Meeting the Mark on Gravel Quality

Virtual Training

December 1, 2020
9:00 am - 12:00 pm (CST) 8:00 am -11:00 pm (MT)

Steve Monlux
(stevemonlux@gmail.com)
406-544-1919
(US Forest Service, Retired)

Presentation Topics

The Benefits of Better Gravel Quality

Gravel Properties and Quality

Clay is the Glue – Lab Testing Fine Materials in Gravel

Understanding Gravel Performance Problems

The Value of Gravel Sampling and Testing

Best Practices for Gravel Sampling, Testing and Acceptance

Ways to Lower Gravel Cost

Best Blading Practices for Gravel Preservation

Construction Methods for Adding Clay to Gravel

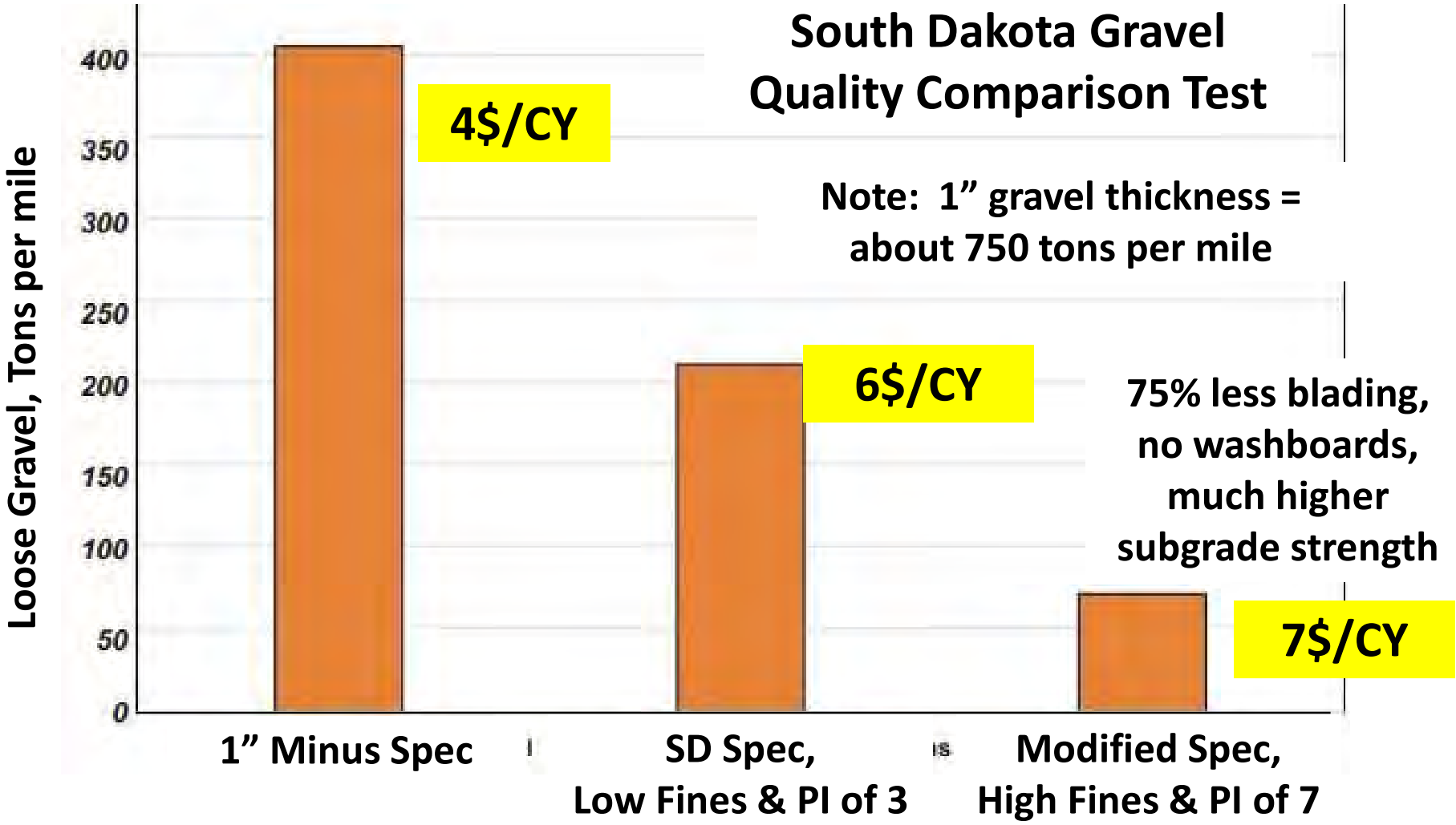
One Page Guides and Other Information

Summary of Primary Points

Benefits of Better Gravel Quality

- Gravel Preservation
  - Reduces gravel shortages
  - Lowers long term costs
- Lowers maintenance costs
- Improves road user relationships
- Improves road user safety

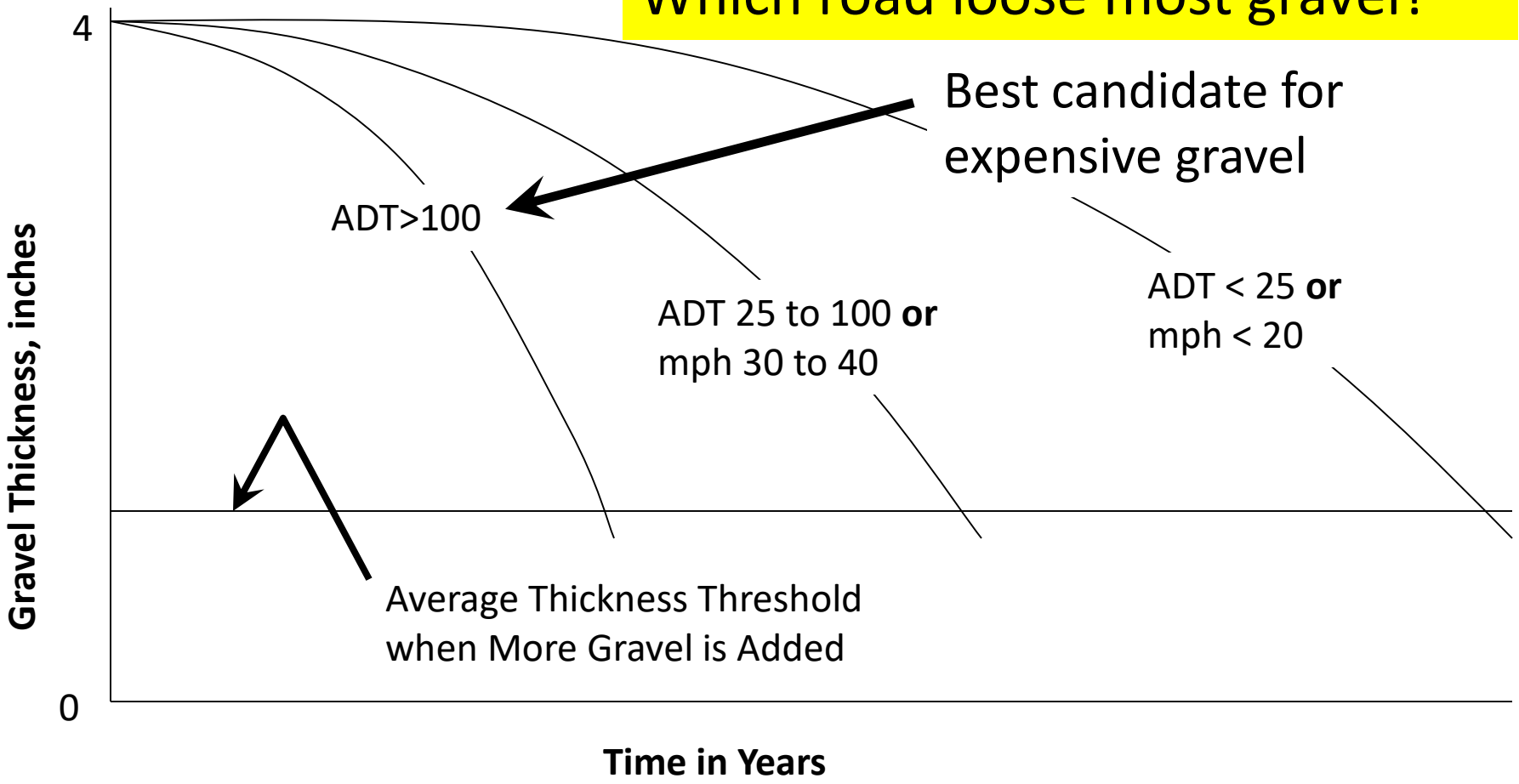
Better Gravel Quality = Less Blading, Gravel Replacement, etc.



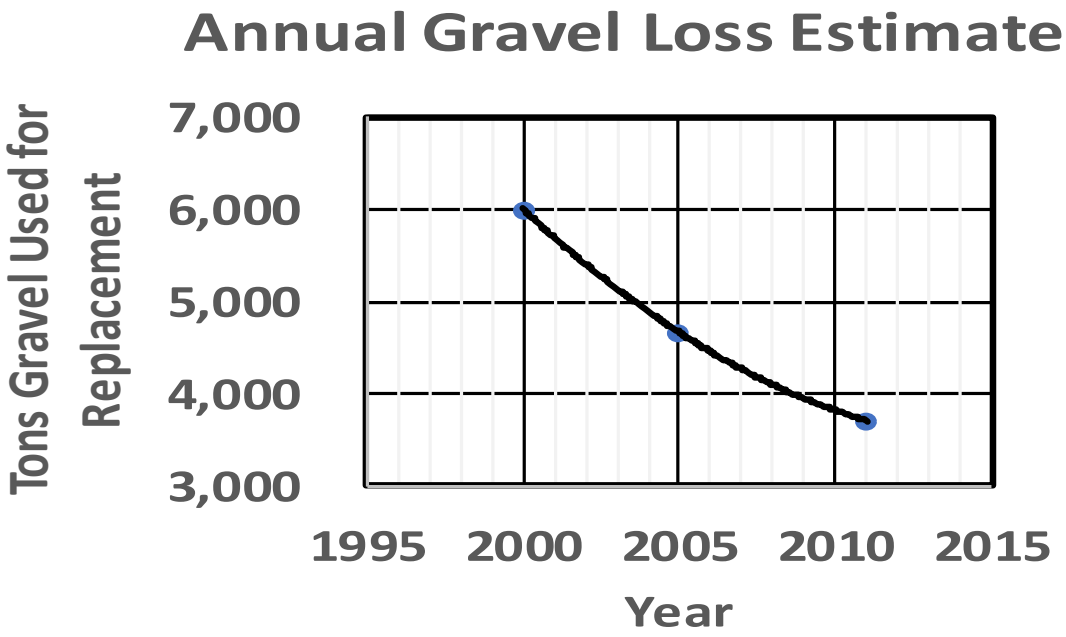
Best Investment → Quality Gravel on High Traffic Roads

ADT = Average Daily Traffic

Which road loose most gravel?



Measuring Benefits

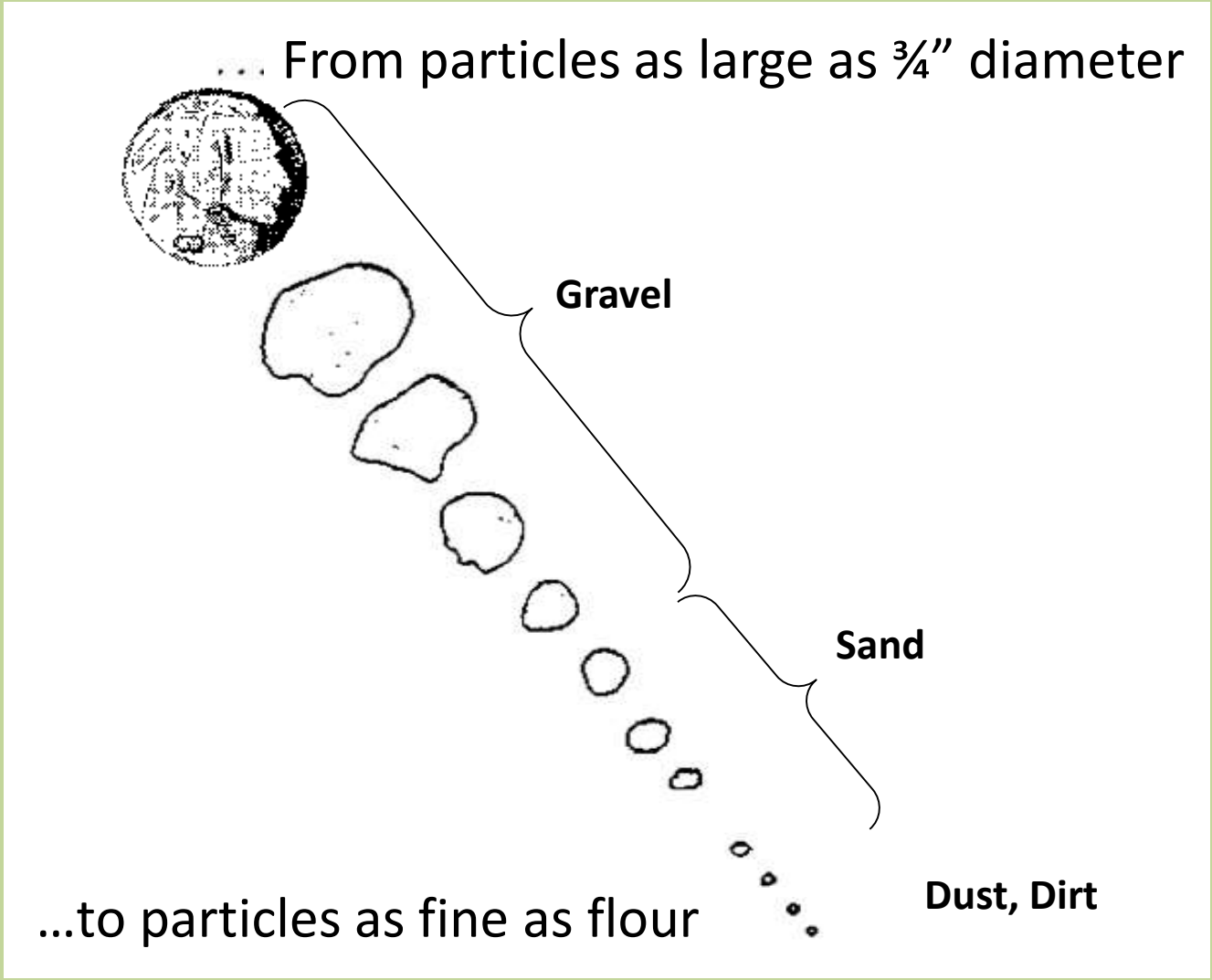


Year of Crushing	Tons Crushed	Tons Used for New Roads	Tons Left in Stockpile Inventory	Tons Used for Gravel Replacement	Years Between Crushing Contracts	Annual Tons Used for Gravel Replacement
2000	50,000	10,000	10,000	30,000		
					5	6,000
2005	50,000	12,000	10,000	28,000		
					6	4,667
2011	50,000	14,000	10,000	26,000		
					7	3,714
2018	50,000	16,000	10,000	24,000		

Gravel Properties & Quality

- Particle Sizes
- Gradation and % Passing
- Gradation Problems
- The “feel” of clay and silt
- Benefits of clay strength

Particle Sizes → Gradation



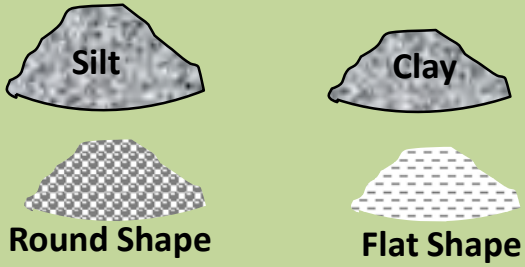
Gravel Specification

- Contains the right amounts of each size (Gradation)
- Has rock fracture for interlock (% Fracture)
- Contains enough clay (Plasticity Index)

Gravel 1” x #4

Sands

Fines (Binder or minus #200, Dust)



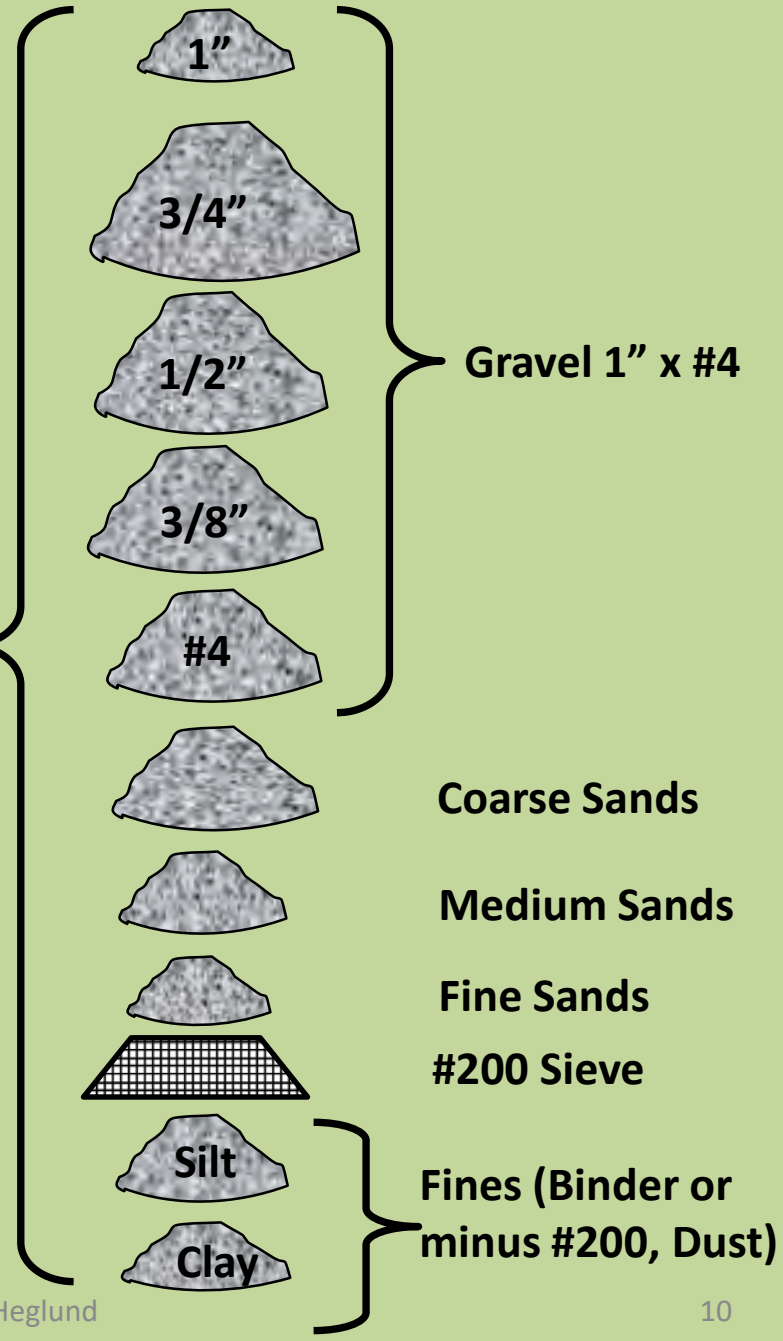
Explain Sieve Sizes

Percent Passing

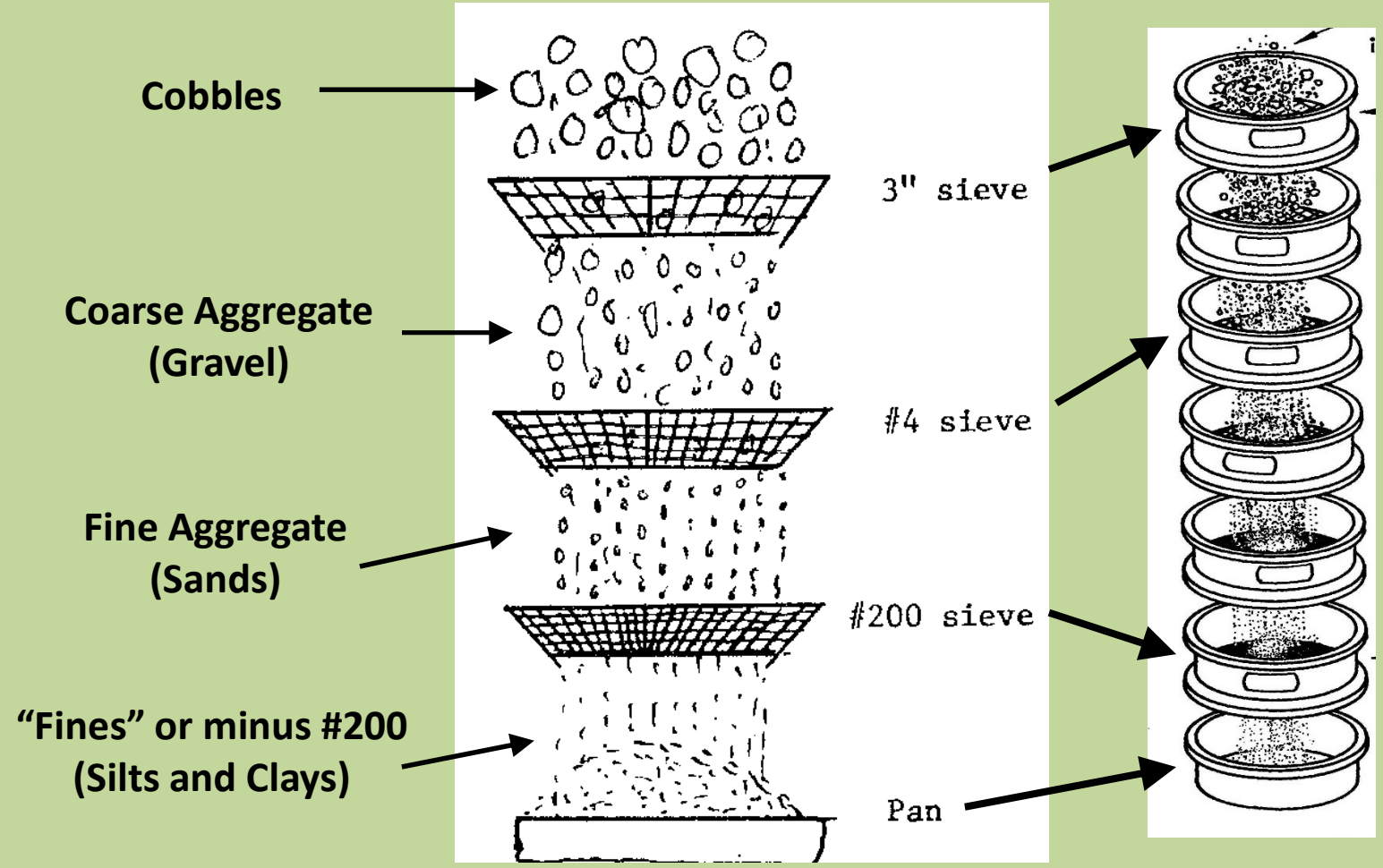
Total Weight Sample = 10 lbs.

Total Weight Passing #200 Sieve = 1#

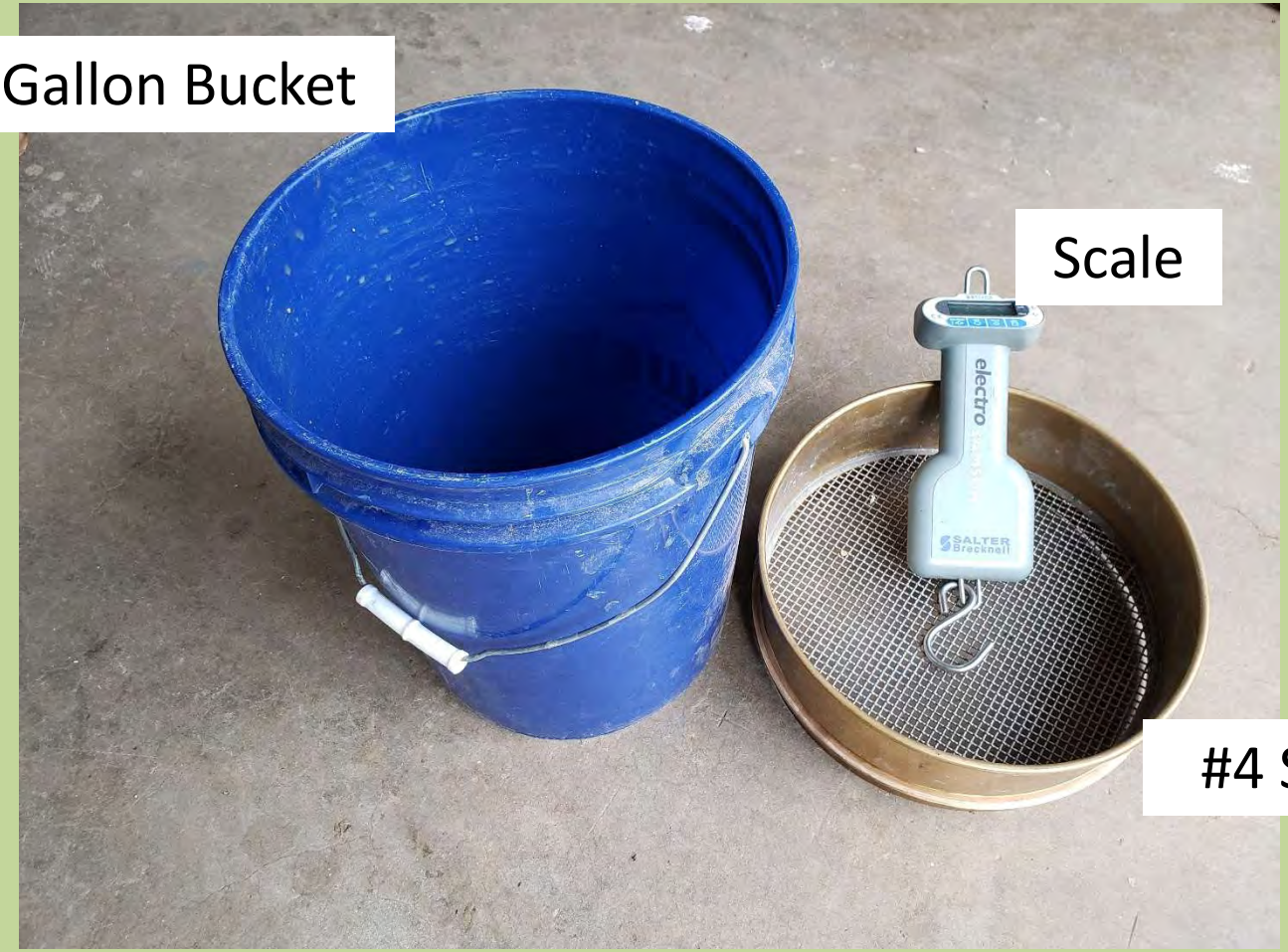
% Pass #200 Sieve 1#/10# → 10%



Lab Gradation Test

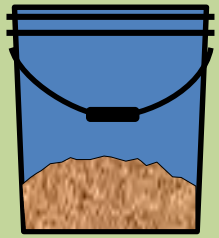


Field Gradation Test Tools



Percent Passing

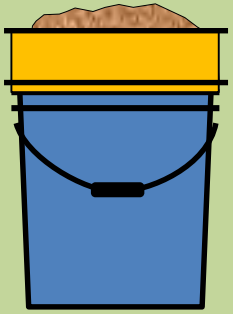
Gravel Sample



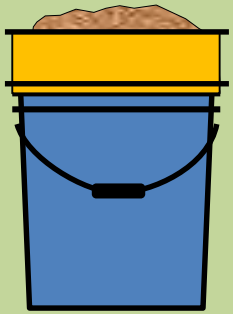
12 lbs

Weigh Gravel and Bucket

Gravel weight = 12 lbs. – 2 lbs. = 10 lbs.



Dump Gravel on #4 sieve



Agitate sieve and bucket

8 lbs

Weigh minus #4 and Bucket

Minus #4 weight = 8 lbs. – 2 lbs. = 6 lbs.

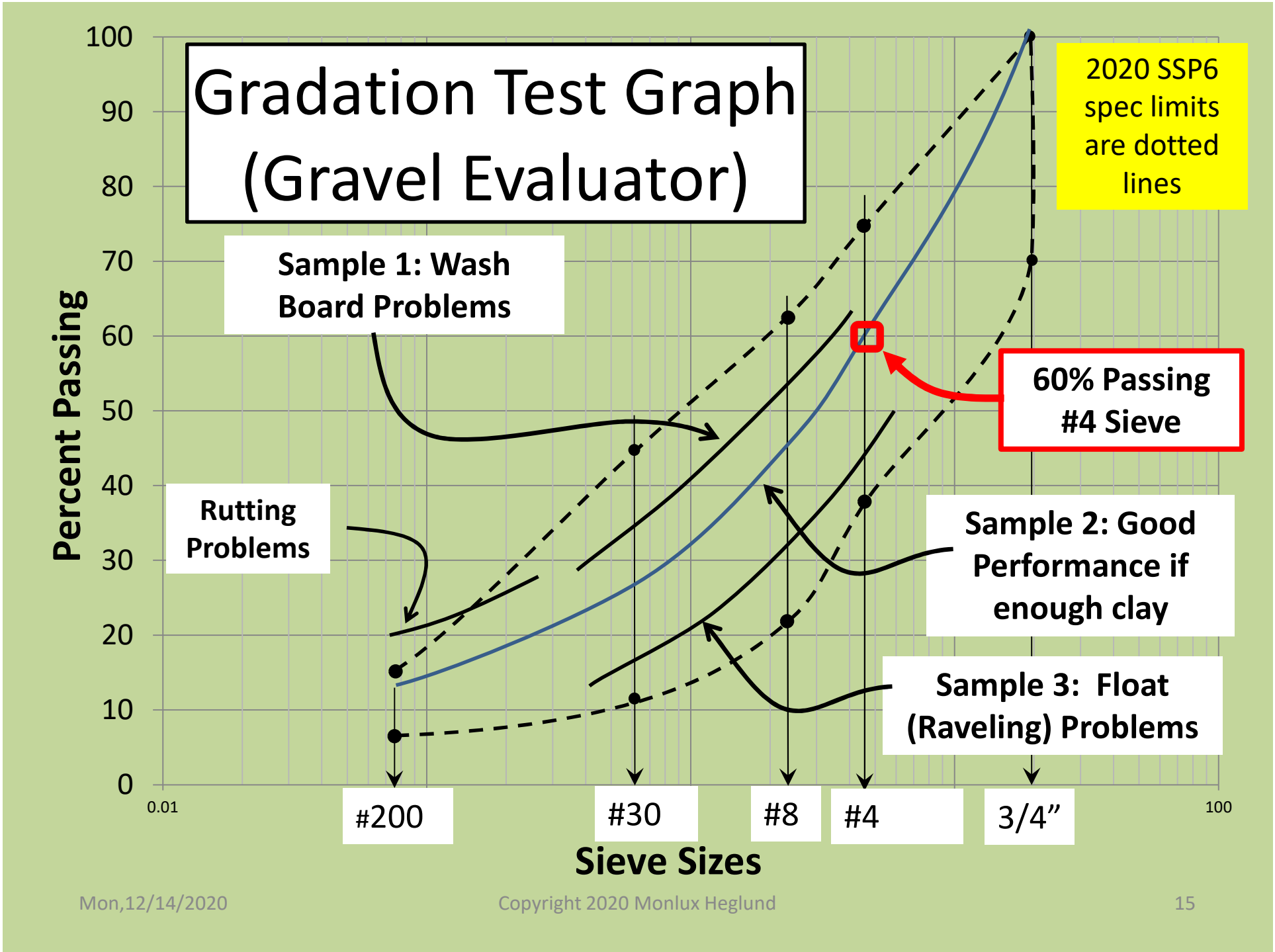
% Pass #4 → 6 lbs./10 lbs. → 60%

Test Result Comparisons

Sieve Size	SSP 6 2020 Spec Limits		Sample 1	Sample 2	Sample 3
	Min	Max			
1"	100	100	100	100	100
3/4"	70	100	100	100	85
No. 4	38	75	66	**60**	44
No. 8	22	62	54	44	33
No. 30	12	45	36	26	16
No. 200	7	15	15	12	7
PI	3	9	6	6	6

All three results are in spec.
Which one will washboard?
Which one will cause float or loose rock/raveling?

Next slide shows simple way to answer these questions



Gradation Rating Exercise

Too Much Rock. Problems?

Good Gravel Surfacing Gradation. Problems?

Too Much Sand. Problems?

Demonstrations to Identify Clay Soil

Pulverize clumps

Add Water, form Ball

Roll Thread

Form Ribbon

Check Dry Strength

Silt and Clay Soil Field Test

- **Silt**
- Hard to roll 1/8” thread, thread falls apart
- Short ribbon
- Dilatancy – Easy to shake out water

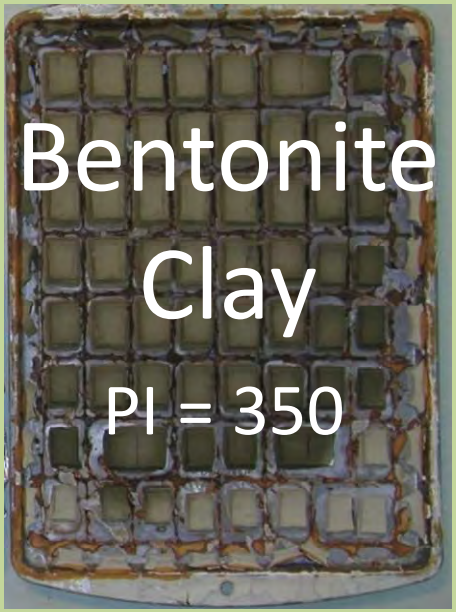
- **Clay**
- Very messy, sticky
- Easy to roll 1/8” thread
- Long ribbon
- Can’t shake out water

Note: When testing in field, coarse sands must be removed

Demonstration: Determine if Pit Run and Overburden Have Clay

- Remove coarse sand
- Add water and try to roll thread
- Sticky mess in hand → Clay
- Note: If you can roll thread with field sample, lab test must show Plasticity Index.

Types of “Binder”: Silt, Lean Clay, Fat Clay



10 lb. silt &
3 lb. water:
30% Moisture

10 lb. clay &
5 lb. water:
50% Moisture

Dry Shrinkage & Expansion

All samples dried at room temperature

Bentonite Sample: drops of water added over 4 hours

Dry Strength Demonstration

- Break dry samples – silt, clay then bentonite
- Higher strength = higher clay content = stronger dry road crust
- Compare dry strengths
  - Silts → no plasticity, very low strength
  - Lean Clay → low plasticity, moderate strength
  - Fat Clay(bentonite) → very high plasticity & strength
- Note: Too much clay causes rutting in Spring season

Question: Has anyone added clay to gravel?

Summary of Primary Points

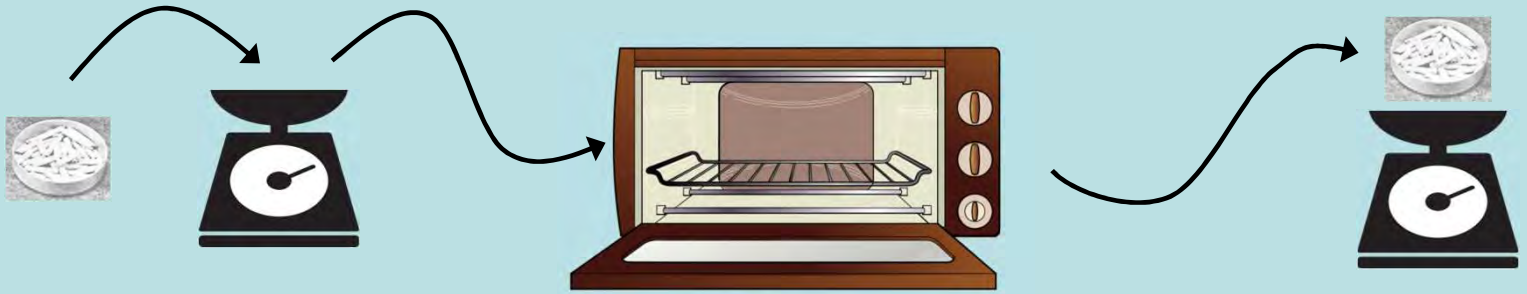
- Correct amount of each particle size reduces loose rock and wash boarding
- Sieve test (% passing) controls amount of each size
- Clay is an essential component in gravel surfacing
- Detecting if clay exists is an easy process

Clay is the Glue -
Lab Testing Fine Materials in Gravel

- Plastic Limit
- Liquid Limit
- Plasticity Index
- Bar Linear Shrinkage

Plastic Limit Expressed as Moisture Content

The plastic limit PL is defined as the water content at which a soil thread with ***1/8" diameter just*** becomes dry enough to crumble.

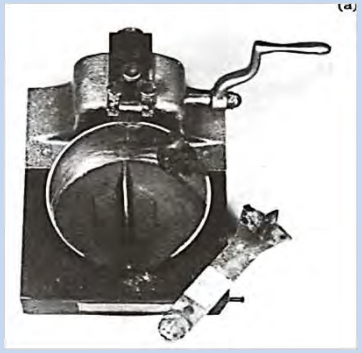


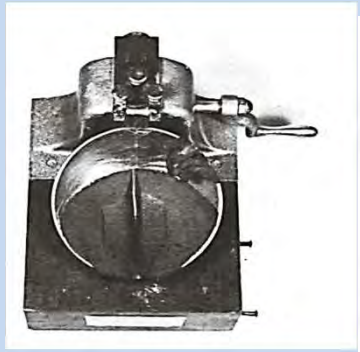
% Moisture = (100) x (weight water)/(dry soil weight)

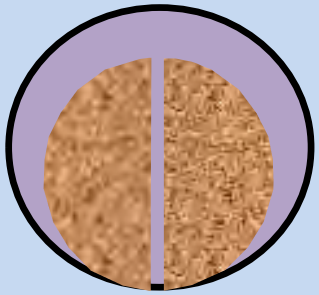
Example:

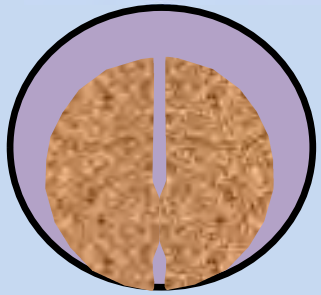
% Moisture = (100) x (10)/(100) = 10%

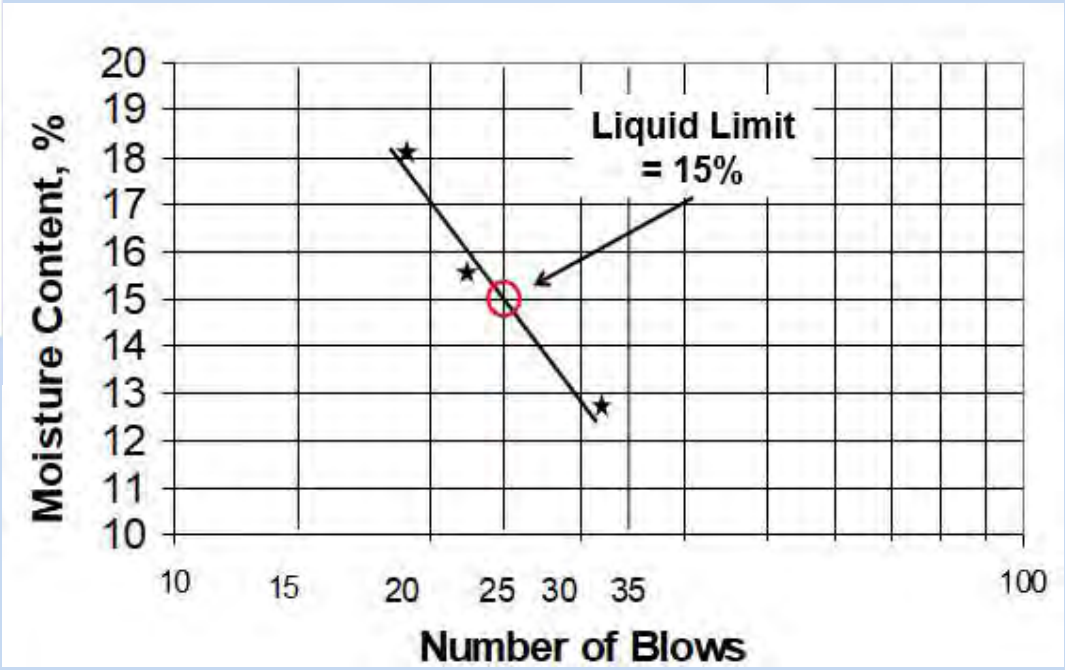
Liquid Limit (LL) & Plasticity Index (PI)











Liquid Limit = % moisture at which groove closes ½ inch after 25 blows

Plasticity Index (PI) = Liquid Limit – Plastic Limit

PI = 15 – 10 = 5

Bar Linear Shrinkage

- Another Test for Clay Content
- Higher shrinkage, greater binding ability
- Test done at liquid limit moisture content
- Simple process (S African test method)
- Bar Linear Shrinkage = % Shrinkage

≈ .49 x PI – 1.2

Minus #40 at LL after molding
10mm x 10 mm x 150 mm
(3/8” x 3/8” x 6” mold shown)

Specimen after drying
for 3 to 12 hours

Understanding Gravel Performance Problems

- Questions
- Factors Affecting Gravel Life
- Types of Problems
- Causes & Solutions
- Improving performance

Questions

What kind of gravel problems do you have?

What causes poor gravel performance?

- How can you reduce the following problems?
- Raveling
- Dusting
- Wash boarding
- Potholes

Primary Factors Affecting Gravel Life (**Gravel Preservation)**

Gravel layers mix with weak subgrade soils

- Drainage: Surface & Subsurface
- Traffic: Speed, Amount & Type
- Road grades and curvature
- Gravel: Gradation, % Fracture, Clay Content, Compaction,
- Maintenance: Blading methods, % crown, dust control, snow removal
- Dust loss from gravel shortens gravel life

Gravel Road Problems & Consequences

Problem	Consequence of Problem		
	Gravel Loss & Budget	Road User Safety, & Public Complaints	Public Health
Dusting	x	x	x
Wash Boarding	x	x	
Raveling	x	x	
Rutting	x	x	
Potholing		x	

Problem and Solution Summary

Problems

- Wash Boarding
- Float (Raveling)
- Dusting
- Gravel Loss

Typical Solutions

Good Gradation

Add Clay – better road crust

Dust Abatement

- Rutting →
- Potholing →

Washboarding

Solutions

Better gradation – less sand

Add clay – better road crust

Note: Rebuild crown and check gravel thickness before adding clay – some gravel is too worn out for this option to work well

Float (Raveling)

Solutions

Better gradation – smaller top size, higher fracture

Add clay – better road crust

Note: Rebuild crown and check gravel thickness before adding clay – some gravel is too worn out for this option to work well.

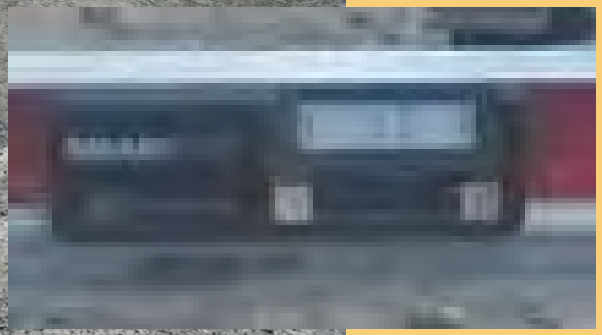
Dusting

Solutions
Chloride treatment
Better gradation
Add clay – better road crust

Note: Rebuild crown and check gravel thickness before adding clay – some gravel is too worn out for this option to work well

Rutting

1.7%
Crown



Solutions
Less clay
Higher crown
Increase gravel thickness

Potholing

Solution
4 to 5% crown

Problem and Solution Summary

Problems

- Wash Boarding
- Float (Raveling)
- Dusting
- Gravel Loss

Typical Solutions

Good Gradation

Add Clay – better road crust

Dust Abatement

- Rutting → Good Gradation, more thickness, higher crown
- Potholing → 4 to 5% Crowns

The Value of Gravel Sampling and Testing

- Contractor quality control (QC) testing
- County quality assurance (QA) testing
- Pay Adjustment

Gravel Sampling and Testing Verifies Quality

- **Contractor** → Quality Control (QC) testing
  - Used for making adjustments to crusher and feed into crusher so specifications are met
  - Some testing may be done on very small samples or "shortcut" methods used to get quick and timely results
- **County/Engineer** → Quality Assurance (QA) testing ensures that:
  - Contract requirements are met
  - Gravel performance life is as expected
- QA testing costs may appear high ($0.30 to $0.40 per ton)
  - Costs seldom exceed 2% of crushing costs
  - 2% is cheap insurance if out-of-spec gravel life is 10% shorter

Engineers Quality Assurance (QA) Gravel Sampling (ND 302 & T2)

- ND 302 & T2 Requirements for sampling
  - Sample Containers: AASHTO T2 → containers that prohibit loss of material
  - Sample Timing: Statistically Random (Pg. 404 in 2019 ND S&T Manual)
  - Sample Frequency (Per 2020 SSP6)
    - Gradation: 3/day or 3/1000 tons
    - Plasticity: 1/5000 tons
    - Shale and % Fracture: 1/10,000
  - Sample Location: Normally flowing stream for crushing but can be stopped belt, stockpile, windrow or truck box
  - Sample Size: For SSP6 gradation, 69 lb. min (44 lb. + 25 lb.) per Pg. 257 in 2019 ND S&T Manual
- Sampling is just as important as testing
- Sampling Bias Examples
  - Unintended Bias – not following accepted sampling practices, using ones that you have used for years.
  - Intended Bias – sampling only when gradation looks good

Quality Assurance (QA) Testing

(Section 302 of 2019 Field Sampling and Testing Manual)

- Testing is done at a consultant lab
- Sample splitting: ND T248, mechanical splitter or quartering
- Gradation: ND T 11 and T 27
- Plasticity Index: ND T 90
- % Fracture: NDDOT4 (coarse aggregate)
- % Shale: ND T 113

Acceptance and Pay Adjustments

Example Contract Price Adjustment for Gravel Surfacing (2020 Spec SSP 6, Section 302.06 B)

Bid Price/Ton, $: 10

	Gradation (SSP6 Sec B.1.)					
Sieve	1"	3/4"	No. 4	No. 8	No. 30	No. 200
Upper Limit	100	100	75	62	45	15
Lower Limit		70	38	22	12	7

Plasticity Index (SSP6 Sec B.2.)	Misc. Properties (SSP6 Sec B.3.)
9	Shale: 12% Max
3	%FF: 10% Min

Date	Sample #	Tons	Gradation Test Results						Gradation Price Adjust	Plasticity Test & Price Adjustment		Misc. Properties Tests & Price Adjust.		Remarks
10,1,20	1	405	100	73	42	18	15	7.1	Gradation Lot 1		Plasticity Index Lot 1: 5000 Tons		Miscellaneous Properties Lot 1: 10,000 Tons	
	2	775	100	85	50	22	18	9.4		4				
	3	1125	100	70	38	19	14	7.6						
Average Test Result			100	76	43	20	16	8.0						Contractor thinks there are dirtier areas of the pit that he can crush
Deviation from spec						2								
Sum of Deviations (A):								2						
Percent Deduction = 5 x (Sum of Deviations, A):								10.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$1,125					
10,2,20	4	1520	100	74	44	20	17	9.2	Gradation Lot 2					Dirty areas of the pit didn't help, contractor indicates he will search for overburden buried during earlier pit reclamation
	5	2020	100	83	48	22	14	7.5						
	6	2520	100	71	29	20	15	8.1		1				
Average Test Result			100	76	40	21	15	8.3						
Deviation from spec						1								
Sum of Deviations (A):								1						
Percent Deduction = 5 x (Sum of Deviations, A):								5.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$698					
10,3,20	7	2820	100	72	40	22	17	9.4	Gradation Lot 3					Avg PI = 2 for 5000 ton lot, Pay Adj Factor = 0.85. Pay Adjustment = .15 x 5000 x $10 = $7500
	8	3450	100	80	44	22	13	6.5						
	9	3920	100	72	29	21	16	8.6		2				
Average Test Result			100	75	38	22	15	8.2						
Deviation from spec														
Sum of Deviations (A):								0						Contractor plans to import 10% overburden containing clay
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0		$7,500			

Acceptance and Pay Adjustments (Pg. 2)

Example Contract Price Adjustment for Gravel Surfacing (2020 Spec SSP 6, Section 302.06 B)

Bid Price/Ton, $: 10

	Gradation (SSP6 Sec B.1.)					
Sieve	1"	3/4"	No. 4	No. 8	No. 30	No. 200
Upper Limit	100	100	75	62	45	15
Lower Limit		70	38	22	12	7

Plasticity Index (SSP6 Sec B.2.)	Misc. Properties (SSP6 Sec B.3.)
9	Shale: 12% Max
3	%FF: 10% Min

Date	Sample #	Tons	Gradation Test Results						Gradation Price Adjust	Plasticity Test & Price Adjustment		Misc. Properties Tests & Price Adjust.		Remarks
10,5,20	10	4450	100	71	41	24	20	11.5	Gradation Lot 4		Plasticity Index Lot 2: 5000 Tons			Contractor indicates imported overburden has PI of 20 and P200 of 60%
	11	5020	100	79	47	27	22	14.8						
	12	5620	100	73	35	25	21	12.4		8		6.5%	(Shale)	
Average Test Result			100	74	41	25	21	12.9				18%	(% Fracture	
Deviation from spec														
Sum of Deviations (A):								0					Miscellaneous Properties Lot 1:	
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					
10,6,20	13	6320	100	69	43	27	22	10.5	Gradation Lot 5					
	14	6950	100	81	51	29	22	13.7						
	15	7780	100	74	36	25	23	11.7		7				
Average Test Result			100	75	43	27	22	12.0						
Deviation from spec														
Sum of Deviations (A):								0						
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					
10,7,20	16	8570	100	71	41	24	20	11.5	Gradation Lot 6					**Plasticity Lot 2** Average = 8.7 --> no deduct
	17	9290	100	79	47	27	22	14.8						
	18	9950	100	73	35	25	21	12.4		11				**Shale Lot 1** Average = 6.5 --> no deduct
Average Test Result			100	74	41	25	21	12.9						
Deviation from spec														
Sum of Deviations (A):								0						
Percent Deduction = 5 x (Sum of Deviations, A):								0.0%						
Deduct = (tons in lot) x (bid price) x (Percent Deduction, B):									$0					

10,000 Ton Pay Adjustment Summary		
Test	Deduction	%
Gradation	$1,823	1.8%
PI	$7,500	7.5%
Shale	0	0.0%
%Fracture	0	0.0%
LA Abrasion	not applicable	
Total:	**$9,323**	

Testing Costs for 10.000 Tons Gravel (1)			
# Tests	$/test	Total $	% of Co
18	$136	$2,448	2.45%
6	$110	$660	0.66%
3	$75	$225	0.23%
3	$95	$285	0.29%
0	$250	$0	0.00%
		$3,618	3.62%

(1) Testing costs from a North Dakota Consulting Lab

Deductions: 1.8% for Gradation & 7.5% for PI

Testing cost is $0.36/Ton

Best Practices for Gravel Sampling, Testing and Acceptance

- Gravel Spec Limits
- Sampling
- Testing
- Acceptance
- Payment
- Reference: Google: “Guide Spec for Gravel Surfacing

Best Practices for Gravel Spec Limits

- Start with State DOT Base Course gradation, add PI and double minus #200
- Investigate sources to determine if modified DOT spec is realistic
- Adjust gradation and PI requirements to fit local pits
- Make a single document as opposed to extensive cross referencing in DOT specs
- Provide options for adding clay
- Get feedback from crushing contractors and consultant labs on the modified DOT spec and approximate costs for crushing and lab testing

Best Practices for Sampling

- Take bucket load samples every two hours to form a miniature stockpile
- Take a composite sample at the end of each day
- Split sample for contractor and engineer testing

Best Practices for Testing

- Test one composite sample each day for acceptance
- Require contractor to test a split of the composite sample

Best Practices for Acceptance

- Base acceptance on average of all daily test results
- Utilize a simple pay adjustment system to avoid disputes and improve gravel quality
- Include a bonus payment as well as reductions

Best Practices for Quantity Measurement & Payment

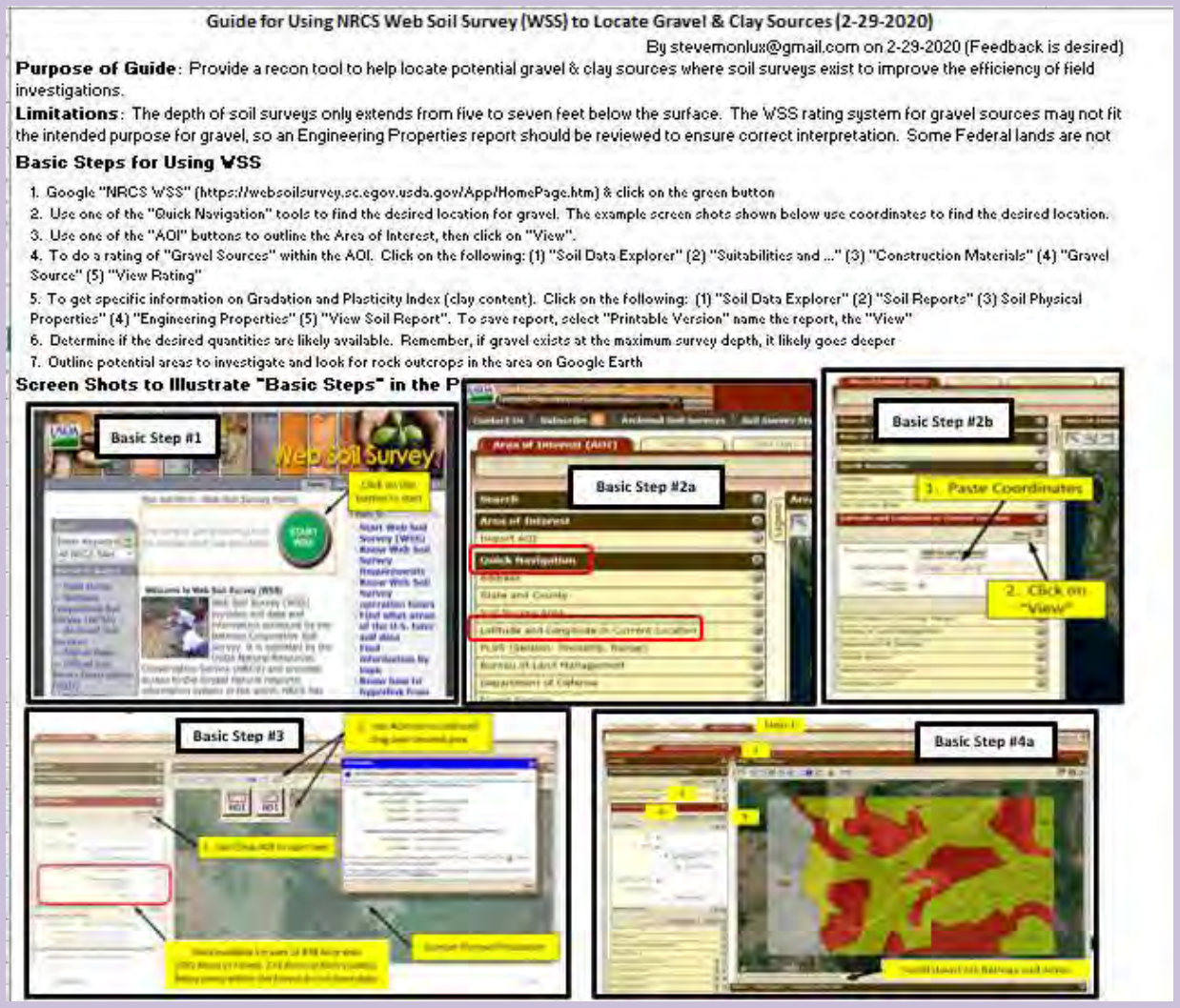
- Use cubic yards for payment to simplify verification
- Measure stockpiles with drone
- Allow payment based on cubic yards stockpiled between 95 and 105% of the “target” quantity

Ways to Lower Gravel Cost

- Crushing Contract Options
  - Higher quantity will lower $/CY
  - Two year contract
  - Stockpiling
  - Visible high walls in pit
- Spec Options
  - Daily acceptance sample testing
  - Final acceptance on average gradation
  - Allow payment for quantity between 95 and 105% of “target” quantity
  - Simple Pay Adjustment system with bonus
- Contract Pit Plan
  - Include test results from previous contract
  - Provide the following for each test hole (**NRCS Web Soil Survey**):
    - Depths of topsoil, overburden and water table
    - **Gradation, PI & % moisture of pit run gravel and overburden**
  - **Realistic spec limits**
  - **Critical crushing contract clauses**

NRCS WSS Guide (Pg.1)

- Remote Recon
- Locate Gravel and Clay Deposits



Guide for Using NRCS Web Soil Survey (WSS) to Locate Gravel & Clay Sources (2-29-2020)

By stevemonlux@gmail.com on 2-29-2020 (Feedback is desired)

Purpose of Guide: Provide a recon tool to help locate potential gravel & clay sources where soil surveys exist to improve the efficiency of field investigations.

Limitations: The depth of soil surveys only extends from five to seven feet below the surface. The WSS rating system for gravel sources may not fit the intended purpose for gravel, so an Engineering Properties report should be reviewed to ensure correct interpretation. Some Federal lands are not

Basic Steps for Using WSS

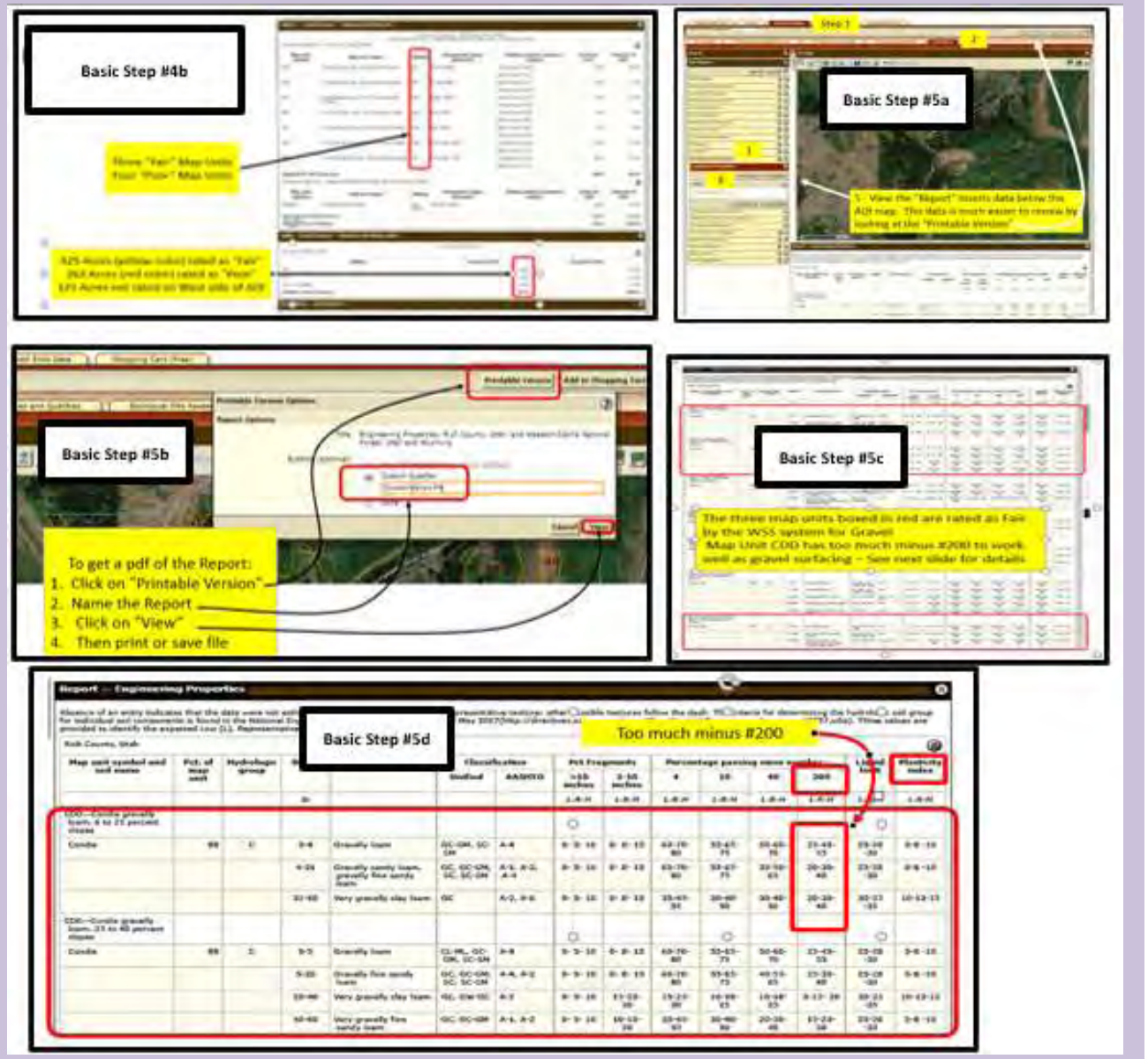
1. Google "NRCS WSS" (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) & click on the green button
2. Use one of the "Quick Navigation" tools to find the desired location for gravel. The example screen shots shown below use coordinates to find the desired location.
3. Use one of the "AOI" buttons to outline the Area of Interest, then click on "View".
4. To do a rating of "Gravel Sources" within the AOI. Click on the following: (1) "Soil Data Explorer" (2) "Suitabilities and ..." (3) "Construction Materials" (4) "Gravel Source" (5) "View Rating"
5. To get specific information on Gradation and Plasticity Index (clay content). Click on the following: (1) "Soil Data Explorer" (2) "Soil Reports" (3) Soil Physical Properties" (4) "Engineering Properties" (5) "View Soil Report". To save report, select "Printable Version" name the report, the "View"
6. Determine if the desired quantities are likely available. Remember, if gravel exists at the maximum survey depth, it likely goes deeper
7. Outline potential areas to investigate and look for rock outcrops in the area on Google Earth

Screen Shots to Illustrate "Basic Steps" in the P

NRCS WSS Guide (Pg. 2)

Gravel & Overburden Data

- Layer Depths
- Gradation
- Plasticity Index



This info by itself will reduce bids – PUT IN CONTRACT!

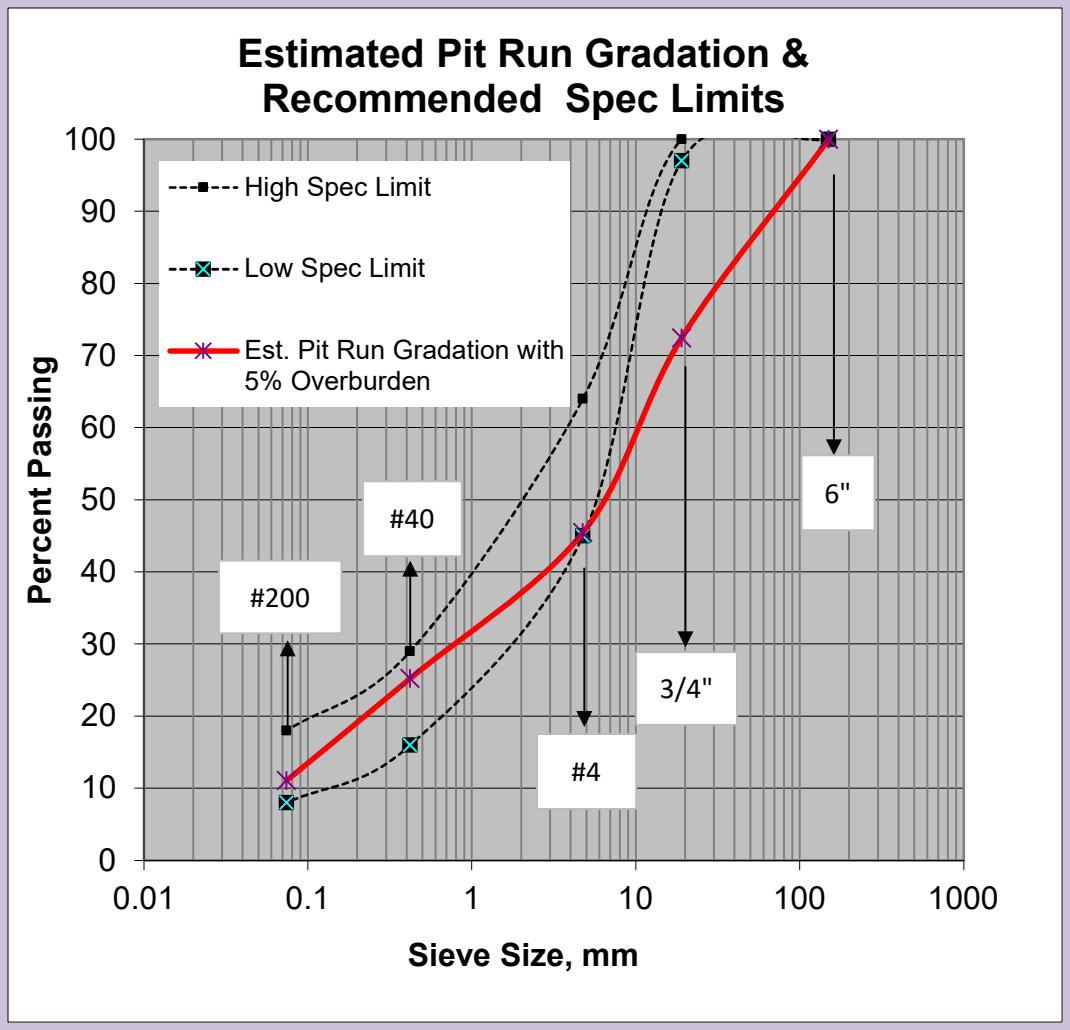
Pit Run and Overburden Gradation

- Reference: “Gravel Source Investigation Guide (3-9-2020)”
- Take a representative sample of overburden in one gallon zip lock bag
- Pick a representative part of the pit run rock sample windrow to sample
- Put cobbles (3” to 12”)in oversize bucket and weigh
- Use ¾” or 1” sieve (12” diameter) and 5 gallon bucket to separate large rock – weigh large rock
- Place sieved gravel in sample sack and weigh
- Lab test overburden and gravel sample for gradation, PI and moisture content.
- Use field weights and lab gradation to determine pit run gradations (see Guide)

Realistic Spec Limits for Clean Gravel Source with Overburden

General Points

1. When crushing, % pass #40 & #200 will increase only several percent
2. Determine amount of overburden or other source of fines to bring #40 and #200 into spec
3. Select realistic #4 limits – 45 to 65 % range is ideal
4. Max size of ¾" or 1" will help reduce raveling (float) and increase fracture
5. Use "Investigation Guide" to estimate PI range



Critical Crushing Contract Clauses

- **Pit Run Test Result Accuracy:** "It is not feasible to ascertain from samples the quality of material for an entire deposit, and variations may be expected. The quality of material in the provided pit is acceptable in general, but may contain layers or pockets of unacceptable materials."
- **Gravel Pit Utilization & Crushing Requirements:** "The Contractor may have to selectively utilize materials from different areas of the source, blend, sort, reject, rescreen or import materials (clay, sand, etc.), **reduce production rates** as well as use special crushing, screening, excavation and other types of equipment to meet specifications. No additional compensation will be given for these efforts."

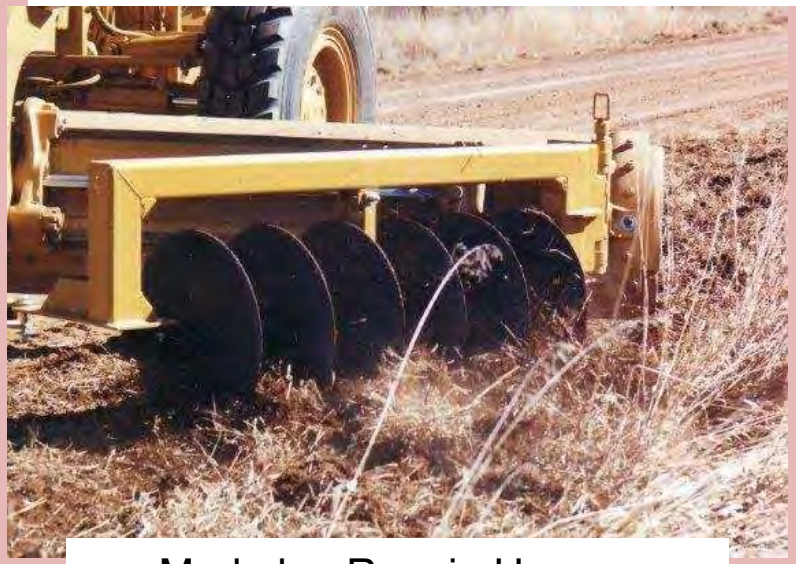
Best Blading Practices for Gravel Preservation

- Adding “fines” from shoulder
- 4 to 5% crown
- Building a road surface crust on compacted gravel

Adding Shoulder Fines can Preserve Gravel

- Adding small amounts of shoulder or ditch line fines to reduce wash boarding and raveling will preserve gravel
- Adding too much fines actually wastes gravel by causing it to rut just like the subgrade when it gets wet.

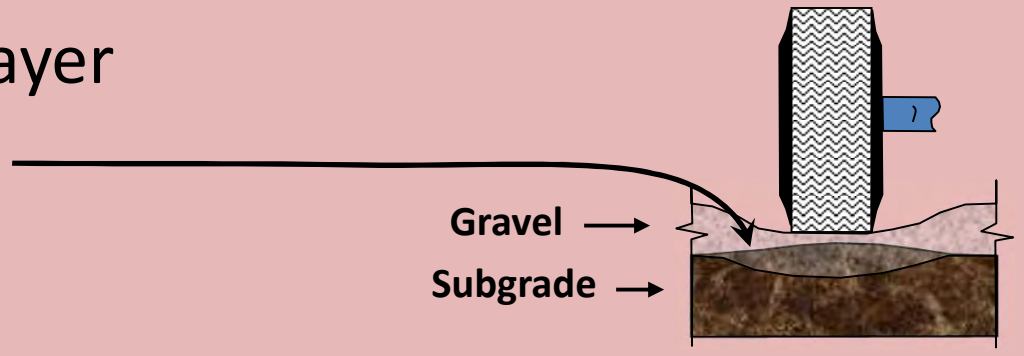
Shoulder Disc for mulching shoulder vegetation, recovering gravel, adding fines



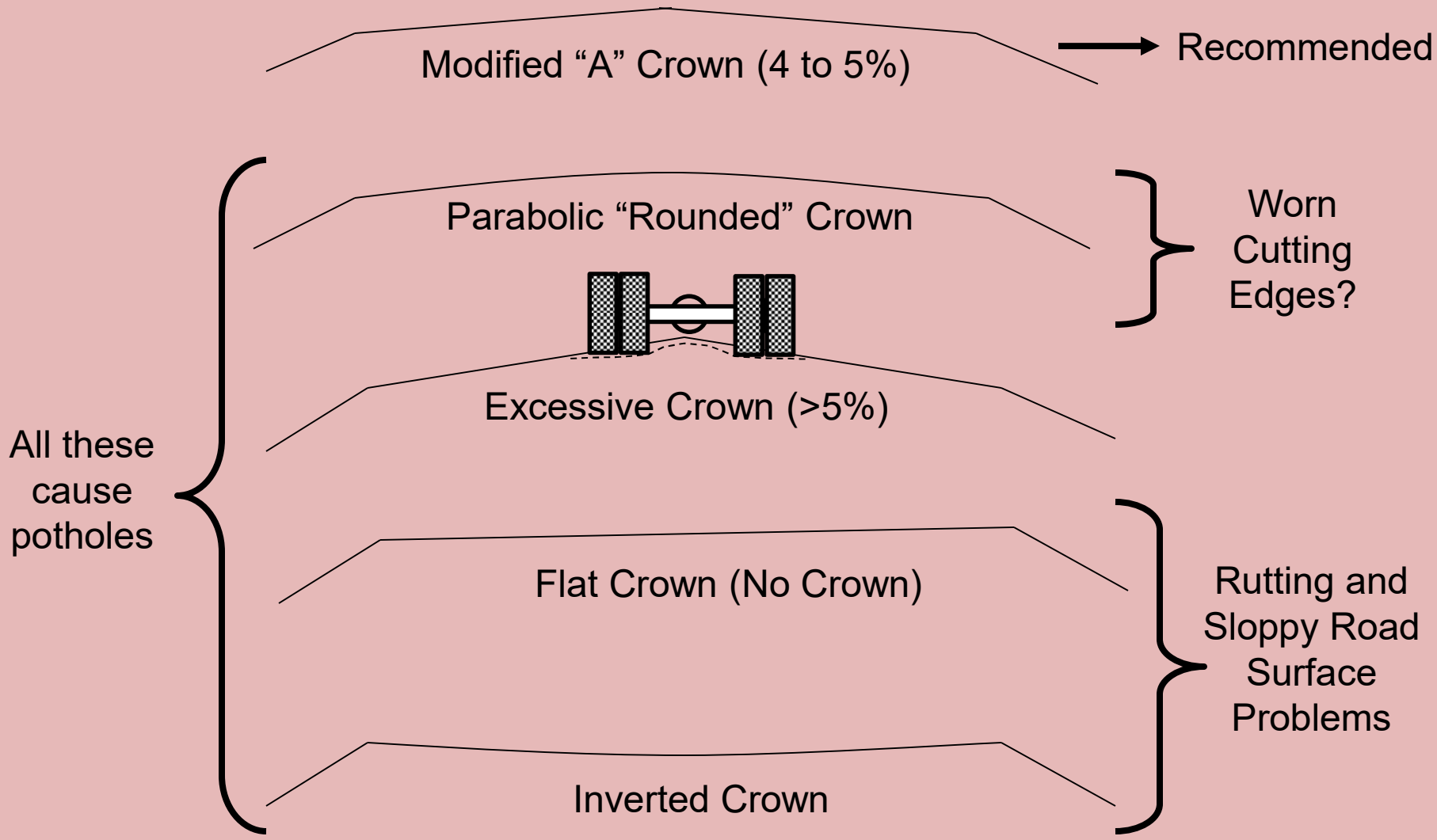
Made by: Ronnie Harvey, Broadus MT, 406-356-4314

Proper Crown Preserves Gravel

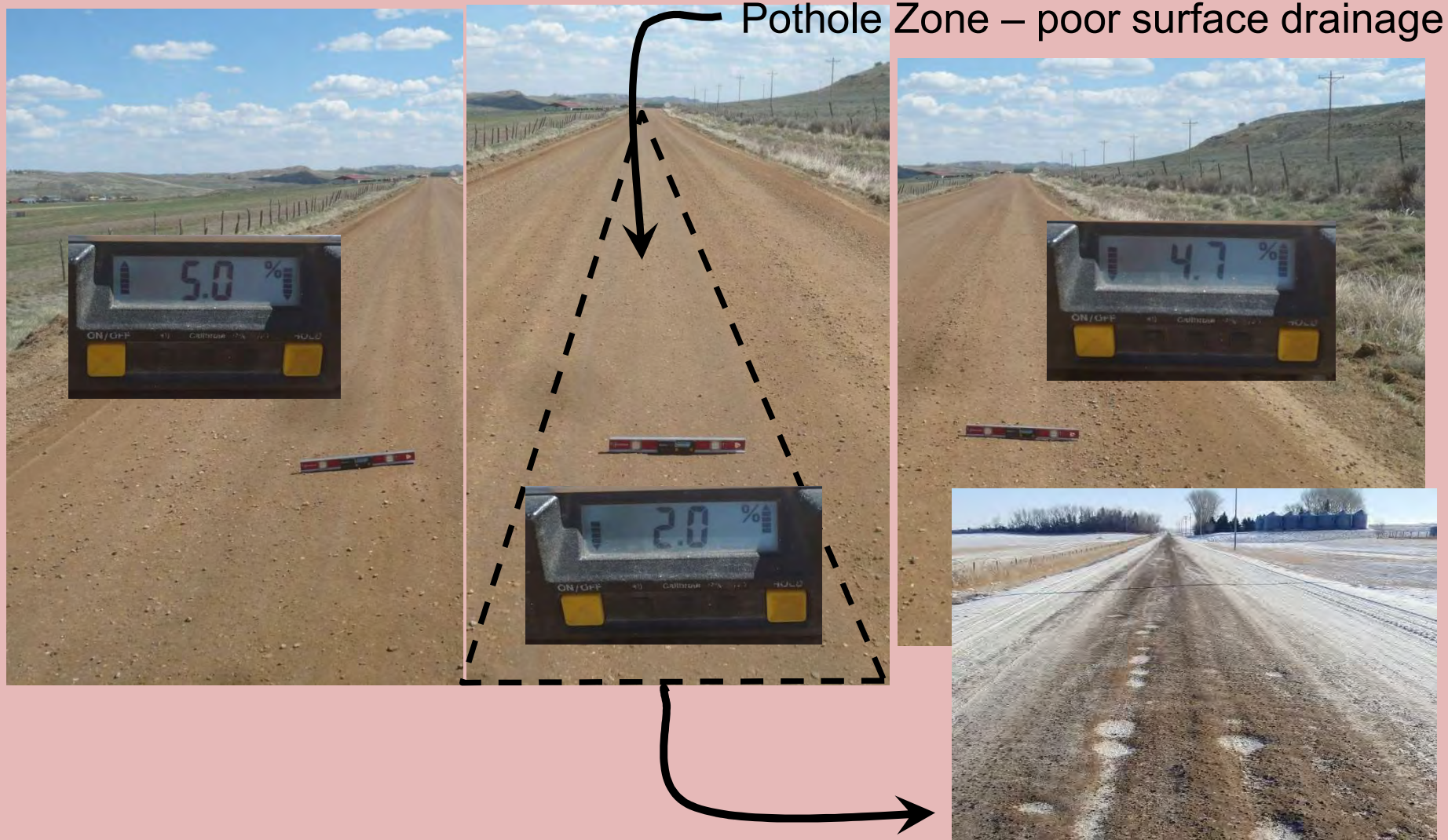
- Crown sheds water & keeps subgrade soils drier
- Dryer subgrade soils are stronger
  - Reduces gravel layer thickness
  - Reduces gravel layer contamination



Types of Road Crowns



Finish Blading with Worn Edges



Rutting & Crown

1.4%
1.7%
2.1%
3.0%
4.0%
4.0%

Higher Crown Benefits

- Reduces pothole formation
- Reduces blading
- Lowers traffic speed which reduces accidents, lowers gravel loss rate
- Lowers complaints (potholes, washboards, loose rock)

Lower Crown Benefits

- Safer on steeper grades
- Safer on road segments that should have guardrail
- Lowers complaints about high crown, but increases complaints about potholes, washboards and loose rock

Blading Practices that Improve Crown Life

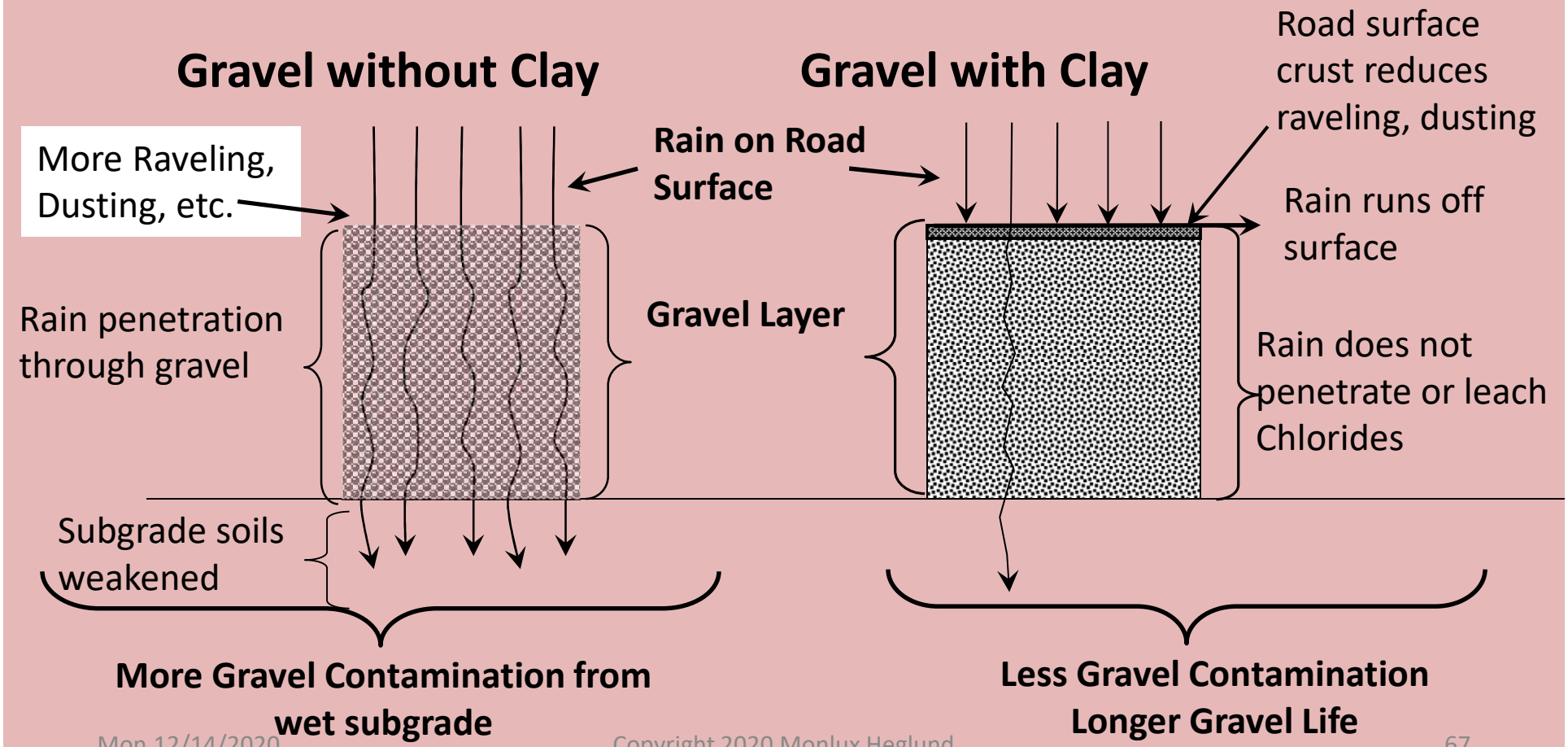
- High gravel moisture and maximum compaction during blading
- Articulate blade frame to compact crown at centerline
- Build 4.5% crowns – trim to 4% after traffic compaction
- Install manual crown meter (Slope Meter Model 2)
- Use some form of carbide or hardened proprietary cutting edges

Road Crust Building Preserves Gravel

- Building a road crust preserves gravel by:
  - Reducing pothole formation, dust, washboards, etc.
  - Reducing need for blading
  - Makes expensive chloride treatments last longer by sealing out water
- **Note:** Gravel must contain clay to build a road crust that sheds water.

Clay Road Crust

- Clay fills voids in gravel, forms road crust, sheds rain, retains chloride, etc.
- Chloride increases clay life by reducing dust



Road Crust Rebuilding Process

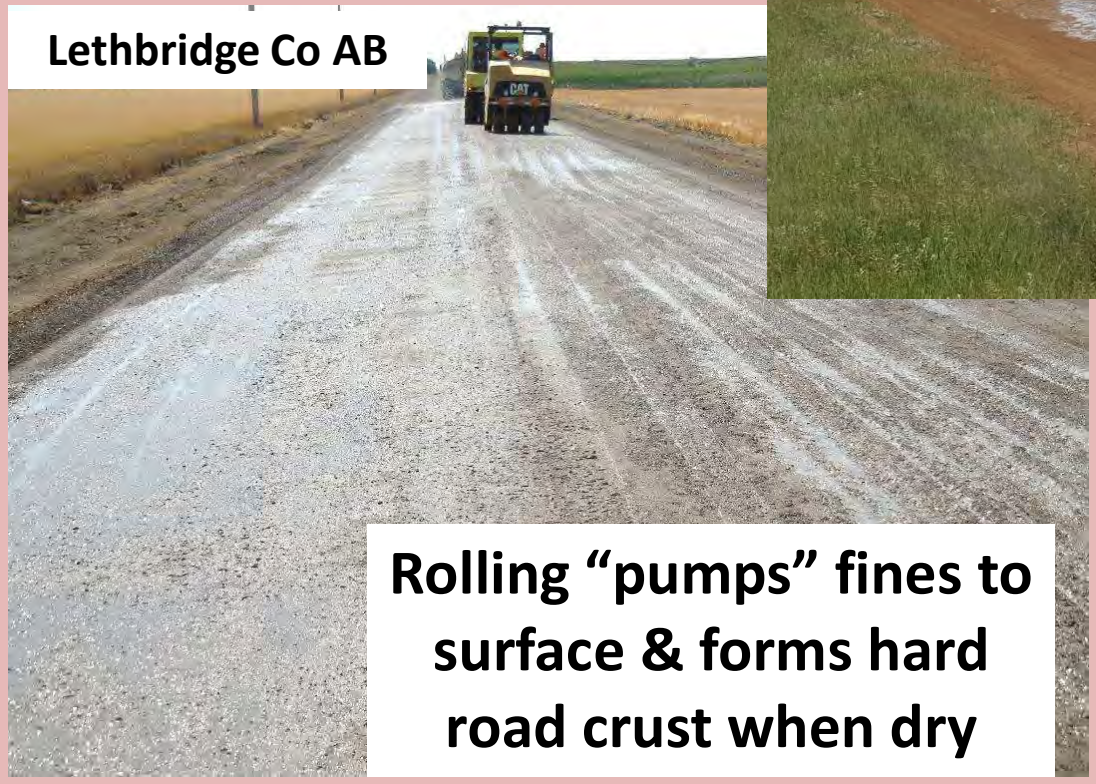
- High Moisture - after rains if possible
- Cut out defects, mix gravel, rebuild 4% crown
- Lightly water if not wet enough to compact
- Compact entire surface
- After compaction is complete,
  - Lightly water surface,
  - Increase roller speed to pump fines to the surface.

Building a Good Road Crust after Compaction

Wet road surface full width – try to limit runoff on shoulders

Stark Co ND

Lethbridge Co AB



Rolling "pumps" fines to surface & forms hard road crust when dry

Road Crust

Compacted Gravel

Water Application helps form Road Crust

Good Road Crust

West Tensleep Road
Bighorn NF, Wyoming - 2006

Summary of Primary Points

- Road Shoulder fines can reduce wash boards and float – add small amounts
- Experiment with higher crowns to see benefits
- Try building a road crust with your gravels to reduce blading

Construction Methods for Adding Clay to Gravel

- Adding Clay While **Crushing Gravel**
- Adding Clay to **Stockpiled Gravel**
- Adding Clay to **In-Place Gravel** on the road
  - **Bentonite Clay slurry spreading by water truck**
  - **Belly dump spreading clay/gravel mixture**
  - **Spreading processed dry bentonite**
  - **In-place mixing dry bentonite and gravel**
  - **In-place mixing gravel with road shoulder and subgrade soils**

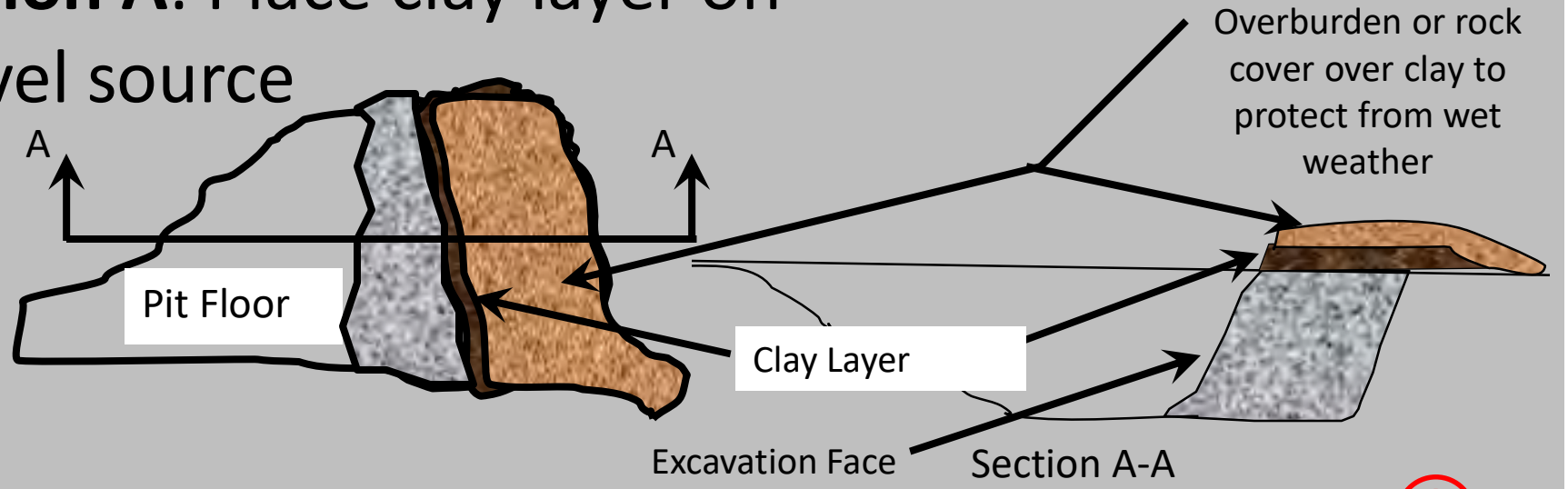
Adding Overburden While Crushing

Campbell County WY

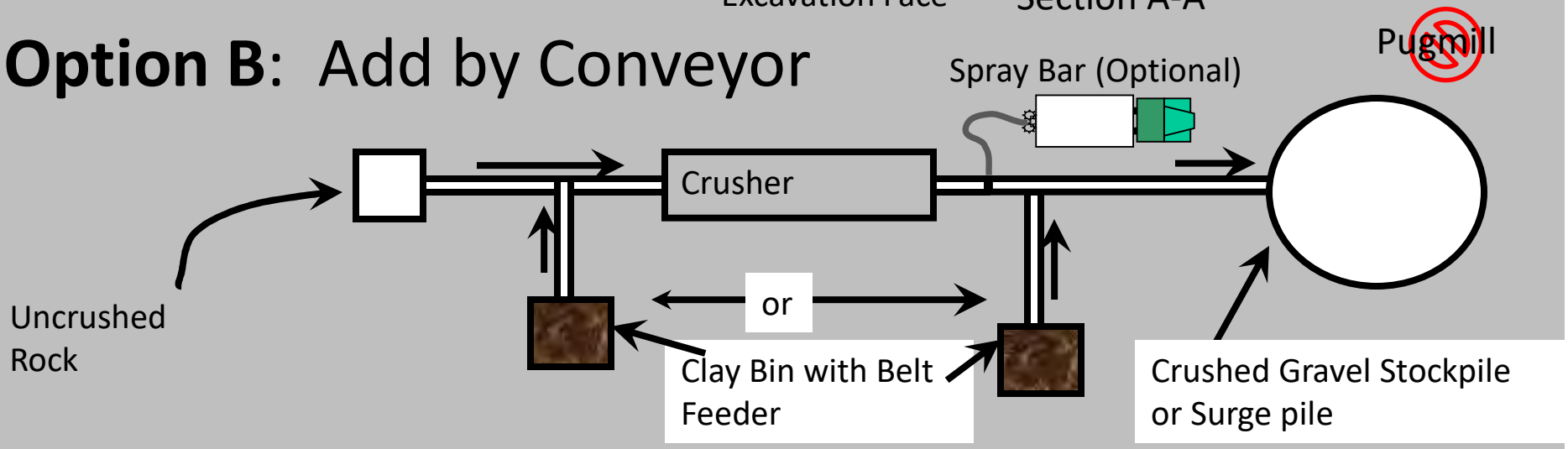
Spreading Reject Fines on Top of Gravel Source

Adding Clay Borrow During Crushing

Option A: Place clay layer on gravel source



Option B: Add by Conveyor



Bin Feeder Components

Variable speed feed belt

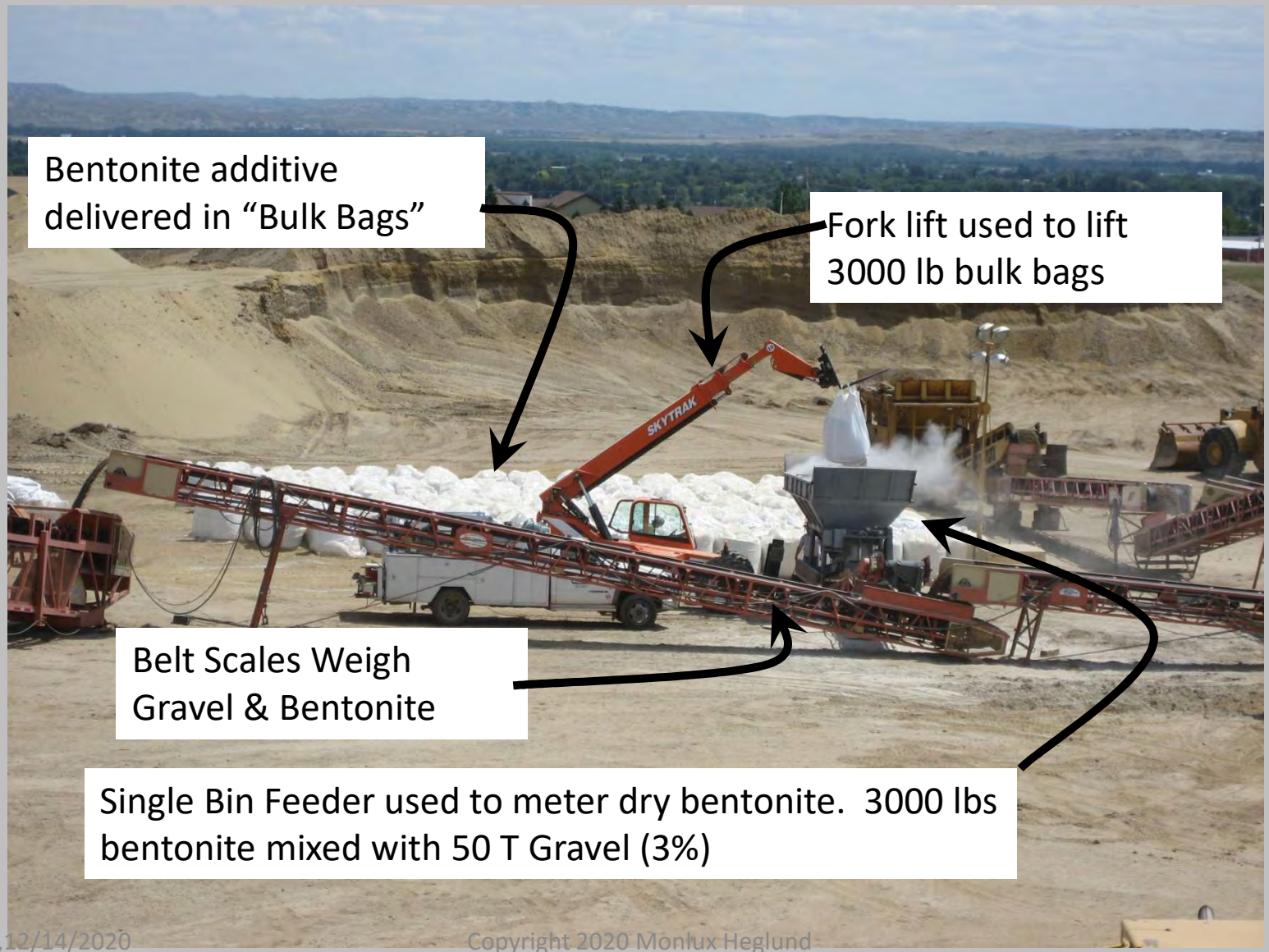
Adjustable gate

Bin Feeder Problem/Solution

Solution: Premix some crushed gravel with clay

Problem: Clay Additive feed is not as uniform as desired

Adding Bentonite with Bin Feeder



Using a Silo to Add Powdered Bentonite While Crushing

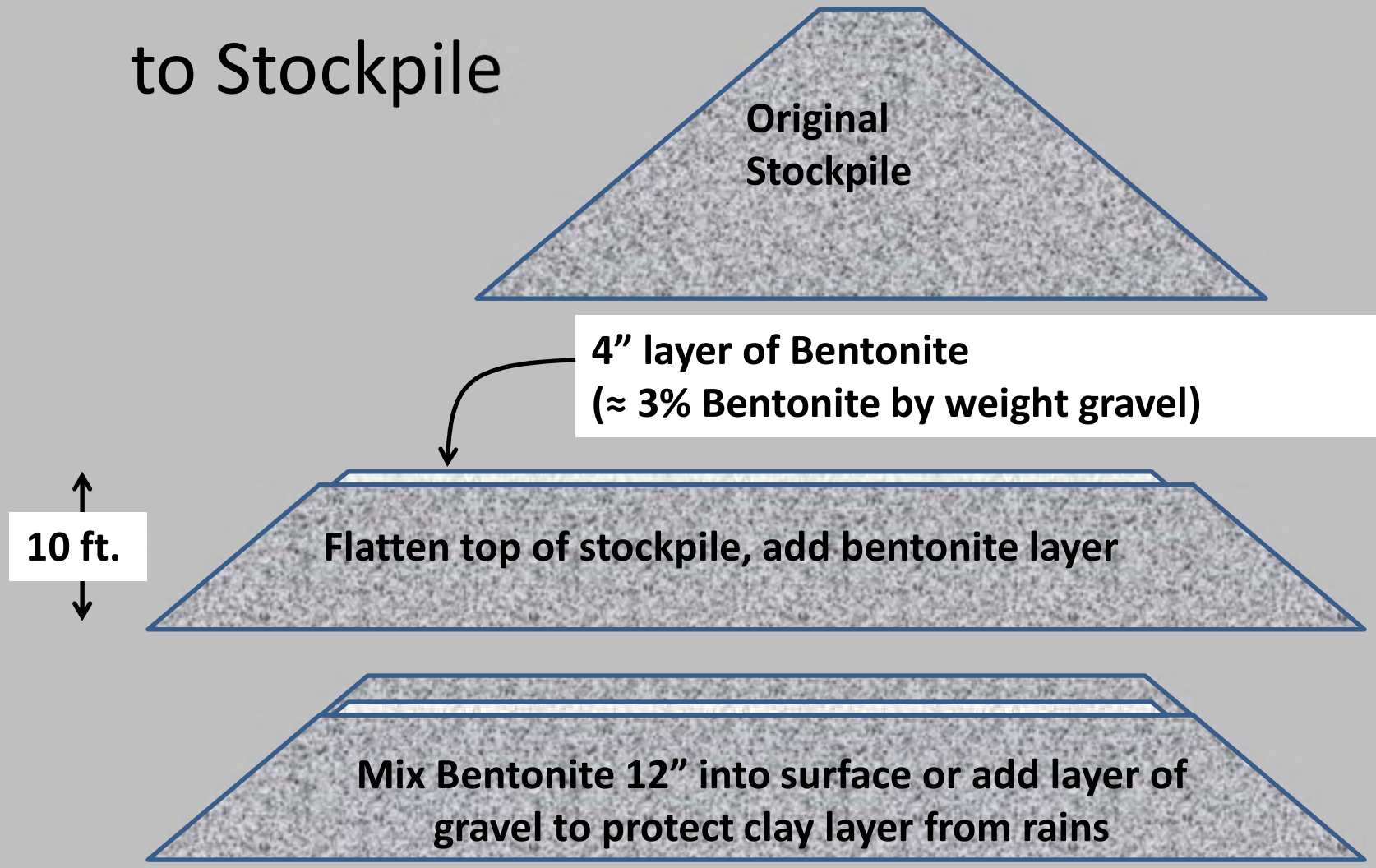
Payette NF, 2010

For stockpiled gravel, note that

(1) Precise dosing accuracy of bentonite with a vane feeder is not necessary and,

(2) Using bulk bags & a bin feeder is usually cheaper

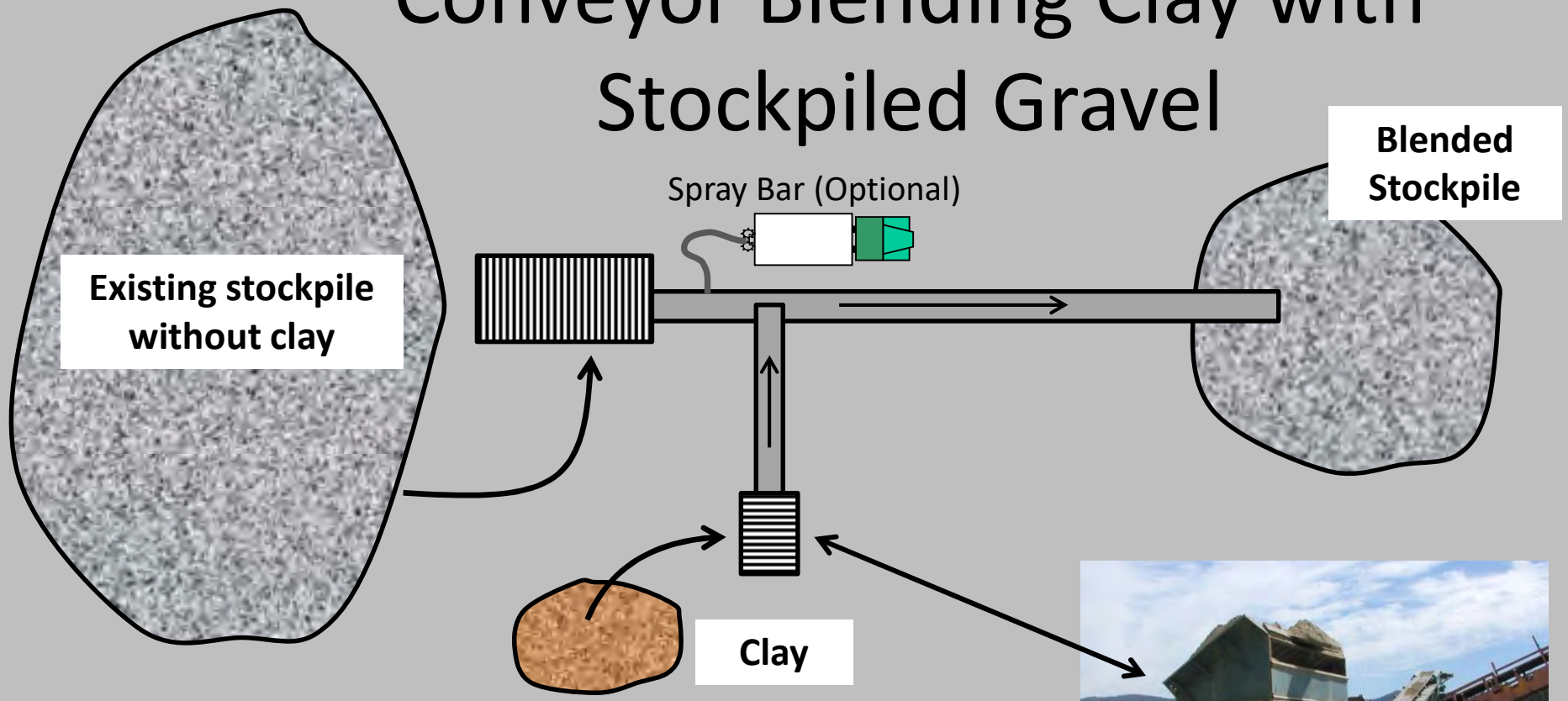
Adding Dry Granular Bentonite or Overburden to Stockpile



Using a Silo and Bin Feeder to Add Bentonite to Stockpiled Gravel

North Fork Duchesne River
Whitaker(Contractor) & CUWCD
Ashley National Forest
Google: mobile concrete dry batch plant

Conveyor Blending Clay with Stockpiled Gravel



Blending by Bucket Load Volume				
% Clay by Volume	1%	2%	3%	4%
# of Clay Buckets	1	1	1	1
# of Gravel Buckets	100	50	33	25
(Note: % by volume ≠ % by weight)				

More accurate with belt or loader scales

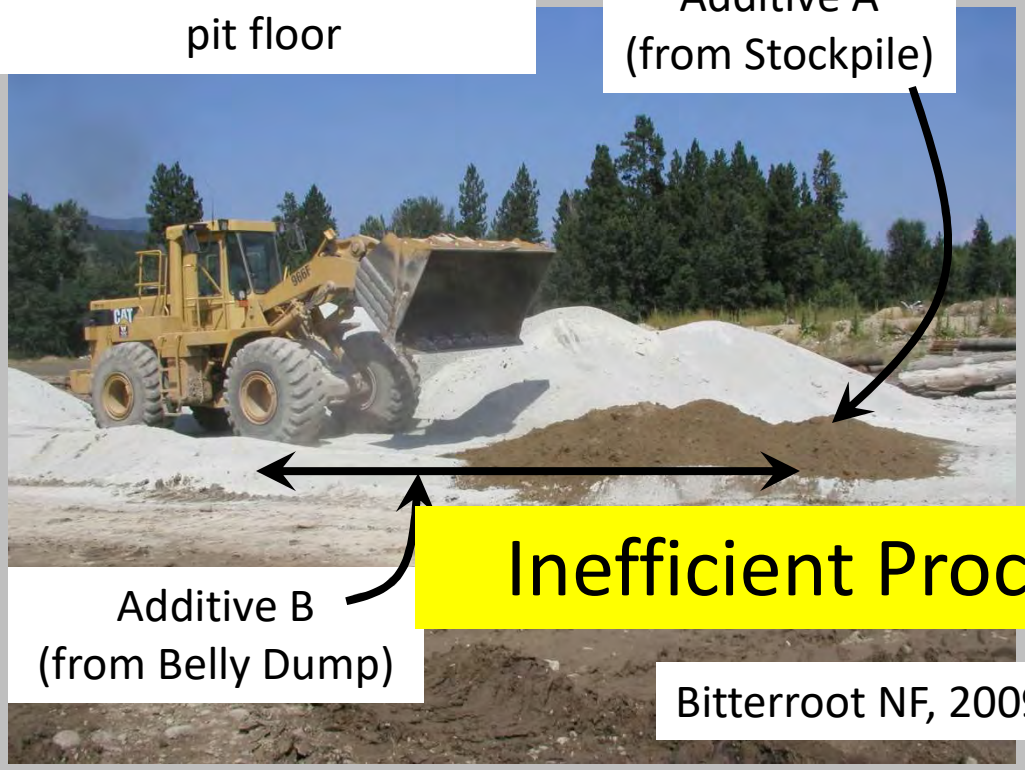
Stockpile Site Blending with Loader

Additive Types: Bentonite, Bank Run Clay or Silt, Calcium Chloride, Bag House Fines, etc.

2. Loader mixes two additives together

1. Loader dumps bucket loads of each additive on pit floor

Additive A (from Stockpile)



Additive B (from Belly Dump)

Inefficient Process

Bitterroot NF, 2009

3. Loader stockpiles blended additives

Stockpile Site Blending with Loader

Teton County ID, Clay Smith (2016)

2 - Cover 25 buckets of gravel with one bucket of bentonite (4% Bentonite)

3 – Load out linear stockpile from end and either re-stockpile or load trucks

Load out direction from end of stockpile

Stockpile Site Platform Mixing with MillRazor®

Richland Co MT 2011
(Prewitt Pit Gravel Stockpile)

Adding Bentonite Clay with Water Truck

Concept: Make bentonite/water slurry, apply with water truck during road blading. **Do not use this method if the existing gravel ruts when wet, is worn out or not thick enough**

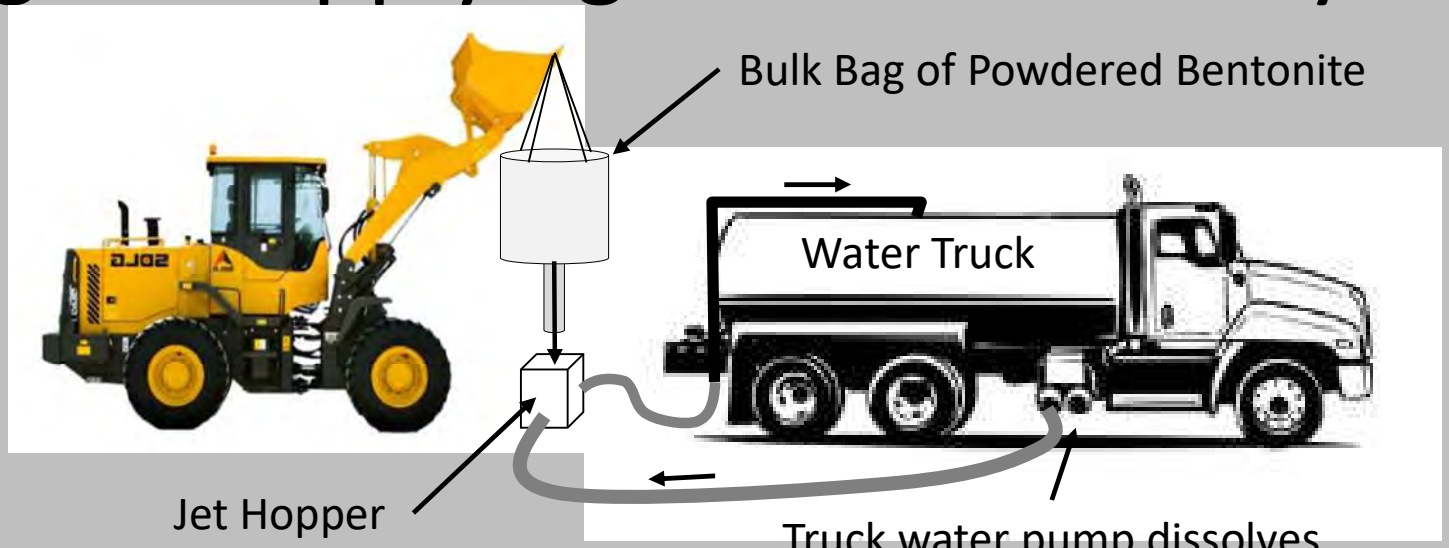
Details: Refer to one page guide

General Process

1. **Do not add clay** to totally worn out gravel or where gravel thickness is less than one inch. Rebuild crown prior to measuring thickness**.**
2. Determine desired clay content (see next slide)
3. Find source of bentonite, determine $ per Ton & $ per road mile
4. Order bentonite in bulk bag(s)
5. Purchase or fabricate a 3 inch “Jet Hopper”
6. Mix 10% bentonite slurry (2400 lb bulk bag/3000 gallons water)
7. Spread slurry on a short section of the worst washboard/raveled road segments and blade mix into gravel surface
8. Determine value of treatment in the Fall & following Spring seasons

Making and Applying Bentonite Slurry

Making Bentonite Slurry



Spreading Slurry

Blade Mixing Slurry

Amount of Bentonite Clay Needed to Fix Existing Gravel Problems

Existing Gravel Problems (Loose Rock, Dust and Washboards)	**% Bentonite Clay**, by Weight Gravel	**Gravel Mix Depth,** Inches	**Bentonite Application Rates,** #/SY	**Bentonite,** Tons per Road Mile for Treatment Width of 20 ft **(a)**
Low	1	1	1.0	6
Moderate	1.5	1.5	2.3	13
High	2	2	4.1	24
Extreme	2.5	2.5	6.3	37

Note: Rebuild crown and check to see if adequate gravel thickness exists

Note: The better the existing gravel gradation the better the benefits

Spread Bank Run Clay with Belly Dump

Concept: Add clay to gravel on the road by spreading a bank run clay and gravel mixture with belly dump. The mixture helps clay flow and spread uniformly during high speed spreading. **Do not use this method** if the existing gravel ruts when wet, is worn out or not thick enough

Details: Refer to one page guide

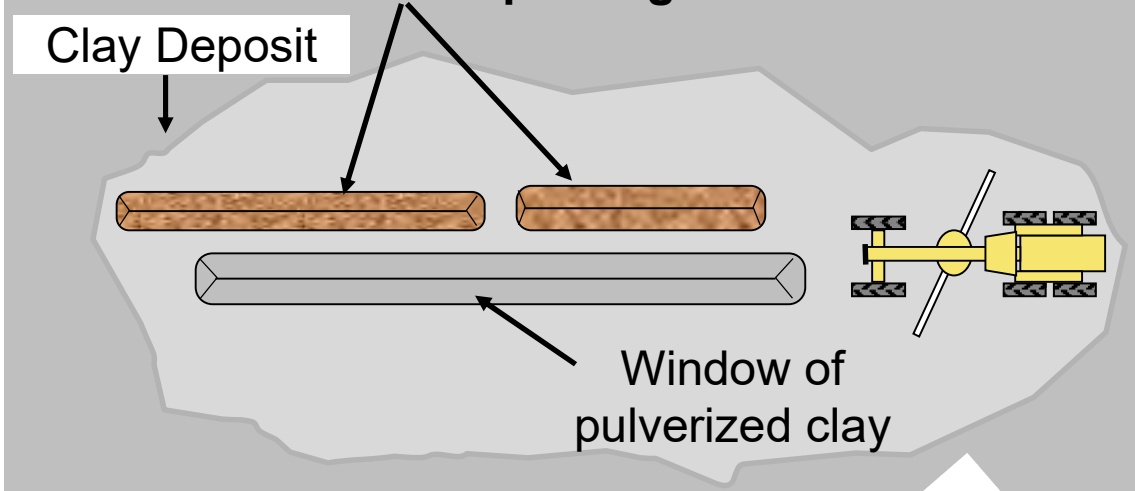
General Process:

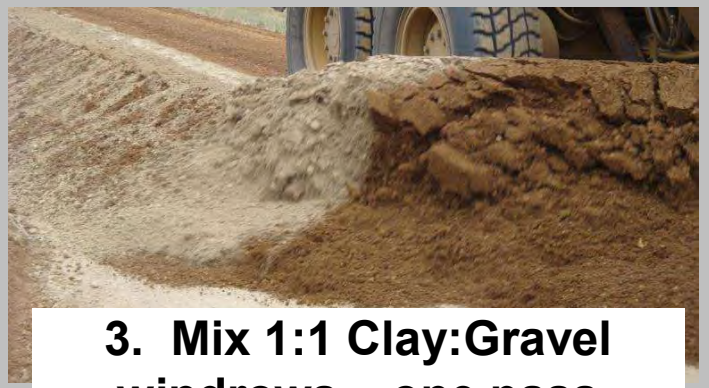
1. **Do not add clay** to totally worn out gravel or where gravel thickness is less than one inch. Rebuild crown prior to measuring thickness**.**
2. Locate bank run clay source, dig holes to check moisture
3. Pulverize clay with blade, tiller or disc then windrow
4. Spread gravel windrow next to clay windrow and blade together
5. Reload belly dump with gravel clay mixture
6. Spread on 300 to 500 feet of road surface → If uneven spread, use more gravel or dryer clay on next load
7. Blade mixture into existing gravel

Belly Dump Clay Spreading

1. Excavate & pulverize clay deposit

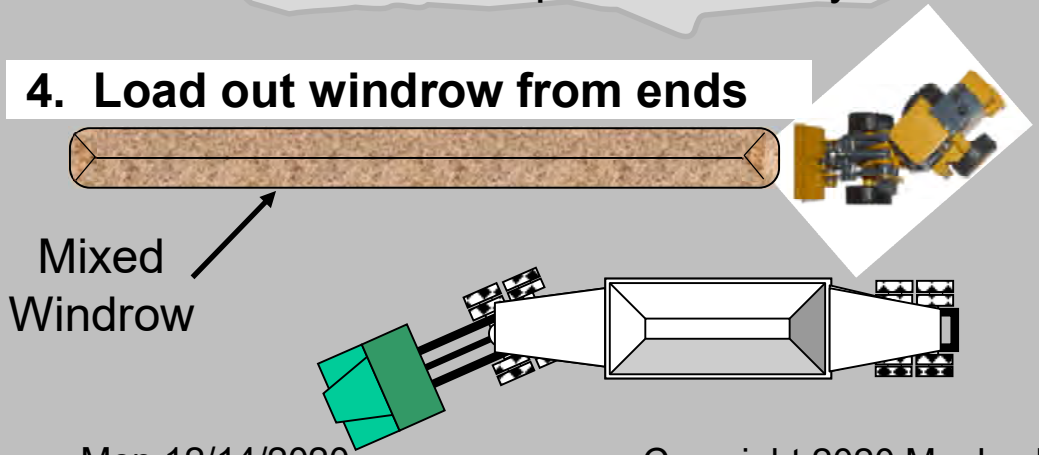
2. Spread gravel in windrow





3. Mix 1:1 Clay:Gravel windrows – one pass

4. Load out windrow from ends



5. Spread on 300 to 500 ft of road

6. Blade Mix, Water and Compact

Amount of Bank Run Clay Needed to Fix Existing Gravel Problems

Existing Gravel Problems (Loose Rock, Dust and Washboards)	**% Bank Run Clay**, by Weight Gravel	**Gravel Mix Depth,** Inches	**Bank Run Clay Application Rates,** #/SY	**Bank Run Clay,** Tons per Road Mile for Treatment Width of 20 ft **(a)**
Low	3	1	3.0	20
Moderate	4.5	1.5	6.9	40
High	6	2	12.3	70
Extreme	7.5	2.5	18.9	110

Note: Rebuild crown and check to see if adequate gravel thickness exists

Note: The better the existing gravel gradation the better the benefits

$$\text{Target Spread Length (ft)} = \frac{\text{(Belly Dump Load, Ton) x 2000 x (Parts clay) ÷ (Parts Gravel +1)}}{\text{(Road width, ft) x (Mixing Depth in inches ÷ 12) x (Gravel Density of 135 lbs/CF) x (ClayTarget \%) ÷ 100}}$$

Clay Spreading Equipment for Fixing "In-Place" Gravel

Spreading Equipment	Type of Clay			
	Local Lean Clay (a)	Fat Clay (Bentonite)		
		Pit Run	Cat Liter (b)	Powder (c)
Belly Dump (Gravel Clay Blend)	☆ ☆ ☆	☆ ☆ ☆	☆ ☆ ☆	☆ ☆
RM Truck & Trailer Distributors	no	☆ ☆	☆ ☆ ☆	no
Asphalt Live Bottom Trailer	?	☆ ☆ ☆	☆ ☆	Dusty
8 Ft. Wide Live Bottom Trailer	?	?	☆	Dusty
Agriculture Fertilizer Spreader	?	?	?	Dusty
Winter Sanding Truck Spreader	☆	☆	☆	Dusty
Pneumatic Trailer	no	no	no	Dusty
Paddle Wheel Scraper	☆ ☆	?	?	no

(a) Lean Clay covers most of the plains states, has to be dried and broken down prior to mixing with gravel - normal PI is 15 to 25 with more than 50% passing #200 sieve

(b) Cat Liter is like Envirogel 12 pellets or similar

(c) Canvas skirts around the discharge area can reduce dust significantly

Truck & Trailer Distributors (RM Equipment)

Type of Clay			
Local Lean Clay (a)	Fat Clay (Bentonite)		
	Pit Run	Cat Liter (b)	Powder (c)
no	☆☆	☆☆☆	no

Courtesy of RM Equipment, Bonners Ferry Idaho

Asphalt Live Bottoms

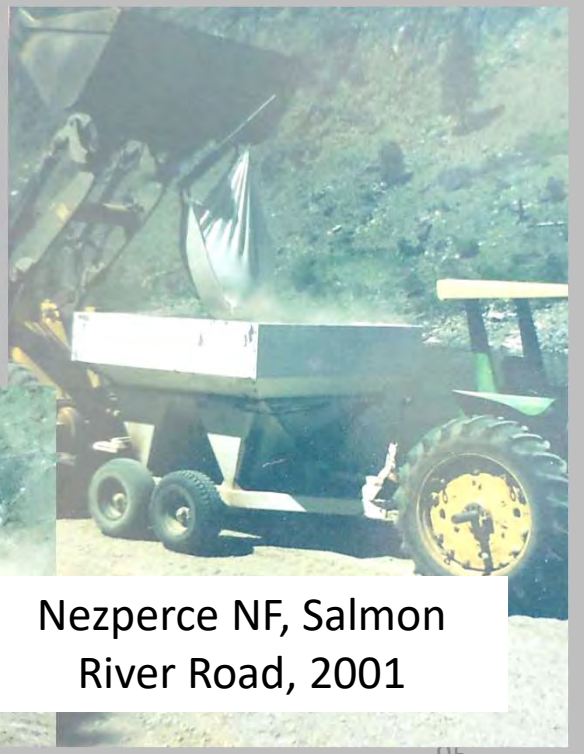
8 Ft. Wide Bottoms

Ag Fertilizer Spreaders

Type of Clay			
Local Lean Clay (a)	Fat Clay (Bentonite)		
	Pit Run	Cat Liter (b)	Powder (c)
?	☆ ☆ ☆	☆ ☆	Dusty
?	?	☆	Dusty
?	?	?	Dusty

"Pit Run Clay" BLM, Leadore, ID – 2010 (Red River is trailer mfg. courtesy Oxford Inc. Moyie Springs ID)

8 foot wide belt trailer, Lethbridge AB 2016



Nezperce NF, Salmon River Road, 2001

Winter Sand Spreaders

Type of Clay			
Local Lean Clay (a)	Fat Clay (Bentonite)		
	Pit Run	Cat Liter (b)	Powder (c)
☆	☆	☆	Dusty

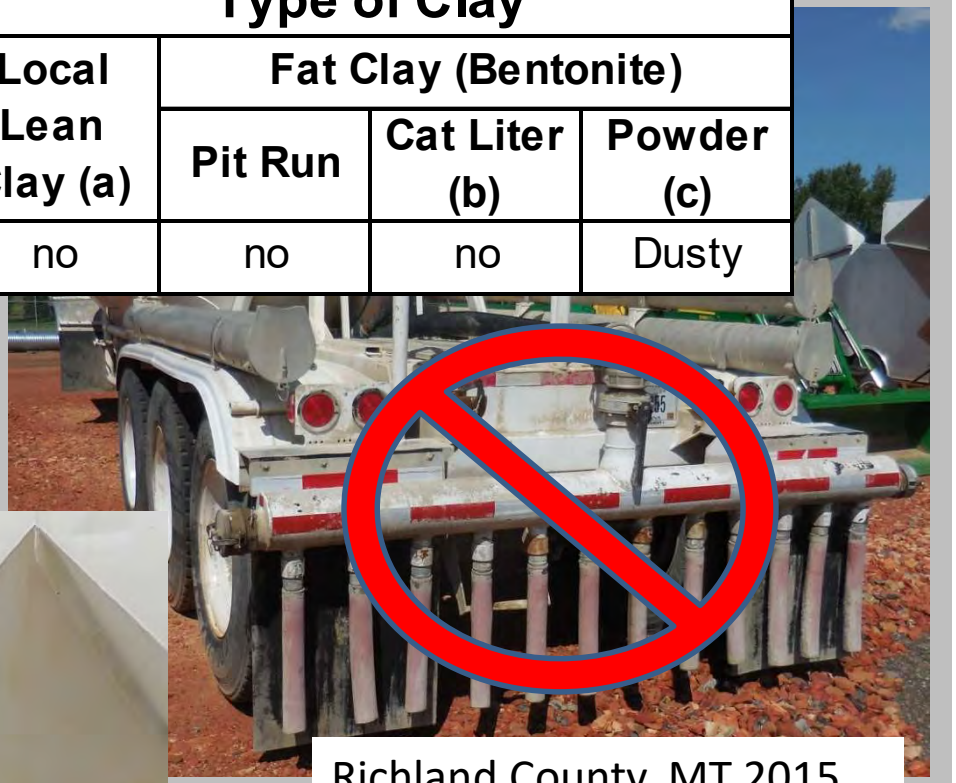
Dry Chloride Spreaders, Calgary AB 2015 & Lethbridge AB 2016

Dry Chloride Spreaders, Quesnel, BC 2004

Note that sand spreaders apply light applications which can work well for annual surfacing maintenance but take many applications to achieve high concentrations

Pneumatic Trailer

Type of Clay			
Local Lean Clay (a)	Fat Clay (Bentonite)		
	Pit Run	Cat Liter (b)	Powder (c)
no	no	no	Dusty



Richland County, MT 2015

Richland County, MT 2017

To minimize dust and maximize output:

1. Open tank vent valve ½
2. Use minimum air to fluffer

Paddle Wheel Scraper "Spreader"

Ronnie Harvey
Rosebud Co MT (2008)

Type of Clay			
Local Lean Clay (a)	Fat Clay (Bentonite)		
	Pit Run	Cat Liter (b)	Powder (c)
☆ ☆	?	?	no

Spread clay by slowly retracting floor – may not work well with bentonite clay

“In-Place” Mixing Options

<table>
<tr><th rowspan="2">Mixing Equipment</th><th colspan="3">Gravel Depths, inches</th></tr>
<tr><th>Less Than 2”</th><th>2 to 3</th><th>More than 3”</th></tr>
<tr><td>Blade (a)</td><td rowspan="3" colspan="2">Problem mixing subgrade into Gravel</td><td>inefficient</td><td>Not practical</td></tr>
<tr><td>Asphalt Zipper®</td><td colspan="2">Multiple passes per lane required, very slow and time consuming</td></tr>
<tr><td>MillRazor®</td><td colspan="2">Very Efficient Option 12’ wide one pass</td></tr>
<tr><td>Reclaimer</td><td colspan="2">Problem mixing subgrade into Gravel</td><td>Problematic?</td></tr>
</table>

(a) Blade mixing is suitable for small areas, requires considerable skill and time to ensure depths and mixing uniformity are adequate. When blade mixing is done well, mix depth and clay tonnage should be increased by 20% to be comparable to rotary mixing (USFS Chloride Stabilization 2006)

“In-Place” Mixing Equipment

On-Road	Pro	Con
Blade	Agency owns machine	Very slow, poor thickness control
Capital Mulcher	Relatively low cost multi-use machine	Needs blade formed loose windrow prior to mixing
Asphalt Zipper	Good mixing	Slower than blade, new machine purchase must make two passes per lane
MillRazor	Good mixing, fast, covers whole lane, injects water, excellent thickness control	New Blade Attachment Purchase
Reclaimer	Relatively fast	Treatment thickness issues, poor mixing, expensive machine purchase, two passes/lane

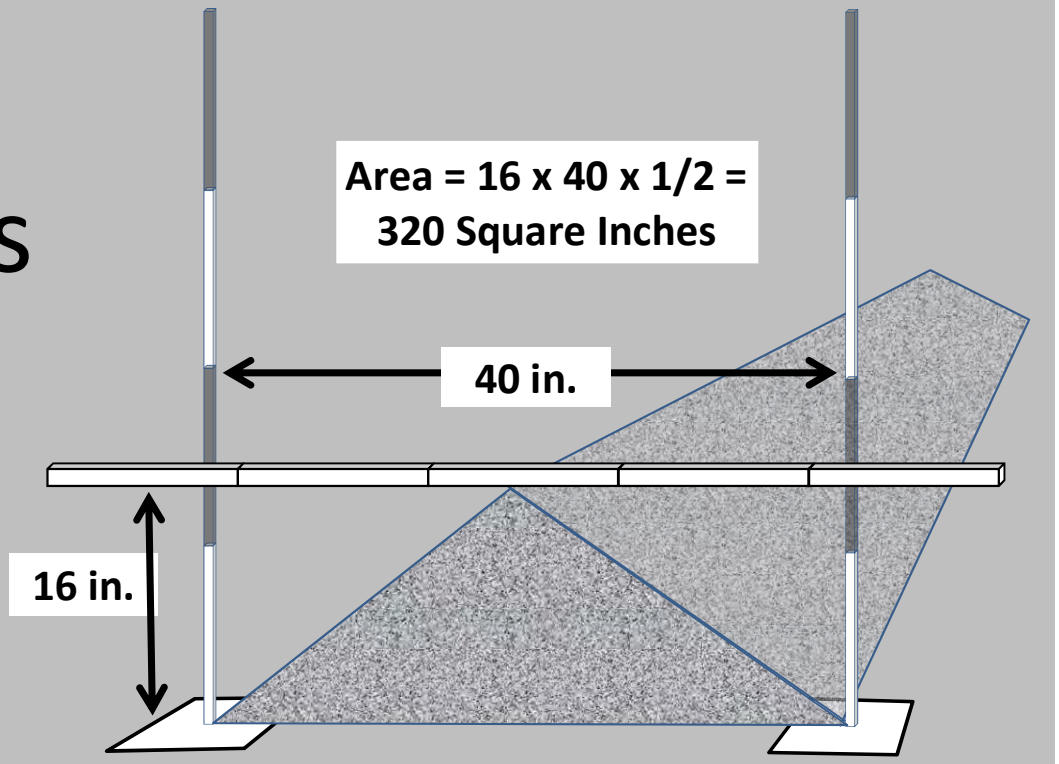
Blade Mixing Dry Chloride

Blade Mixing Bentonite in Bags

- Water road and rebuild crown (4 to 5%)
- Measure gravel thickness
- Build windrow and measure

* Determine bag spacing

- Put bags on windrow
- Mix windrow adding water if necessary
- Blade to 4% to 5% crown
- Compact



Bentonite Bag Spacing in Feet (50# bags)

Percent Bentonite	Windrow Size in Square Inches								
	200	300	400	500	600	700	800	900	1000
1	32.7	21.8	16.4	13.1	10.9	9.4	8.2	7.3	6.5
1.5	21.8	14.5	10.9	8.7	7.3	6.2	5.5	4.8	4.4
2	16.4	10.9	8.2	6.5	5.5	4.7	4.1	3.6	3.3
2.5	13.1	8.7	6.5	5.2	4.4	3.7	3.3	2.9	2.6
3	10.9	7.3	5.5	4.4	3.6	3.1	2.7	2.4	2.2

Assumes 110 lbs./CF loose unit weight in windrow

Mix with Capital Industries Mulcher

“Zipper” Mixing

Photo from Zipper Website, 2016

Owners indicate this is a very slow machine and extremely noisy

MillRazor® Blending of Chloride, Bentonite & Water, 2” Deep

- Blends Chloride & Bentonite with Gravel
- Removes all gravel potholes, washboards & loose aggregate
- Injects water to achieve road crust

Rocky View County, Calgary AB 2015

MillRazor® Mixing Gravel, Bentonite, Calcium Chloride & Water

Richland County MT 2010, 2011
(CR 130 & Brorson Rd)

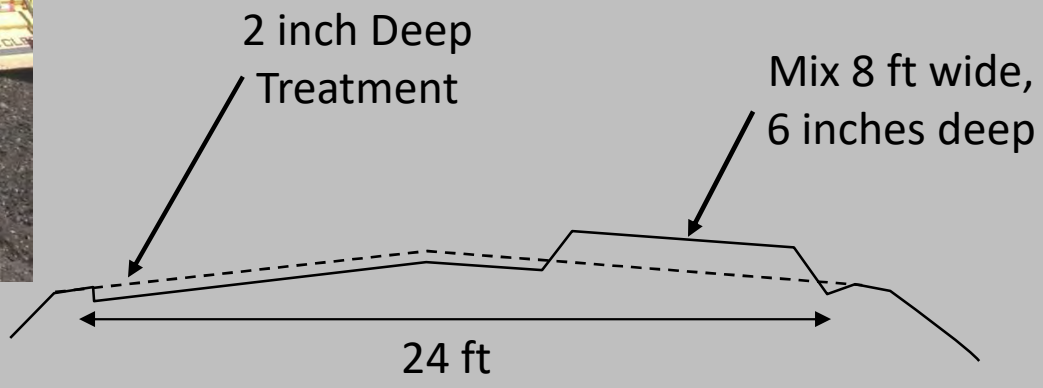
“In-Place” Blending, Mixing with Reclaimers

Johnson Co, WY, 2010
(Bomag Reclaimer)

“In-Place” Blending, Mixing with Reclaimers

BLM, Leadore, ID, 2010 (Bros Reclaimer)

Johnson Co, WY, 2012
(Bomag Reclaimer)



In-Place Mixing Gravel with Subgrade

- Blade mixing shoulder soils
  - Rutting will occur if too much added
  - Clays will add binder and road surface crust
  - Silts will only create dust
- Iowa method of mixing gravel and clay subgrade
  - Must know gravel depth and gradation of both gravel and subgrade
  - Gravel and subgrade must be consistent
  - See guide for more information.

Primary Points

- Many ways to improve gravel with different clays
- **Clay is not the answer** where gravel is worn out or not thick enough
- Be cautious about the amount used
- Try different amounts on the same road
- Learn what works best
- Think “outside the box”→ Paddle Wheel Scraper

One Page Guides and Other Information

Power Point Slide #	Document Title
14	2020 SSP 6 Specification for Gravel Surfacing
27	South African Bar Shrinkage Test
43	Acceptance and Pay Adjustment Form for 2020 SSP 6 Gravel Spec
45	2020 Guide Spec for Gravel Surfacing
53	Guide for NRCS Web Soil Survey (WSS)
56	Guide for Gravel Pit Investigation
88	Guide for Adding Bentonite with Water Truck
110	Gradation Optimization for Granular Surface Materials (Iowa TR-685)
92	Guide for Adding Clay with Belly Dump Trailer

Summary of Primary Points

- Better quality gravel can lower long term costs
- Clay binder improves gravel performance.
- Testing for Clay is critical
- Gravel gradation and the amount of clay work together.
- Sampling and Testing is cheap insurance
- Consider spec options that have worked well for others
- Good blading practices help gravel preservation
- There are many ways to add clay while crushing gravel and also to gravel already on the road