Erosion Control and Re-spread Depths

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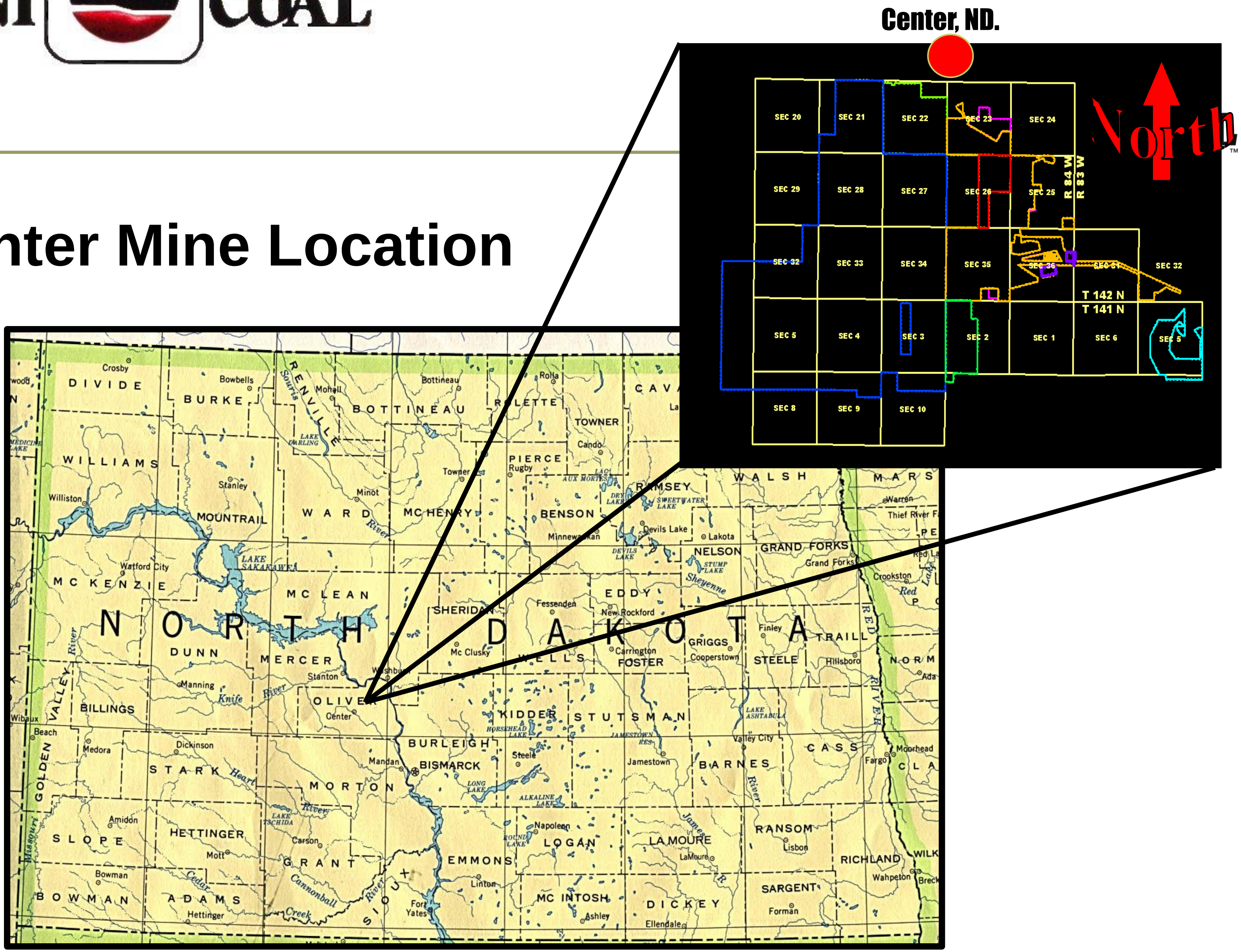
My Time With You Today:

- Myself and BNI Coal, who we are
- Soil Erosion
  - Land Management View
  - Sediment Transport
  - Erosion Control
- Data Review of Soil Re-spread Depths

BNI COAL

Center Mine Location



ALLETE

QUICK FACTS

- Started mining in Center in 1970 – Unit 1 (1.5 million tons/yr)
- Unit 2 started in 1977 (4.2 – 4.5 million tons/yr)
- Deliver approximately 90,000 tons/week

WHO IS BNI COAL?

North Dakota Operations:
BNI Coal, Allete Renewable Resources, Inc, MP, Allete Clean Energy, and Rendfield Land Company, Inc.


North Dakota Award for Excellence
in Surface Coal Mining & Reclamation

presented to

BNI Coal, Ltd.

for

**Implementing Special Soil Handling Practices to
Improve the Quality of Subsoil on Reclaimed Lands**

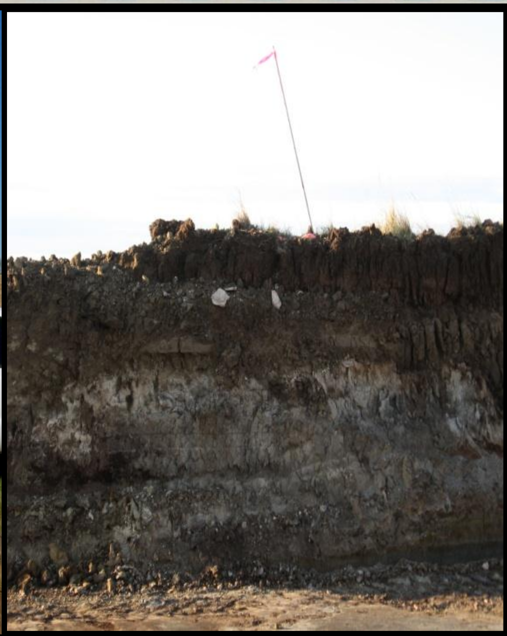
October 3, 2012
by

North Dakota Public Service Commission

Kevin Cramer
Commissioner

Brian P. Kalk
Chairman

Bonny M. Fetch
Commissioner

BNI receives conservation award

With 80 years of experience in the lignite industry, BNI Coal has established itself by producing the lowest-cost lignite for Minnkota Power Cooperative's Milton R. Young Station.

But recently the Center, N.D.-based company has received praise for its commitment to sound land use and reclamation practices.

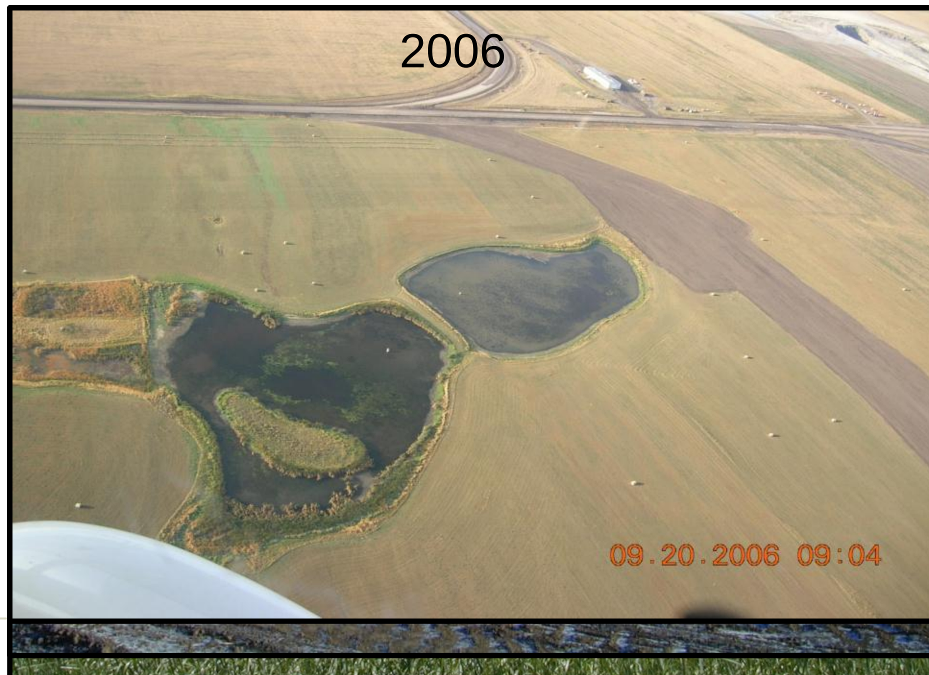
The Oliver County Soil Conservation District, whose board is composed of local landowners, presented BNI with its highest Conservation Achievement Award. It's the first time in 61 years the award wasn't received by a landowner.

"To be recognized by the Oliver County Soil Conservation District for our reclamation practices really defines the culture of BNI Coal," said Jay Volk, BNI environmental supervisor. "BNI does not view reclamation as simply a regulatory requirement, but more importantly a commitment to the environment, landowners, neighbors, county and our customers."

BNI mines approximately 4.5 million tons of coal every year, which is the equivalent of 210 acres. Getting that coal above ground requires excavating trenches as deep as 140 feet.

Mining and reclamation plans are carefully monitored by the North Dakota Public Service Commission's reclamation division. Volumes of premining data are compiled and submitted to the North Dakota Public Service Commission for review.

When mining is finished, BNI replaces the overburden and shapes and contours the area to its final topography. The subsoil and topsoil are replaced, surface rocks are removed and the area is re-vegetated according to the approved plan. □



North Dakota Award for Excellence
in Surface Coal Mining & Reclamation

presented to

BNI Coal, Ltd.

for

Supporting and Participating in
Sporting Chance's Hunting Program

October 7, 2010
by

North Dakota Public Service Commission

Tony Clark	Kevin Cramer	Brian P. Kalk
Commissioner	*Chairman*	*Commissioner*

A DAY AT THE MINE

On to Today’s Topics

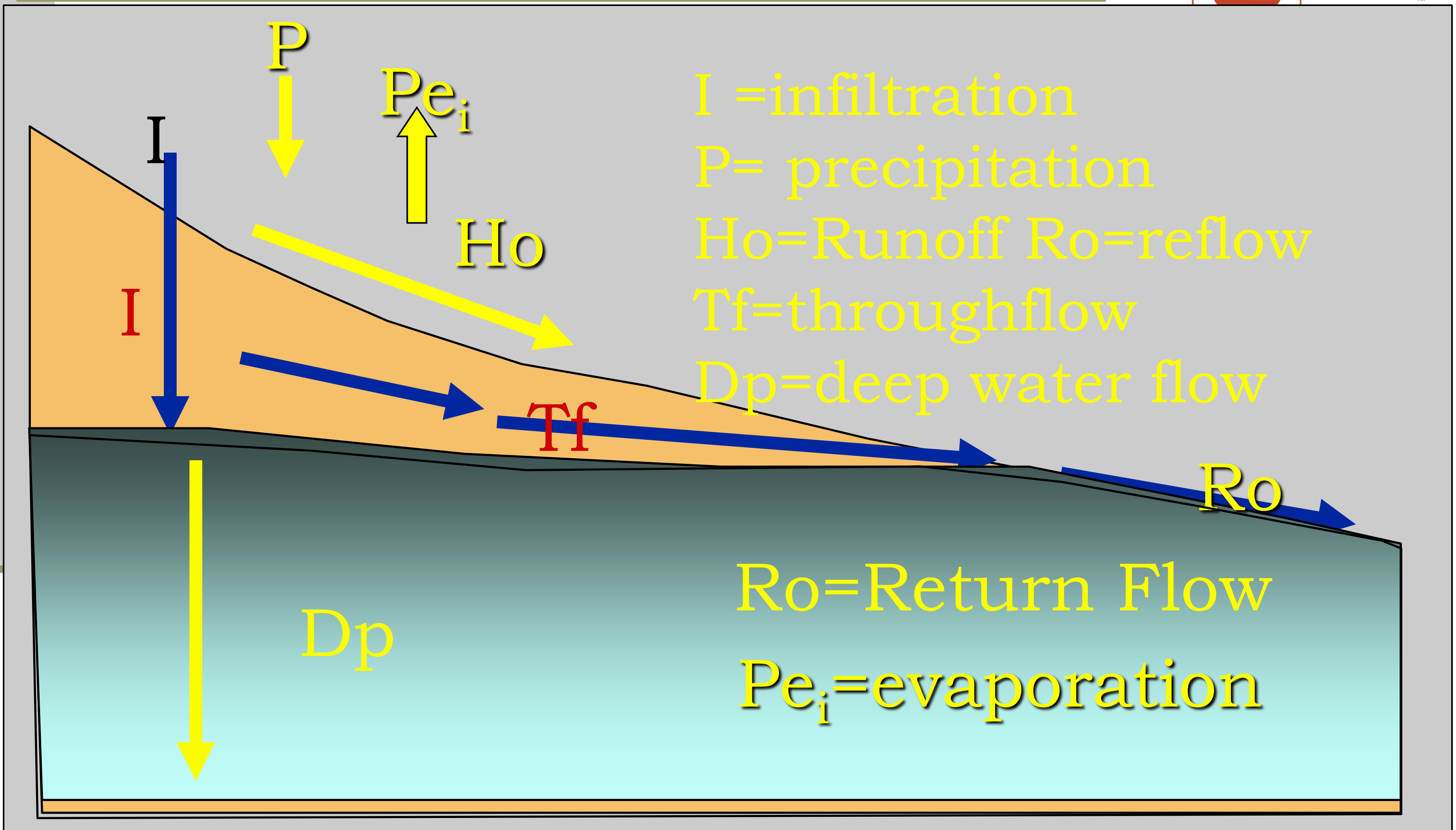
- We all know the basics of erosion processes, sediment transport, and erosion control and most know the basics of what to do to minimize, prevent, or be proactive/reactive to these (or our permits tell us)…….. But:

- Do we understand the root cause and the land management side? Do we understand the landscape water flow?

Erosional Factors

- Rainfall erosivity
  - Amount and Intensity
- Soil erodibility – spend time on this
  - How the soil responds to rainfall energy – texture, aggregation, clays harder to detach – sands harder to move, silts worst
- Topography
  - Slope length – defines energy runoff will have to transport
  - Steepness – the steeper = more energy
- Management
  - Reduce local erosion – leave cover on surface – promote infiltration
  - Change runoff path – Diversions (eliminate amount of water)
  - Slow down and spread out runoff => dissipates energy and lets sediment settle out = better water quality downstream

LANDSCAPE WATER FLOW

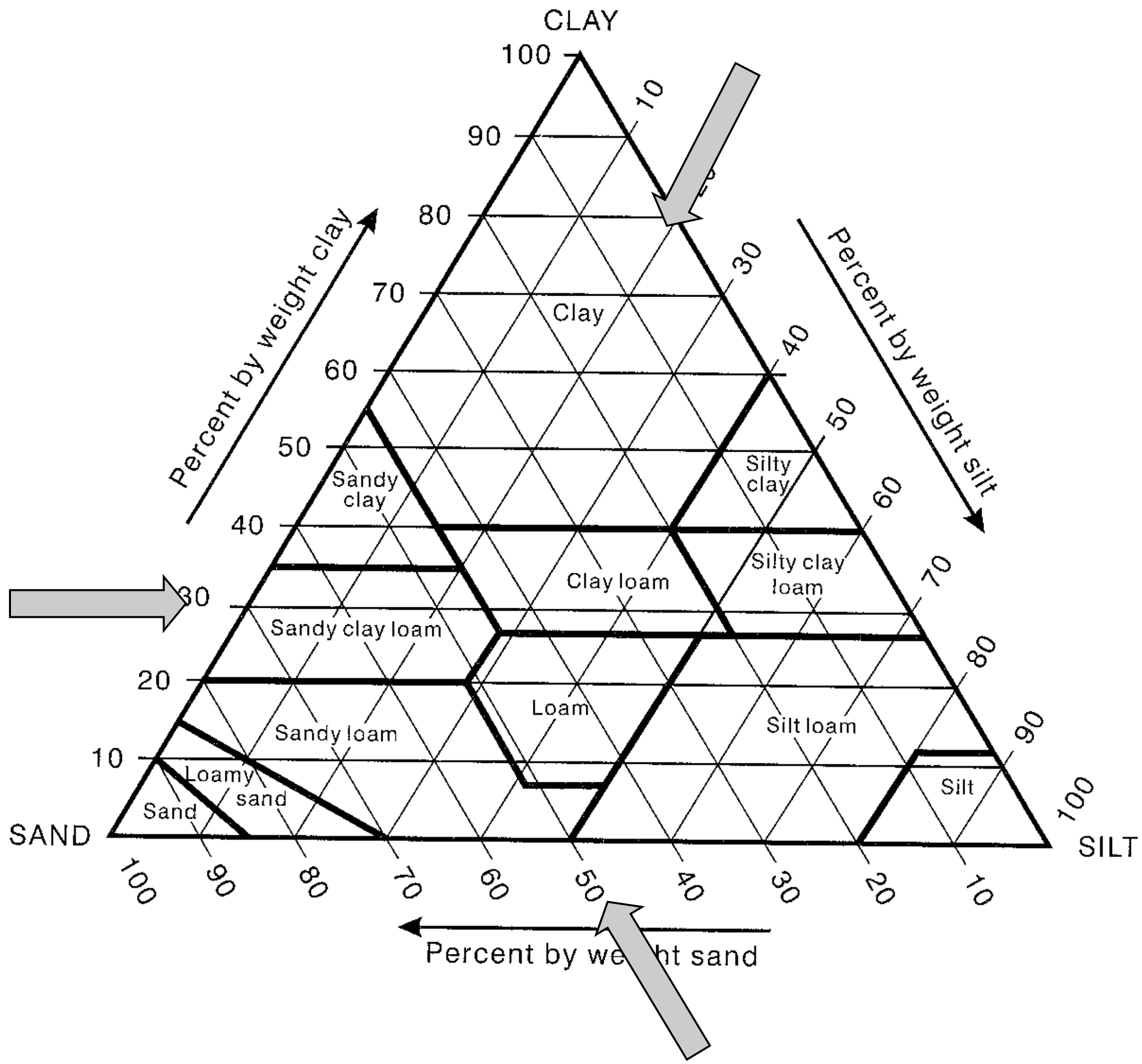


Cant control P, can work on slowing down Ho, increasing I and Dp....We are stuck with Texture and slope

Soil classes & particle sizes

- Texture
  - EX: 50% sand,
    20% silt
    30% clay?

Sandy Loam



Soil Texture

- 1) water flow potential,
- 2) water holding capacity,
- 3) vegetation – direct effects

Shallow Gravel

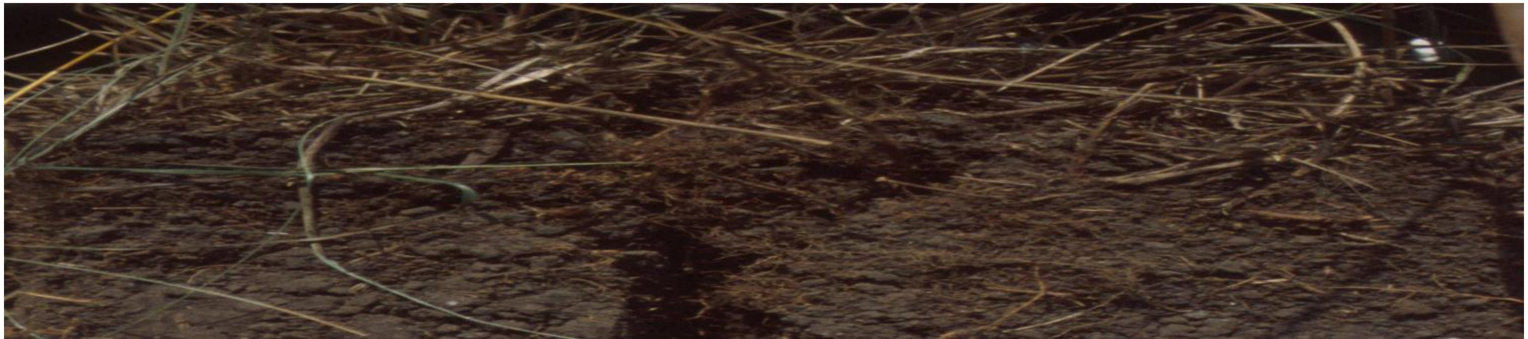
Thin Upland

Silty

Vegetation

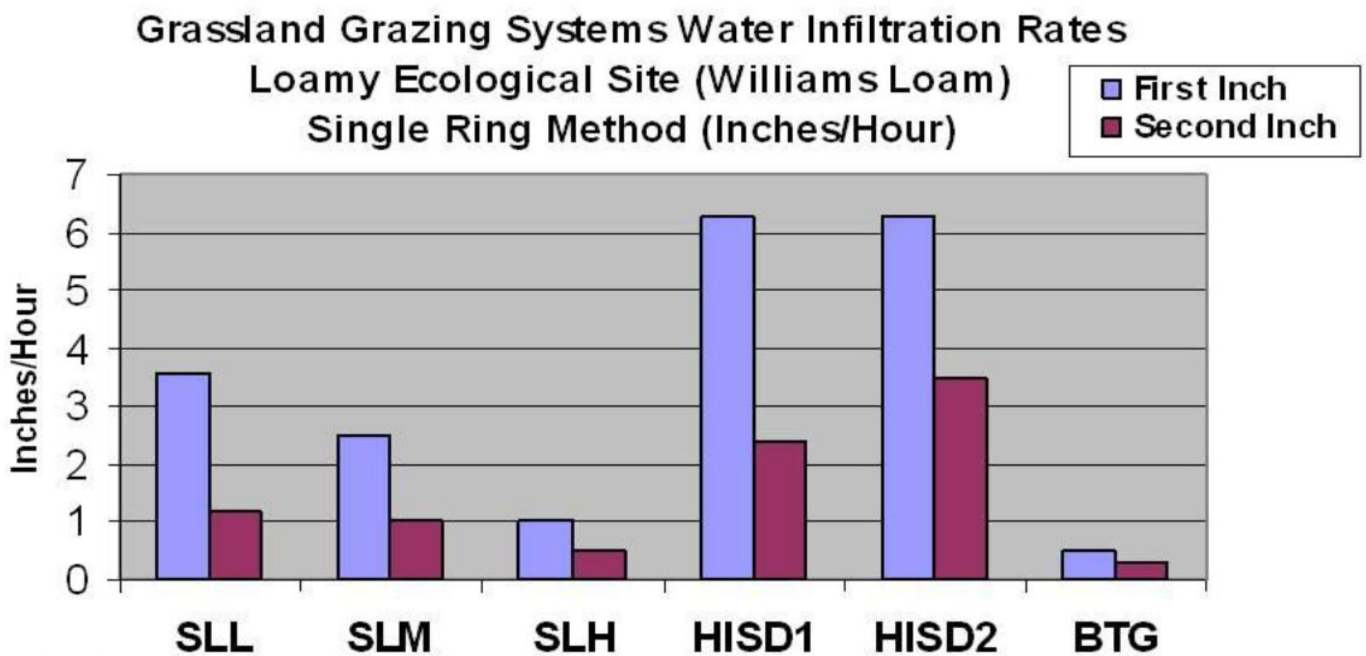
How does percent cover, species diversity, or land use affect vegetation and runoff?

Does Localized Management Affect Runoff?



Infiltration Rates Correlate with Management

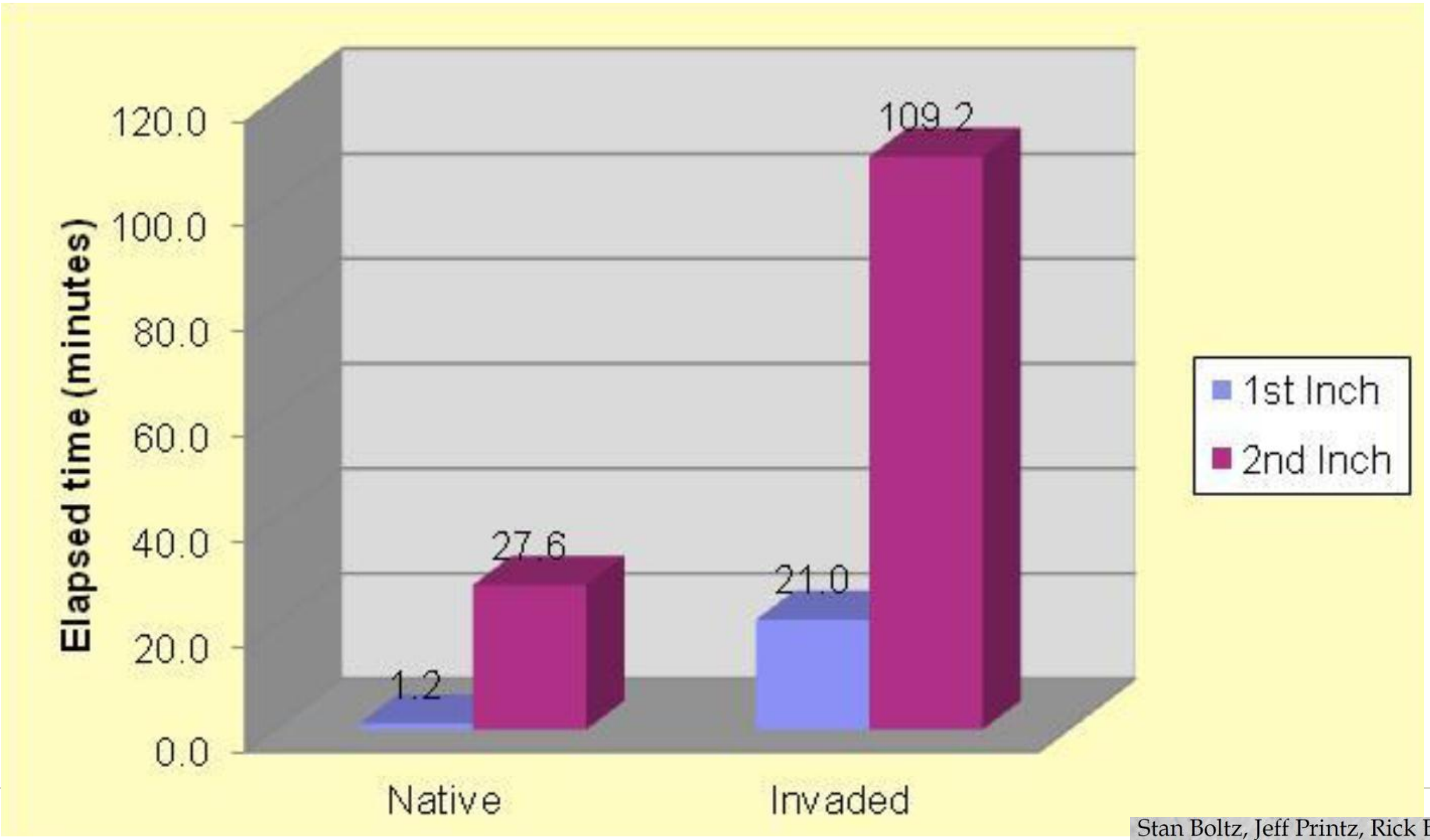
Infiltration Rates



SLL- Kentucky bluegrass dominated
SLM- Kentucky bluegrass dominated
SLH - Kentucky bluegrass dominated
HISD1- Diverse native community
HISD2- Diverse native community
BTG- Brome Tame Grass Pasture

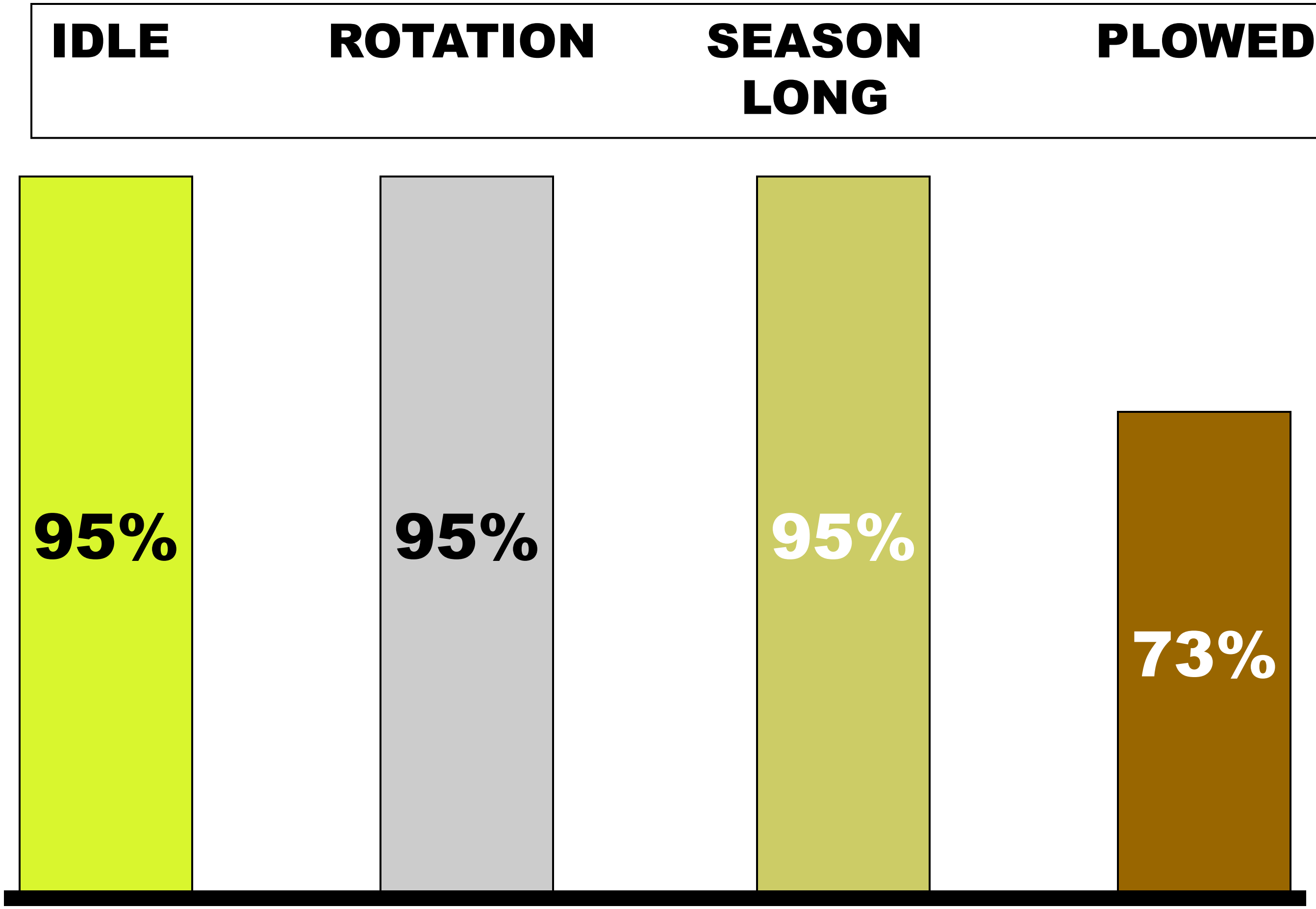
Dr. Jimmy Richardson and Dr. Jay Volk
Stan Boltz, Jeff Printz, Rick Bednarek
USDA Natural Resources Conservation Service

Infiltration – Native vs. Invaded



Stan Boltz, Jeff Printz, Rick Bednarek
USDA Natural Resources Conservation Service

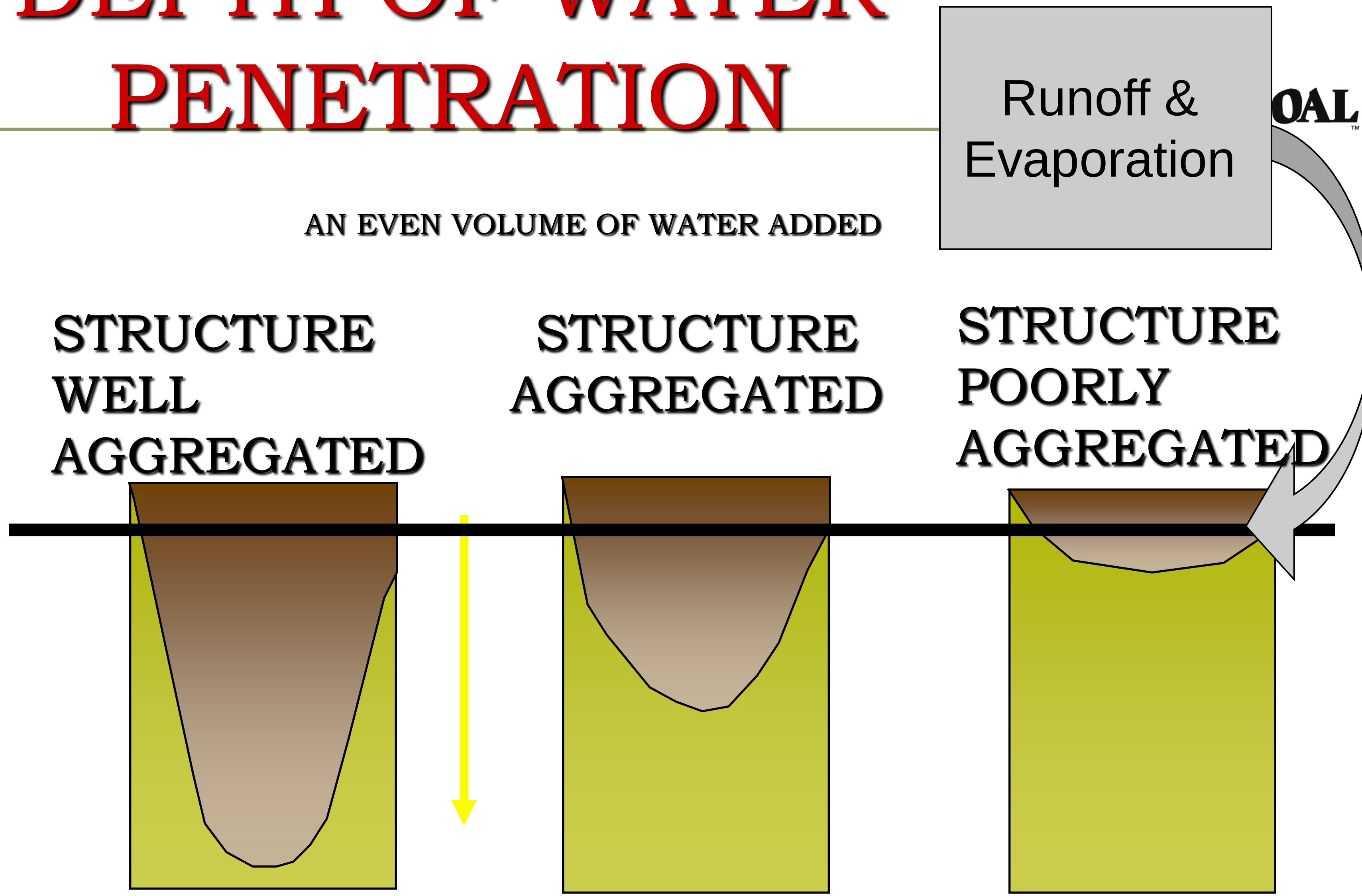
% STABLE AGGREGATES SURFACE 6”



Disturbed Lands?

Soil in jar example?

DEPTH OF WATER PENETRATION



Aggregation: What kind of structure does a disturbed soil have?

I Would Argue These Soils Have Different Structure – How's Ho/I Affected

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Can anybody tell me about these soils?

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Structure

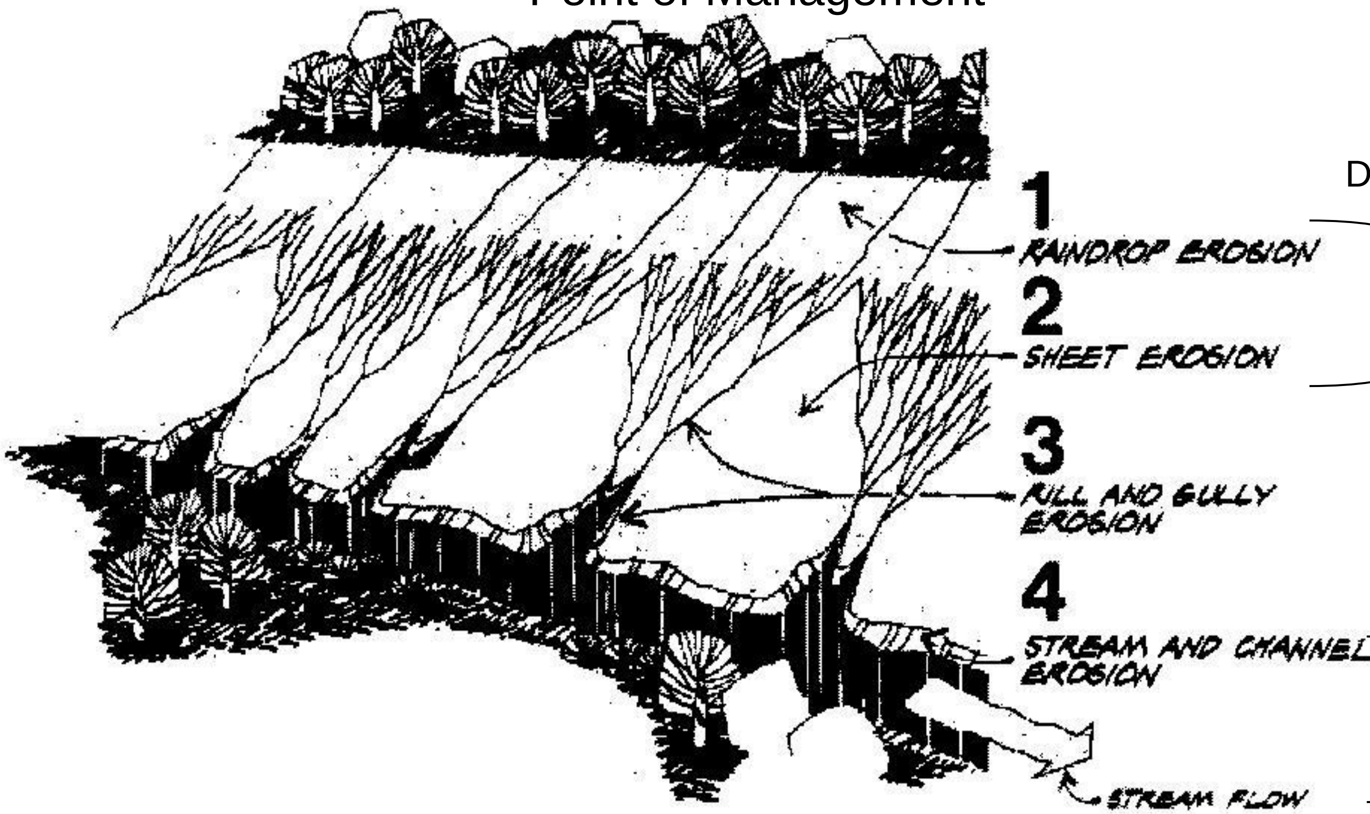
So How Does Knowing About Landscape Water Help me Understand Erosion?

- Pro active Verses Reactive
  - Understand how much and how fast water
    - Many modeling methods are excellent tools but more insight can be gained by understanding localized management
- Slow water prior to the point of disturbance
  - Buffers (what kinds), what utilization of these buffers, what species (broad leaf or grasses) ect.
- Landscapes can work with you to dissipate water quicker

Understanding Management Can Only Help You So Much, You Still Have To Be Smart About Your Disturbance and How You Manage It

Four Types of Soil Erosion on Exposed Slope

Point of Management



Detachment

Raindrop impact

Sheet Flow

Transport

Raindrop impa

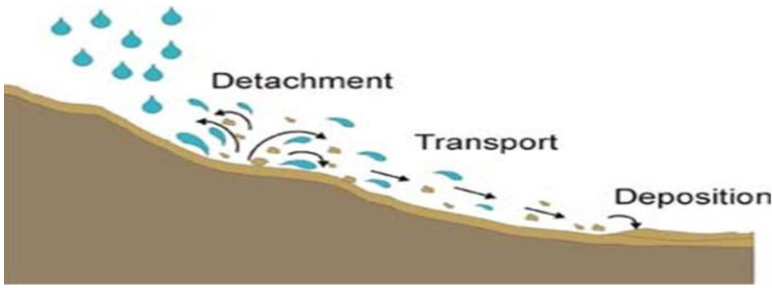
Sheet Flow

Your permit likely tells what bmp to use in a slope as this, but does it tell you what you can do above the point of disturbance? Buffers, diversions, ponds, ect.

Deposition

The Erosion Process

- Soil erosion is a multi-step process:
  - Soil particle/aggregate detachment
  - Soil particle/aggregate transport
  - Soil particle/aggregate deposition
- There must be **detachment** and **transport** for erosion to occur
- **Deposition** (sedimentation) will occur somewhere downstream



Control of Soil Erosion by Water

- Detachment limiting strategies
  - Reduce raindrop impact (“Stop the Drops”)
  - Reduce runoff
  - Reduce detachment capacity of runoff
  - Increase soil resistance to erosive forces
- Transport limiting strategies
  - Reduce runoff volume
  - Reduce runoff transport capacity (“Slow the Flow”) – How do we transport less?

Example – No-Till or Mulched Area

- Detachment – how limited
  - Raindrop impact detachment is very low due to high surface cover percentage – "stop the drops"
  - Flow shear detachment is low due to slower water movement caused by residue obstructing flow path
  - Soil is resistant to erosion because of low disturbance
- Transport – how limited
  - Raindrop transport is limited by surface residue
  - Flow transport is limited by increased infiltration, lessening runoff – "slow the flow"
  - Flow transport is further limited by small dams created by surface residue

What Side Is Limiting Detachment and Transport

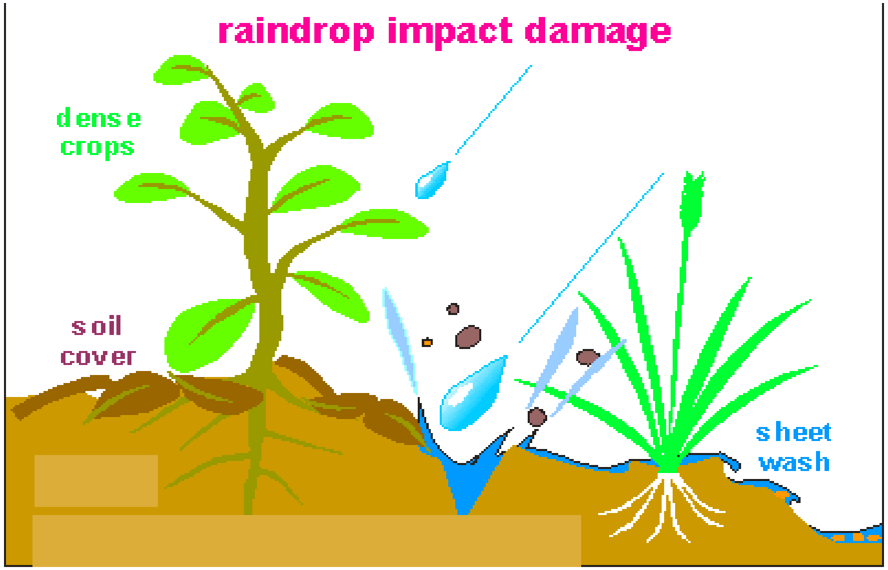
*Over tillage breaks macropores

Detachment

- There are many sources of force and energy required to detach soil particles & aggregates:
  - Raindrop impact
  - Shallow surface flow shear
  - Concentrated flow shear
  - Many more, at larger scales

Rain drops average 1- 7mm and can hit ground at 20+ mph; can dislodge particles 3-5’ away (USDA)

Detachment


raindrop impact damage
dense
crops
soil
cover
sheet
wash


USDA-NRCS

Transportation

- Many of the same processes contribute force and energy for soil particle & aggregate transport:
  - Raindrop impact
  - Shallow surface flow
  - Concentrated surface flow
  - Channelized flow
  - Others

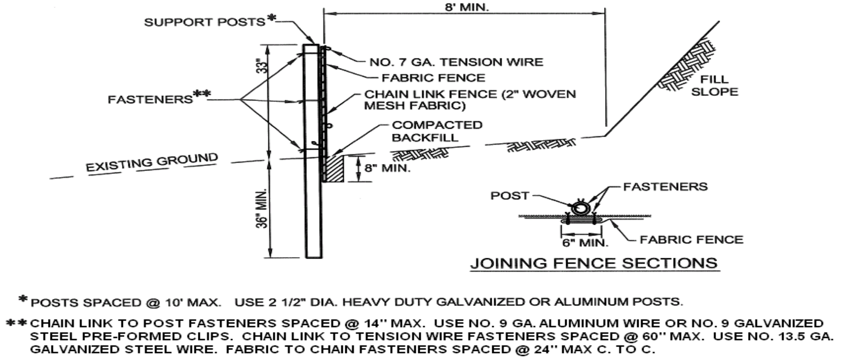
Transportation

Vegetated Diversions

Rock Rip-Rap

Reduce Transport Capacity

- Slow the flow
  - Barriers
    - Must let water pass, though slowly
    - Must be flow-stable, even after use
    - Must be where maintenance is possible
  - Reduce slope steepness
    - Channel must be of adequate capacity
- Increase infiltration



Three Basic Take Home Points On Erosion

- Focus on Understanding 3 Areas
  - Know your permit…..Did not talk about this, but in this holds a key to success
  - Understand how specific land management affects infiltration, runoff, and ultimately erosion potential
  - Focus on strategies that limit the detachment of soil and transport of soil particles

DATA REVIEW of SOIL RE-SPREAD and DEPTHS

Sarah Flath
The Coteau Properties Company
Beulah, ND

2009 ASMR Meeting
Billings, MT

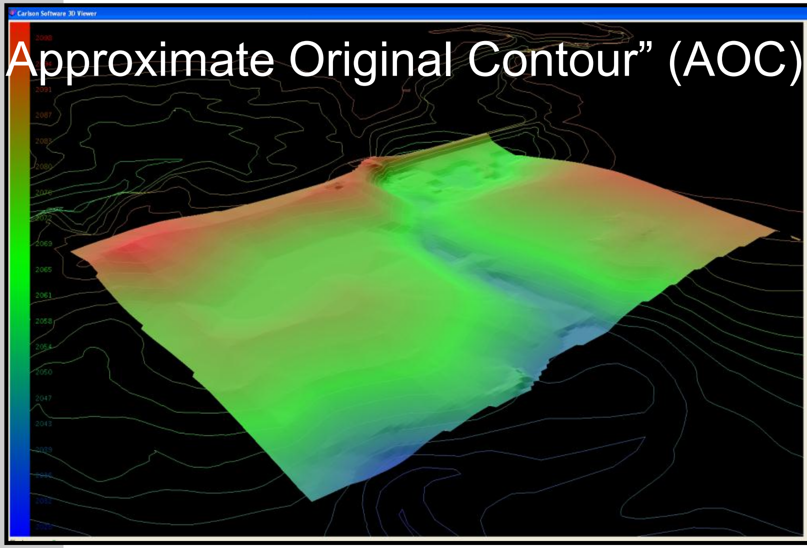
SPGM – Removal Overview






- Salvage all topsoil and enough subsoil to meet required re-spread depth

Re-Spread - Overview



SPGM Re-spread Thickness

Texture	SAR	TS/SS inches
Medium	<12	24 inches
Coarse	<12	36 inches
NA	12-20	36 inches
NA	>20	48 inches

- Based on recommendations made by Doll et al. (1984)?

Introduction

- Three decades of research on soil salvage and replacement
- Soil respread may be the most important part of the restoration process but also the most costly
  - The optimal depth is the minimum amount of soil necessary to maximize reclamation success
- Our regulations developed 20+ years ago

(Flath, 2009)

Background (Re-spread Depths)

- Researchers have suggested that shallower depths may be acceptable (Fox, 1993; Kirby et al., 1993; Redente et al., 1997; Schladweiler et al, 2005).

- Long term site development has been studied (Bowen et al., 2005; Redente et al., 1997; Wick et al., 2005).

(Flath, 2009)

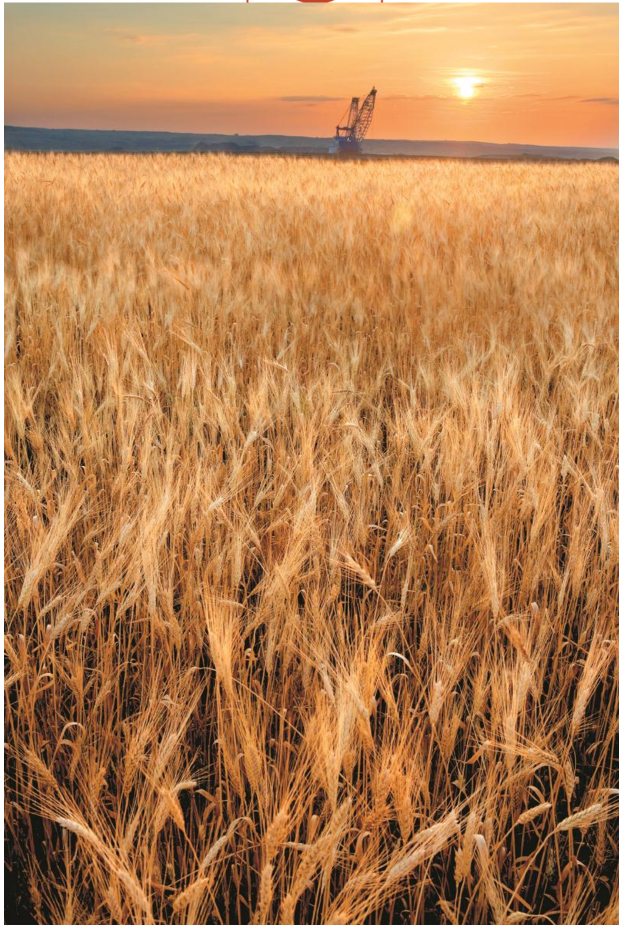
Data Review - Rangelands

- Rangeland
  - Diversity is often higher with shallower respread depths (Bowen et al., 2005; Redente et al., 1997; Schladweiler et al., 2005; Wick et al., 2005).
  - Seasonality is improved by shallower depths because it allows C4 grasses to be able to compete with C3 grasses (Wick et al., 2005).
  - Production and cover increase linearly with soil thickness to an optimal depth, after which additional soil has no marked increase (Power et al., 1981; Merrill et al., 1998; Redente and Hargis, 1985).
  - Production sets the lower limit for respread depths (Merrill et al., 1998), is a good indicator of many site characteristics (Hargis and Redente, 1984), is widely used by research and is the primary concern for most landowners.
  - Multiple studies included native and introduced species and concluded the same depth was necessary for both (Introduced verses native and C3 verses C4)

(Flath, 2009)

Data Review - Cropland

- Cropland
  - Depth necessary to maximize cropland production may be greater than for perennial grasses (Merrill et al., 1998 and Power et al., 1981).



(Flath, 2009)

Data Review – Do Depth Requirements Change With Time?

- Three studies

- Study 1
  - Redente et al. (1997) revisited a **10 year old site** with varying soil depths (15, 30, 45 and 60 cm) respread over generic spoil.
    - Results were the same as earlier (Redente and Hargis, 1985), with 60 cm maximizing production.
    - **Site maturation did not affect the appropriateness of respread depth recommendations**

(Flath, 2009)

Data Review – Do Depth Requirements Change With Time?

- Study 2

- Bowen et al. (2005) follow up study of Schuman et al. (1985) of varying topsoil depths (0, 20, 40, 60 cm) respread over generic spoil
  - **Respread depth recommendations didn't change after 24 years.**
    - Although shallower respread depths improved diversity and species richness, 40 cm was still necessary to maximize production and cover.

(Flath, 2009)

Data Review – Do Depth Requirements Change With Time?

- Study 3

- Wick et al. (2005) follow up study of Merrill et al. (1998) with moderately sodic spoil (SAR = 14.6) and Power et al. (1981) with sodic spoil (SAR = 25)
  - After **30 years** there was only a **weak relationship** between soil depth, soil properties, production, cover and diversity (Wick et al., 2005).
  - **Changes in soil properties as the site matured did not make initial respread recommendations inadequate.**

(Flath, 2009)

Data Review: Generic Spoil (SAR <12)

- Spoil without negative properties can act as a rooting medium (Redente and Hargis, 1985) so shallow soil depths are adequate.
  - Spoil acts as the subsoil of the reclaimed site (DePuit, 1984).
  - Depth of soil doesn’t determine the depth of the root zone, but may effect nutrient and water status of the upper portion (Redente and Hargis, 1985).

(Flath, 2009)

Data Review: Generic Spoil (SAR <12)

- **40 cm may be adequate** (Bowen et al., 2005; Pinchak et al., 1985; Schuman et al., 1985).
- Greenhouse and field trials found that a **minimum of 46 cm** is required (McGinnies and Nicholas 1980, 1983).
- Barth and Martin (1984) **recommended 50** cm of soil.
- Redente and Hargis (1985) reported a slight increase in **production from 45 cm to 60 cm** of soil but later found similar production between respread depths (Redente et al., 1997). **Shallower depths had higher diversity.**

(Flath, 2009)

Data Review: Generic Spoil (SAR <12)

- Other than Redente and Hargis's (1985) research, **50 cm maximized production**. Their research found that some depth between 45 and 60 cm is necessary.
  - Data suggests the optimal soil depth over generic spoil for maximum productivity, diversity, and operational efficiency is 50 cm

(Flath, 2009)

Data Review: Coarse Textured (SAR <12) Spoil

- If spoil is coarse textured, soil is necessary to increase the water holding capacity of the root zone (Omodt et al., 1975).
- A **minimum of 70 cm** of soil is necessary (Halvorson et al., 1986).
- **81 cm** maximized perennial grass production (Merrill et al., 1998).
- **69 cm resulted in 85% productivity** of annual crops, so **through extrapolation, 81-89 cm** is necessary (Halvorson and Doll, 1985).

(Flath, 2009)

Data Review - Sodic Spoil (SAR >20)

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- Sodic spoil is unfavorable for plant growth (Sandoval and Gould, 1978)

- A layer of soil over spoil can act as a buffer against negative effects, if it is thick enough for the root zone of plants (Hargis and Redente, 1984)

- **70 cm maximized perennial grass production**, but **90 cm was required for annual crops** (Power et al., 1981; Barth and Martin, 1984).

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(Flath, 2009)

Data Review - Sodic Spoil

- Other research found **90 cm may be necessary, no matter the vegetation type** (Power et al, 1976; Redente et al., 1982).

- When 25, 50, 75 and 100 cm of soil were respread, **100 cm was necessary** (Power et al., 1985; Merrill et al., 1985).
  - **Maximum production** may have been reached at some depth in between **75 and 100 cm**

- **Roots of native grasses** are not found abundantly below **90 cm** (Power et al., 1982; Coupland and Johnson, 1965).

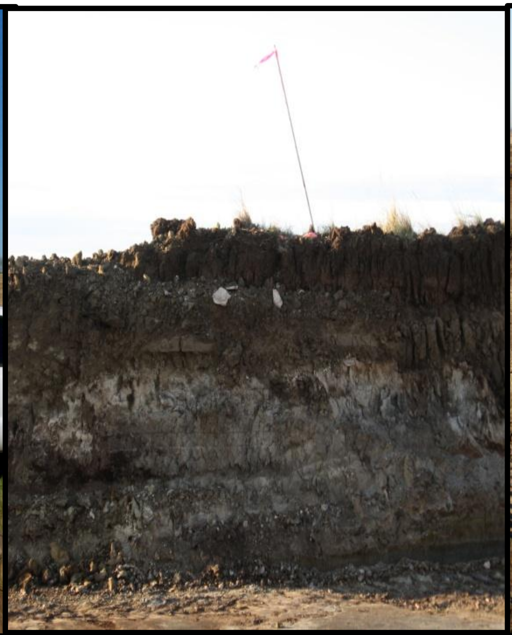
(Flath, 2009)

Conclusions – Re-spread Depth Review

- Diversity and seasonality shown to increase with lower re-spreads
- Depth requirements stable long term
- SAR < 12
  - Approximately 50 cm
- SAR <12 (Coarse texture)
  - Approximately 80-90 cm
- Sodic Spoil (SAR >20)
  - 70 – 100 cm or approximately 90 cm

Quantity Verses Quality

- Don’t focus strictly on soil volume but keep in mind soil quality
  - Is there better material?
    - Remember, what is easy today, likely wont make tomorrow as easy. Time is money – Do it right today.



Quality Verses Quantity

- People reclaiming land have to be equally in tune to quality as quantity
    - Soil signs – pulling, color, dried color, vegetation
    - Sometimes it is better not to take the soil
- Positive benefits
  - Long term productivity of land
  - Data indicates that higher quality material may minimize stresses in non-normal years.
    - Reclaimed soils when wet/dry
    - Vegetation stresses – compounded wet/dry

Questions

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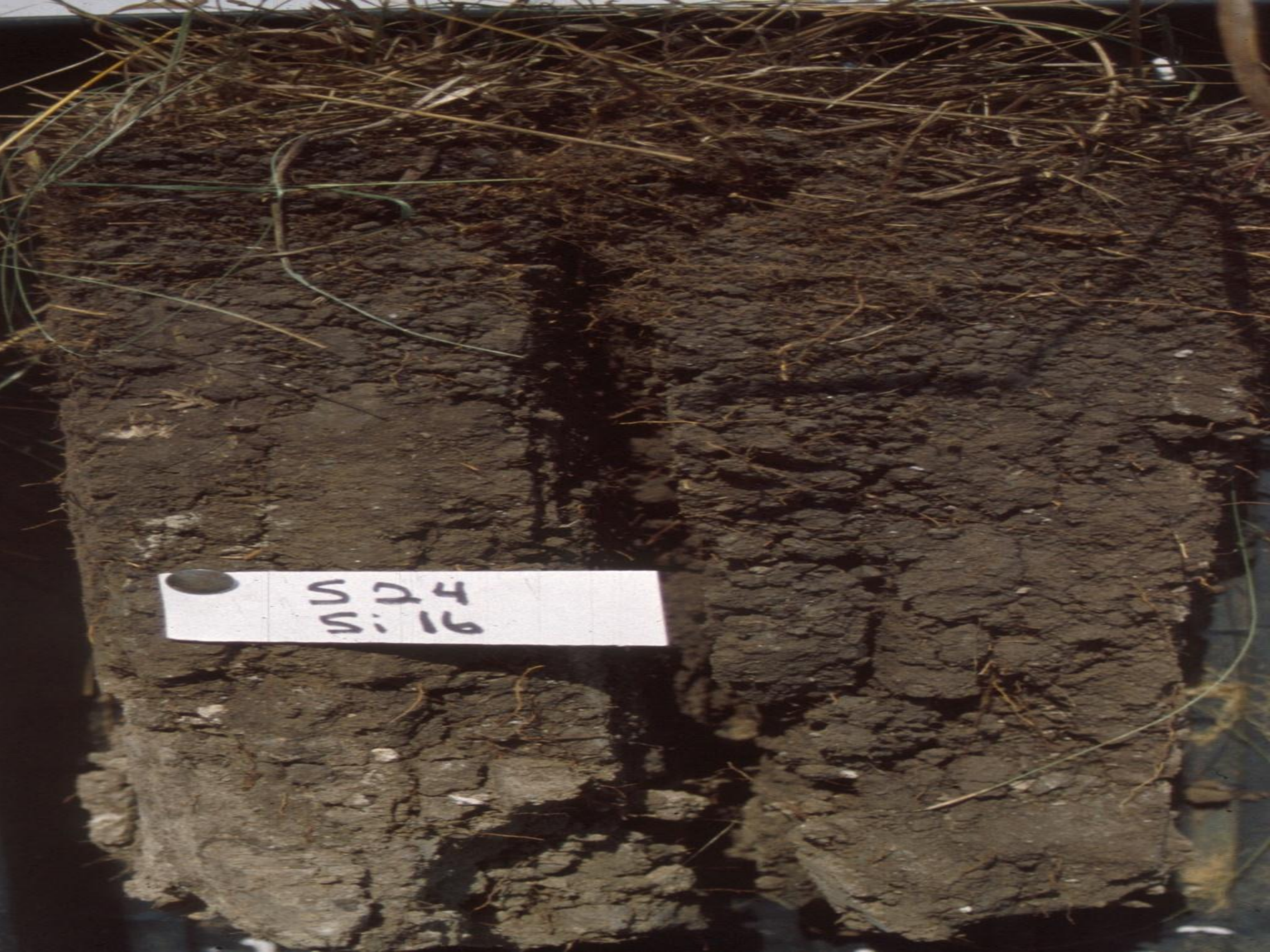
What can you tell me about these soils?


S31


S14
S18


S24
Si 16

Critical to Soil Reclamation

- Best available soil material handling methods
  - Moisture content
  - Re-spread paths
  - Equipment selection

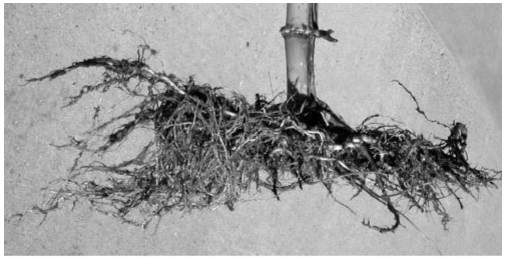
Minimize Compaction

Compaction - Definition

- Compaction – typical silt loam contains about 50% pore space (25% water and 25% air volume at field moisture capacity); remaining 50% is soil particles and organic matter
- Soil Compaction is a process that first occurs when the force from wheel traffic pushes aggregates together. If the applied force is great enough the aggregates are destroyed.
  - Some data show axle loads of 10 tons - subsoil
- Result – dense soil with few large pores

How Does Compaction Effect Reclamation

- Zone directly below the topsoil has higher bulk densities (1.7 – 1.9 Mg m^{-3})and very low hydraulic conductivity
  - Usually see negative yield responses in years of weather stresses (high and low precip)
- As bulk densities increase, porosity and pore size decrease
- Decreased infiltration, permeability, and rooting depth – lateral rooting



Soil Handling

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Scraper

Truck/Shovel

Is Compaction Different Between Equipment?

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Methods to Minimize Compaction

- End dumps without traffic – Most Literature*
- End dumps with traffic
- Scrapers – Most Literature*

Table 7. Mean penetrometer resistance values for soil treatments on the Denmark Plots.

Treatment	Depth (cm) 23-46	Depth (cm) 46-69	Depth (cm) 69-91
	MPa		
Truck placed root media w/o traffic	1.26 b†	1.30 b	1.11 b
Truck placed root media with traffic	1.54 ab	1.57 ab	1.47 ab
Scraper placed root media	1.88 a	1.90 a	1.78 a

† The same letter within a column indicates no significant difference at the 0.05 level.

Darmody et al. 2002)

Table 8. Crop yields in response to rear-dump truck placed and scraper placed root media at Denmark Mine in southern Illinois, 1985-91.

Treatment	Soybean	Corn
	kg/ha	
Truck placed root media w/o traffic	1,254 b†	6,208 a
Truck placed root media with traffic	1,003 c	4,452 b
Scraper placed root media	1,003 c	3,951 b
Undisturbed Cisne/Stoy soil	1,630 a	6,459 a

† Values followed by the same letter within a column are not significantly different at the 0.05 level

Darmody et al. 2002)

Re-Spread with 20" Lifts – 35 acre Tract

- Area re-spread with intention of minimizing bulk densities using scrapers.
  - 34 bulk densities samples taken
- Bottom Lift
  - Ranged from 1.13 g/cm^3 to 1.39 g/cm^3
  - Average of 1.29 g/cm^3
- Middle Lift
  - Ranged from 0.98 g/cm^3 to 1
  - Average of 1.27 g/cm^3

Bulk Density - Undisturbed