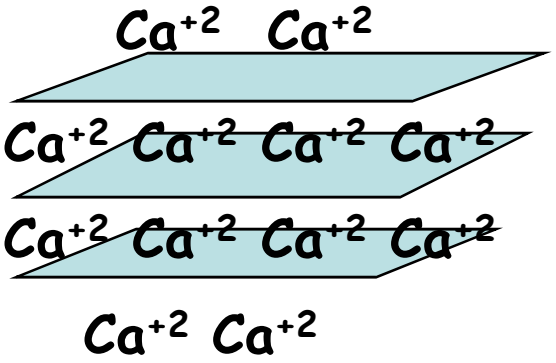
InfiltratioNhance™

Top dressing of hay to retain moisture

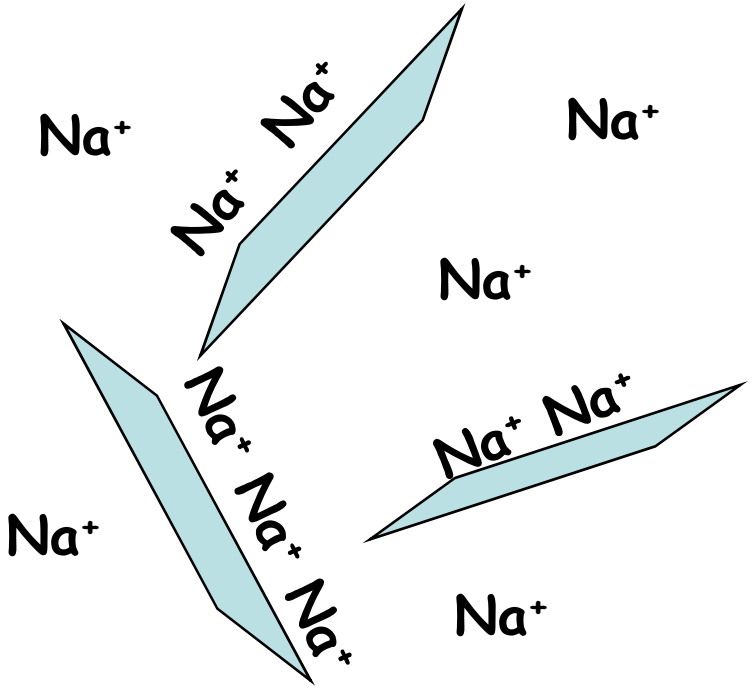
7 months of treatment, May

20 months of treatment (June)

Sodicity and soil structure



Clay particles or platelets in soil are held together by Ca^{+2} ions



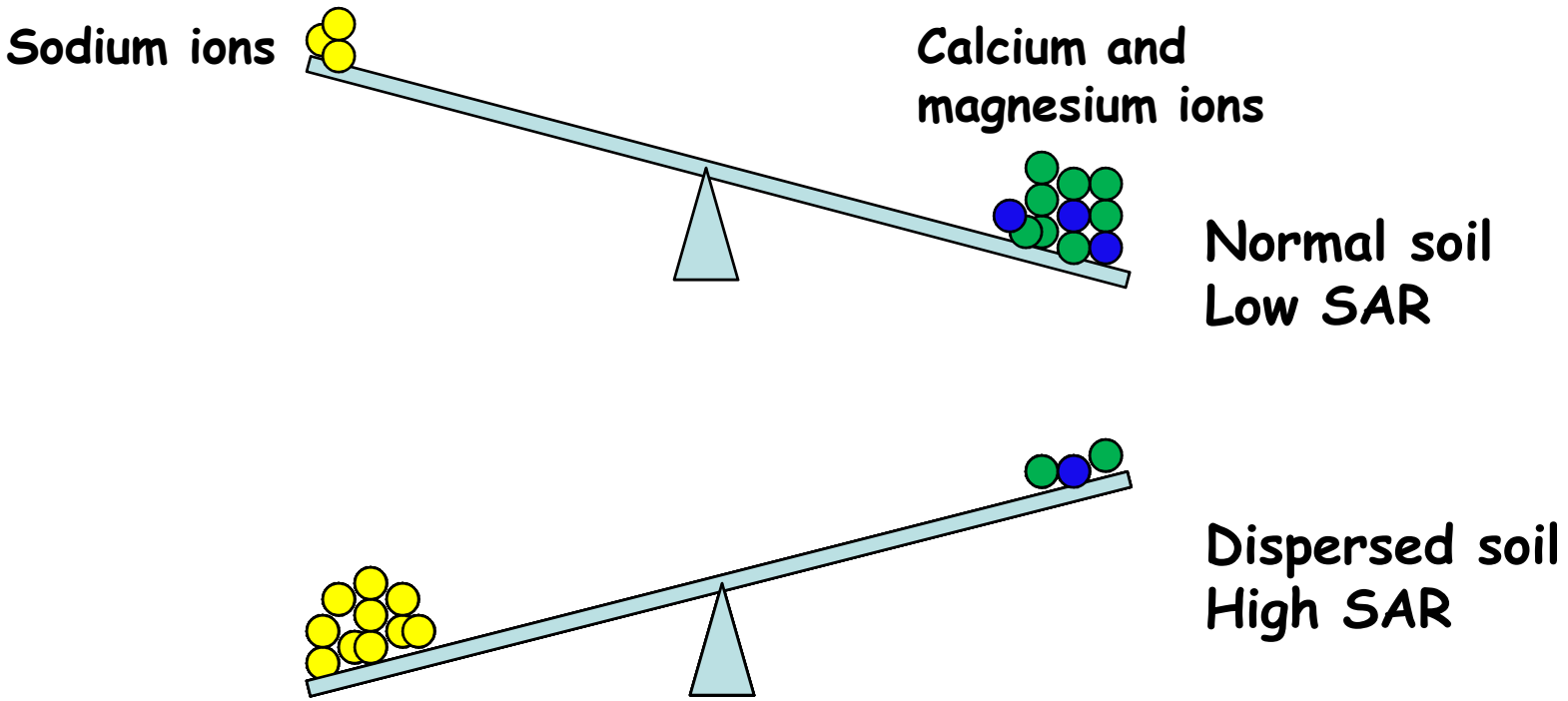
High concentrations of Na^{+} ions can displace the Ca^{+2} and cause the clay particles to disperse

Sodium adsorption ratio (SAR)

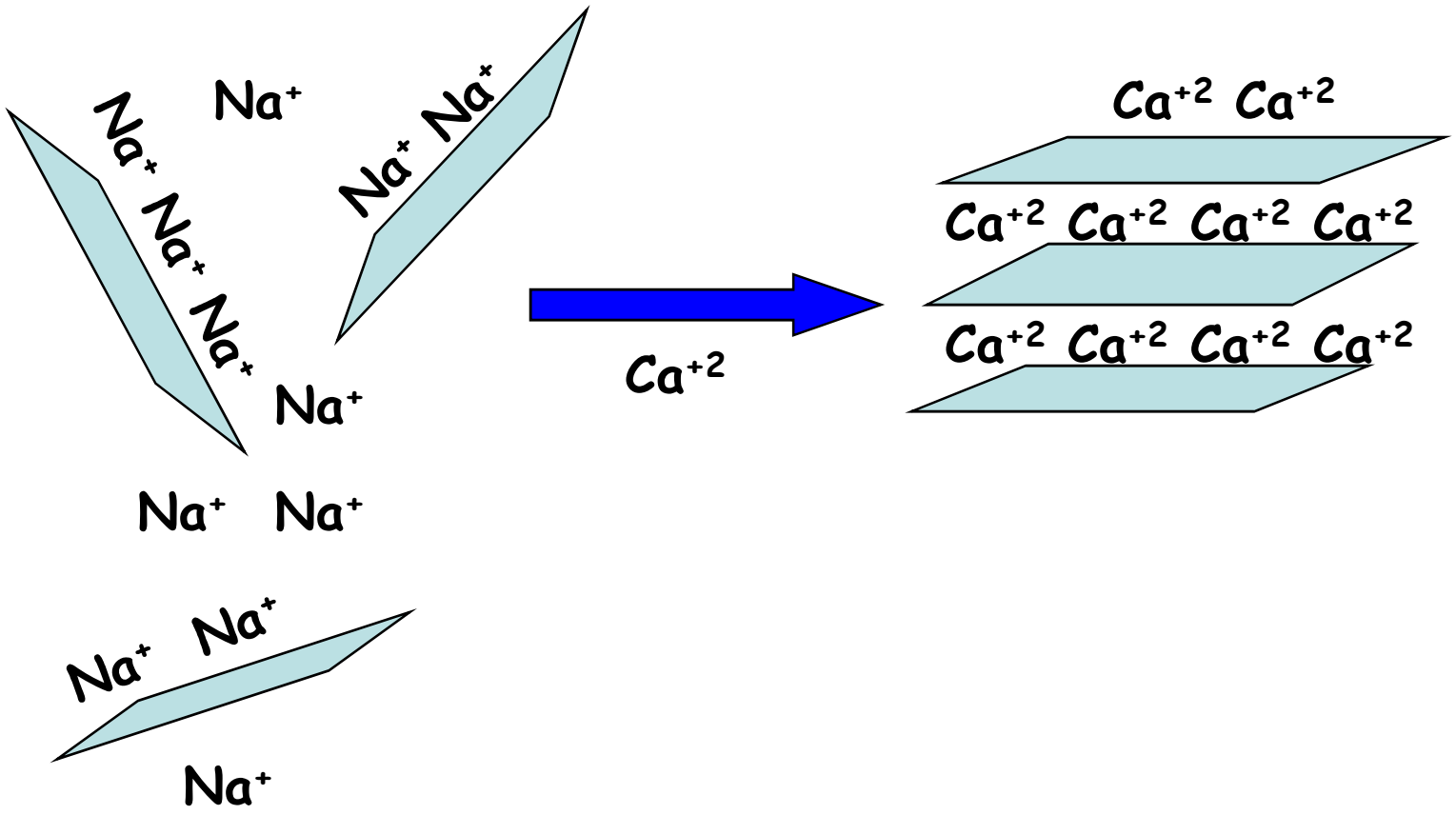
$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{+2}] + [Mg^{+2}]}{2}}}$$

Units are **meq/L**

The SAR is an index of sodicity – an excess of Na^{+} in the soil compared to Ca^{+2} and Mg^{+2}


Sodium ions
Calcium and
magnesium ions
Normal soil
Low SAR
Dispersed soil
High SAR

Calcium is required to fight sodicity

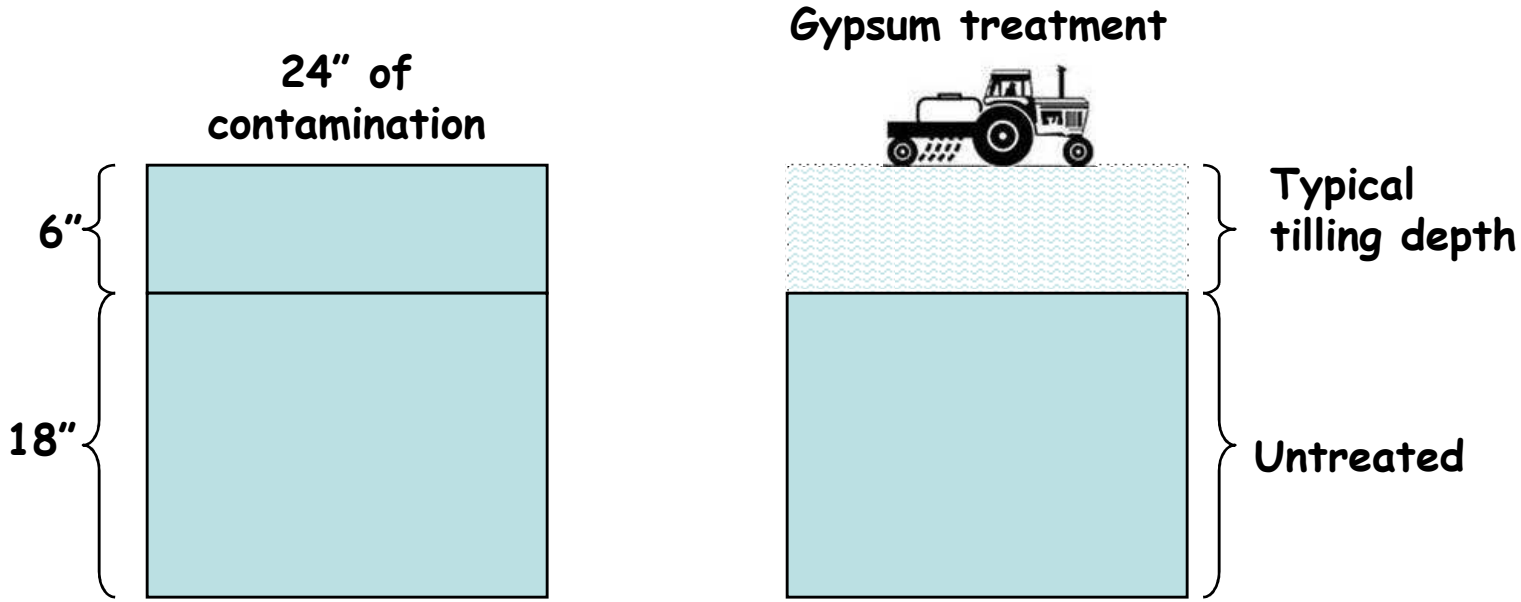


Problems with gypsum

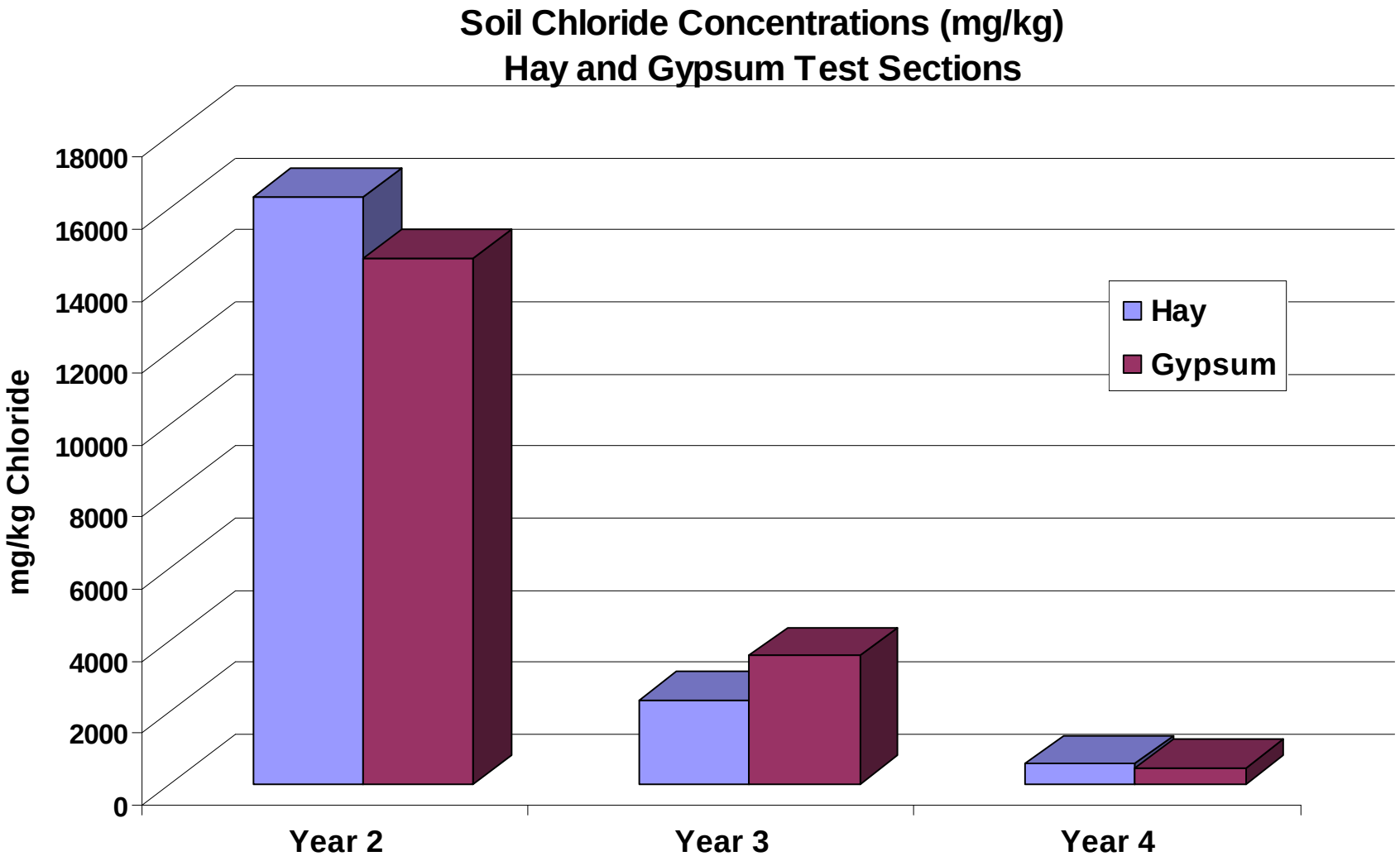
- Gypsum mobilizes potassium and magnesium in the soil
- Gypsum solubility is very low (2.5 g/L)
- Gypsum requirements for typical brine impacted soil and water requirements:

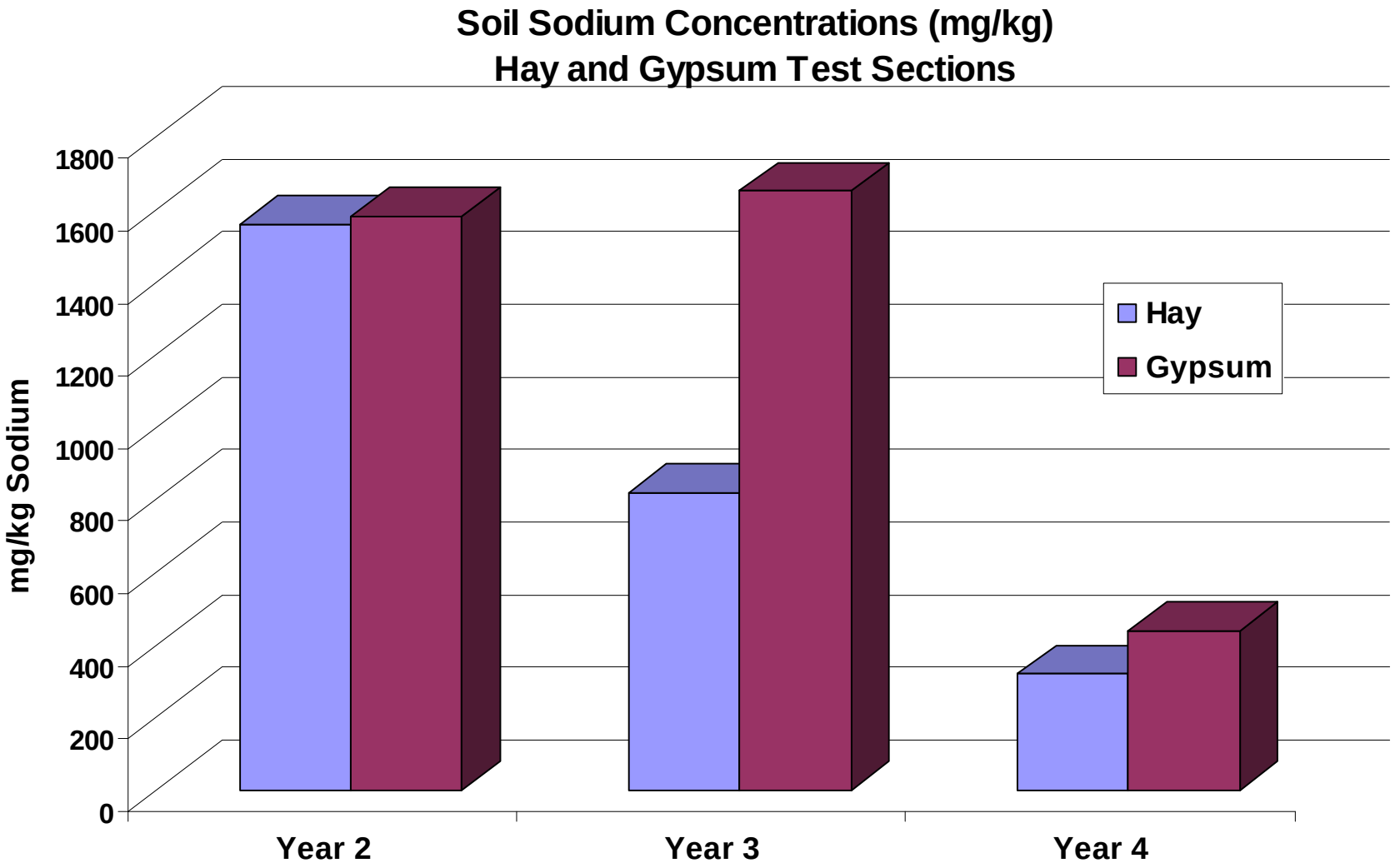
Increment thickness treated (in)	lbs gypsum per 1000 ft^2	Inches of infiltration water required
6	527	40.6
12	1054	81.2
18	1581	121.8
24	2108	162.4

Due to the low solubility of gypsum, gypsum is typically effective only within the depth to which it is incorporated into soil



During remediation of a brine spill test plots compared gypsum to hay + fertilizer

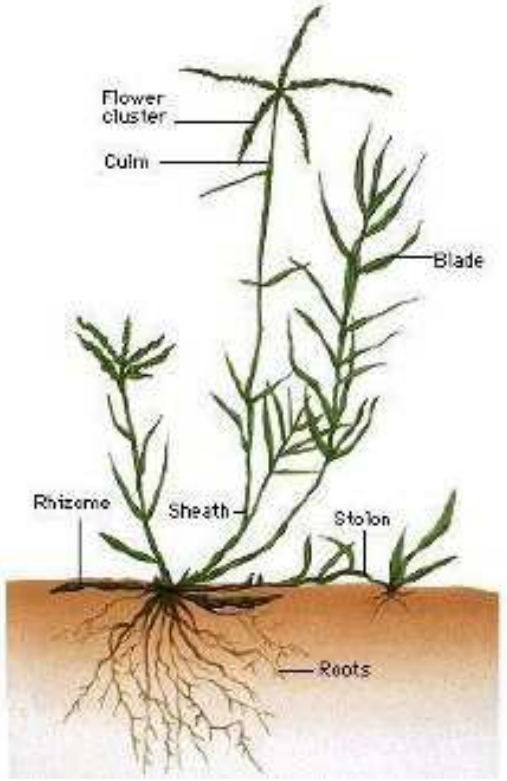




Faster revegetation seen in the hay treated plot; hay treated plot was two years ahead of the gypsum treated plot in terms of revegetation

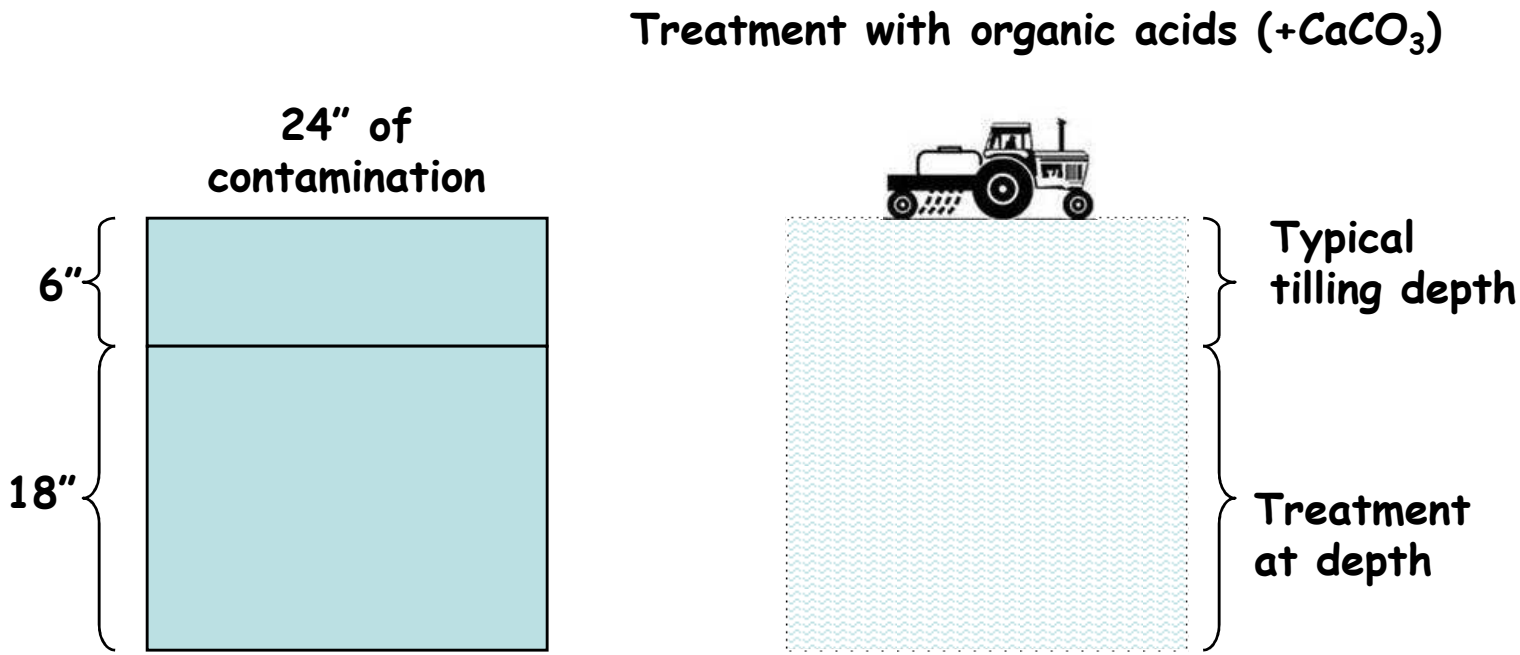
The Chemistry

- Decaying organic matter produces organic acids
- Plant roots release organic acids into the soil
- Organic acids chemically react with $CaCO_3$



$$CaCO_3 + RCOOH \text{ ->> } Ca^{+2} + RCOO^- + CO_2$$

The much higher solubility of organic acids can result in deeper penetration into the soil profile treating sodicity below tillage depth



This is how it can feel trying to remediate a brine spill


There are tools we can use though to make the job easier

There are going to be rough spots and everyone has to be patient


Any Questions?
SCENIC
TURNOUT
AHEAD