Maintenance and Management of Gravel Roads

2024

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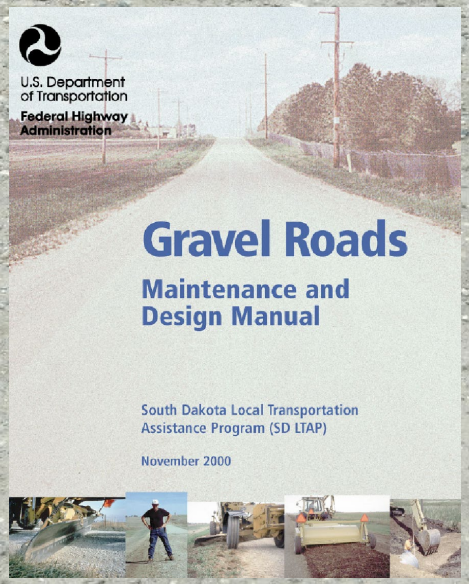
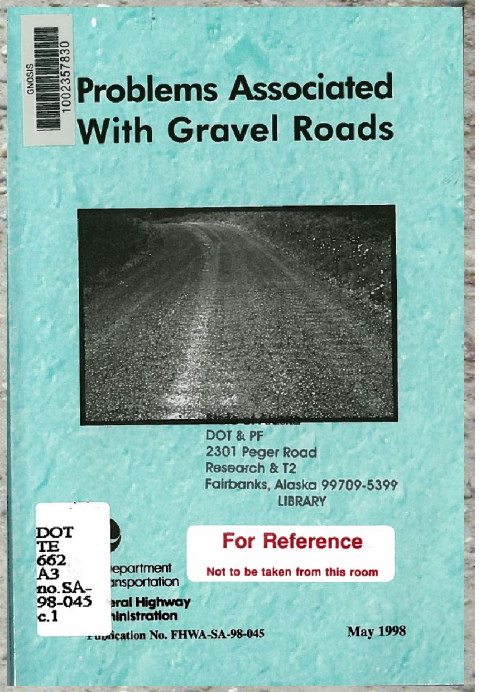
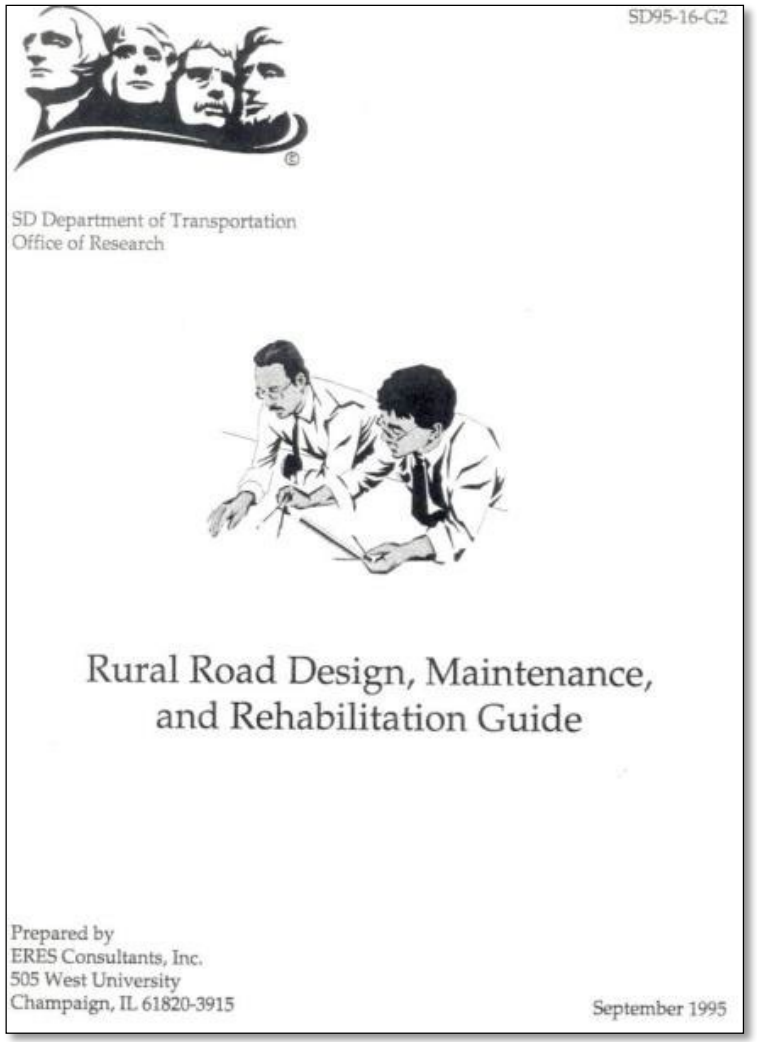
Gravel Road Most Have LIterature





Barnes and Connor, 2017

Good example of a Low Volume Rd Design Guide



Good guidance, non-technical, accommodates unpaved road design.

Your best bet for a great resource:

The FHWA *Gravel Roads* manual – currently out of print, but is available online

Resource: Maintenance and Management of Gravel Roads

Special Thanks To

Ken Skorseth, Program Manager (Retired)

South Dakota Local Transportation Assistance Program

South Dakota State University

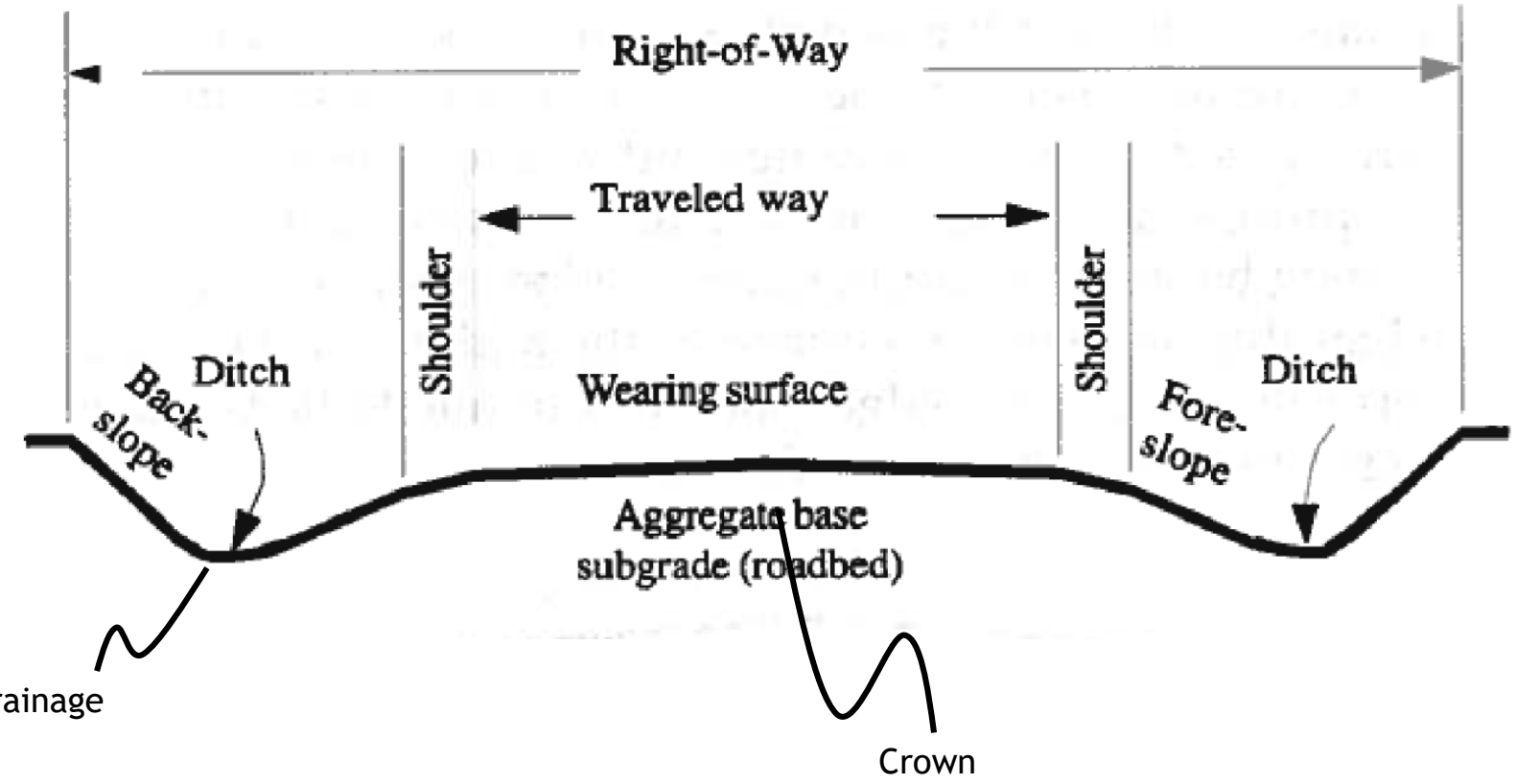
Brookings, South Dakota, USA

A few goals for this course:

- Open Discussion and honest questioning; please share your experience!
- We hope to provide everyone with at least a few points to help maintain gravel roads
- We will answer your questions as best we can

Let’s Get Started!

The GOSPEL of Good Gravel!



Barnes and Connor, 2017

FHWA, 1998

From AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)

US Customary						
	Total roadway width (ft) by functional subclass					
Design speed (mph)	Major access	Minor access	Recreational and scenic	Industrial/ commercial access	Resource recovery	Agricultural access
15	–	18.0	18.0	20.0	20.0	
20	–					
25	18.0					
30	18.0					
35	18.0					
40	18.0					
45	20.0					
50	20.0					
55	22.0					
60	22.0	–	–	–	–	–
Note: Total roadway width includes the width of both traveled way and shoulders.						

What minimum roadway width needed? Speed and classification (use) dependent.

Exhibit 1. Guidelines for Total Roadway Width for New Construction of Very Low-Volume Local Roads in Rural Areas

From AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)

US Customary

Design speed (mph)	Total roadway width (ft) by functional subclass					
	Major access	Minor access	Recreational and scenic	Industrial/ commercial access	Resource recovery	Agricultural access
15	–	18.0	18.0	20.0	20.0	22.0
20	–	18.0	18.0	20.0	20.0	24.0
25	18.0	18.0	18.0	21.0	21.0	24.0
30	18.0	18.0	18.0	22.5	22.5	24.0
35	18.0	18.0	18.0	22.5	22.5	24.0
40	18.0	18.0	20.0	22.5	–	24.0
45	20.0	20.0	20.0	23.0	–	26.0
						–
						–
						–

rs.

Very Low-Volume

Agricultural Access Classification: Minimum roadway width is 24 ft at 20 to 40 mph design speed, increases to 26 ft if design speed is 50 mph

Roadway crown shape is critical!

Crown should be straight like the roof of a house, NOT arched like a loaf of bread.

Crown should be at or near ½ inch per ft (or 4%), but not to exceed 6%.

Example:

24 ft roadway should have….approx. 6 inches of crown. (vertical difference between the shoulder and centerline)

From AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)

US Customary

Design speed (mph)	Total roadway width (ft) by functional subclass					
	Major access	Minor access	Recreational and scenic	Industrial/ commercial access	Resource recovery	Agricultural access
15	–	18.0	18.0	20.0	20.0	22.0
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25	18.0	18.0	18.0	21.0	21.0	24.0
30	18.0	18.0	18.0	22.5	22.5	24.0
35	18.0	18.0	18.0	22.5	22.5	24.0
40	18.0	18.0	20.0	22.5	–	24.0
					–	26.0
					–	–
					–	–
					–	–

rs.

Very Low-Volume

Agricultural Access Classification: Minimum roadway width is 24 ft at 20 to 40 mph design speed, increases to 26 ft if design speed is 50 mph

From AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)

- Are we providing widths on our roads that are in line with AASHTO guidelines?
- Are we maintaining our roads to that width?
- Do we have roads that are too wide or too narrow or both?

Good Gravel Roads

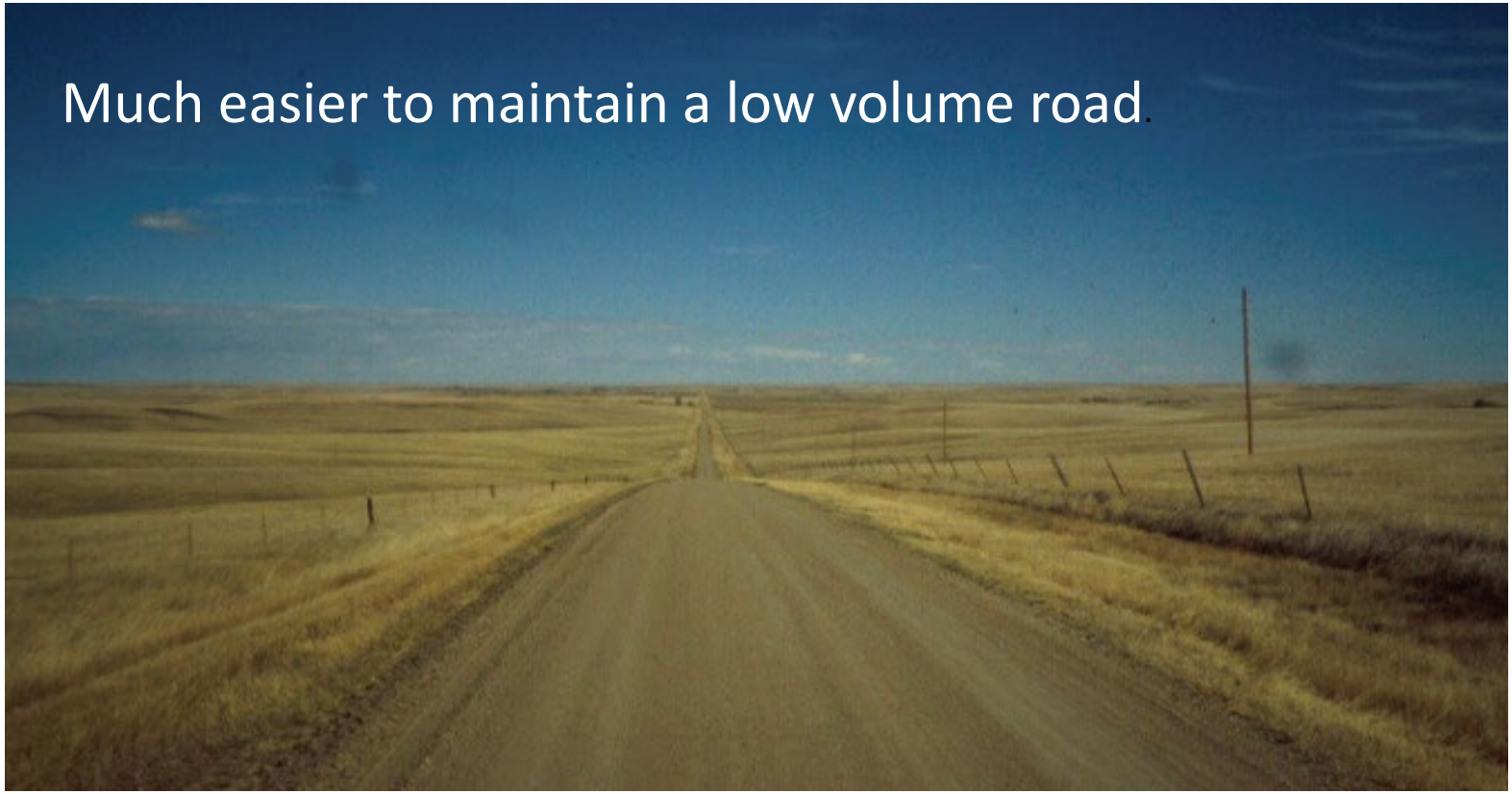
Crown

Every road must have crown.


Lack of crown 2% or less


Adequate 4% Crown


Actually an inverted crown!!


Much easier to maintain a low volume road.

Some roads have too little crown, this one has too much.

Imagine a cattle trailer on this road.

About 13 inches on a 20′ top

Too much crown tend to force traffic to drive in the middle of the road!

Constructing a new rural road – great if you can afford it

How many local gravel roads were built

The compaction and construction blading as shown here was seldom done

How those roads look 70 years later

Good Gravel Roads

There are two primary things to understand in doing good Gravel Road Maintenance:

- The use of the Motorgrader
- The use of good surface gravel

(Each is as important as the other!!)

Key learning objectives

- The grader operator must understand the correct shape needed on the roadway.
- Supervisors need to know this as well, and support proper methods and means to accomplish common goals.
- Gravel road performance depends almost entirely on quality and quantity of the surface gravel.
- Corrugation, excess loose material, and excessive windrows are primarily due to poor quality of surface gravel.

Key learning objectives

- Maintenance is the primary way in which we take care of the significant capital investment in the roads we travel.
- Maintenance can significantly affect the performance of our roadways, in both positive and negative ways.
- Properly trained and supported maintenance staff is critical to the long-term success of all road departments, and the importance of day-to-day maintenance and operations are not to be underestimated.

Good Gravel Roads

- Good Gravel requires QA/QC at the stockpile
- Good Gravel requires good stockpile management
- Good Gravel will reduce maintenance requirements
- Good Gravel will reduce or eliminate corrugation
- Good Gravel cannot overcome poor grader practices
- Good Gravel requires proper shape/crown and shoulder maintenance

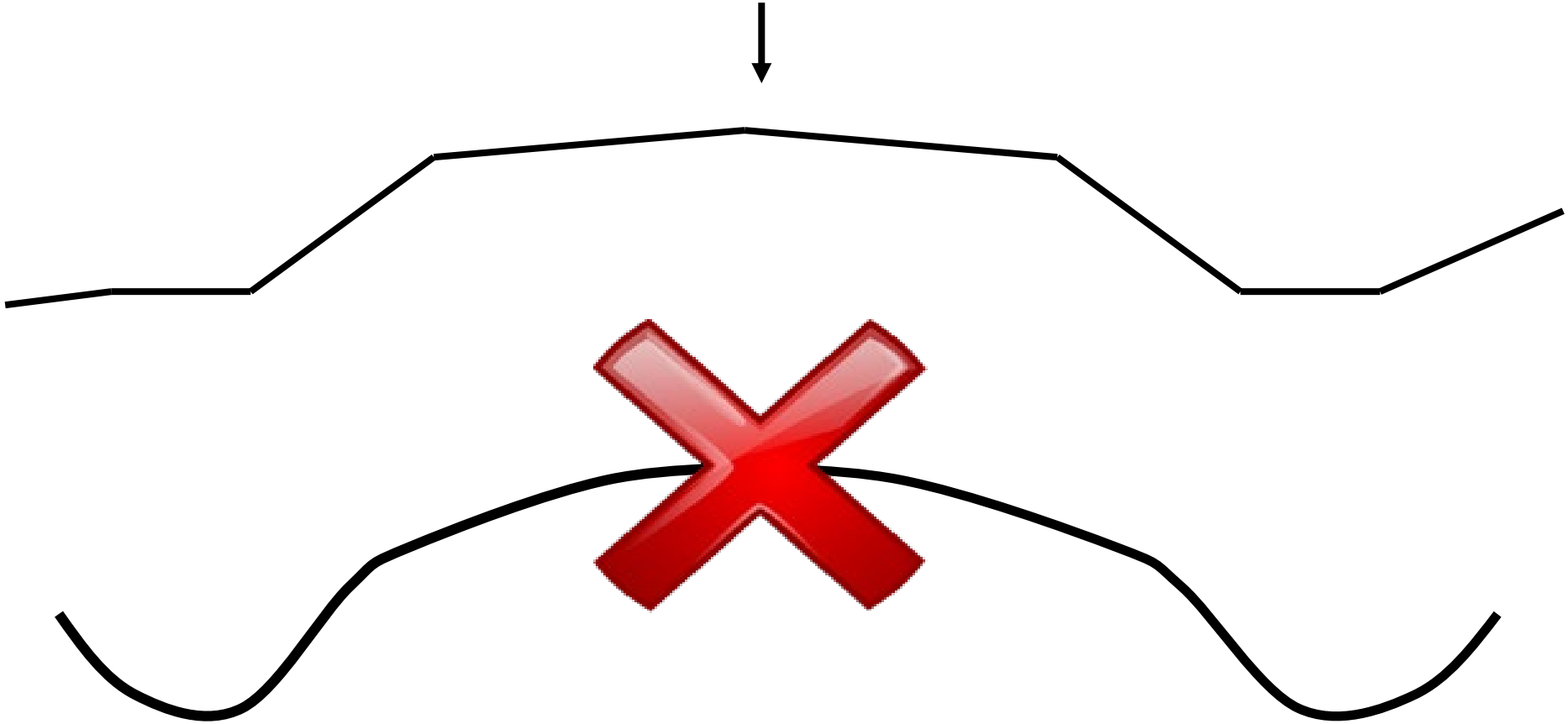
Roadway crown shape is critical!

Crown should be straight like the roof of a house, NOT arched like a loaf of bread.

Crown should be at or near ½ inch per ft (or 4%), but do not exceed 6%.

Example: 24 ft roadway should have approx. 6 inches of crown.

You want crown shaped like this



Maintaining Gravel Roads

- Understanding correct shape of the roadway cross-section is the most important knowledge an operator can possess.
- Gravel roads constantly change shape! Operators and supervisors have to deal with this.

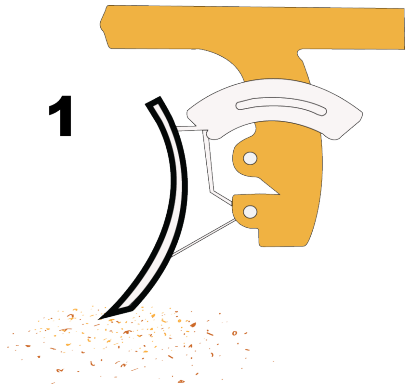

06/07/2012

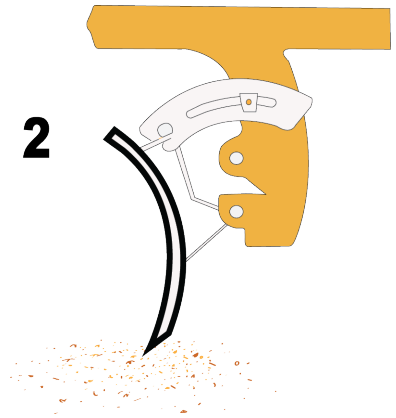

06/07/2012

Maintaining Gravel Roads

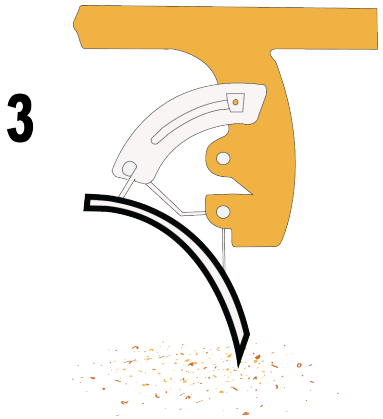
Important things to understand about the use of the motorgrader:

- Moldboard Angle
- Moldboard Pitch
- Motorgrader Stability
- Operating Speed
- Articulation
- Windrows





Which pitch is correct for maintenance blading?



This device can be helpful

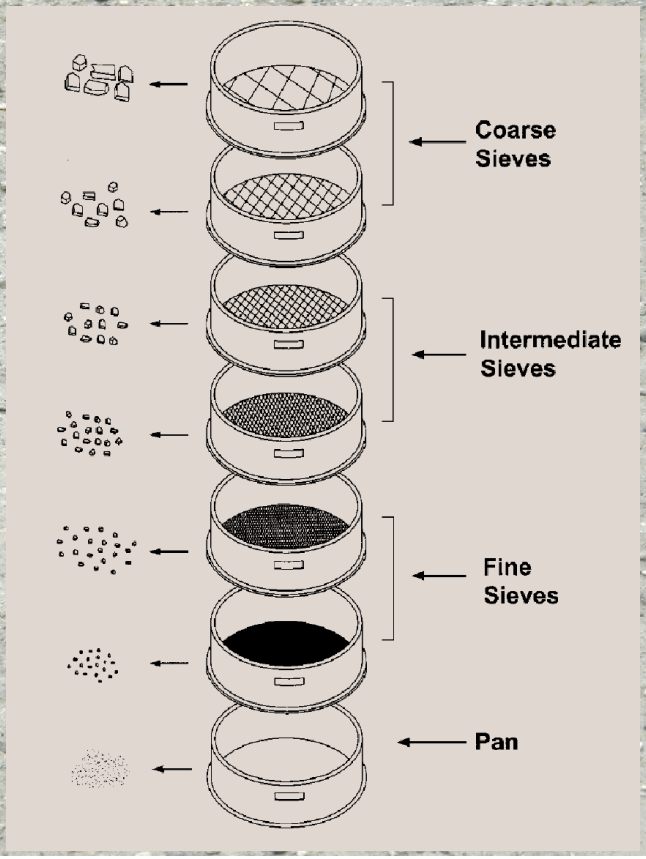
But only if it's a <u>crown</u> gauge!

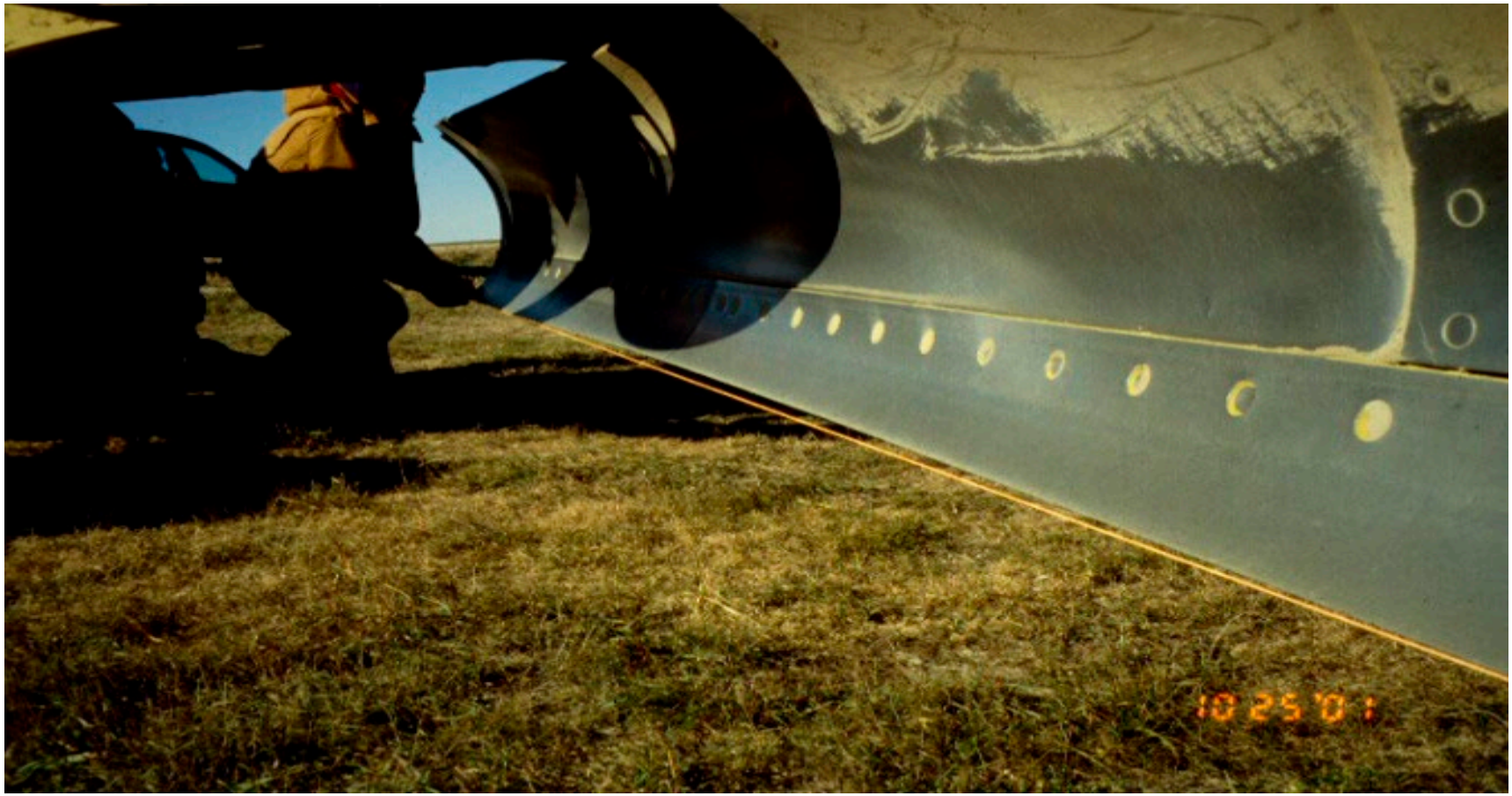
Slope Control systems on motorgraders are a great aid in construction and rehabilitation

Electronic Slope Reading

A simple carpenter level or smart level

Gradation of Aggregate

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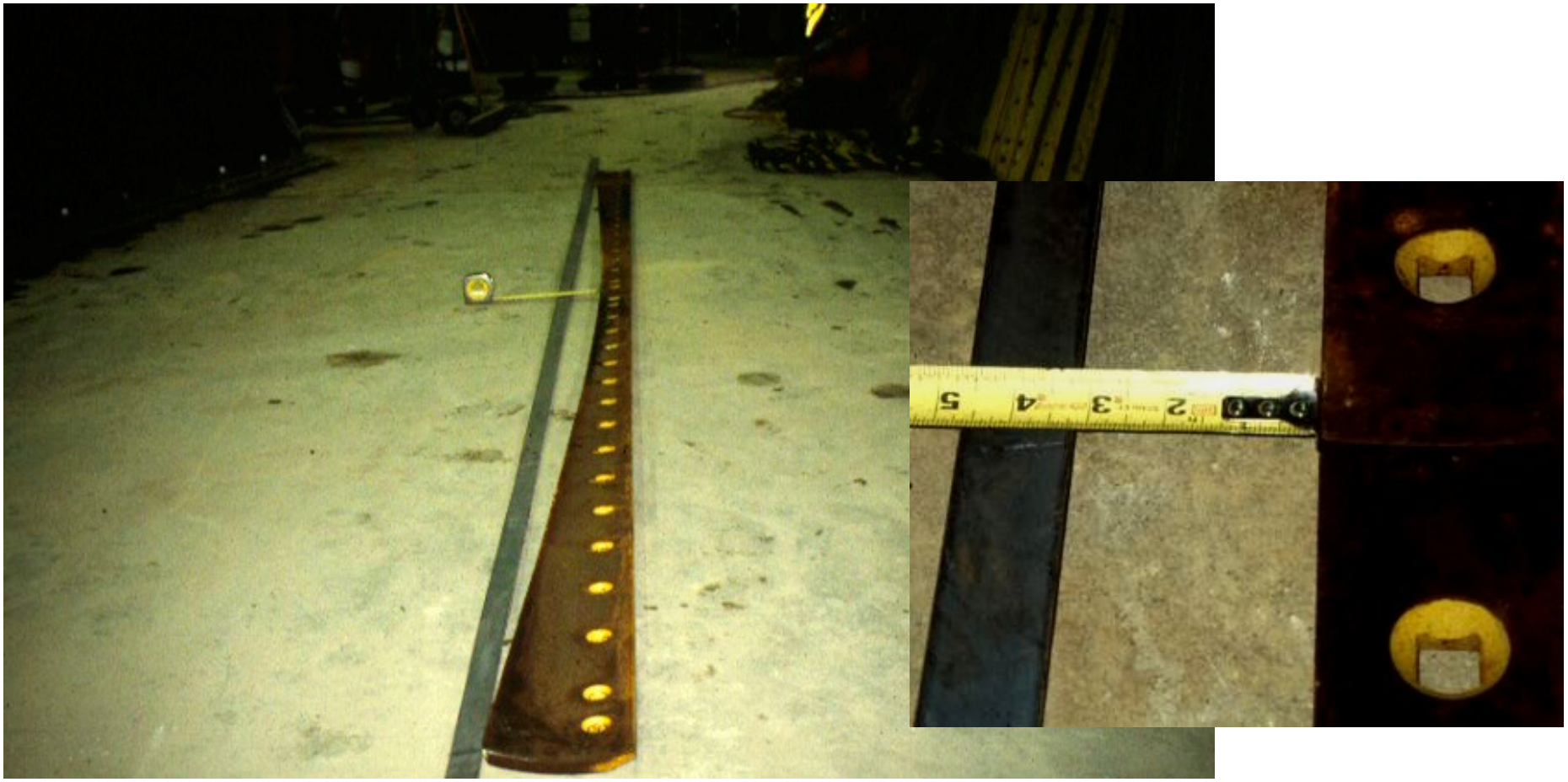
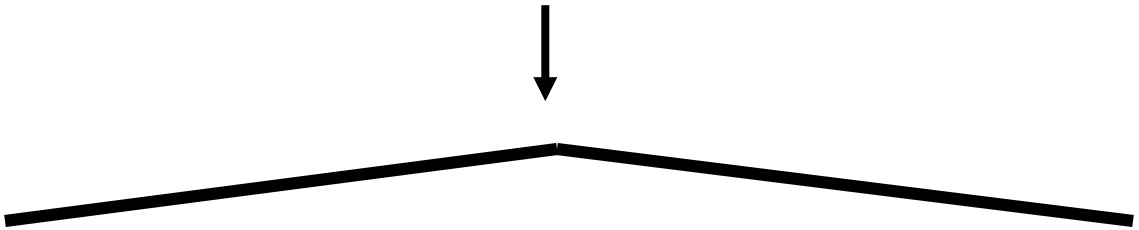


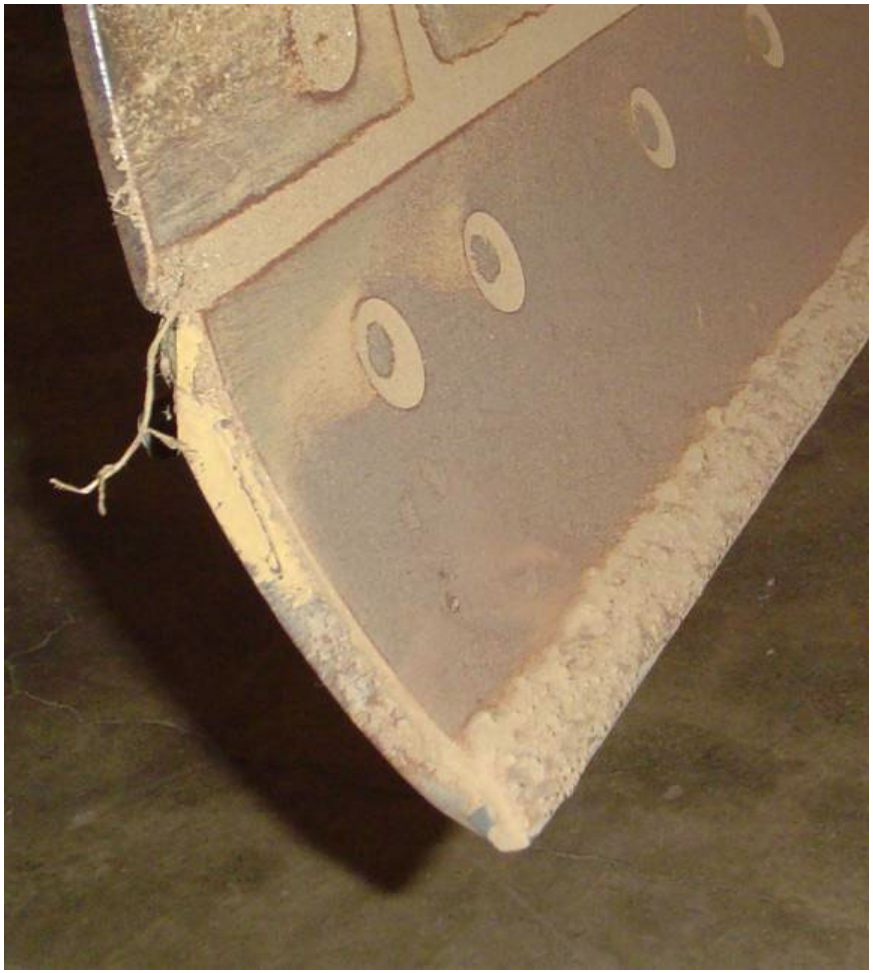
You want crown shaped like this



Not like this

Maintaining Gravel Roads

Carbide Cutting edges are one possible answer – expensive, but can give up to two years of use




772B

Crown should be at or near ½ inch per ft (or 4%), Do not exceed 6%!

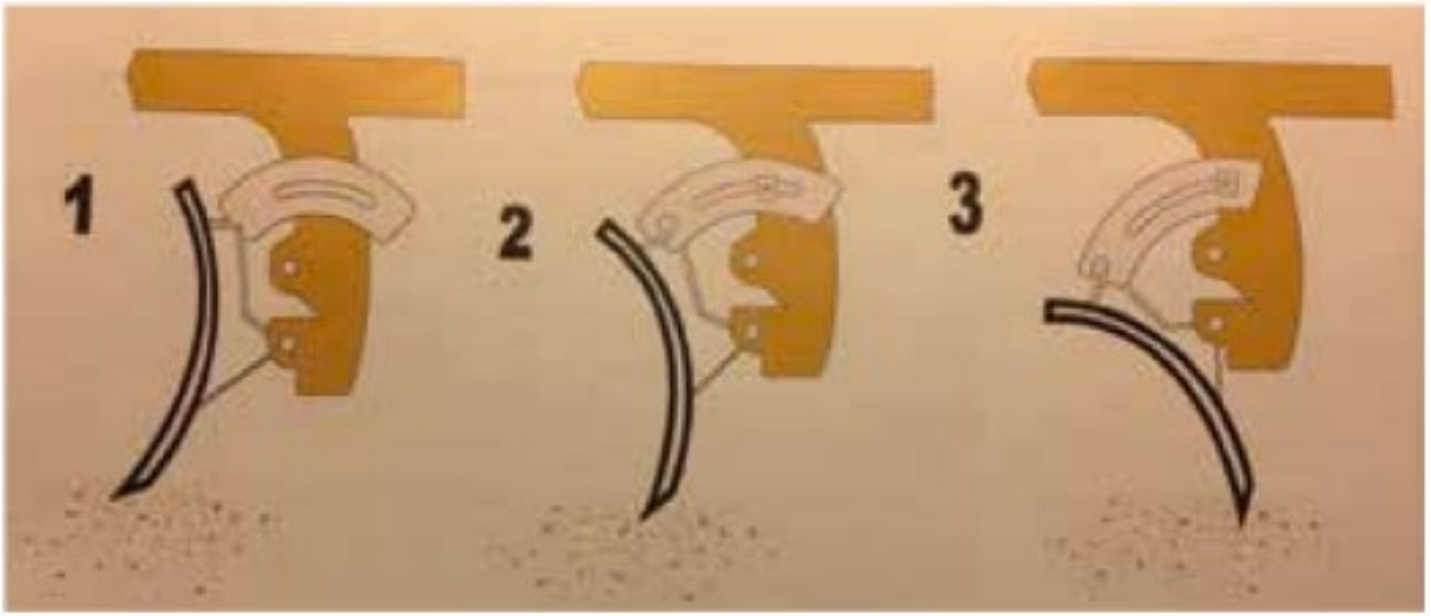
Example: 24 ft roadway should have approx. 6 inches of crown.

Crown should be straight like the roof of a house.

Motor Graders and General Unpaved Road Maintenance

- Using a motor grader is the most efficient and effective way to maintain unpaved roads.
- Use of a compaction method is important as well!
- What to do and what not to do… both are important considerations.

What is each blade pitch used for?



Smoothing Procedure

1) Determine the road length for smoothing.
2) Place temporary work zone traffic control.
3) Tilt the moldboard forward to create a dragging action.
4) Angle the moldboard at 30 to 45 degrees to spread the loose material.
5) Tilt the front wheels 10 to 15 degrees from vertical in the direction the aggregate is rolling across the blade.
6) Repair minor defects by hand.
7) Consider periodically blading the surface against traffic to eliminate aggregate drift at bridges, culverts, intersections, and railroad crossings.

Moldboard Angle

May have to adjust moldboard angle to get across centerline

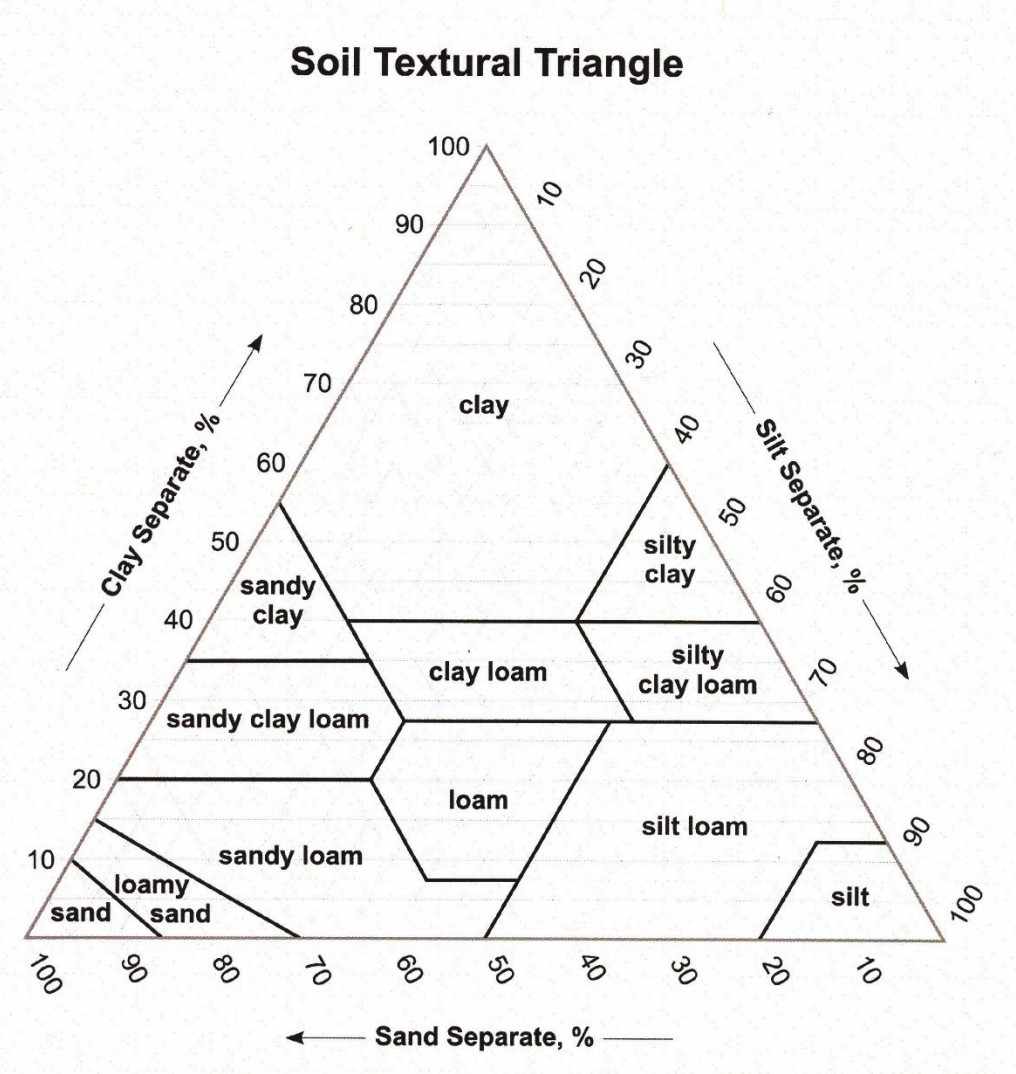
Not Controversial…

- The motorgrader operator must understand the correct shape needed on the roadway.
- There are special shaping situations such as driveways, intersections, bridge approaches, etc. that need to be understood as well.
- But thereafter, how a gravel road performs depends on quality and quantity of the surface gravel.

Controversial????

- Washboarding, excess loose material, and excessive windrows are primarily due to poor quality of surface gravel.

Classification of fines



Subgrade Soil Strength Parameters

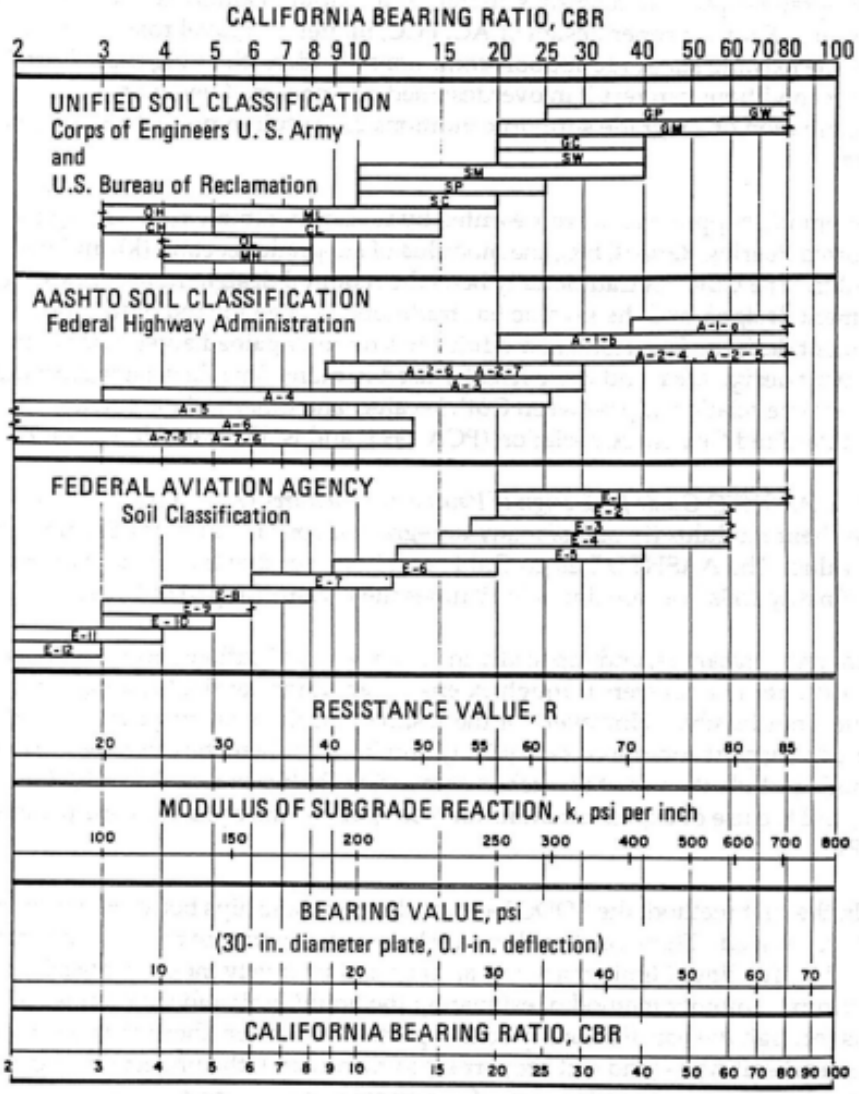


Figure 7.1. Approximate relationship of soil parameters (PCA 1984).

[Rural Road Design, Maintenance, and Rehabitation Guide (sdstate.edu)]

Managing Gravel Quality and Quantity

Gravel Testing procedures: Sieve Analysis

Standard Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM C136) – YouTube

AASHTO T27 ASTM C136 – YouTube

NDDOT Standard Specification – 2008 Edition

CLASS OF AGGREGATE AND SPECIFICATION LIMI

B. Specific Requirements.

Table I: Aggregates for Subgrade Repair, Trench Backfill, Bases, and Surfacing

Sieve Size Percent Passing	Permeable Trench Backfill	Aggr. for Subgrade Repair[5]	Aggr. for Blended Base	Shldr. Aggr. Surface	Aggr. Base[5]	Permeable Base Aggr.	Aggr. Surface
	2	3	3M	4	5	7	13
3"		100					
1-1/2"							
1-1/4"							
1"			100		100	100	100
3/4"	100	80-100	80-100	100	90-100	95-100	70-100
5/8"							
1/2"						85-100	
3/8"	50-95					60-90	
No. 4		35-85	35-85	35-85	35-70	15-25	
No. 8						2-10	
No. 10	0-15						38-75
No. 16							
No. 30	0-4	20-50	20-50	10-50	16-40		22-62
No. 50							
No. 100							
No. 200		0-15	4-10	7-17	4-10	0-3	
Shale[1]		12%	12%	15%	12%	8%	
L. A. Abrasion[1]				50%	50%	40%	12-45
Plasticity Index[2]							
Fractured Faces[3]				10%	10%	85%	

Footnotes for Tables I and II:

[1] Maximum Allowable Percentages.

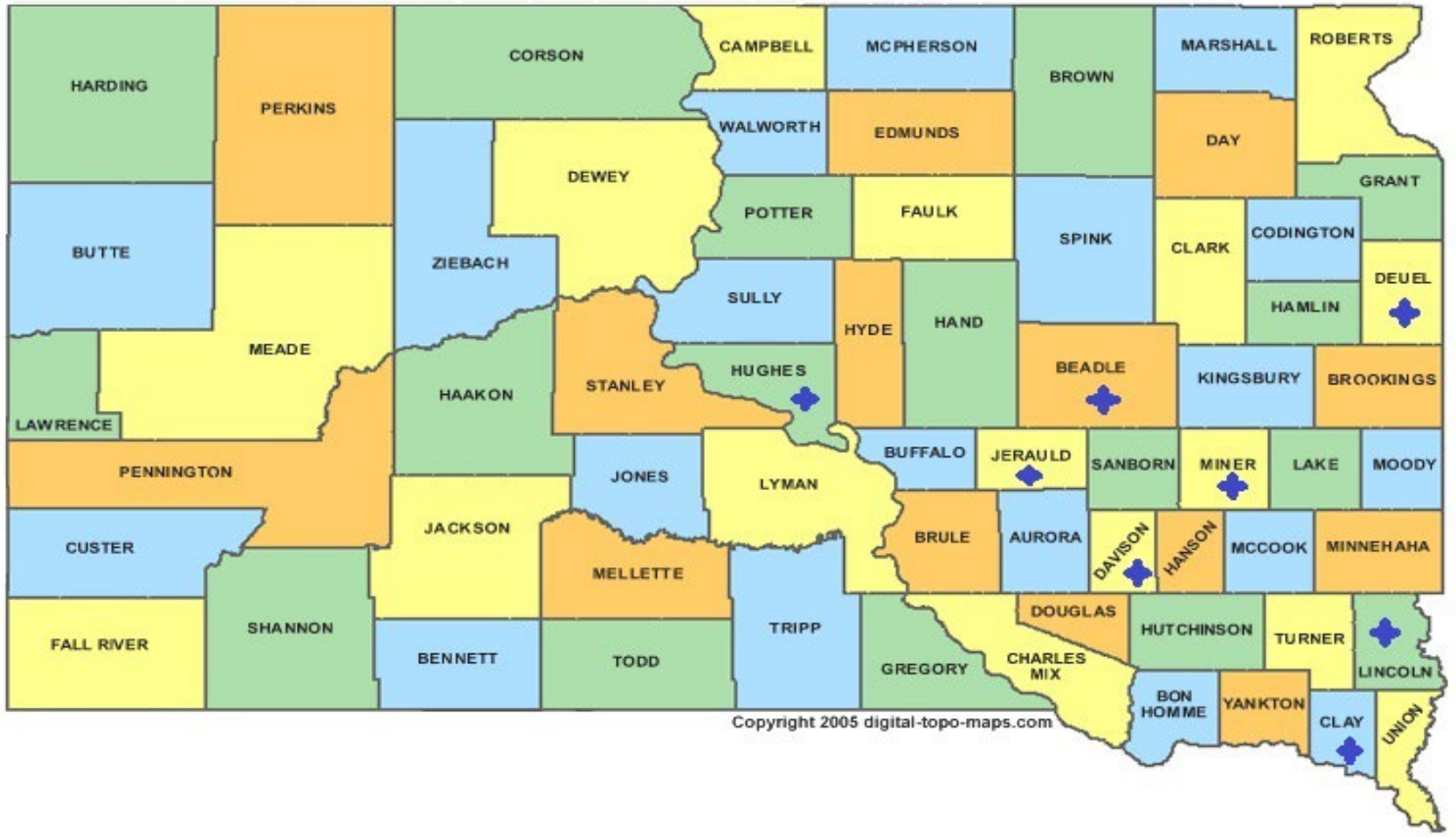
[2] Maximum allowable unless range shown. N.P. = Non Plastic as per AASHTO T-90. Use material passing the No. 40 sieve (standard method). For Class 5 aggr determined from the following formula: Max. allowable PI for Class 5 = 10 - (% Passing No. 40 Sieve / 10) — 7-15

[3] Minimum weight percentage allowable for the portion of the aggregate retained on a No. 4 sieve having at least 1 fractured face for Classes 4, 5, 13, 27, 29, 31 — 12%

[4] Minimum percentage of material passing a No. 4 sieve that is composed of fractured material produced by a crushing process. The Contractor shall demonstrat — 50%

[5] Salvaged Base meeting the requirements of Section 302 and 817 may be substituted for Cl. 3 or Cl. 5 virgin aggregate, unless otherwise specified on the Plans. — 10%

Recent validation check of material quality in SD



Gradation/PI Tests

List of Gravel Sources	Why these sites chosen?
Deuel County A	Previous data seems inaccurate
Deuel County B	
Beadle County	
Miner County	
Hughes County	
Mitchell Township	Study contrast in local materials used on unpaved road
Lincoln County	
Clay County	
Jerauld County	

Summary

Source	Gradation	PI
Deuel County A	Failed	Failed (No PI)
Deuel County B	Failed	Failed (No PI)
Beadle County	Failed	Passed (5)
Miner County	Failed	Passed (6)
Hughes County	Failed	Passed (4)
Mitchell Township	Failed	Failed (No PI)
Lincoln County	Passed	Failed (no PI)
Clay County	Failed	Passed (7)
Jerauld County	Failed	Passed (4)

Gravel Quality Issues

- Gradation problems generally confined to small percentage retained on 1 in. sieve (SDDOT Gravel surfacing spec requires 100% passing 3/4 in. sieve.
- Generally good on the split between coarse and fine aggregate on the #40 sieve.
- SDDOT Standard Specification requires minimum plasticity index (PI) of 4 and maximum of 12
  - Only five of nine samples had PI.
  - Maximum PI tested was 7.

Part of the problem in not getting plasticity:

Managing Layer Thickness: Coring a Gravel Road:


CRSP

Over two inches of thickness deviation

Example of test pit in existing gravel road

Calculate spread rates on gravel projects

It requires 407 cubic yards (570 tons) to place <u>one inch</u> of gravel on 1 mile of a 20 ft road top.

A 25-ton load of gravel covers only 320 linear ft to place <u>one inch</u> of gravel on a 20 ft road top.

This means….

- If you are not measuring layout distances, you are NOT laying out consistent layers of gravel.
- Do you have another way? Teach me!

Note: this is an adequate layer for maintenance, but <u>not</u> adequate thickness to carry legal loads during spring thaw!

Deep Layer Needed to Carry Heavy Loads

Table 4.2. Suggested gravel layer thicknesses for new or reconstructed rural roads.

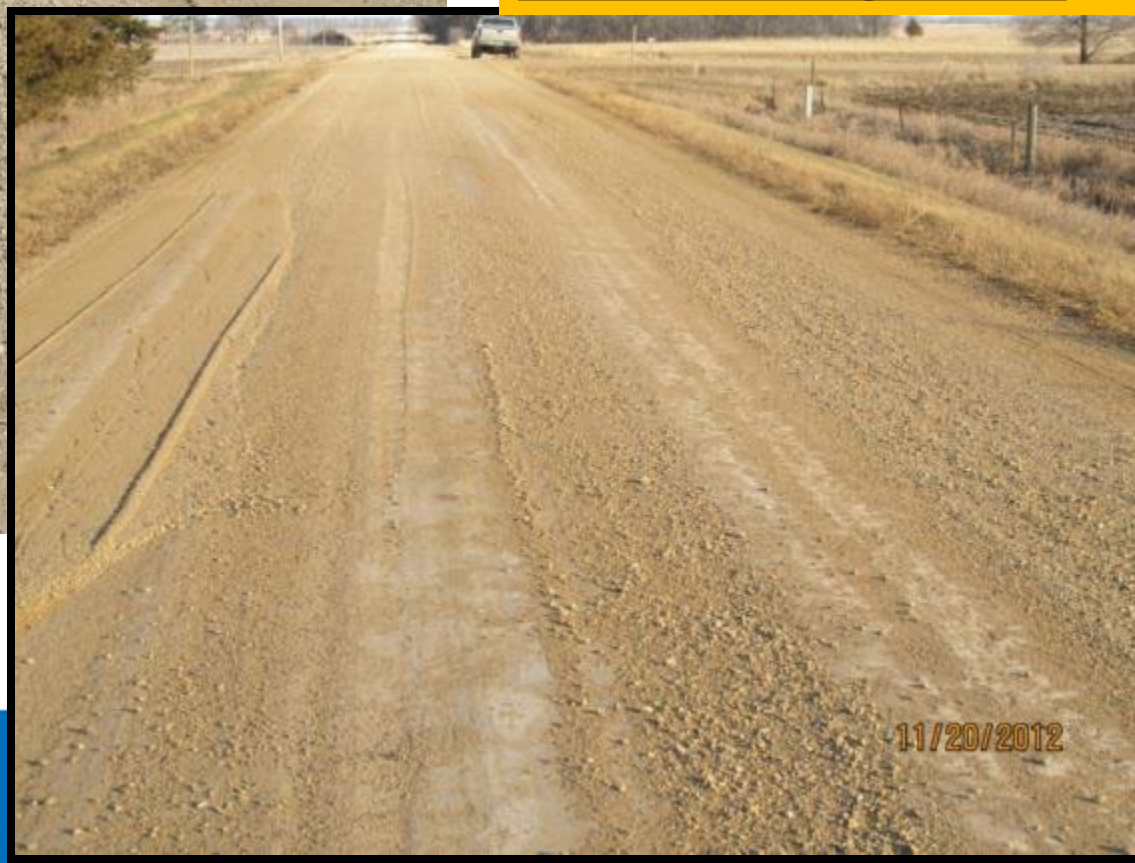
Estimated daily no. of heavy trucks	Subgrade support condition[1]	Suggested minimum gravel layer thickness, mm (in)
0 to 5	Low	165 (6.5)
	Medium	140 (5.5)
	High	115 (4.5)
		215 (8.5)
		180 (7.0)
		140 (5.5)
		290 (11.5)
	Med	230 (9.0)
	High	180 (7.0)
25 to 50	Low	370 (14.5)
	Medium	290 (11.5)
	High	215 (8.5)

14.5 inches of gravel needed to carry 25 to 50 trucks per day over weak subgrade!

Notes. [1] Low subgrade support: average CBR ≤ 3 percent; medium subgrade support: 3 percent < average CBR ≤ 10 percent; high subgrade support: average CBR > 10 percent. [2] CBR = California Bearing Ratio of the in-place subgrade soils. Methods of estimating CBR are discussed in section 7 of this document.

Some Thoughts on Gravel Quality

Same operator
Same road
Same day
<u>Different gravel</u>



SDDOT/SDLTAP Surface Gravel Study Project Update

Lessons Learned Thus Far

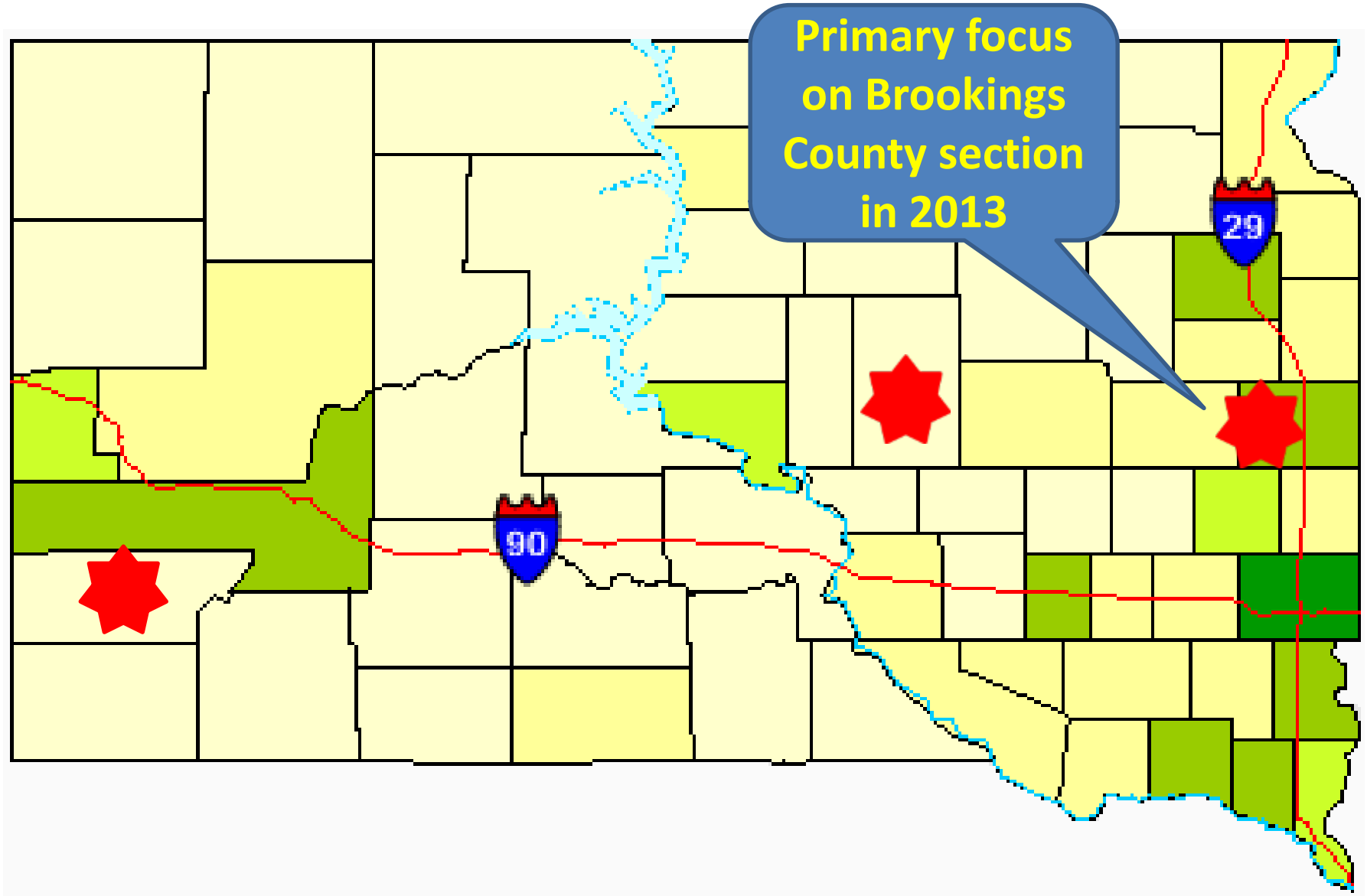
Reason for Project

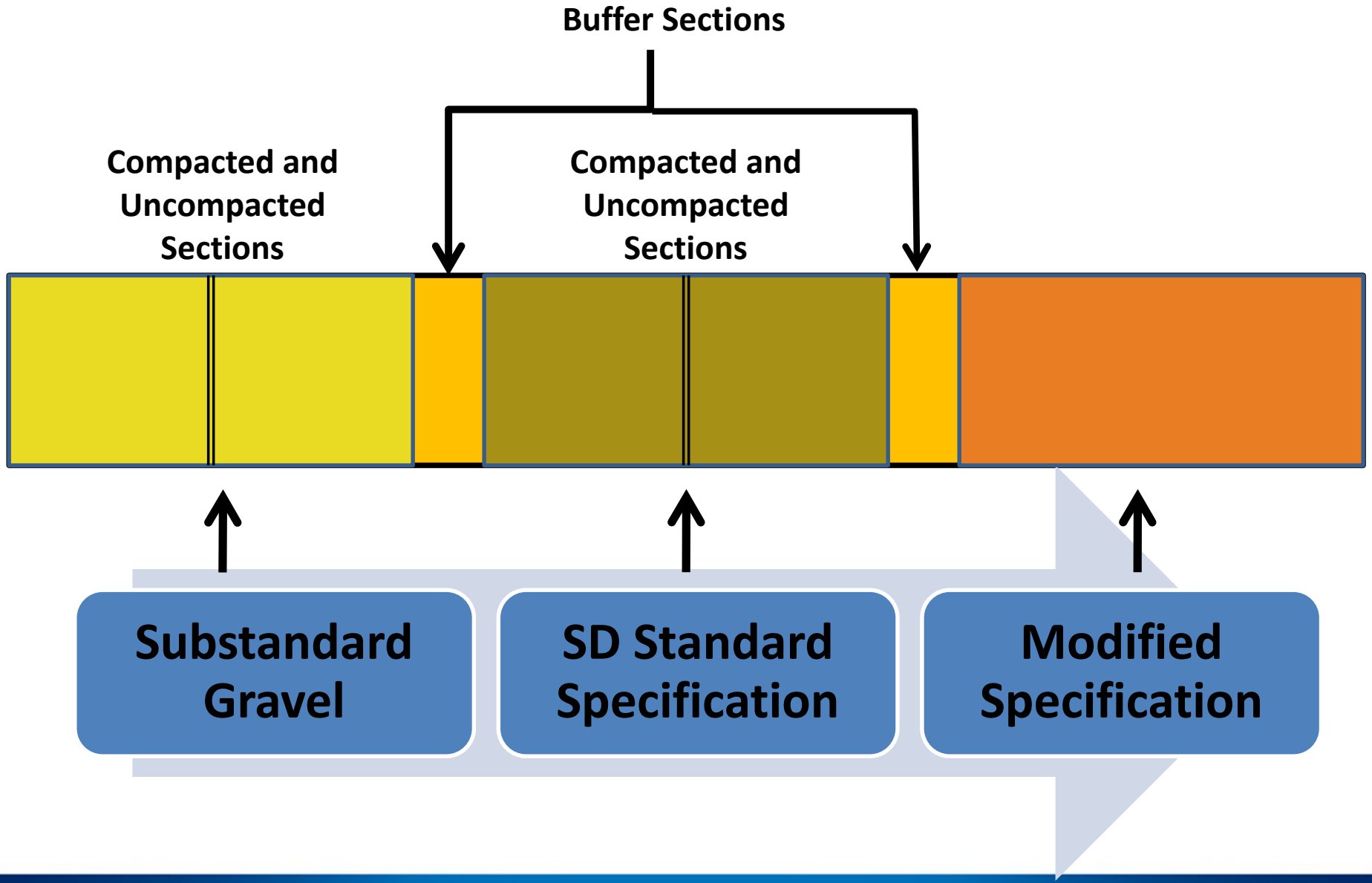
- More than 75% of local roads in SD are unpaved – managing them is a challenge!
- Biggest complaints from public are:
  - rough condition (generally from corrugation
  - "washboard" in surface)
  - too much loose aggregate on the surface makes it hard to control a vehicle.
- **How critical is gravel quality to this and how does it affect total cost of maintenance?**

Focus of Test Project

- Primary focus is on effect of gravel quality on life-cycle cost of gravel road maintenance
- Three types of gravel used in study:
  1. Substandard but commonly used: meets no spec except top size control – 1” minus.
  2. Barely meets SDDOT Gravel Surfacing Spec: percent passing #200 sieve is low and/or plasticity index (PI) at bottom of range at 4
  3. Modified to meet SDDOT Spec: higher minimums of 10% passing #200 sieve and PI at 7.

Three test sections were built:




Buffer Sections
Compacted and Uncompacted Sections
Compacted and Uncompacted Sections
Substandard Gravel
SD Standard Specification
Modified Specification

Each section was built with three to four inches of new gravel after existing surface was prepared and shaped. Compaction/non compaction comparison as well.

One of the biggest challenges was finding gravel that meets the modified SDDOT Specification: "Shall have minimum plasticity index (PI) of seven". (Even higher minimum was considered in project planning)

One way to meet modified spec – blend different material from separate sources

This was done on one section in Brookings Co and one section in Custer Co

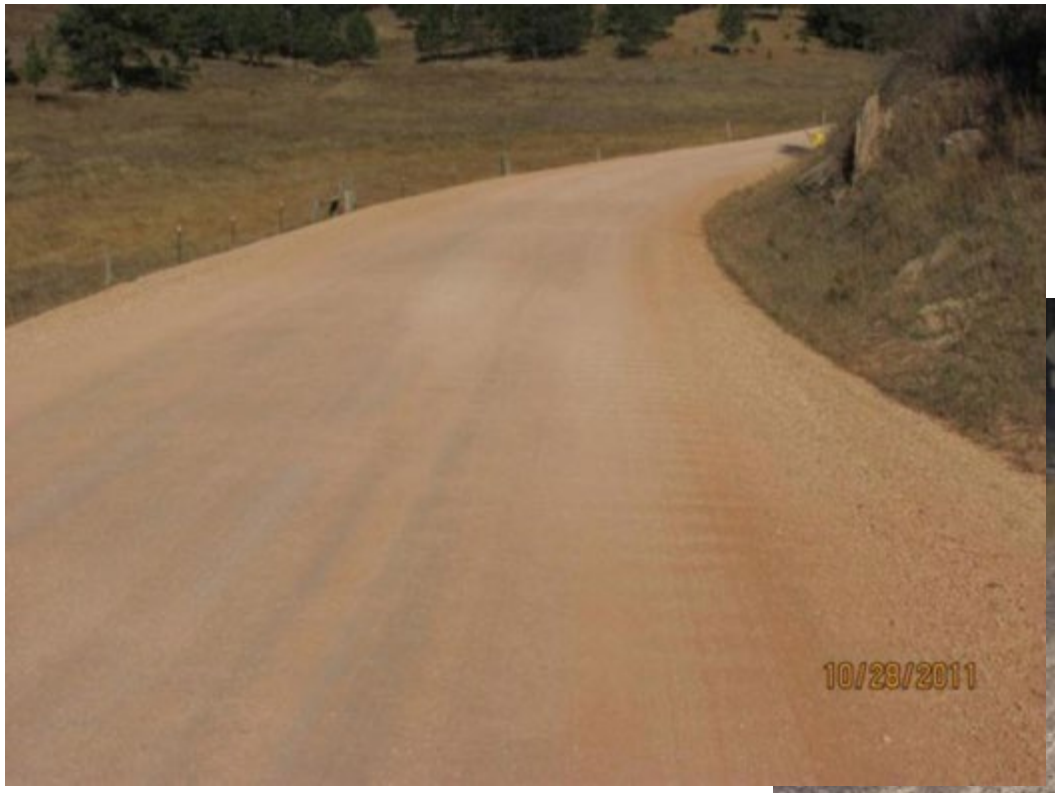
Is this the future?

More blending or “manufacturing” to get high quality gravel – processing from a natural clay source here:

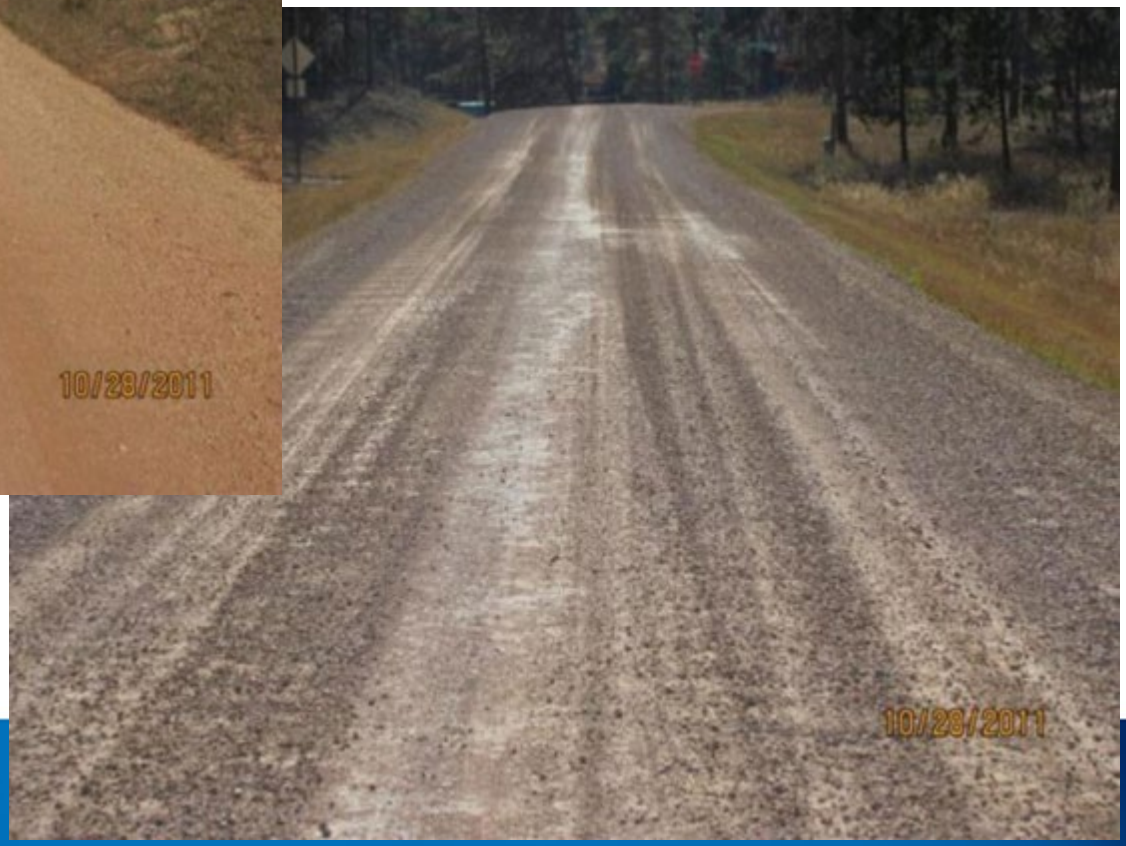
Road mixing natural clay to get a high quality surface gravel


Please note this area

Some sections showed contrast in performance quickly due to gravel quality



Custer County Test Sections



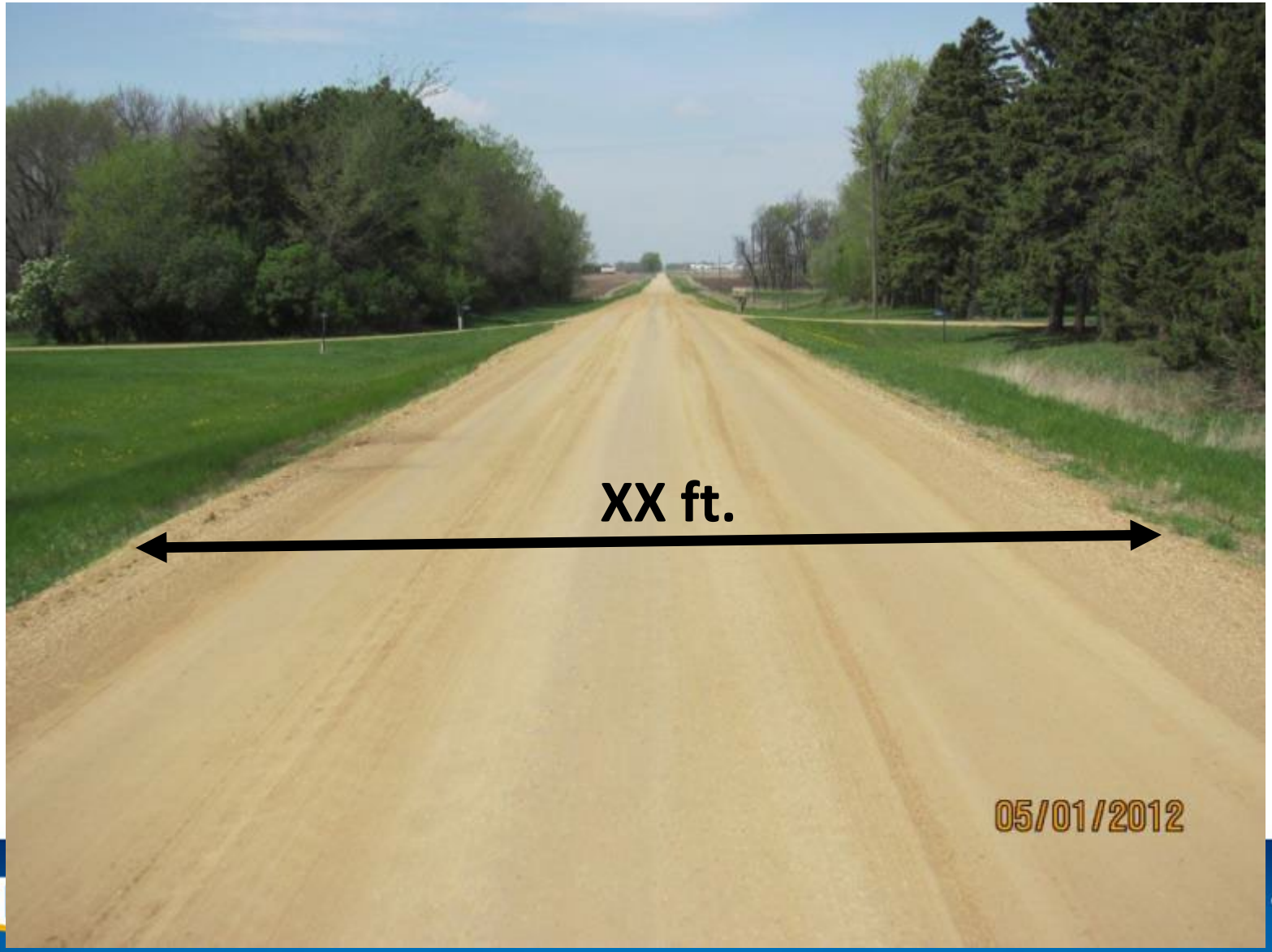
Current Status of Project

- SDLTAP has accumulated photo documentation on all sections over the past two years.
- Measurement and documentation has been done on these distress types in 2012 & 2013:
  1. Accumulation of loose aggregate (float)
  2. Changes in top width from time of construction
  3. Presence of corrugation (washboard) on surface
  4. Change in roadway crown

The float test (loose aggregate)

Simply remove loose aggregate from a 10 inch cross section, weigh it and convert that to a one-mile section

Change in top-width is measured on traveled way – hinge point to hinge point



Corrugation (washboard):

Hard to quantify in extent, fairly easy to measure severity

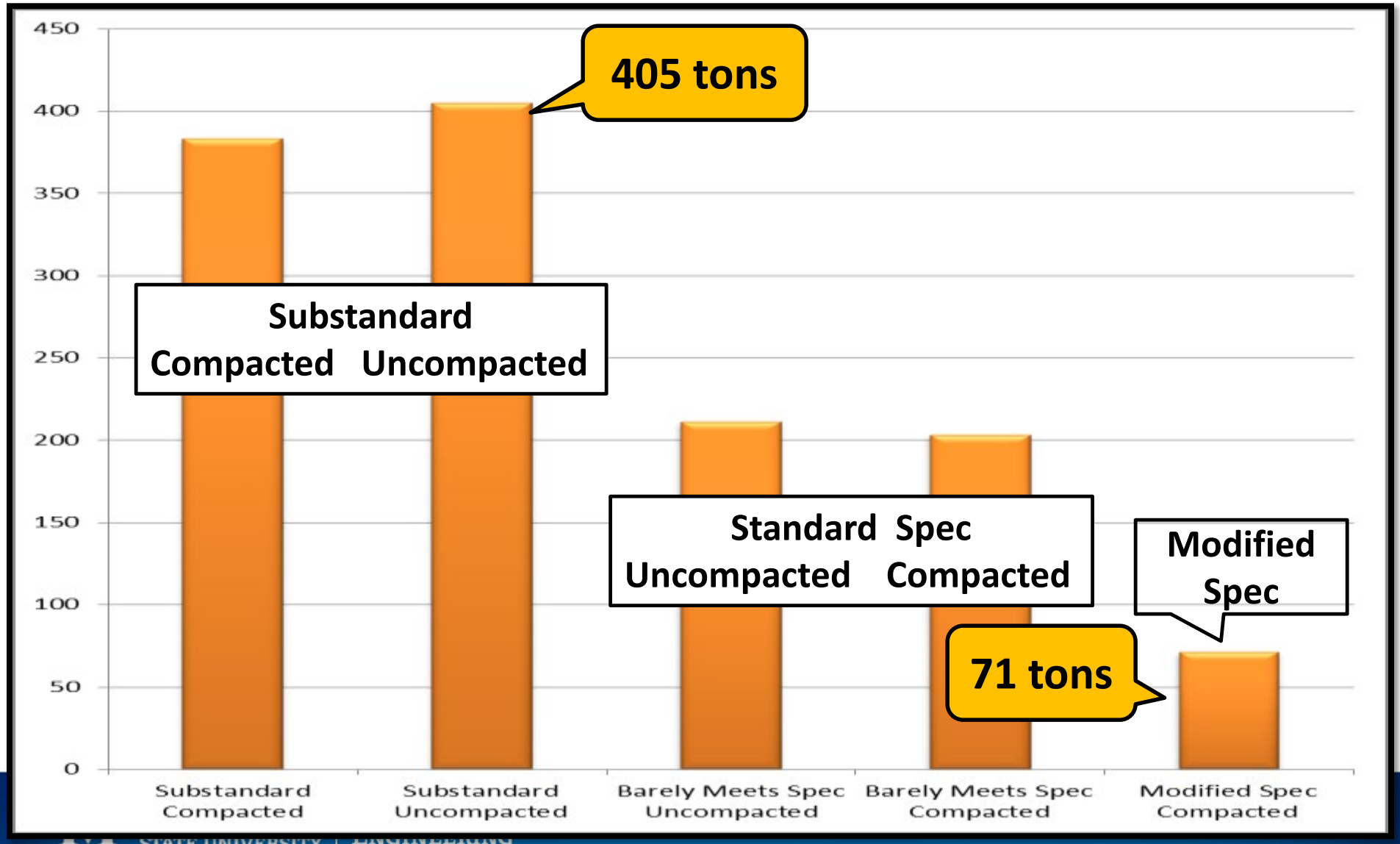
Difference in 2012 & 2013 maintenance seasons:

Station **SD-BK-1**

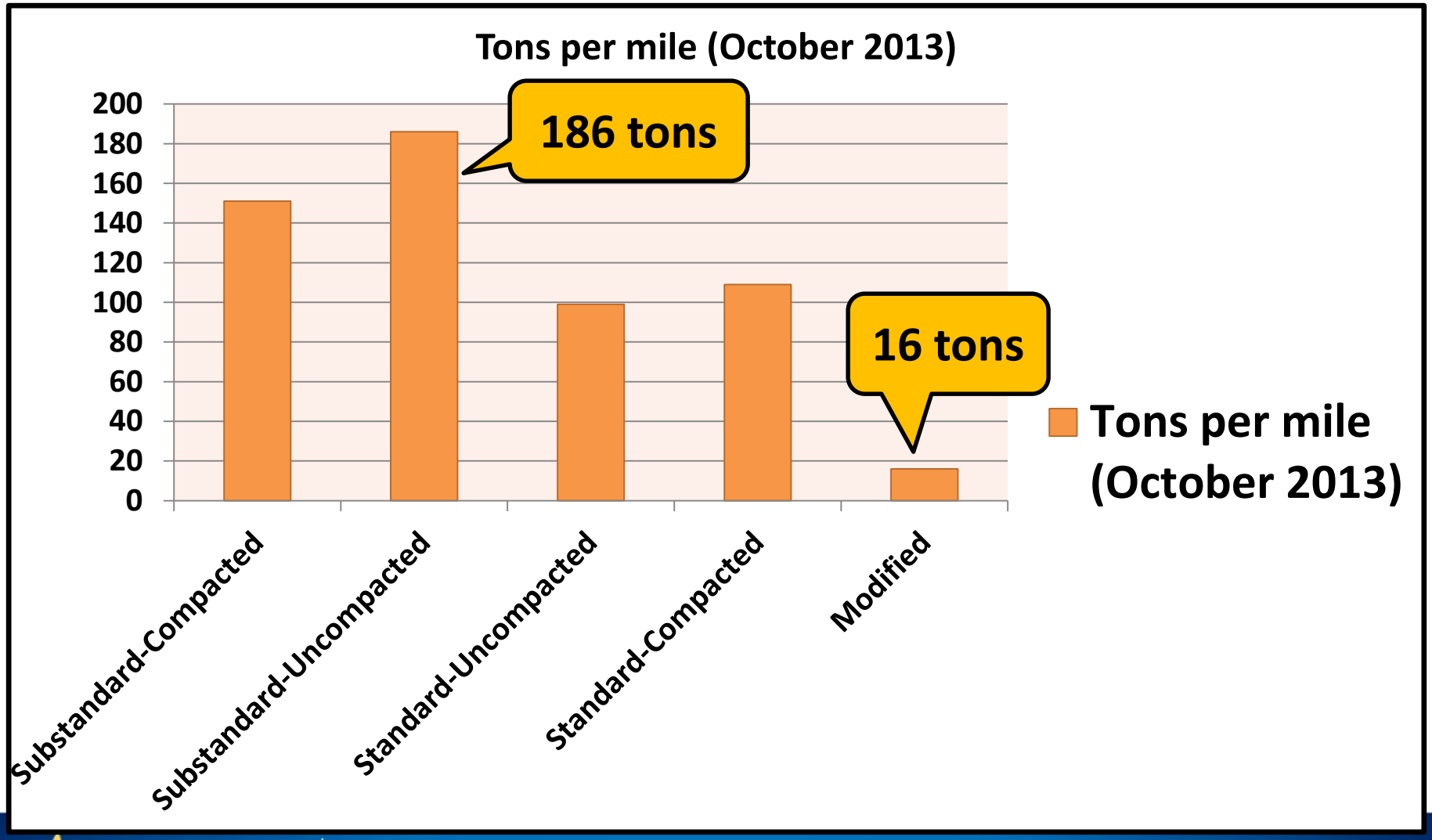
Date	Precip
10/01/2013	
10/02/2013	
10/03/2013	
10/04/2013	
10/05/2013	
10/06/2013	
10/07/2013	
10/08/2013	
10/09/2013	
10/10/2013	
10/11/2013	
10/12/2013	1
10/13/2013	0
10/14/2013	1
10/15/2013	
10/16/2013	
10/17/2013	
10/18/2013	47 *
10/19/2013	03
10/20/2013	--
Totals :	**2.94**

Cooler, wetter season in 2013 – 2.94 inches of rain in previous 20 days – most of that in three days prior to the last test.

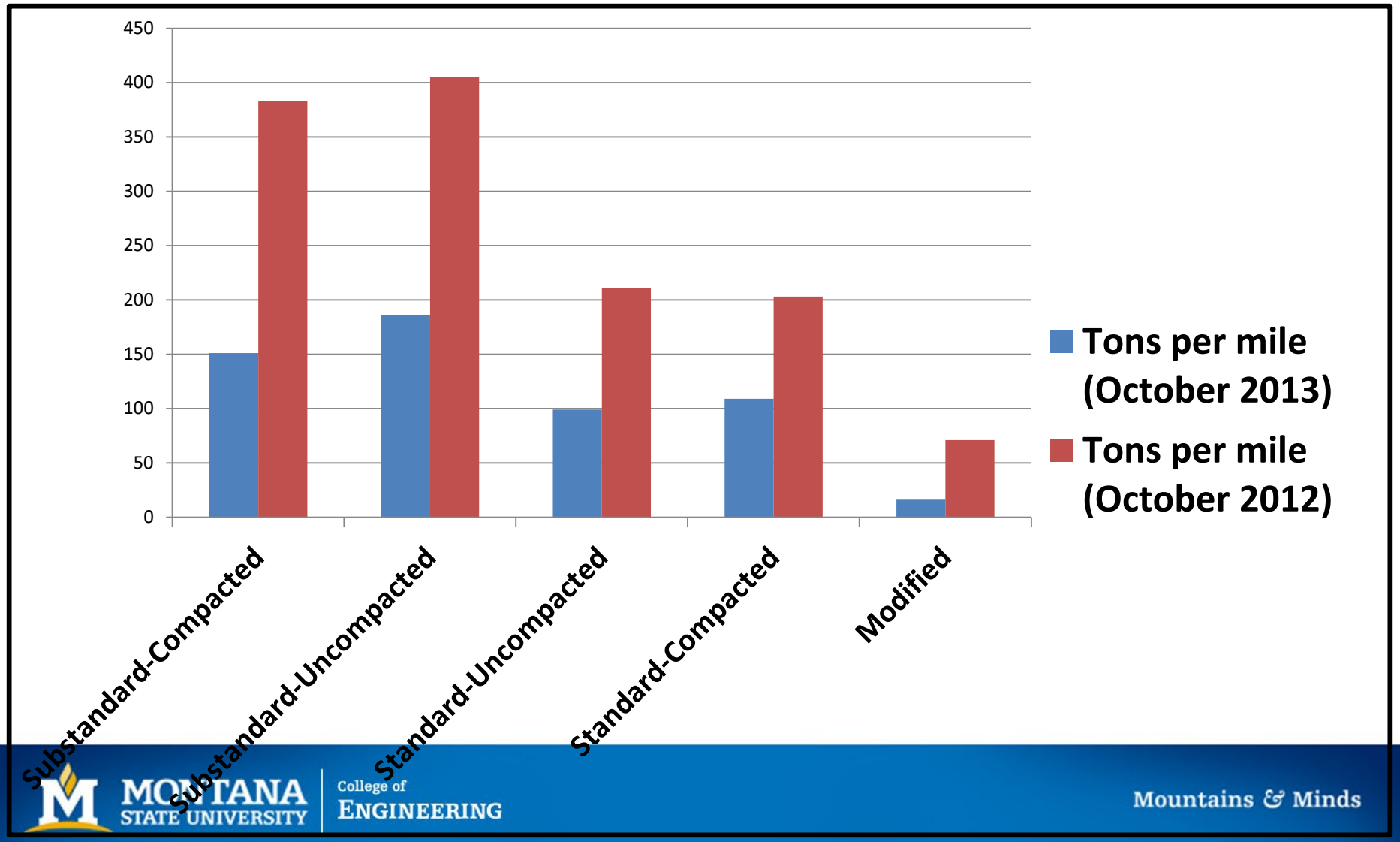
Brookings Section – Loose Aggregate 2012



Brooking Section – Loose aggregate 2013



Loose aggregate comparison 2012 & 2013

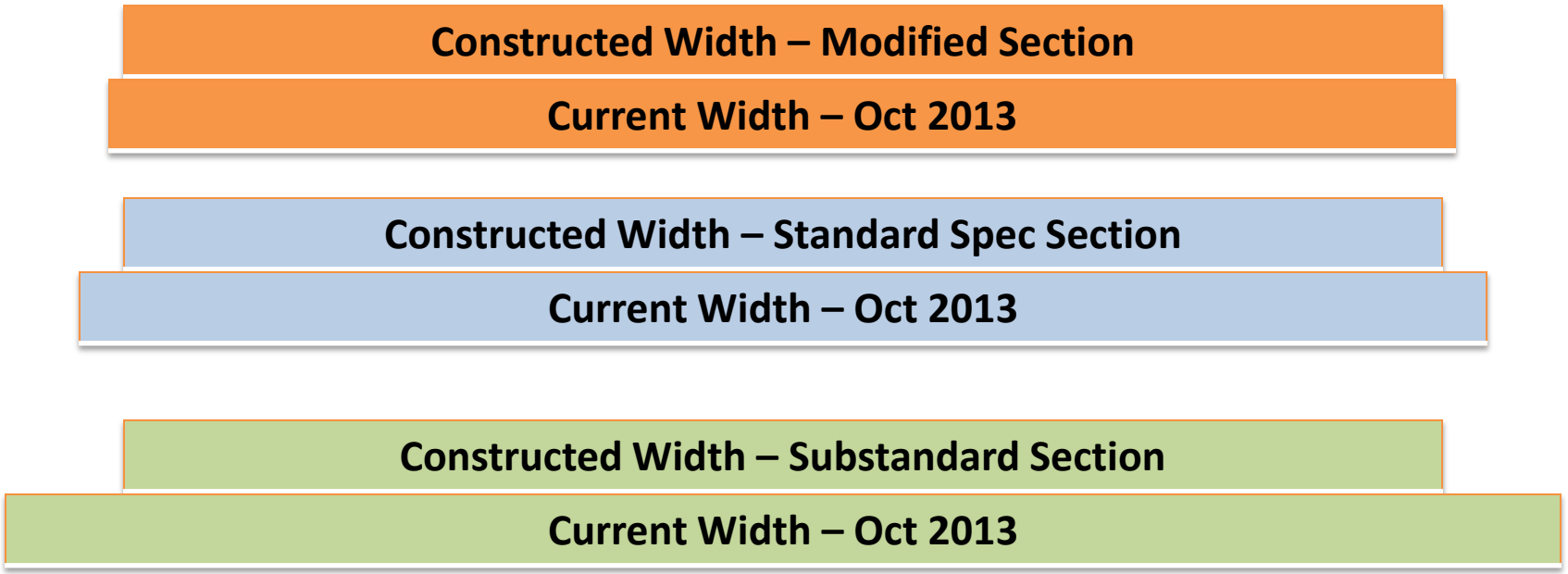


Corrugation (Washboard)

- No corrugation observed on any sections meeting at least minimum standard specification.
- However, substandard section had the beginning of light corrugation only two days after blade maintenance after nearly three inches of rain.

Change in Roadway Surface Width

Constructed Width – 21.5 ft on all sections



Current width ranges from 22 ft on modified section (top bar) to 25.25 ft on substandard section (bottom bar)

Substandard section – aggregate has moved outward over 4 ft since construction

Modified section has moved outward only six inches since construction

View of Substandard section – 10-18-13

View of Modified section – 10-18-13

Does the modified section rut in wet weather? No, virtually no rutting observed.

Any traffic on this road?

Concluding Points

- Meeting basic SDDOT standard surface gravel specification reduces loose aggregate by 1/3 to 1/2.
- Widest differential was in Brookings County near end of corn harvest in 2012 with 405 tons of loose aggregate on substandard section to only 71 tons on modified section.
- No corrugation ever observed on standard or modified material.

Concluding Points (Con't)

- Most interesting fact thus far: Brookings has done blade maintenance up to four times on substandard section to only once on modified!
- A negative aspect: we are getting a lot of push-back from aggregate producers who would prefer to produce as they always have – no close control of % passing the #200 sieve and no attention to the plasticity index.

Maintenance Challenges After Construction or Rehabilitation:

We have problems due to excessive precipitation???

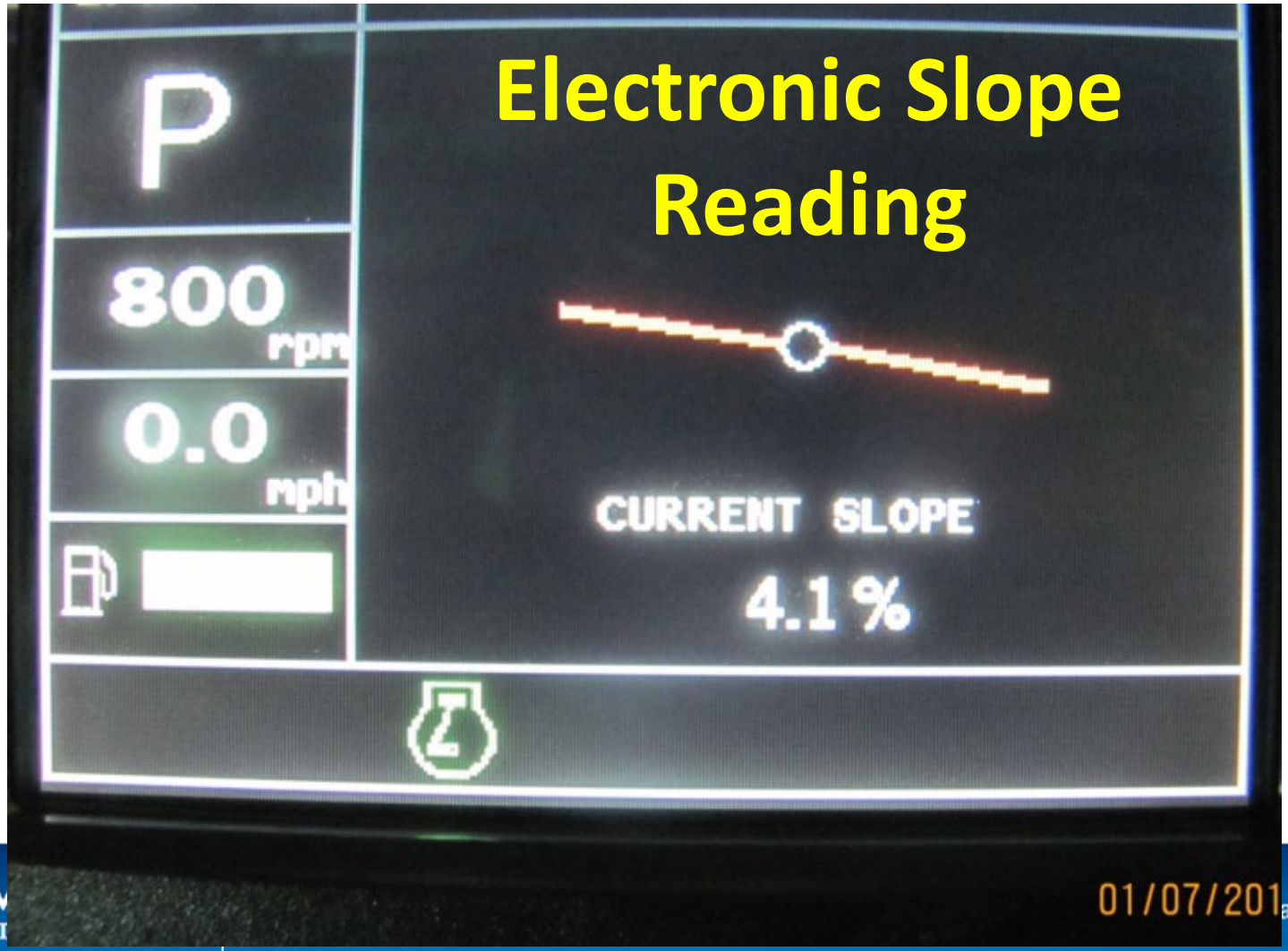
10 inches average annual rainfall

Nearly 200 inches average annual rainfall

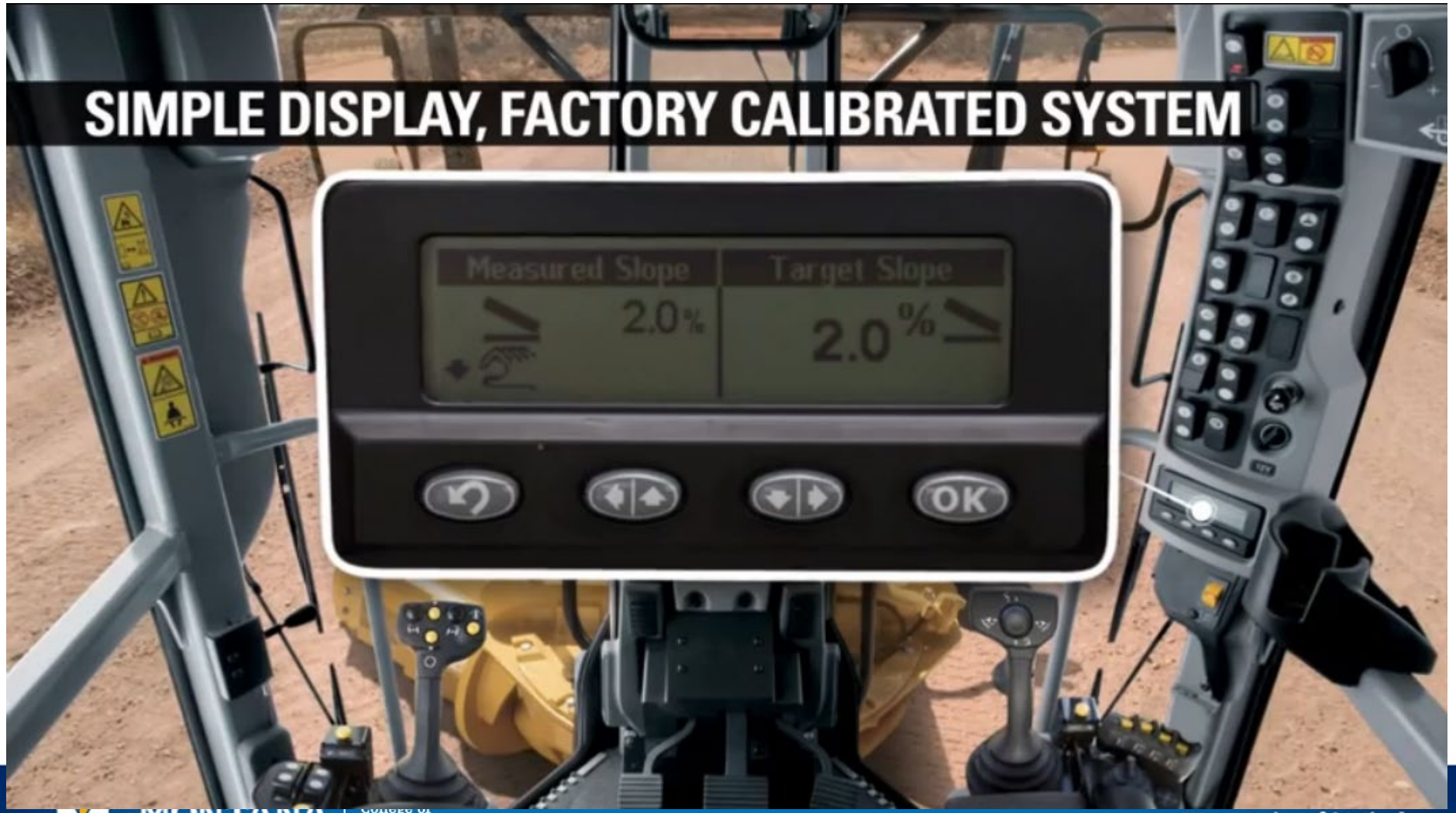
Maintaining no crown

A crown gauge is helpful

In the motorgrader cab: On-board electronics are coming to the market very quickly



Slope Control systems on motorgraders are a great aid in construction and rehabilitation



Electronics only work if the operator accepts it!

Good surface drainage

Crown should be near ½ inch per ft

(4% drop on the cross slope)

Example: 24 ft. roadway width should have near 6

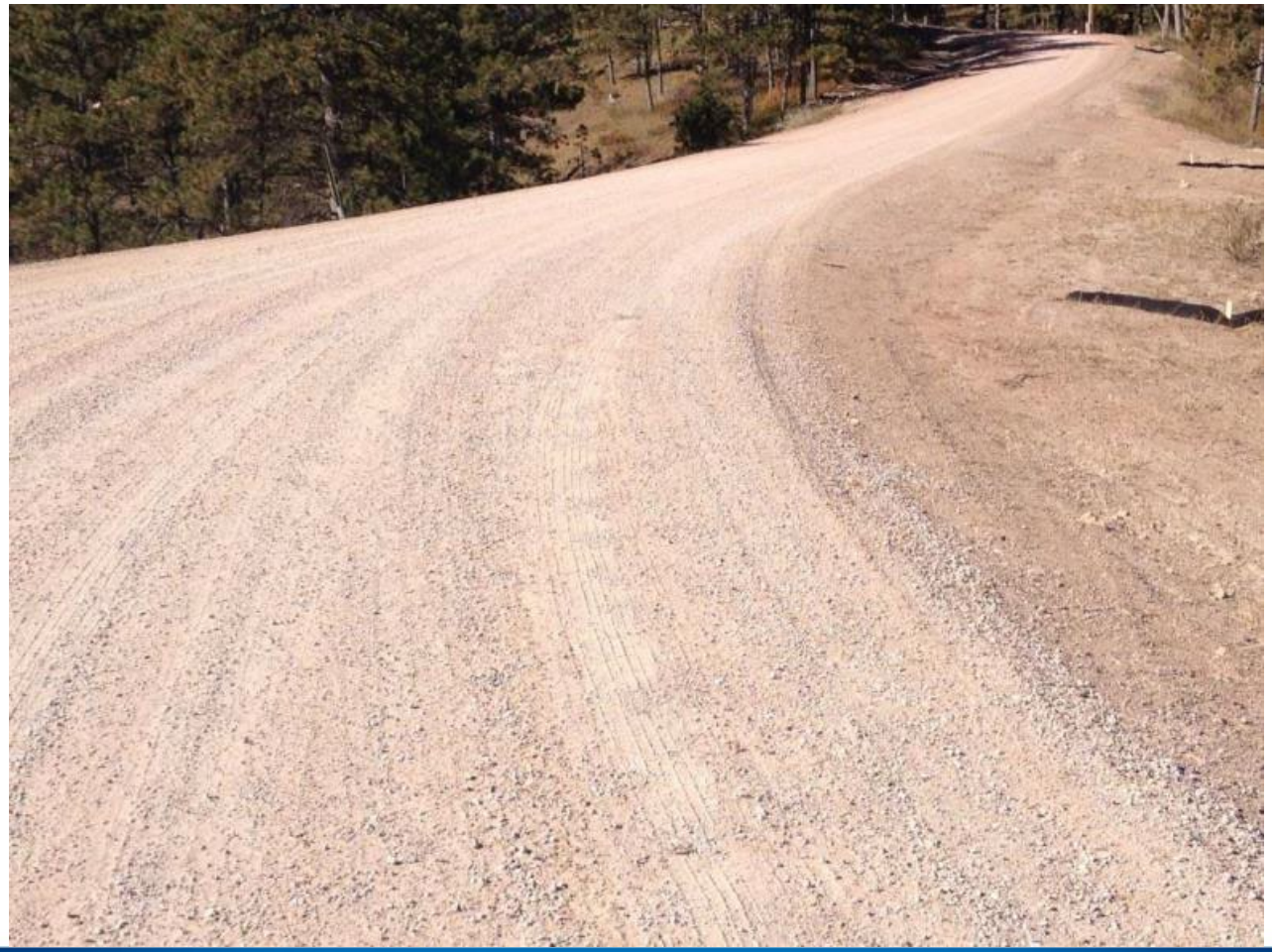
6 inches over 12 feet, 6 inches of crown per side

The Next Challenge – High Shoulders!

Reasonably good cross section on low volume road with poor horizontal and vertical alignment

Some thoughts on roads with severe horizontal and vertical alignment problems

Drainage is critical

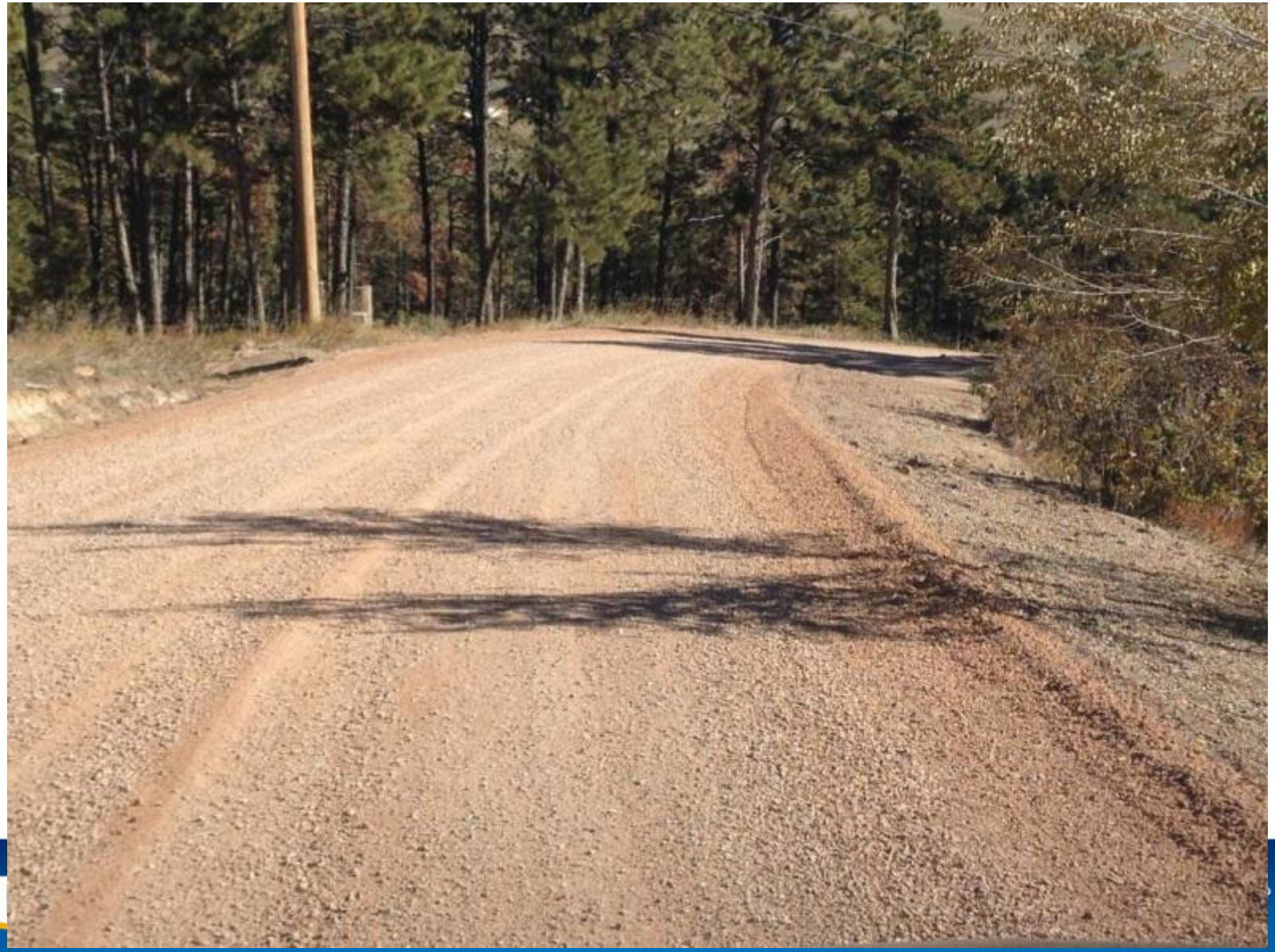


Just as critical is surface aggregate quality

Most of the surface is tightly bound here

Surface aggregate has good overall gradation and relatively small top size.

Virtually no corrugation on day of observation



Recent roadway reshape is very good

Drainage run-out to carry water away from road with erosion control – good practice.

Good culvert installation under driveway


NO
OUTLET

Case Study from Meade County, SD Experience with Alternatives to Paving

Information from:

Mr. Ken McGirr

Meade County Highway Supt

Sturgis, SD

- **Elk Vale Road**
  - **Located directly east and north of Rapid City**
  - **Serves a growing area just off of exit 61 on Interstate Highway 90**
  - **Classification: Rural Major Collector**
  - **Became impossible to maintain as gravel surface**

Recent Traffic Count Breakdown

- Northbound
  - 12/04/2012 299 total vehicles 22 trucks
  - 12/05/2012 319 total vehicles 28 trucks
  - 12/06/2012 317 total vehicles 22 trucks
- Southbound

Average 635 vehicles per day and average 103 trucks per day (16% of total volume)

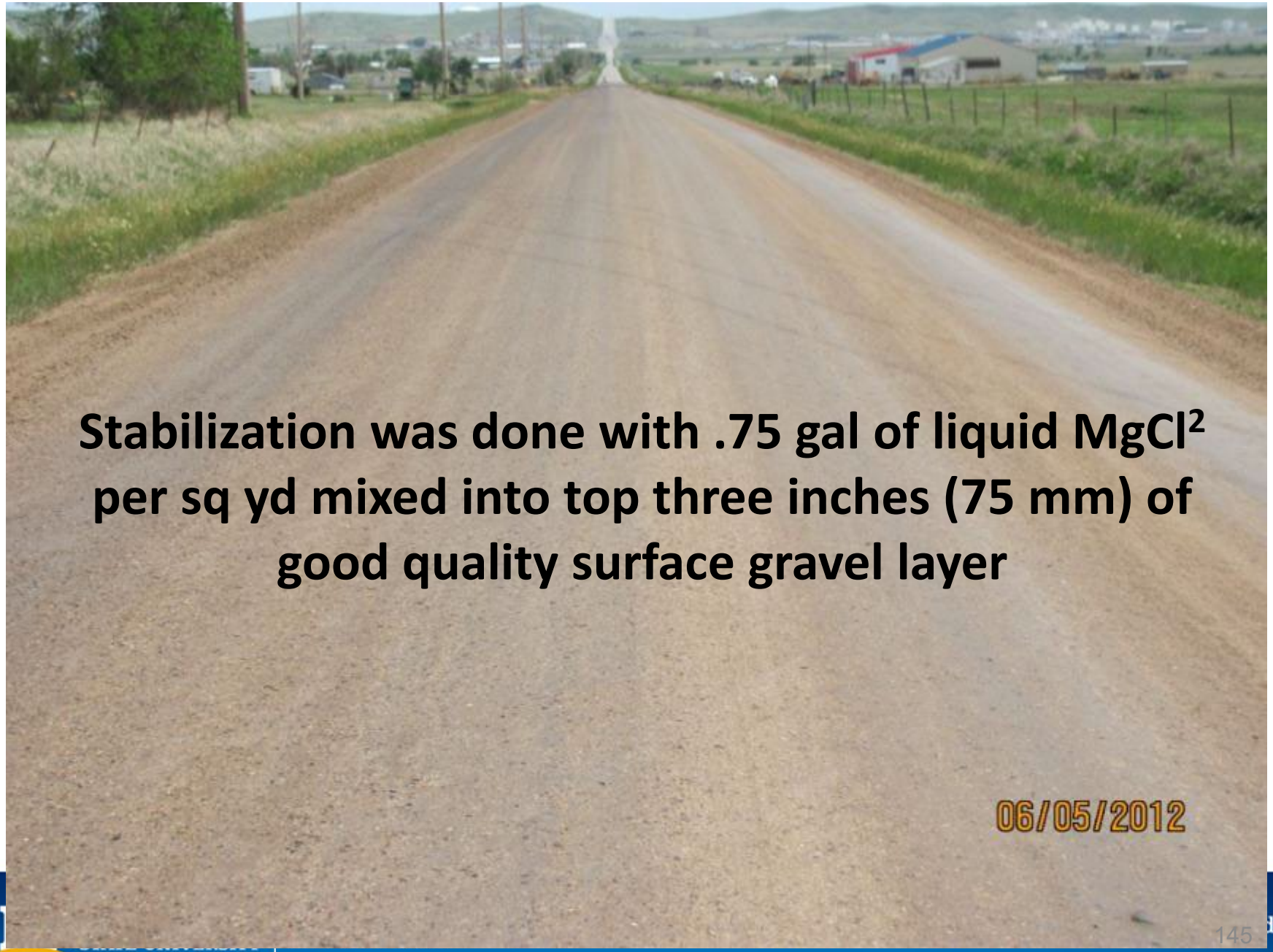
- **Total***
  - **12/04/2012 610 total vehicles 91 trucks**
  - **12/05/2012 658 total vehicles 120 trucks**
  - **12/06/2012 636 total vehicles 98 trucks**

***Meade County count tallied over 700 vehicles in earlier count with 25% trucks**

A difficult area for system-wide road management – Multiple jurisdictions, etc.

Originally constructed in May, 2011. Excellent performance after first year

Close-up view of stabilized surface


Stabilization was done with .75 gal of liquid $MgCl^2$ per sq yd mixed into top three inches (75 mm) of good quality surface gravel layer
06/05/2012

No significant loose aggregate and no corrugation even on 7% grade.

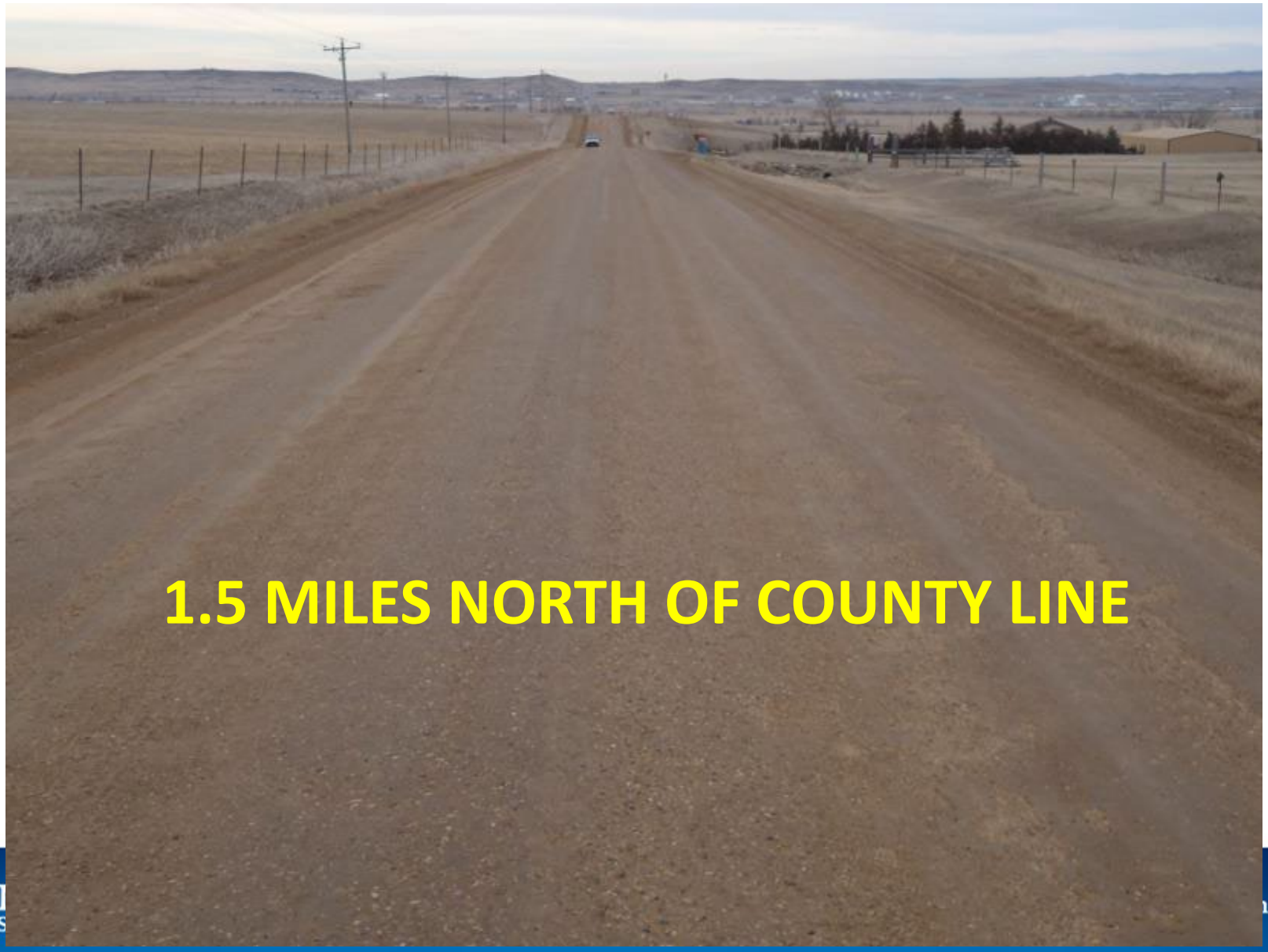

No blade maintenance was done between construction in summer of construction season (Year 0) and surface retreatment in summer of following year!
06/05/2012


Phone call from citizen – “If you had enough money to pave this road, why didn’t you save enough to put striping on it”
06/05/2012

End of season condition assessment

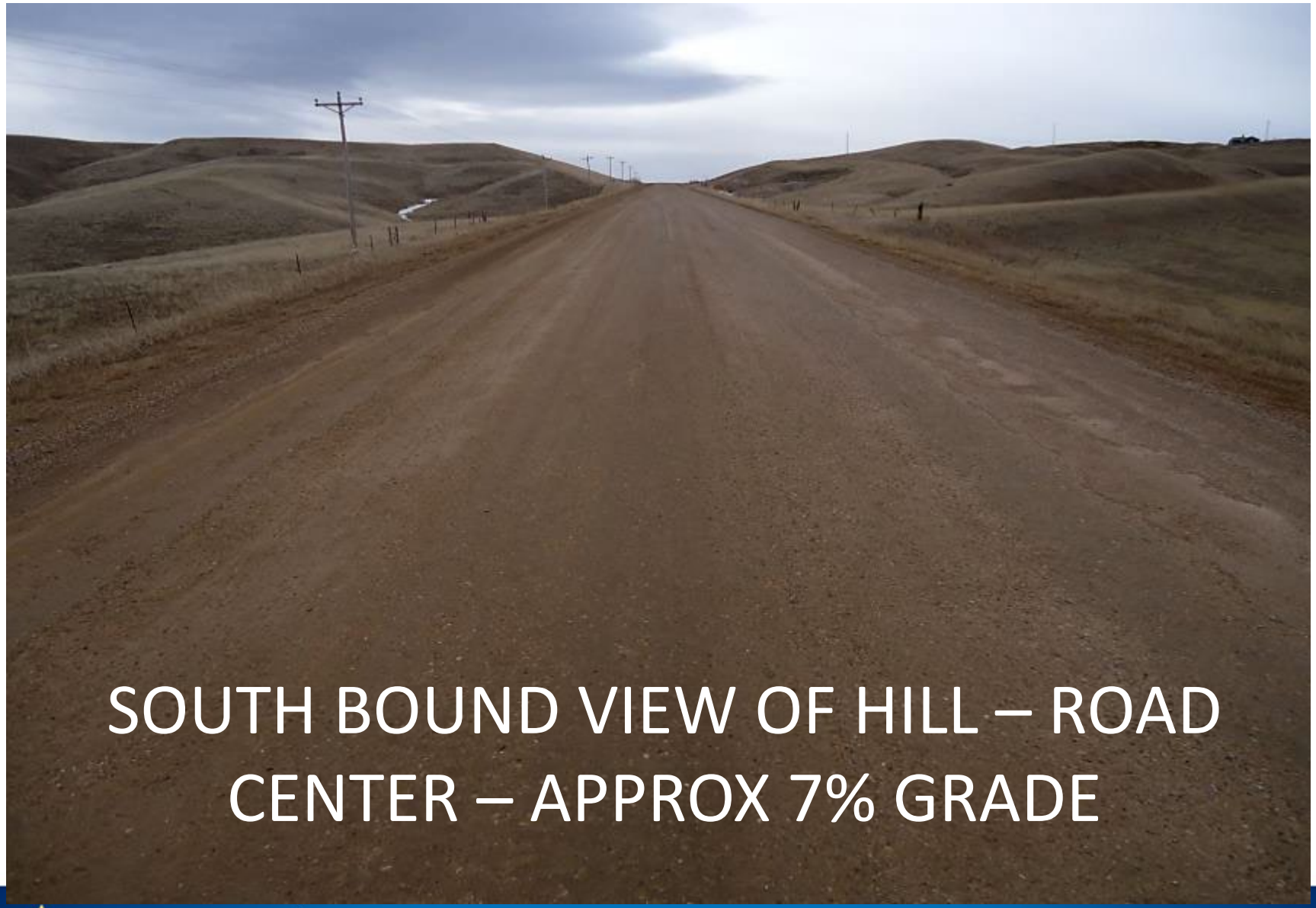
Skid marks from recent incident, 1 year later

Observation February, 1 year later…

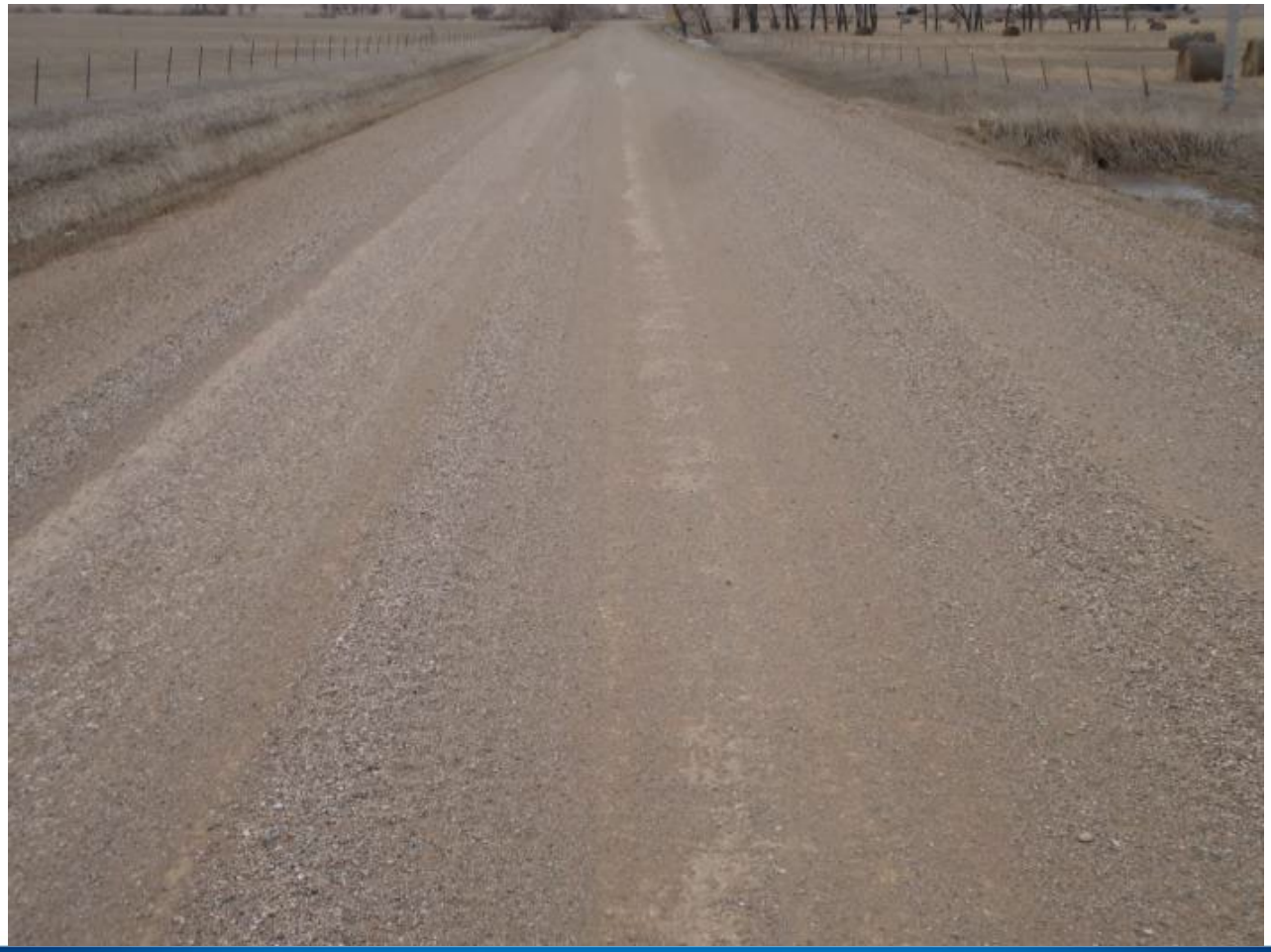


Same location – left shoulder

Same location – right shoulder


SOUTH BOUND VIEW OF HILL – ROAD CENTER – APPROX 7% GRADE

COMPARISON TO UNTREATED SECTION: 1 MILE NORTH OF TREATED SECTION



Wrap-Up Discussion:

Issues contributing to historically poor performance of roads in the network…

Issues contributing to historically poor performance of roads in the network…

1. Using unsuitable materials?
2. Lack of on-site investigation prior to construction?
3. Full scope of the project were not well defined?
4. Limiting scope to addressing only the most serious drainage deficiencies?
5. Improper shaping of the roadbed and inadequate compaction?
6. Poor contract administration: Limited leadership and governance?
7. Few aggregate sources, some were not even tested, and those that were, may not have been compliant?
8. Diversion of road maintenance funding for other administrative priorities?

A little about training

- A great need in our industry
  - Management level
  - Field supervisors
  - Operators

Management Training

- Clear communication on expectations must be conveyed to field staff.
- Does everyone have the same goals?
- Is management too preoccupied with the primary roads?
- Gravel roads become very low priority and consequently reach failed or near failed condition before work is done?

Field Supervisor Training

- **May not understand the right geometry needed on a gravel road (different than pavement).**
- **Consequently do not know how to convey to operators (in-house or out sourced) what is needed for good maintenance.**
- **Supervisors and operators develop adversarial relationship – the team breaks down!**

Operator Training

- Too often no training given on desired roadway shape (geometry) and bad habits are developed.
- Little or no mentoring by skilled operators who could communicate what they know.
- Great lack of training in our technical colleges or trades training centers for this field.
- No recognition for doing a good job!

Q: What do you see?

Q: What do you see?

Q: What do you see?

Q: What do you see?

Q: What do you see?

Get ready to face the challenges of maintaining gravel roads in the future!

Good Luck and Thank You!