TTI: 0-6985

Innovative Tools and Techniques to Accelerate Pavement Construction Workshop: Workshop Materials—PowerPoint

Technical Report 0-6985-P7

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6985-P7.zip

Innovative Tools and Techniques to Accelerate Pavement Construction Workshop

Project 0-6985
Perform Feasibility Study on Use of Innovative Tools and Techniques to Accelerate Pavement Construction

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Outline

Pavement Evaluation Procedures

- Description and criteria in selecting candidate projects
- Descriptions of the available tools for pavement testing

Traffic Control Timing Strategies

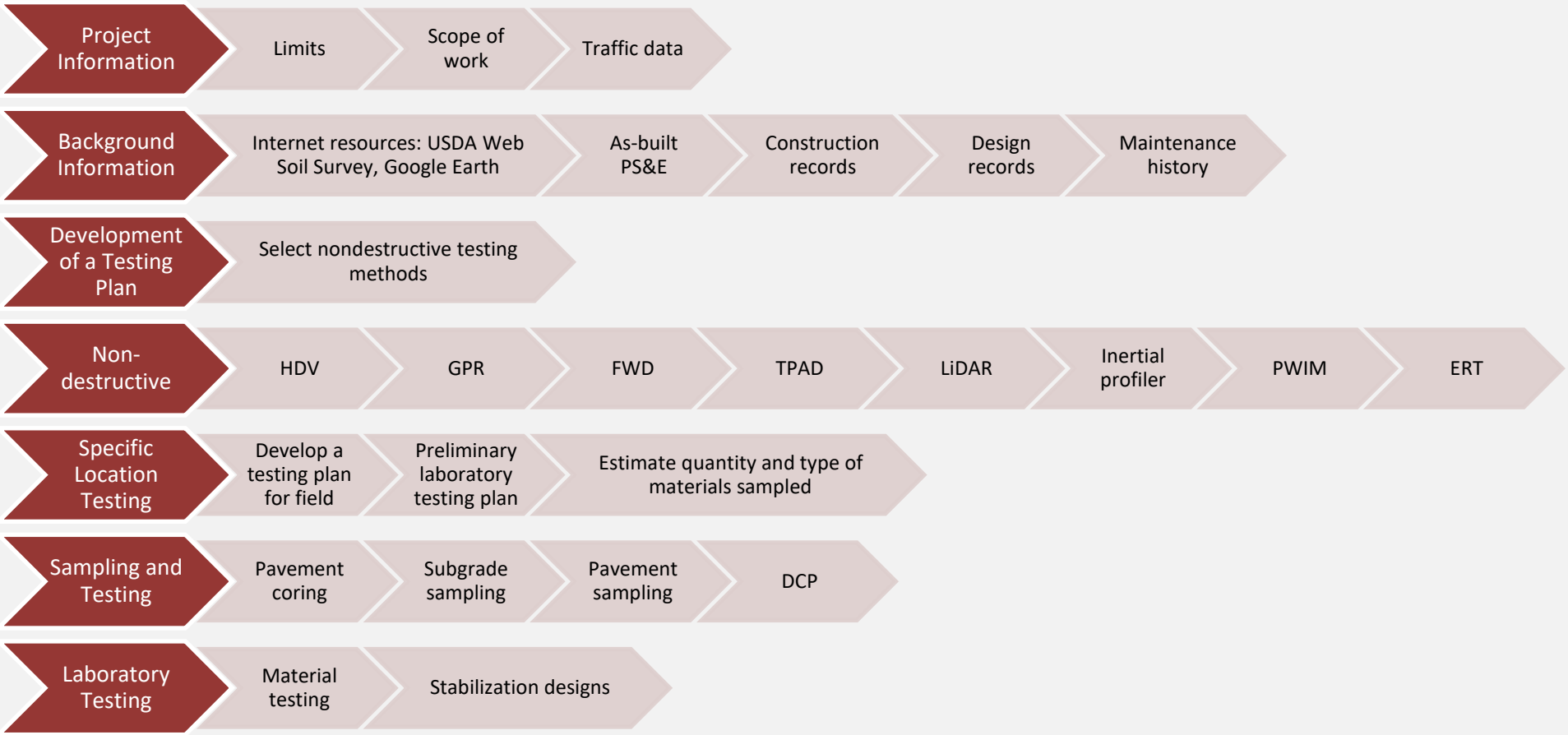
- Data needed for evaluation
- Descriptions of software for evaluating traffic control

SH 6 Case Study

- Pavement evaluation
- Traffic control timing
- Time/cost savings

PAVEMENT EVALUATION PROCEDURES

Pavement Evaluation Procedures



Pavement Evaluation Procedures

Project Information → Limits → Scope of work → Traffic data

- Project programming information
- TxDOT manuals
- TxDOT Form 2440 (Design Concept Conference)
- TxDOT Form 2124 (Traffic Data Request)
  - Request basic highway traffic data for pavement design
  - Base year/beginning year: Letting year
  - Forecasted 20 year: Letting year + 20 years
  - Forecasted 30 year: Letting year + 30 years
    - Only needed for perpetual and rigid pavement designs
  - Slab thickness (8" unless otherwise specified): Use 8"
  - Structural number (3 unless otherwise specified): Use SN = 3

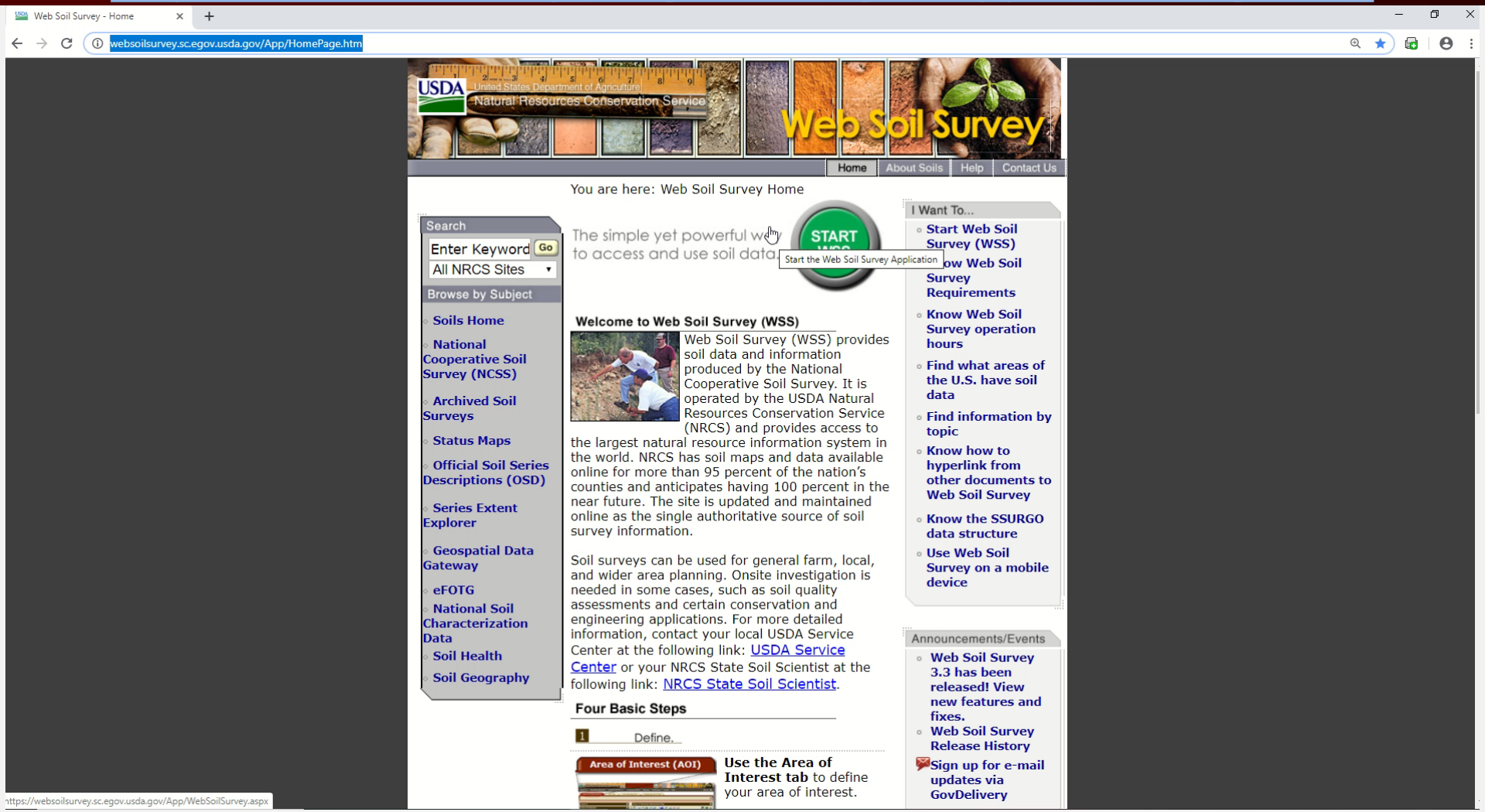
Pavement Evaluation Procedures

Background Information | Internet resources: USDA Web Soil Survey, Google Earth | As-built PS&E | Construction records | Design records | Maintenance history

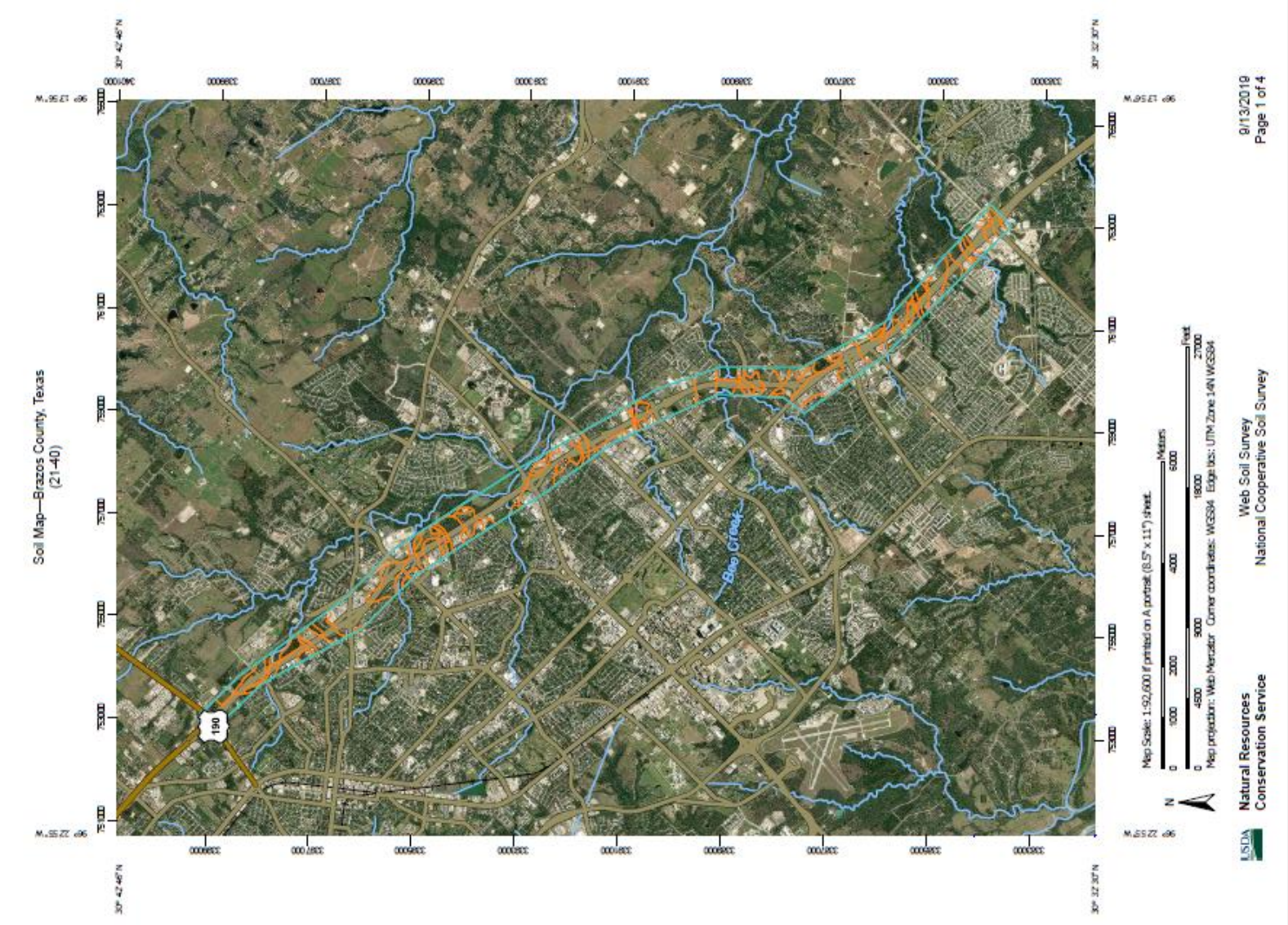
- United States Department of Agriculture (USDA) Web Soil Survey
  - PI of soil
  - Gypsum content
  - Organic content
  - Water table elevation

Web Soil Survey

https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm



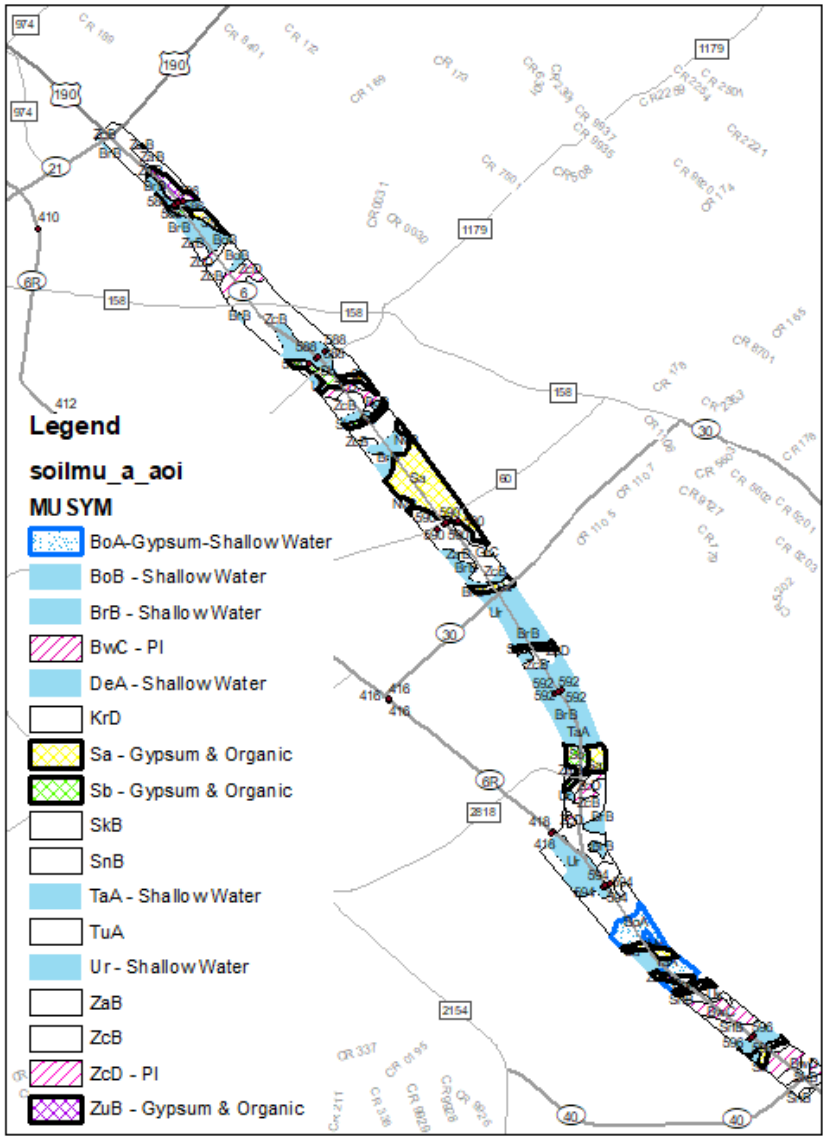
Soil Survey


Soil Map—Brazos County, Texas
(21-40)
190
Bee Creek
Map Scale: 1:92,600 if printed on A portrait (8.5" x 11") sheet.
Meters
Feet
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84
Natural Resources
Conservation Service
Web Soil Survey
National Cooperative Soil Survey
9/13/2019
Page 1 of 4

Soil Survey

Soil	Description	PI	Gypsum (%)	Organic (%)	Depth water table (cm)	Depth water table (ft)	Ac	% area	Concerns
BoA	Boonville fine sandy loam, 0 to 1 percent slopes	16.3	1	0.75	23	0.75	104	3.90%	G, W
BoB	Boonville fine sandy loam, 1 to 3 percent slopes	18.8	0	0.75	23	0.75	47.8	1.80%	W
BrB	Boonville-urban land complex, 0 to 3 percent slopes	22.9	0	0.75	23	0.75	468.1	17.40%	W
BuA	Burleson clay, 0 to 1 percent slopes	42.1	0	1.82	>200	6.56	6.1	0.20%	O, PI
BwC	Burlewash fine sandy loam, 1 to 5 percent slopes	31.2	0	0.71	>200	6.56	113.1	4.20%	PI
BwD	Burlewash fine sandy loam, 5 to 8 percent slopes	22.2	0	0.64	>200	6.56	10.2	0.40%	
DeA	Derly-Rader complex, 0 to 1 percent slopes	25.9	0	0.67	23	0.75	34.2	1.30%	W
GrC	Gredge fine sandy loam, 1 to 5 percent slopes	27.7	0	0.75	>200	6.56	18.4	0.70%	
KrD	Koether-rock outcrop complex, 3 to 12 percent slopes	2	0	0.75	>200	6.56	16.1	0.60%	
NvB	Navasan loamy fine sand, 0 to 3 percent slopes	2.5	0	0.35	153	5.02	11.9	0.40%	
PaC	Padina loamy fine sand, 1 to 5 percent slopes	2.5	0	0.42	>200	6.56	0.1	0.00%	
ReC	Rehburg loamy fine sand, 1 to 5 percent slopes	10.1	0	0.58	107	3.51	4.7	0.20%	W
RuC	Rosanky-urban land complex, 2 to 5 percent slopes	21.1	0	0.51	>200	6.56	8.3	0.30%	
Sa	Sandow loam, frequently flooded	16.8	2	1.29	145	4.76	342.9	12.70%	G,O
Sb	Sandow-urban land complex, frequently flooded	16.8	2	1.29	145	4.76	88.9	3.30%	G,O
SkB	Shiro loamy fine sand, 1 to 3 percent slopes	18.9	0	0.58	>200	6.56	22.9	0.80%	
SnB	Singleton fine sandy loam, 1 to 3 percent slopes	24.3	0	0.58	>200	6.56	73.8	2.70%	
TaA	Tabor fine sandy loam, 0 to 2 percent slopes	27	0	0.62	34	1.12	87.6	3.30%	W
TuA	Tabor-urban land complex, 0 to 2 percent slopes	18.7	0	0.58	>200	6.56	125.1	4.60%	
Ur	Urban land						145.5	5.40%	W
Us	Ustarents, clayey	42	0	0.75	>200	6.56	20.3	0.80%	PI
ZaB	Zack fine sandy loam, 1 to 5 percent slopes	22.5	0	0.48	>200	6.56	98.8	3.70%	
ZcB	Zack-urban land complex, 1 to 5 percent slopes	29.1	0	0.56	>200	6.56	675.2	25.10%	
ZcD	Zack-urban land complex, 5 to 8 percent slopes	32.4	0	0.56	>200	6.56	114.8	4.30%	PI
ZuB	Zulch fine sandy loam, 1 to 3 percent slopes	24.9	1	1.08	>200	6.56	54	2.00%	G,O

Soil Data in ArcMAP



Pavement Evaluation Procedures

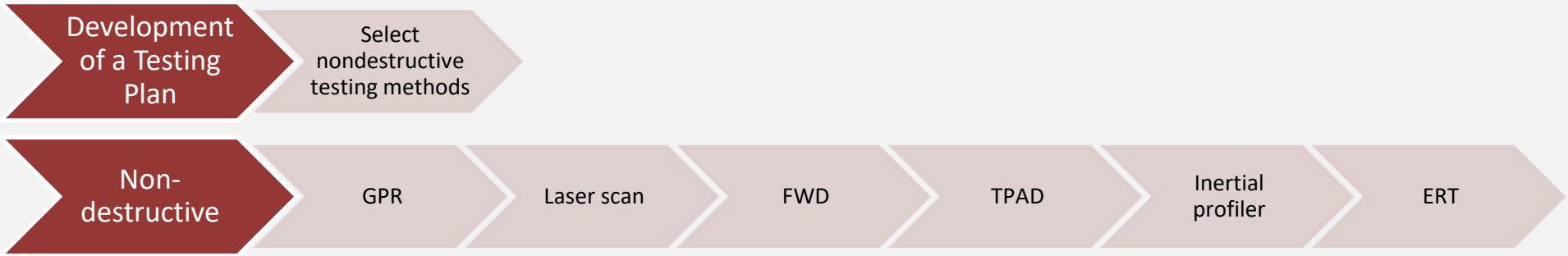
Background Information | Internet resources: USDA Web Soil Survey, Google Earth | As-built PS&E | Construction records | Design records | Maintenance history

- As-built PS&E
  - Plans online
- Construction records
  - Sitemanager
  - District records
- Design records
  - Plans online, pavement designs
  - District records

Pavement Evaluation Procedures

- Maintenance history
  - Maintenance Management System (MMS)
  - Pavement Management Information System (PMIS)
  - Texas Maintenance Assessment Program (TxMAP)
- District pavement engineer
- Other sources of information
  - Statewide planning map

Pavement Evaluation Procedures



- Combine preliminary data
- Collect air-launched GPR
  - Analyze GPR along with preliminary data
    - Collect nondestructive structural testing
      - FWD
      - TPAD
- Determine other testing needs
  - Laser scan
  - Inertial profiler
  - ERT
  - Ground-coupled radar

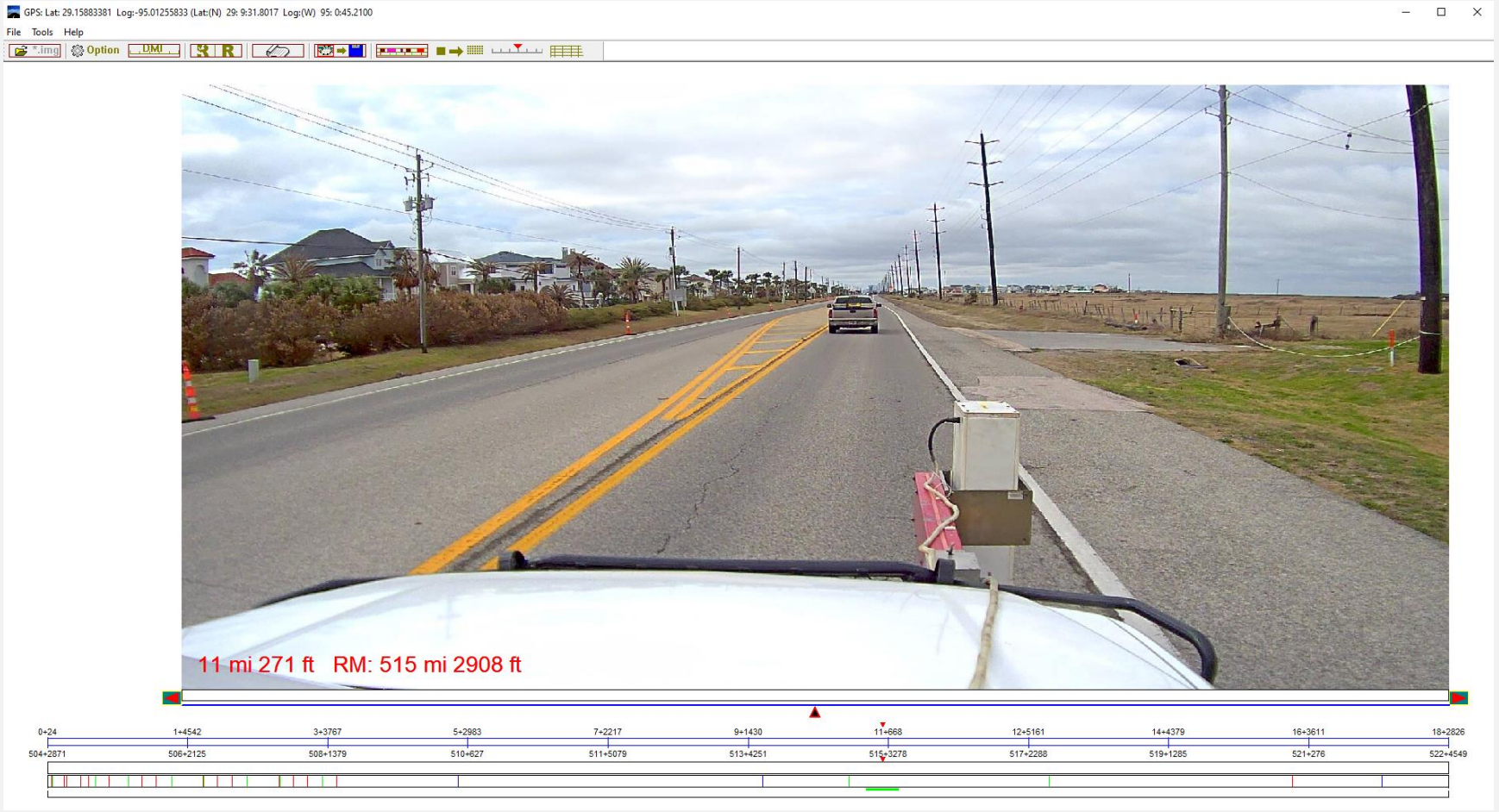
Pavement Evaluation Tools

Development of a Testing Plan → Select nondestructive testing methods

Non-destructive → HD video → GPR → FWD → TPAD → Laser scan (LiDAR) → Inertial profiler → p-WIM → ERT → DCP

High-Definition Video (HDV)

- HDV is a high-definition video system to document the pavement's surface condition
- Data for design, performance monitoring, and construction
- Collected at highway speeds; traffic control not needed



High-Definition Video (HDV)

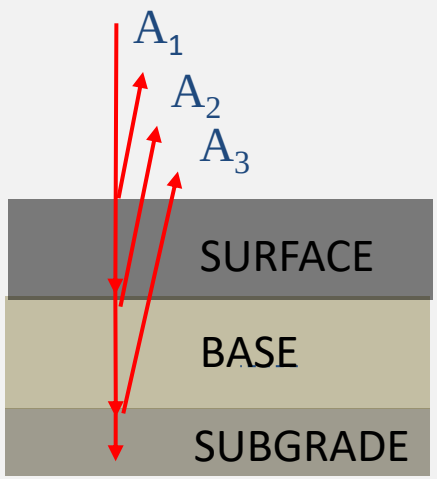
- Benefits for accelerated construction
  - Forensic investigations of existing pavement structures
  - Engineers can make timely decisions due to the ease of data collection and analysis
  - Data are used to support the following functions:
    - Forensic studies
    - Support pavement management activities at both project and network levels
    - Supplement other testing data
  - Information for construction
- Limitations and availability
  - PaveCheck software is needed to view as a video; otherwise, individual images can be viewed
  - TxDOT currently owns several systems in various districts

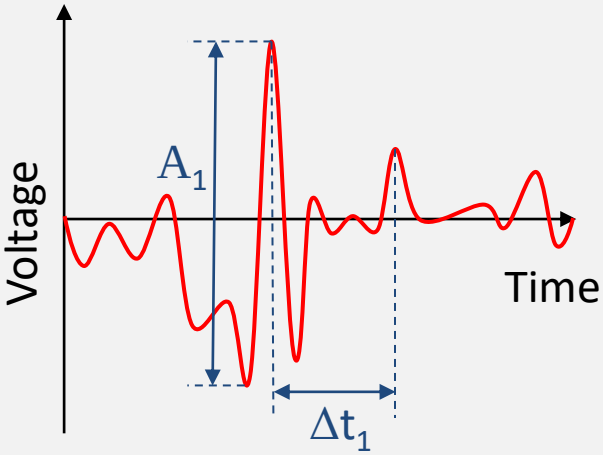
Ground-Penetrating Radar (General)

- Radar systems to characterize pavement layer quality, thicknesses, and subsurface anomalies

Ground-Penetrating Radar (General)

- Method
  - Transmits pulses of radar energy
  - Pulse is reflected at significant layer interfaces
  - System captures reflected waves (voltage vs. time)



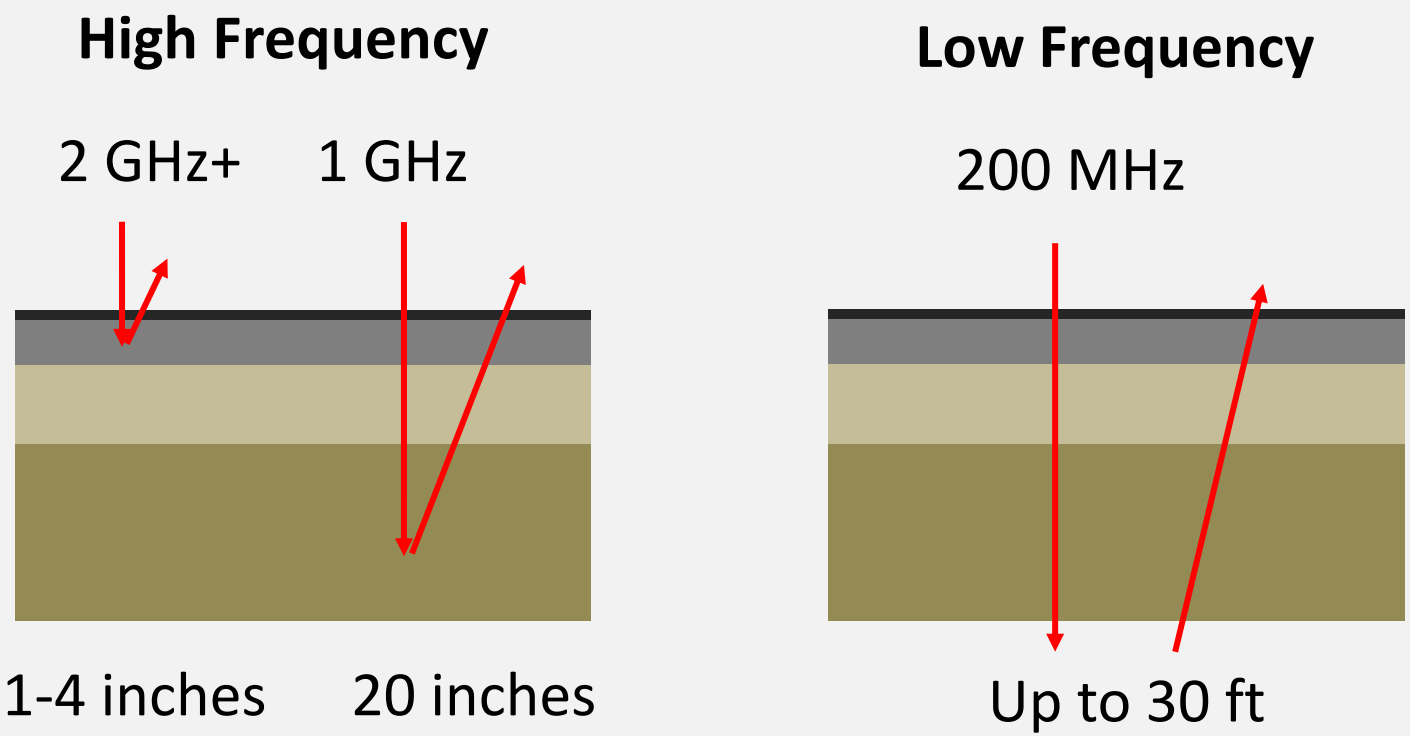


- Dielectric (ε) and distance (d) calculation:

$$\varepsilon_1 = \left[\frac{1+A_1/A_m}{1-A_1/A_m}\right]^2 \qquad d_1 = \frac{c*\Delta t_1}{2\sqrt{\varepsilon_1}}$$

Ground-Penetrating Radar (General)

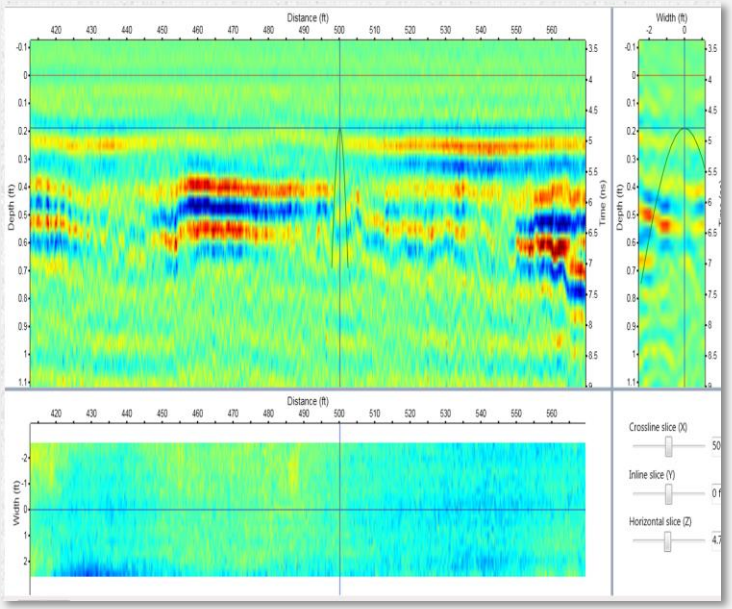
- Air- and ground-coupled systems
- Antenna frequency vs. penetration



Ground-Penetrating Radar (General)

- Data analysis
  - PaveCheck (TTI) or vendor software

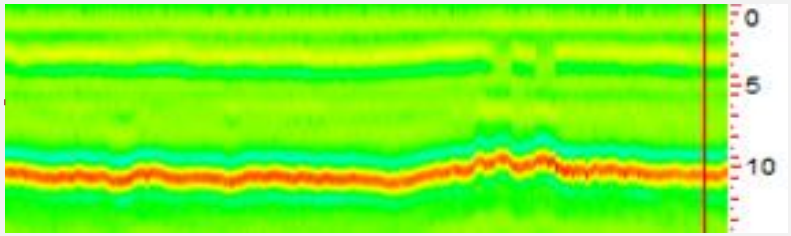
PaveCheck

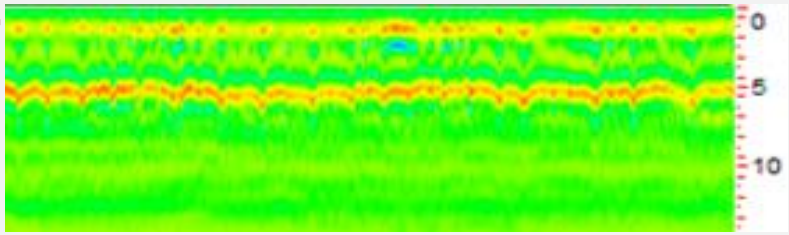


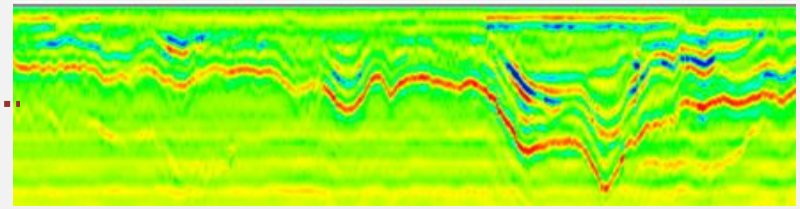
3D Radar

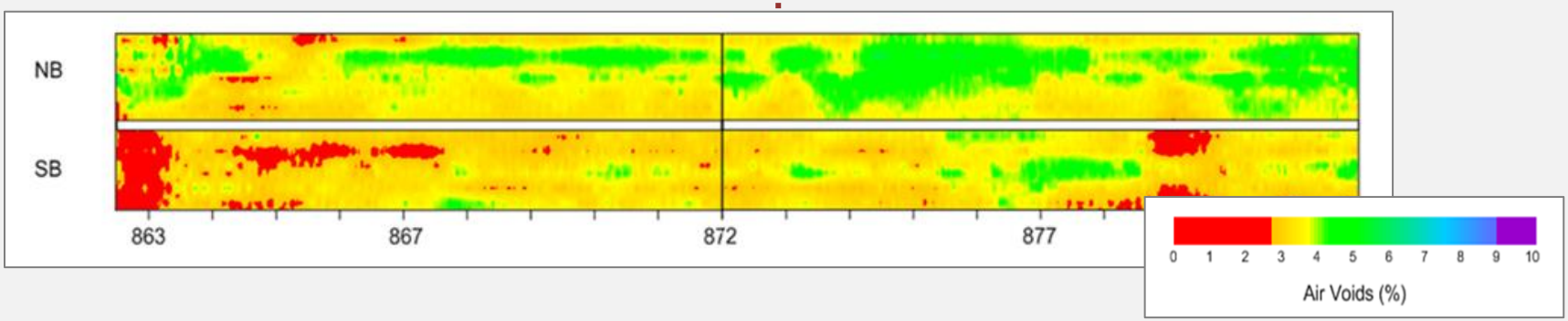
Ground-Penetrating Radar (General)

- Identify
  - Layer thickness
  - Subsurface distress
  - Structure discontinuities
  - Moisture damage
  - Layer density
  - Compaction uniformity









Ground-Penetrating Radar (General)

- Benefits for accelerated construction
  - Efficient forensic investigations
  - Assess alternative M&R strategies
  - Timely decision making
- Limitations and availability
  - Technical expertise required
  - Light weight or slag, false problem areas
  - Coring is not eliminated (need reference truth)

Air-Coupled GPR, 1-GHz Antenna System

- Integrated HD video and GPS
- Highway speed data collection
- 20-inch penetration depth
- Data analysis with PaveCheck
- TxDOT owns 5 antennas

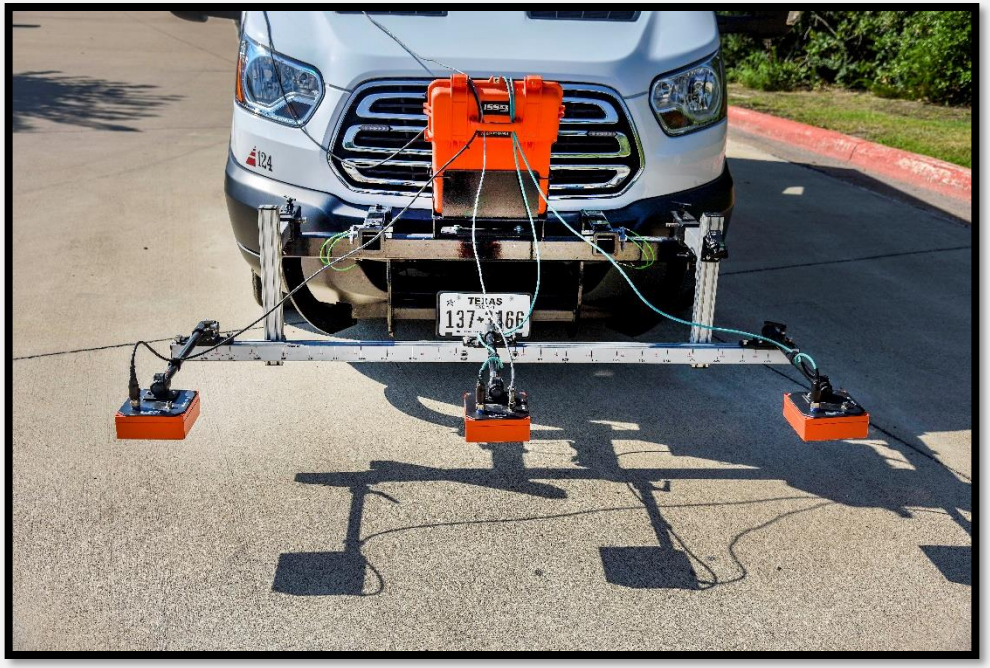
Air-Coupled GPR, Step-Frequency 3D Radar

- 32 channels, 200-MHz to 3-GHz step frequency
- Integrated video possible
- Highway speed data collection
- 6 ft wide, high resolution for shallow and deep layers, up to 2.5 ft
- Data analysis with Examiner software
- TxDOT owns 1 system

Ground-Coupled GPR, 200 MHz to 2.5 GHz

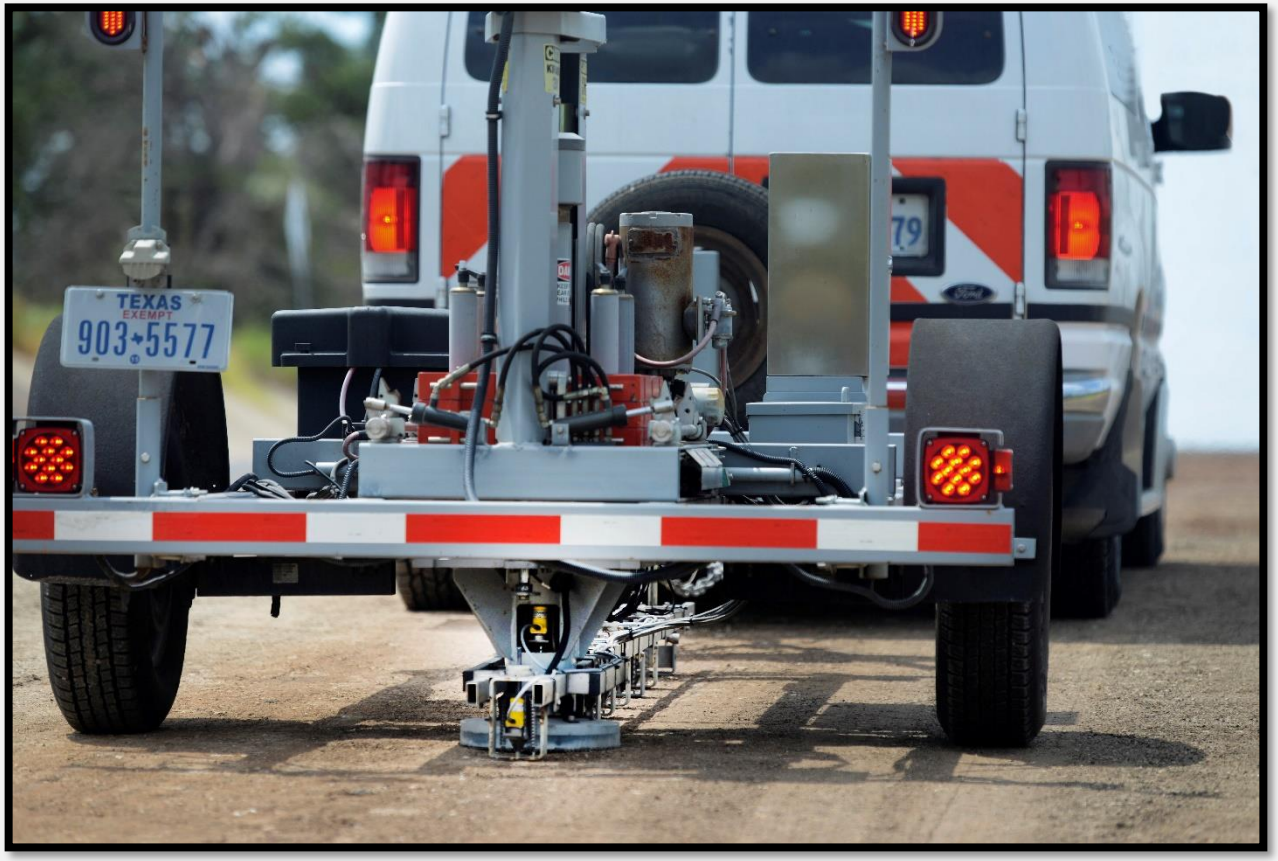
- Walking speed data collection; traffic control needed
- Data analysis with Radan by GSSI
- Between surface to 30-ft penetration depth, depending on antenna
- Locate sink holes, honeycombing, buried fuel tanks, archeological sites, and aquatic springs
- Multiple systems needed to characterize at different depths
- TxDOT owns 5 systems

Air-Launched GPR, 2-GHz Rolling Density Meter



- Cart or vehicle mounted, 1 to 3 antennas
- Walking or slow vehicle data collection; traffic control needed
- Surface dielectric correlated to density
- Requires coring to correlate for each unique mix design
- TxDOT owns 1 three-channel system
- Potential replacement for density testing

Falling Weight Deflectometer



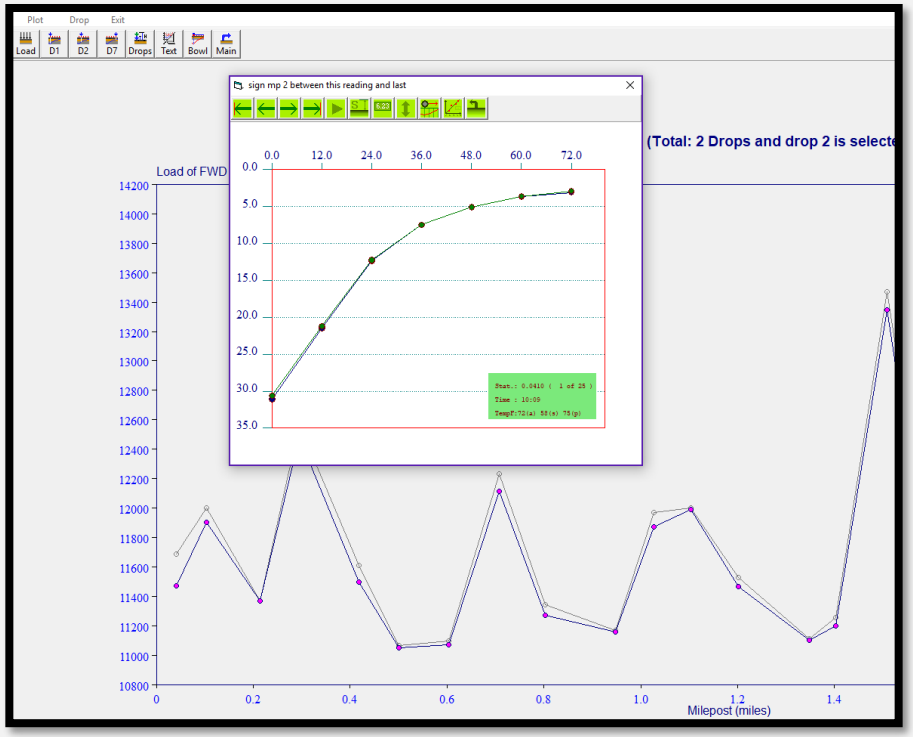
- Load-deflection response testing system
- Used to characterize pavement layer stiffness
- Static data collection; traffic control required

Falling Weight Deflectometer

- Method
  - Heavy falling weight creates deflection basin (simulates a heavy moving wheel load)
  - Geophones on surface record deflections
  - Layer stiffnesses are backcalculated using a linear elastic model
- Collection
  - Collect at least 30 drops per section
  - Typical test spacing 0.1 mi

Falling Weight Deflectometer

- Data analysis
  - MODULUS® program by TTI
  - Identify layer stiffness and uniformity



Falling Weight Deflectometer

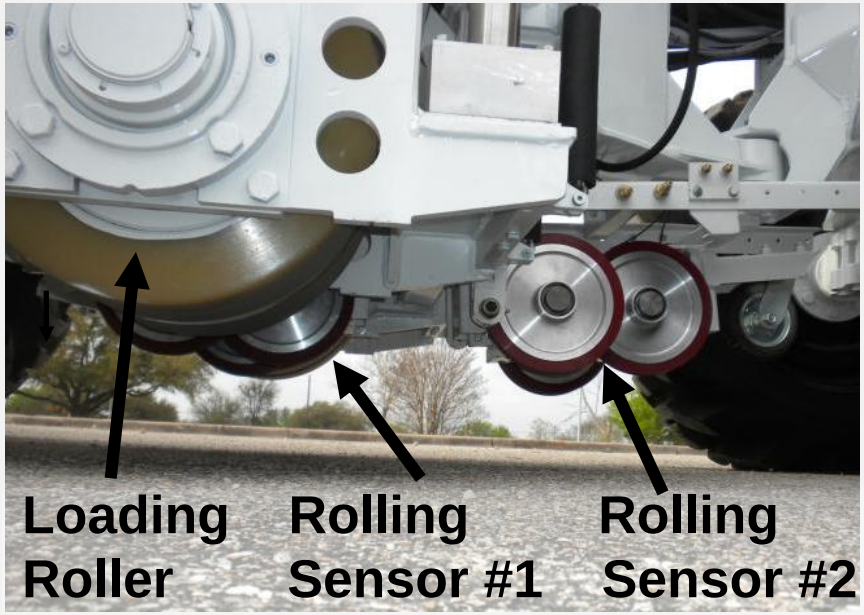
- Benefits for accelerated construction
  - Efficient forensic investigations
  - Assess alternative M&R strategies
  - Timely decision making
  - Useful for project- and network-level analysis
- Limitations and availability
  - Not suitable for layers <3 inches thick
  - Traffic control required
  - TxDOT owns 15 FWDs

Total Pavement Acceptance Device (TPAD)

- Rolling dynamic deflectometer for continuous deflection profiling
- Slow driving speed (traffic control needed)

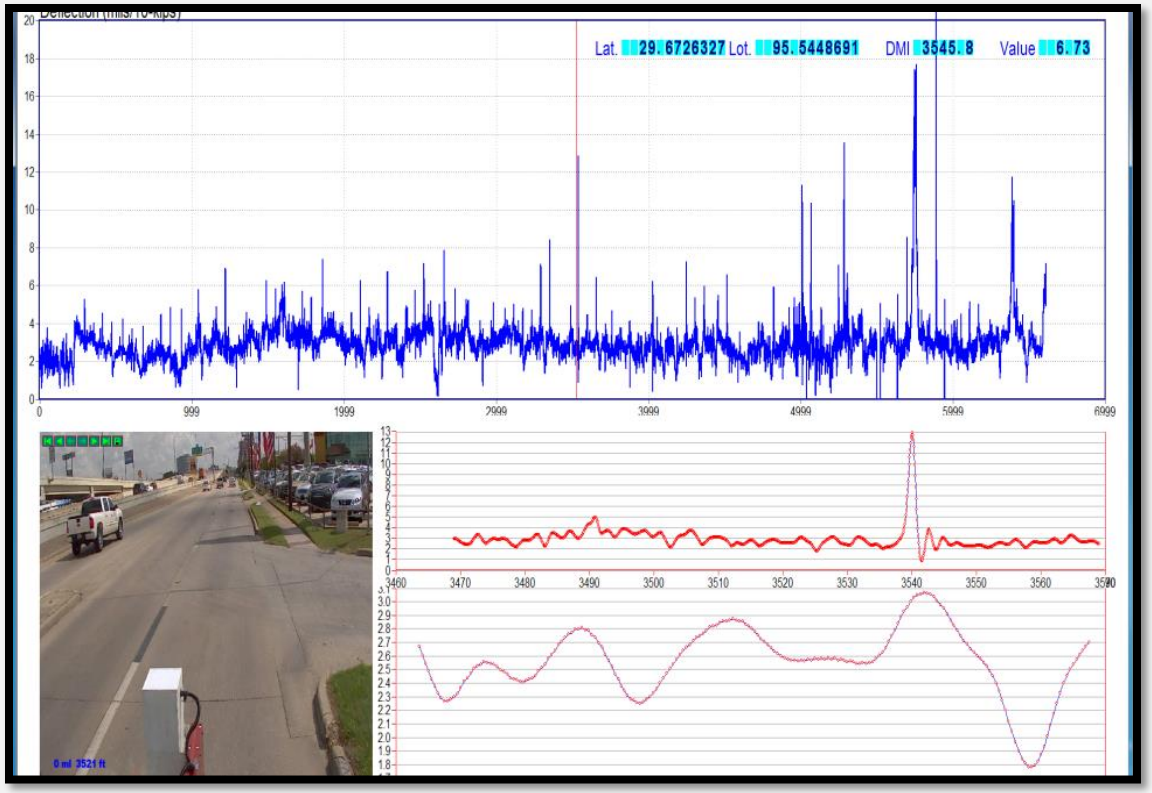
TPAD

- Method
  - Heavy vibrating wheel creates continuous deflection basin, measured by 2 rolling sensors
  - Layer stiffness backcalculated similarly to FWD
  - Integrated GPR, GPS, and HD video



TPAD

- Data analysis
  - Custom program developed by TTI
  - Note outlier deflections or backcalculate moduli



TPAD

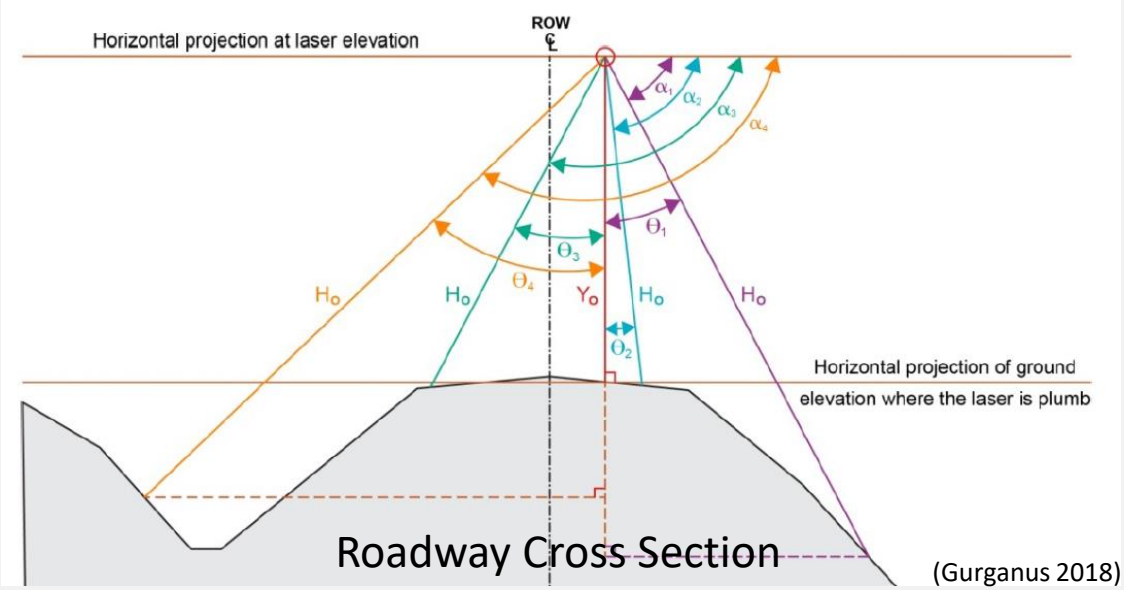
- Benefits for accelerated construction
  - Efficient forensic investigations
  - Assess alternative M&R strategies
  - Timely decision making
  - Test of load transfer in jointed concrete
- Limitations and availability
  - Not suitable for layers <3 inches thick
  - Traffic control required
  - TxDOT owns 1 TPAD

Mobile LiDAR Scanner

- Laser-based imaging system
- Provides a right-of-way geometric evaluation to predict surface drainage behavior
- Freeway speed data collection

Mobile LiDAR System

- Method
  - Scanning array of laser pulses
  - Returning pulse provides <u>reflectivity</u> of surface and <u>distance</u> in relation to the angle
  - Correction with inertial and accelerometer data



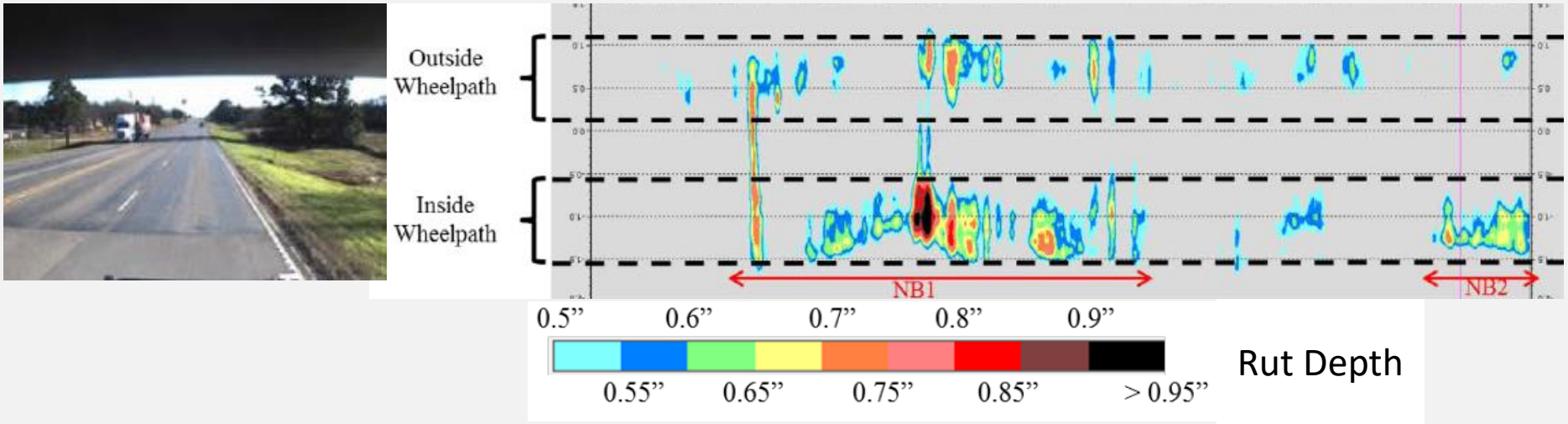
(Gurganus 2018)

Mobile LiDAR System

- Equipment
  - SICK laser scanner
  - Cameras
  - GPS
  - Inertial measurement unit
  - 3D accelerometer
- Constructed by Roadscanners (Finland)

Mobile LiDAR System

- Measures
  - Rutting
  - Cross slope
  - Ditch depths and grade
  - Drainage basins
- Data analysis programs under development



(Gurganus 2018)

Mobile LiDAR System

- Benefits for accelerated construction
  - Forensic evaluation for drainage problems
  - Information for new construction
  - More suited for asset management
- Limitations and availability
  - Complexity of data analysis
  - TxDOT owns 1 system

Inertial Profiler

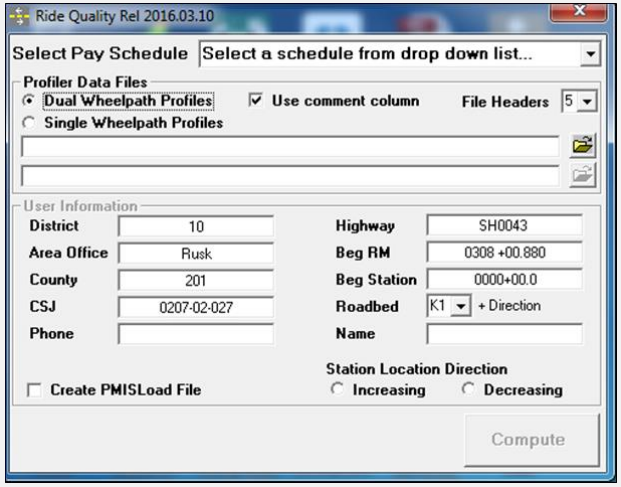
- Laser and inertial roughness profiler to quantify ride quality
- Data collection at high speeds

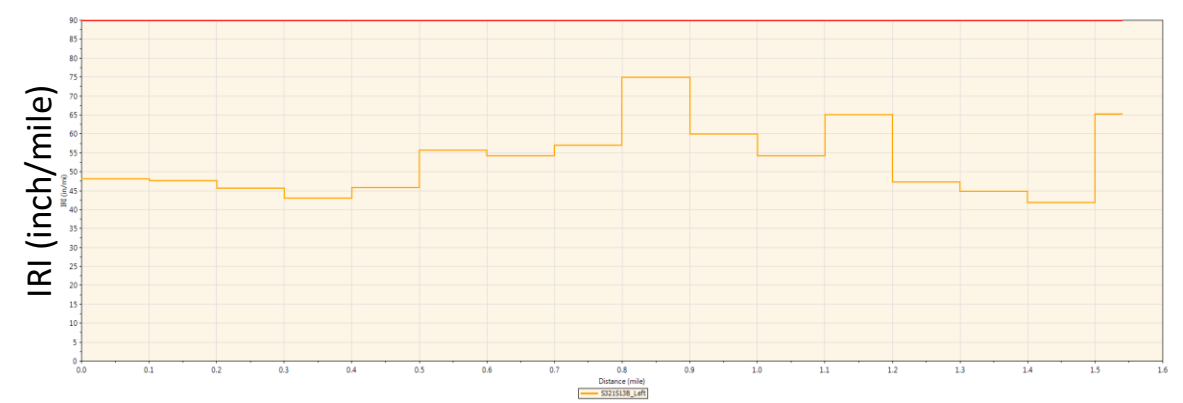
Inertial Profiler

- Method
  - Tex-1001-S
  - The profile in each wheel path is collected with spot lasers and corrected with inertial data
  - Profiles can be used to calculate the international roughness index (IRI)

Inertial Profiler

- Data analysis
  - TxDOT Ride Quality software
  - Various simulations with profile data:
    - Vehicle dynamics
    - Profilograph
    - Power spectral analysis
    - Grinding
    - Straight edge





Inertial Profiler

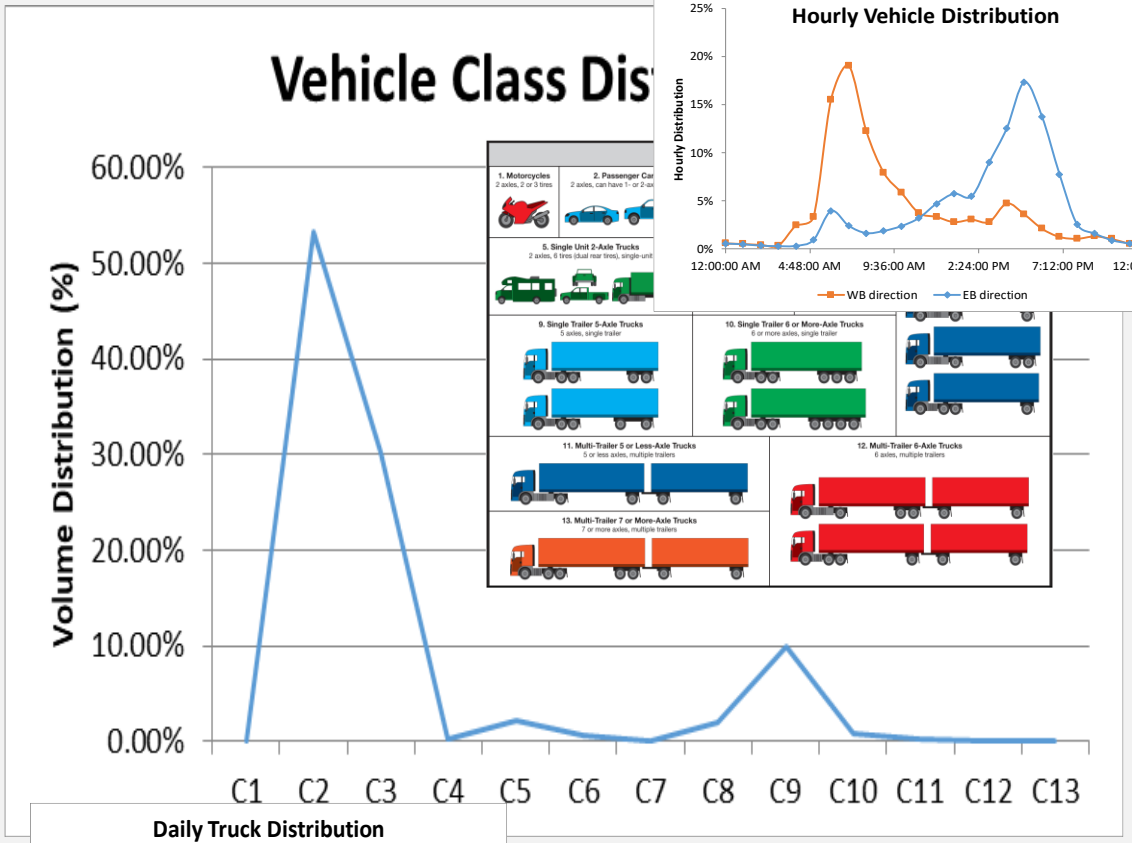
- Benefits for accelerated construction
  - Identify location and severity of rough spots to then select an appropriate treatment for long-term functionality
  - Timely decision making
- Limitations and availability
  - Not suitable for stop-and-go environments
  - Annual certification for QC/QA and network inventory
  - TxDOT owns 5 profilers

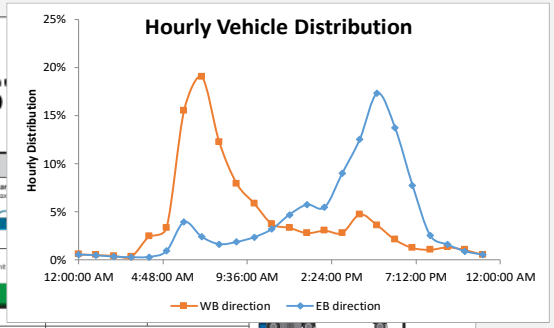
Portable Weigh in Motion (p-WIM)

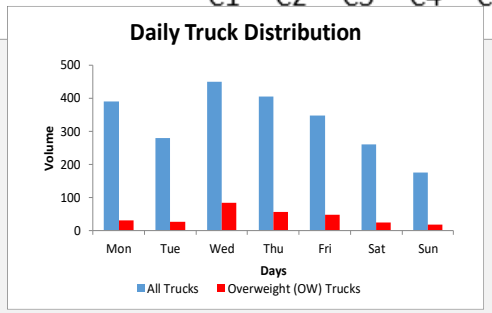
- General
  - The p-WIM is a traffic data collection system that is used to measure traffic characteristics
  - Traffic control is required for the setup and removal of the system; however, it is not required during data collection
- Measured properties
  - Site-specific field traffic measurements including:
    - Traffic volume
    - Vehicle classification
    - Axle loads
    - Vehicle weights

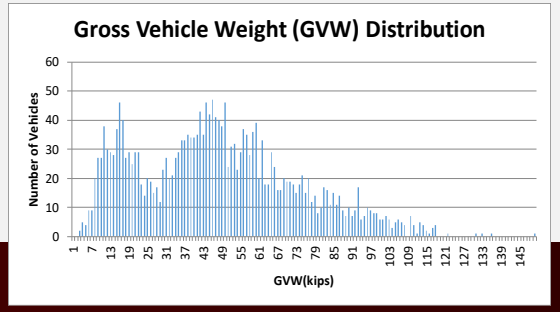
p-WIM

SOUTH
349
TEXAS

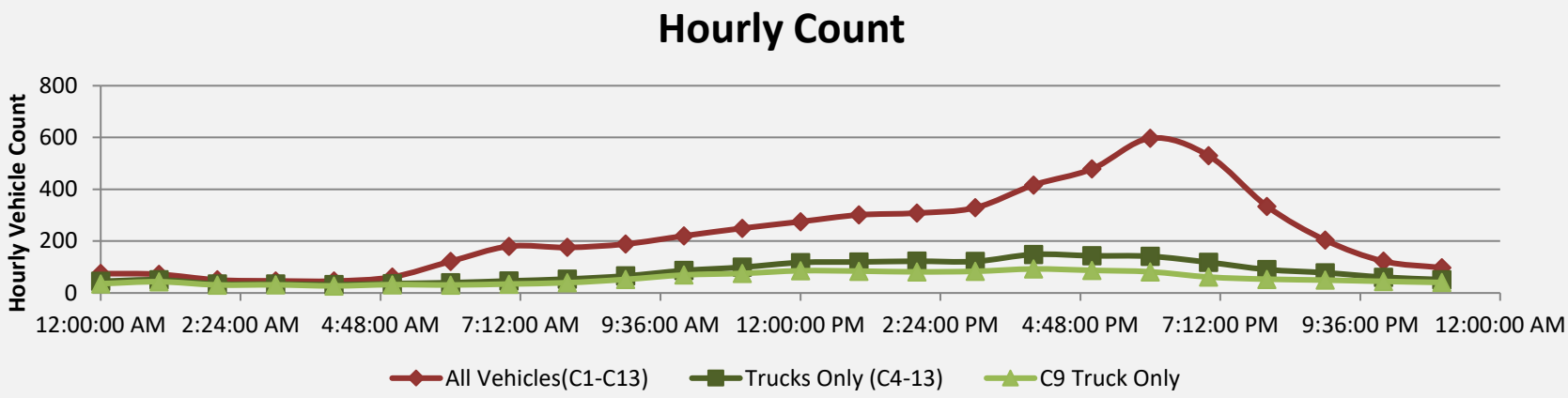

Vehicle Class Dis
Volume Distribution (%)
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
1. Motorcycles
2 axles, 2 or 3 tires
5. Single Unit 2-Axle Trucks
9. Single Trailer 5-Axle Trucks
5 axles, single trailer
10. Single Trailer 6 or More-Axle Trucks
6 or more axles, single trailer
11. Multi-Trailer 5 or Less-Axle Trucks
5 or less axles, multiple trailers
12. Multi-Trailer 6-Axle Trucks
6 axles, multiple trailers
13. Multi-Trailer 7 or More-Axle Trucks
7 or more axles, multiple trailers


Hourly Vehicle Distribution
Hourly Distribution
25%
20%
15%
10%
5%
0%
12:00:00 AM
4:48:00 AM
9:36:00 AM
2:24:00 PM
7:12:00 PM
12:00:00 AM
WB direction
EB direction

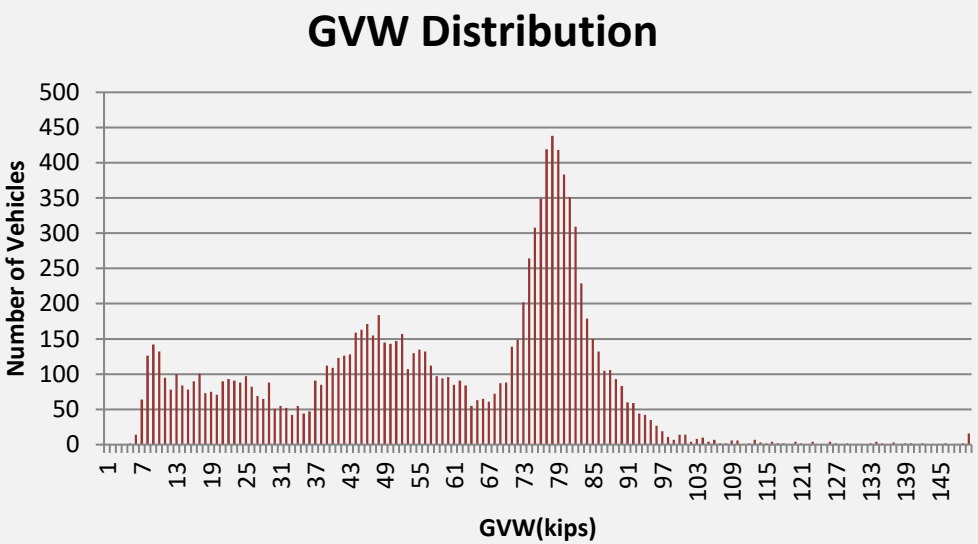

Daily Truck Distribution
Volume
500
400
300
200
100
0
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Days
All Trucks
Overweight (OW) Trucks


Gross Vehicle Weight (GVW) Distribution
Number of Vehicles
60
50
40
30
20
10
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
133
139
145
GVW(kips)

p-WIM Example Data



18-kip ESAL	Total	Daily
Steering Axles	2316	386
Single Axles (Non-steering)	1492	249
Total Single Axles	3808	635
Tandem Axles	10403	1734
Tridem Axles	373	62
Quad Axles	78	13
Total 18-kip ESAL	14662	2444
Truck Factor(TF)	1.27	1.27



p-WIM

FLEXIBLE — Average TF per Hwy per District						
District	**FM Rds**	**IH Rds**	**RM Rds**	**SH Rds**	**US Rds**	**District Avg**
Abilene		1.15			1.41	1.28
Amarillo	1.54	1.09				1.32
Atlanta	0.98	1.22			0.97	1.06
Austin		1.29		1.15	1.12	1.19
Bryan				1.22		1.22
Corpus Christi					1.44	1.44
El Paso		1.08	1.07			1.08
Fort Worth		1.13		1.11		1.12
Lubbock		0.98			1.13	1.06
Odessa	1.65	1.30	1.63	1.59	1.51	1.54
Paris				0.88		0.88
Pharr					0.91	0.91
San Angelo				1.25		1.25
San Antonio		1.14				1.14
Waco				1.22	1.23	1.23
Wichita Falls					0.96	0.96
Overall Avg TF per Hwy =	**1.39**	**1.15**	**1.35**	**1.20**	**1.19**	**1.18**

RIGID — Average TF per Hwy per District						
District	**FM Rds**	**IH Rds**	**RM Rds**	**SH Rds**	**US Rds**	**District Avg**
Abilene		1.32			1.63	1.48
Amarillo	1.78	1.25				1.52
Atlanta	1.13	1.44			1.12	1.23
Austin		1.86		1.33	1.54	1.58
Bryan				1.41		1.41
Corpus Christi					1.66	1.66
El Paso		1.24	1.23			1.24
Fort Worth		1.30		1.28		1.29
Lubbock		1.13			1.30	1.21
Odessa	1.91	1.60	1.74	1.86	1.88	1.80
Paris				1.02		1.02
Pharr					1.05	1.05
San Angelo				1.60		1.60
San Antonio		1.31				1.31
Waco				1.39	1.39	1.39
Wichita Falls					1.12	1.12
Overall Avg TF per Hwy =	**1.61**	**1.38**	**1.48**	**1.41**	**1.41**	**1.39**

Average (Avg) & TF Ranges per Hwy per District | Ongoing Work in Progress

p-WIM

ADT & ADTT Lane Distribution (%) for a 4-Lane Hwy with 2 Lanes in One Direction | Ongoing Work in Progress

%age ADT (All Vehicles) Distribution per Lane				%age ADTT (Trucks Only) Distribution per Lane			
District	**Hwy**	**Outside Lane (OL)**	**Inside Lane (IL)**	**District**	**Hwy**	**Outside Lane (OL)**	**Inside Lane (IL)**
Amarilla	IH 40	62%	38%	Amarilla	IH 40	86%	14%
Austin	SH 130	55%	45%	Austin	SH 130	84%	16%
Corpus Christi	IH 69	59%	41%	Corpus Christi	IH 69	72%	28%
El Paso	IH 10	56%	44%	El Paso	IH 10	73%	27%
Odessa	FM 1788	63%	37%	Odessa	FM 1788	68%	32%
Odessa	IH 20	57%	43%	Odessa	IH 20	70%	30%
Odessa	SH 302	67%	33%	Odessa	SH 302	84%	16%
Odessa	SH 349	79%	21%	Odessa	SH 349	90%	10%
Pharr	US 281	61%	39%	Pharr	US 281	85%	15%
Wichita Falls	US 287	58%	42%	Wichita Falls	US 287	86%	14%
Average (ADT) =		62%	38%	**Average (ADTT) =**		80%	20%
Min (ADT) =		55%	21%	Min (ADTT) =		68%	10%
Max (ADT) =		79%	45%	Max (ADTT) =		90%	32%

p-WIM

- Benefits for accelerated construction
  - Site-specific data
  - Engineers can make timely decisions due to the ease of data collection and analysis
  - Data are used to support the following functions:
    - Planning
    - Design
    - Forensic studies
    - Support pavement management activities at both project and network levels
    - Supplement other testing data
- Limitations and availability
  - This is an emerging technology from recent research; TTI has 5 systems

Electrical Resistivity Tomography (ERT)

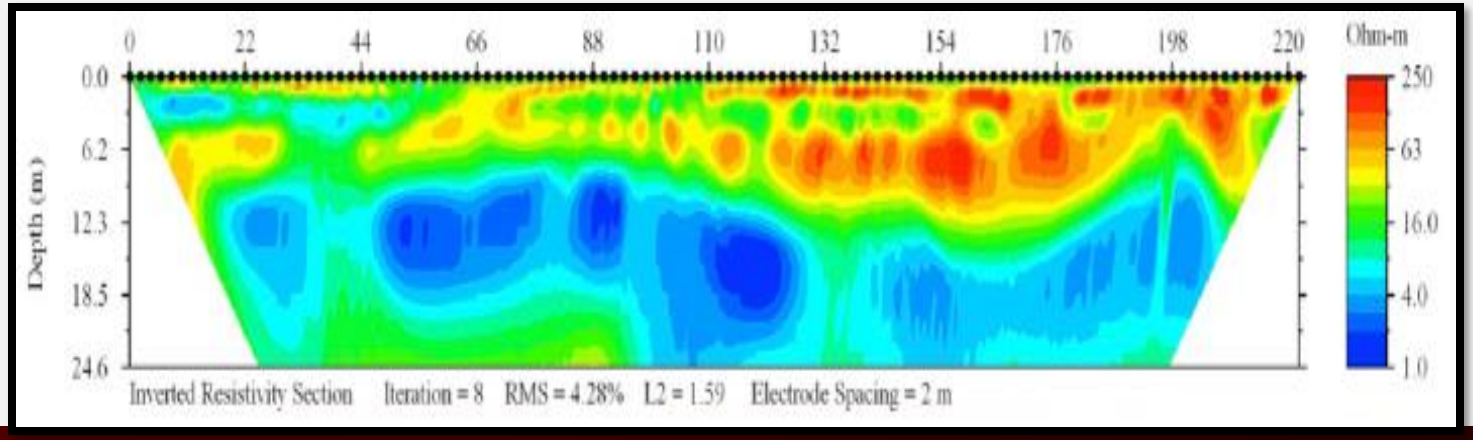
- ERT is used to conduct a geophysical survey that can indicate subsurface geological conditions
- ERT is a geophysical method[1] that provides an image of the bulk electrical resistivity structure in a vertical plane beneath a linear array of metal electrodes planted in the ground and connected by a multi-core cable

Reference:

1. USDA. Web Soil Survey. 2019. www.websoilsurvey.nrcs.usda.gov, accessed November 8, 2019.

ERT

- Measured properties
  - A predefined sequence of measurements is made of the voltages that develop across selected pairs of electrodes
    - For any single measurement, the pair of electrodes chosen to measure voltage acts as a receiver (RX); the pair of electrodes chosen to inject and withdraw current acts as the transmitter (TX)
    - The dipole-dipole measurement protocol is typically used for this type of survey
  - Data analysis
  - Customized software is used to generate a graphical display of the voltages measured in the field, normalized by the injected current and multiplied by a geometric array factor that is appropriate for the dipole-dipole configuration
    - An automated inversion procedure is executed in the software to generate an Earth resistivity section (tomogram, shown below)
  - The tomogram shows bulk resistivity, which can indicate potentially saturated soils

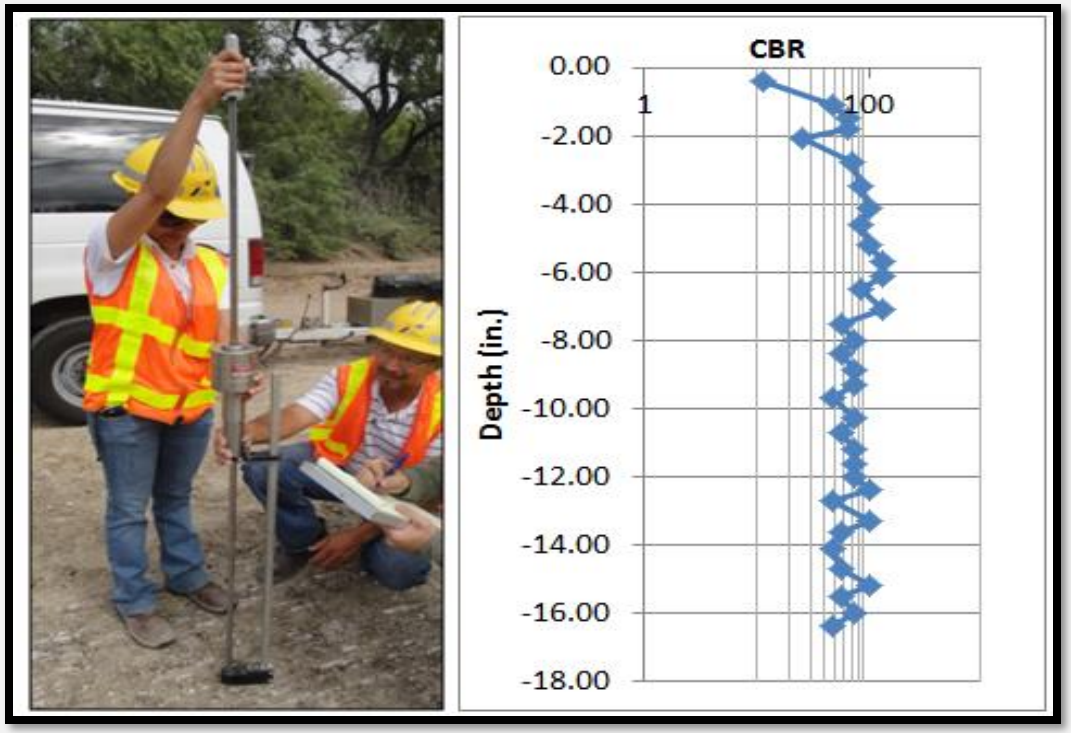


ERT

- Benefits for accelerated construction
  - Engineers can make timely decisions in the design phase that will mitigate construction delays caused by subgrade with high moisture content
- Limitations and availability
  - Experienced personnel are needed to collect and analyze the data
  - Contact TTI to schedule testing

Dynamic Cone Penetrometer (DCP)

- General description
  - Penetration depth per blow to assess the in-situ strength of undisturbed soil or compacted materials
  - Applications for use include:
    - Forensic investigations
    - Checking compaction uniformity
    - Verifying layer moduli



DCP

Texas A&M Transportation Institute

Form DCP:

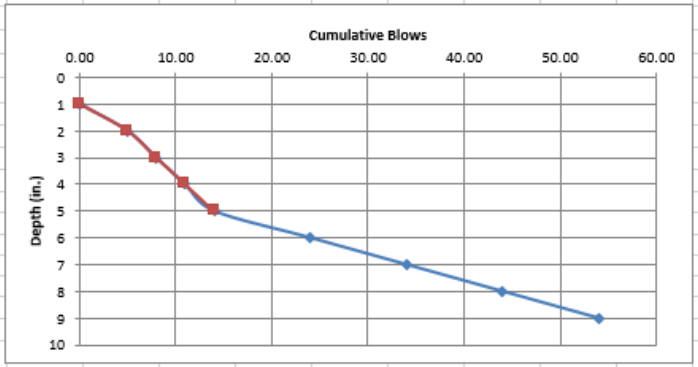
For use with DYNAMIC CONE PENETROMETER TESTING

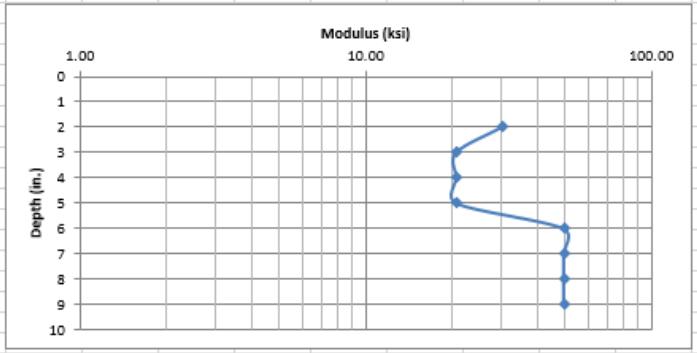
District		Location/Site Number	
Roadway		Test Description	
Test Date		TRM	

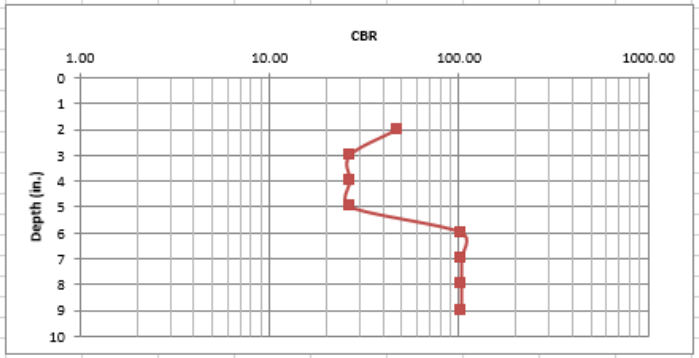
	Inches			
Surface Zero	0			
	Slope	Intercept	CBR	E (Ksi)
Layer 1				
Layer 2				
Layer 3				

Site Photo

# Blows	Penetration (in)	Cumulative Blows	Cumulative Penetration	CBR	E (ksi)
0	1	0	1.00		
5	2	5	2.00	47.3	30.1
3	3	8	3.00	26.7	20.9
3	4	11	4.00	26.7	20.9
3	5	14	5.00	26.7	20.9
10	6	24	6.00	102.8	49.5
10	7	34	7.00	102.8	49.5
10	8	44	8.00	102.8	49.5
10	9	54	9.00	102.8	49.5







Data analysis

- Excel spreadsheet developed to assist with data analysis
- Identify layer thicknesses
- Estimate relative strength with depth
- Estimate
  - Verify layer moduli
    - $M_r = 2.55 \times CBR^{0.64}$

      Where:

      M_r is = ksi
  - California bearing ratio (CBR)
    - $CBR = 292 \div P_r^{1.12}$

      Where :

      CBR = %

      Penetration ate, P_r = depth/blow

DCP

- Benefits for accelerated construction
  - Check uniformity of layer compaction
  - Estimate layer moduli
- Limitations and availability
  - Cost-effective tool that is commercially available for purchase
  - Several TxDOT districts own DCPs; contact district laboratory

Additional Training Workshops - TxDOT

1. Flexible Pavement Design

Covers both FPS 21 and MODULUS 7

- Collection and processing of Falling Weight Data
- Running FPS21
- Students work numerous problems
- Content of pavement design Report

Available to be taught in TxDOT Offices (2 days) or Virtually (1.5 days)

TxDOT Contact Roberto Trevino-Flores Maintenance Division

2. Ground Penetrating Radar Collection and Analysis

Covers both data collection and processing of GPR data

- Computing Layer thickness and identifying defects
- Identify section breaks
- First step in Pavement rehabilitation process

Available to be taught in TxDOT offices (1.5 days) or Virtually (1 day)

TxDOT Contact Jenny Li Maintenance Division

Additional Training Workshops - TTI

3. Rubbilization of Concrete Pavements

- Project selection including up-front testing required
- Running FPS21 to get HMA thicknesses
- Review of Specifications

Available to be taught in TxDOT Offices (1 day) or Virtually (1 day)

TTI Contact: Tom Scullion

4. Full Depth Reclamation of Flexible Pavements

- Project selection including up-front testing required
- Pavement Thickness Design
- Lab testing
- Details of construction and inspection

Available to be taught in TxDOT offices (1 day) or Virtually (1 day)

TTI Contact Stephen Sebesta

TRAFFIC CONTROL TIMING STRATEGIES

Work Time Frames

Work Week Description	Time Frame		Weather Charged	Holidays Charged
5-Day	7:00 am-6:00 pm	Monday-Friday	Yes	No
6-Day	7:00 am-6:00 pm	Monday-Saturday	Yes	No
7-Day	7:00 am-6:00 pm	Monday-Sunday	Yes	No
Standard	7:00 am-6:00 pm	Monday-Friday	No	No
Calendar Day	7:00 am-6:00 pm	Sunday-Saturday	Yes	Yes
Nighttime Only	30 min. after sunset to 30 min. before sunrise		No	No
Other – as shown on plans (examples below)				
24/7 (Continuous)	12:00 am to 12:00 pm	Sunday-Saturday	Yes	Yes
72-Hr Weekday (Continuous)	12:00 am to 12:00 pm	Tuesday-Thursday	Yes	Yes
57-Hr Weekend (Continuous)	8:00 pm to 5:00 am	Friday-Monday	Yes	Yes
Nighttime with Restricted Daytime	9:00 am to 4:00 pm 8:00 pm to 5:00 am	Monday-Friday	No	No

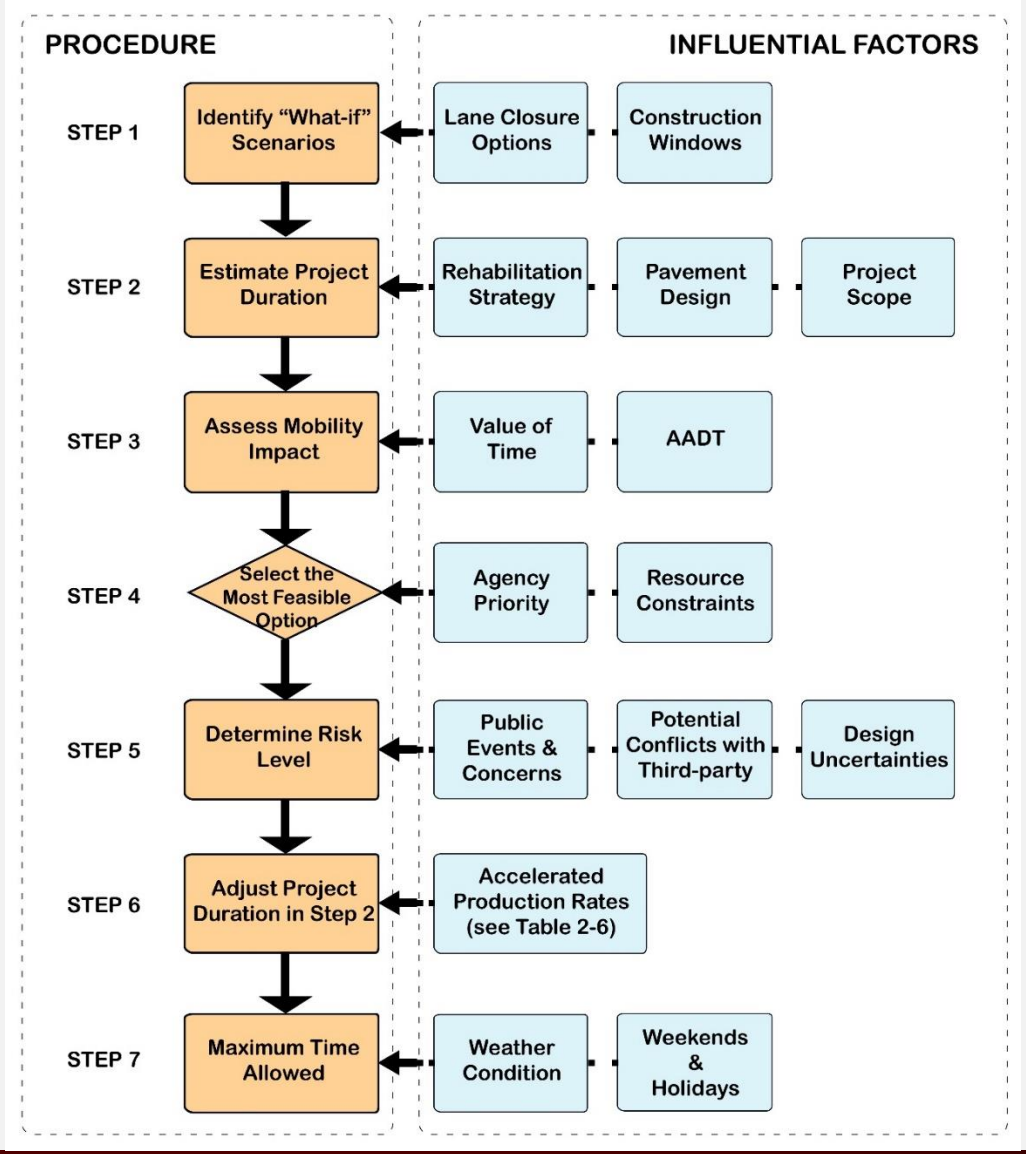
Understanding Time

- Weather and holiday impacts
  - Significant impact based on time frame of work allowed, weather, and holidays to actual days available to work
  - Table shows effects of weekends, average rain days including too wet to work after rain, and holidays on overall number of days available to work based on Tyler, Texas, historical weather
  - For this example, only 184 days out of 365 (50% of year) available to work; when establishing the work time frame and charges, consider these factors

Table 3: Working Day Example, Tyler Texas

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Calendar Days	31	28	31	30	31	30	31	31	30	31	30	31	365
Weekend Days	8	8	8	8	10	8	10	10	8	10	8	8	104
Weekday Rain	3	4	4	4	6	4	3	4	2	4	4	5	47
Too Wet	2	2	2	2	1	1	1	1	1	1	2	3	
Holidays	2	1			1		1		1		2	3	11
Working Days	16	13	17	16	13	17	16	16	18	16	14	12	184

Evaluating Time and Traffic Control Scenarios



Cost and Time Savings

- When evaluating a project, the time and cost savings should include the following:
  - Cost difference between placing new material and keeping the existing material
    - Any treatment of the existing, such as stabilization, should be captured in the cost of retaining the existing material for comparison purposes
  - Time to remove existing and reconstruct the layers, for all sections where the existing will be reused in the new pavement structure
    - Any time for treatment of the existing, such as stabilization, should be captured in the evaluation of days for comparison purposes
  - An evaluation of traffic control closure options
    - User delay costs
    - Overall project time based on closure strategy

Software

- CA4PRS
  - In production – update to web-based program

Construction Scenario	Schedule Comparison		Cost Comparison ($M)			Max. Peak Delay (Min)
	Total Closure	Closure Hours	User Delay	Agency Cost	Total Cost	
One Roadbed Continuous (24/7)	2	400	5.0	15.0	20.0	80
72-Hour Weekday	8	512	5.0	16.0	21.0	50
55-Hour Weekend	14	770	14.0	17.0	31.0	80
10-Hour Night-time Closures	220	2,220	7.0	21.0	28.0	30

SH 6 CASE STUDY

SH 6 Case Study

Project Information
- Limits
- Scope of work
- Traffic data

Background Information
- Internet resources: USDA Web Soil Survey, Google Earth
- As-built PS&E
- Construction records
- Design records
- Maintenance history

Development of a Testing Plan
- Select nondestructive testing methods

Non-destructive
- HDV
- GPR
- Laser scan
- FWD
- TPAD

Specific Location Testing
- Develop a testing plan for field
- Preliminary laboratory testing plan
- Estimate quantity and type of materials sampled

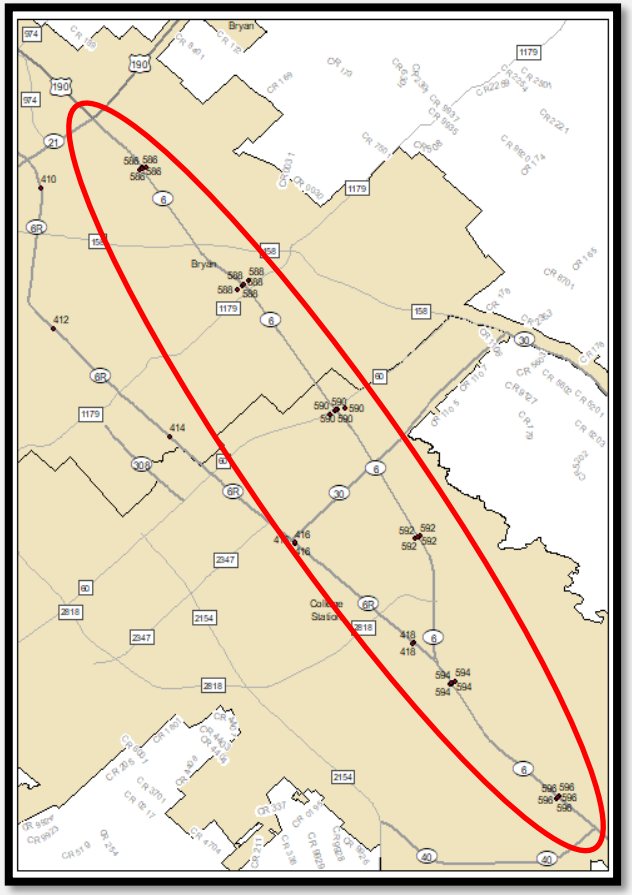
Sampling and Testing
- Pavement coring
- Subgrade sampling
- Pavement sampling
- DCP

Laboratory Testing
- Material testing
- Stabilization designs

SH 6 Case Study

Project Information | Limits | Scope of work | Traffic data

Widen to min. 3 lanes both directions



SH 6 Traffic Data

WIM History Truck Factor (ESAL/Truck) Flex 1.22, Rigid 1.41

	Project Information				Flexible	Rigid
Location	Initial ADT (2019)	Final ADT (2039)	% truck	Design Period	Cumulative ESALs (Adj ESALs)	Cumulative ESALs
US 190 to SH 30						
SB or NB ML	57948	81127	13	20	82,366,454 (57,656,518)	95,194,017
SB FR	11433	13720	7.6	20	8,563,635	9,897,315
NB FR	19891	27847	7.4	20	16,093,596	18,599,976
SH 30 to Rock Pr.						
SB or NB ML	77755	108857	11.7	20	99,468,036 (69,627,625)	114,958,959
SB FR	11691	23382	7.6	20	13,452,582	15,547,656
NB FR	15493	21690	7.3	20	12,365,873	14,291,706
Rock Pr. to SH 40						
SB or NB ML	37905	53067	15.7	20	65,067,708 (45,547,395)	75,201,203
SB FR	19646	23575	7.4	20	14,327,820	16,559,202
NB FR	13714	16457	7.5	20	10,136,901	11,715,598
US 190 to SH 30						
SB or NB Mainlane	57948	93326	13	30	138,353,696	159,900,583
SB FR	11433	14924	7.6	30	13,566,966	15,679,854
NB FR	19891	32034	7.4	30	27,032,817	31,242,846
SH 30 to Rock Pr.						
SB or NB Mainlane	77755	125226	11.7	30	167,079,970	193,100,621
SB FR	11691	29535	7.6	30	27,506,343	31,790,118
NB FR	15493	24952	7.3	30	20,771,313	24,006,189
Rock Pr. to SH 40						
SB or NB Mainlane	37905	61047	15.7	30	109,296,525	126,318,115
SB FR	19646	25643	7.4	30	22,698,605	26,233,634
NB FR	13714	17901	7.5	30	16,059,325	18,560,367

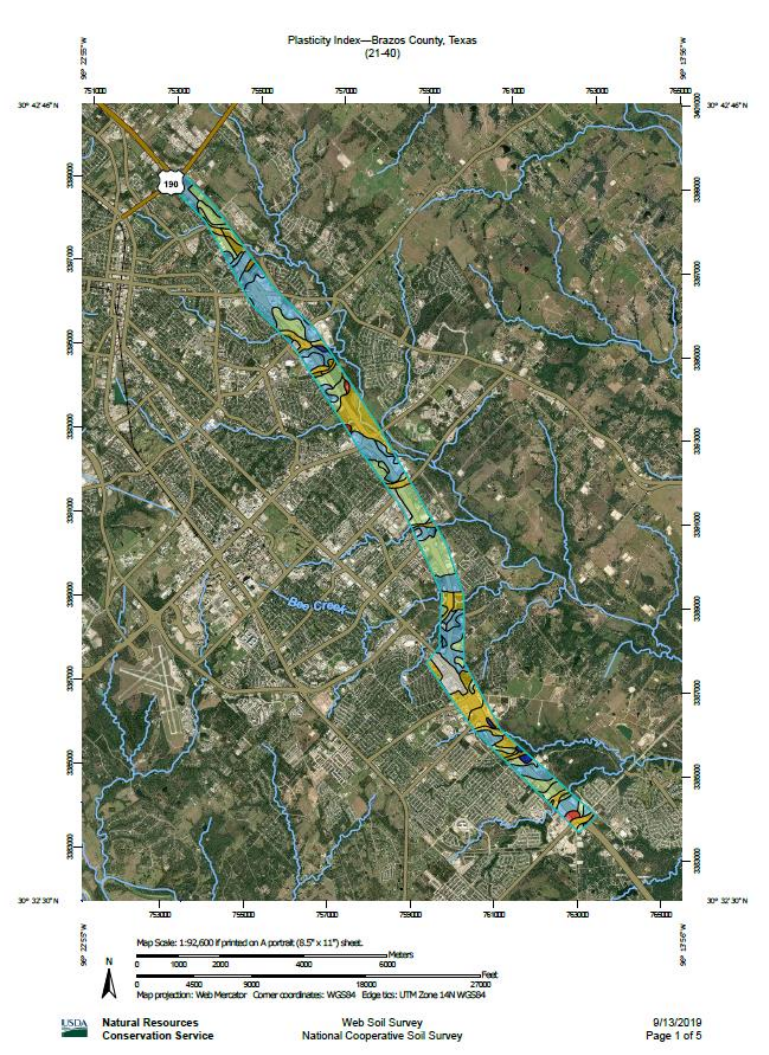
SH 6 Case Study

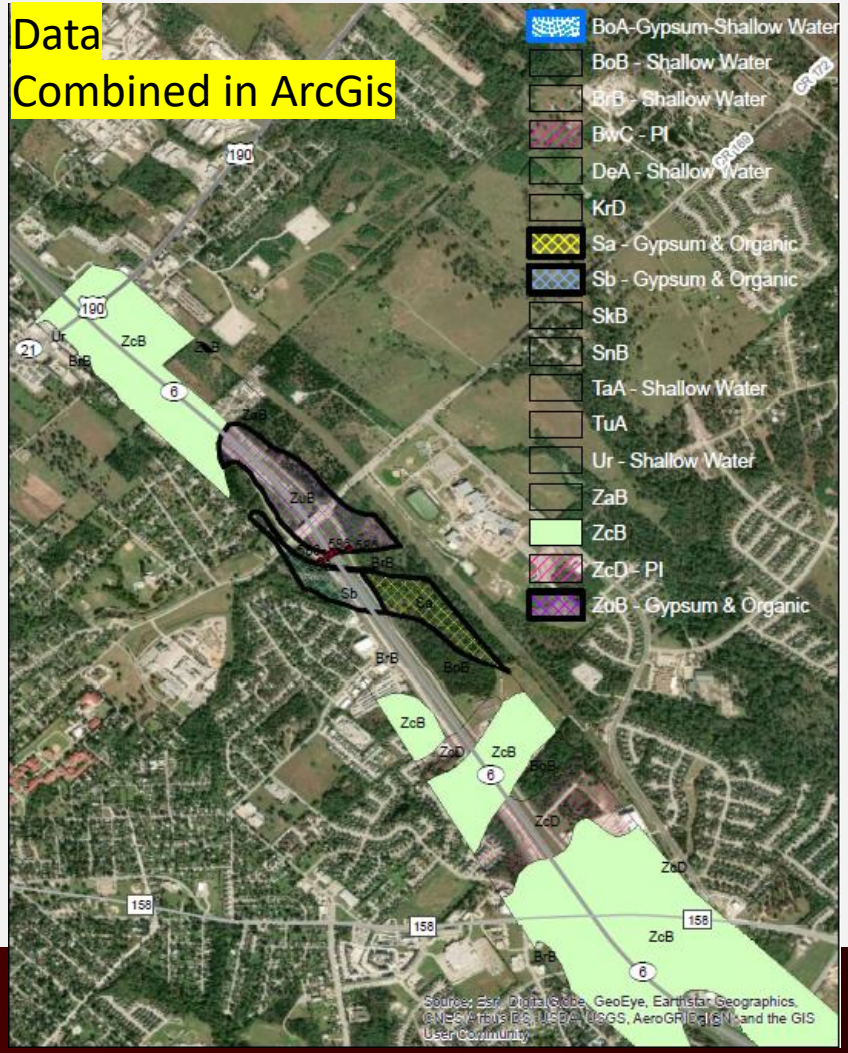
Project Information | Limits | Scope of work | Traffic data

- Objectives
  - Identify surface and subsurface defects
  - Evaluate structural condition
  - Identify causes of distress and verify with field coring
  - Propose rehabilitation strategies
  - Recommend widening side (to inside or outside)

SH 6 Case Study

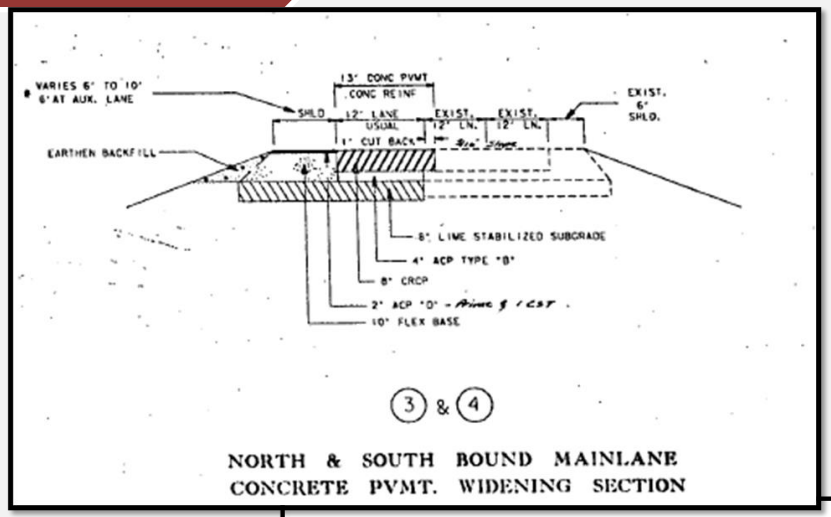
Background Information → **USDA Web Soil Survey** → As-built PS&E → Construction records → Design records → Maintenance history

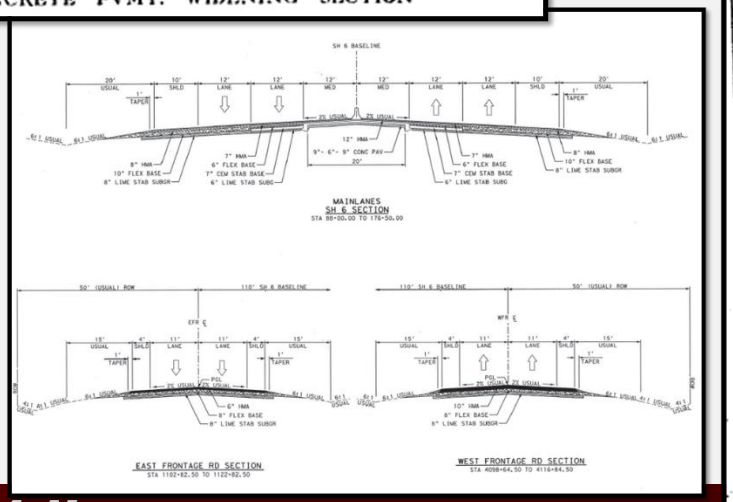


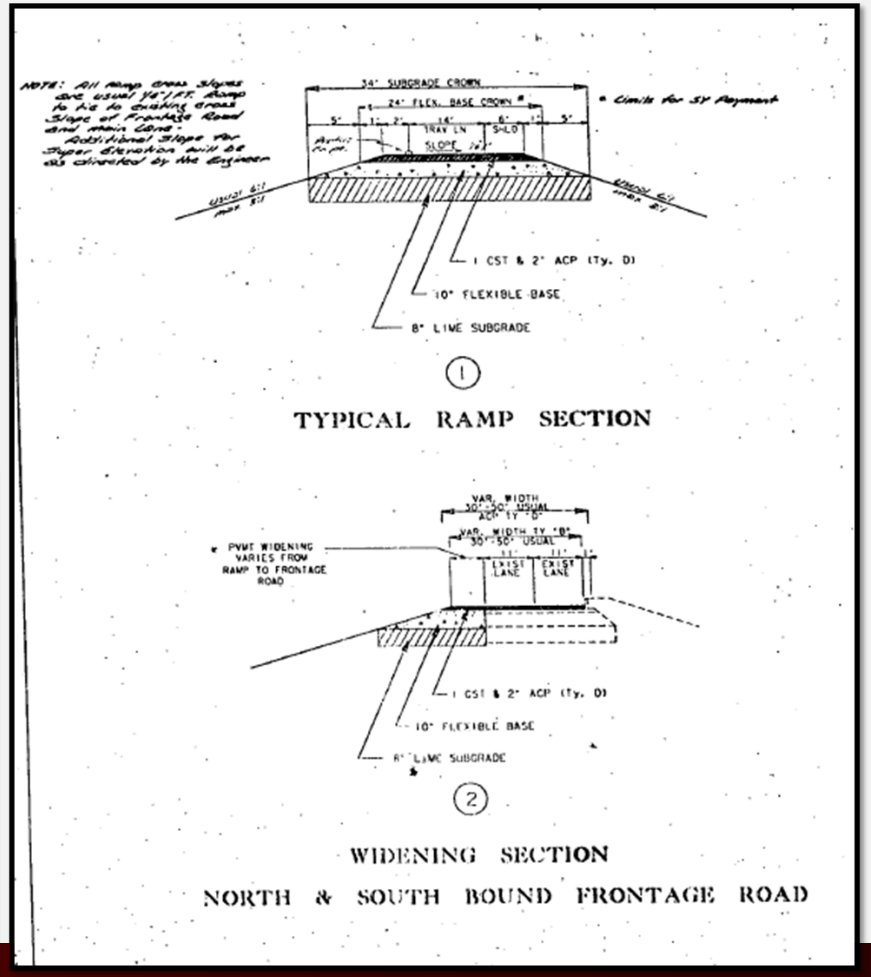


SH 6 Case Study

Background Information | USDA Web Soil Survey | **As-built PS&E** | **Construction records** | **Design records** | Maintenance history







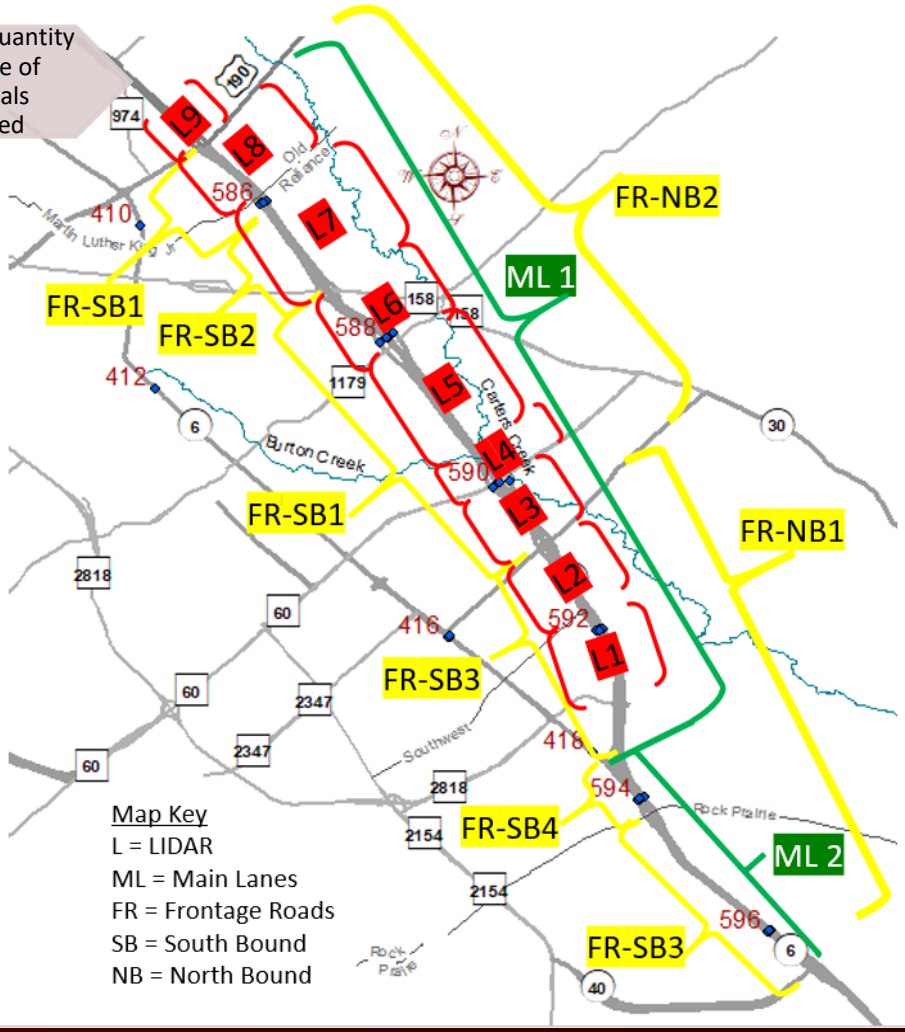
Development of a Testing Plan → Select nondestructive testing methods

SH 6 Case Study

Non-destructive → GPR → Laser scan → FWD → TPAD → Inertial profiler → ERT

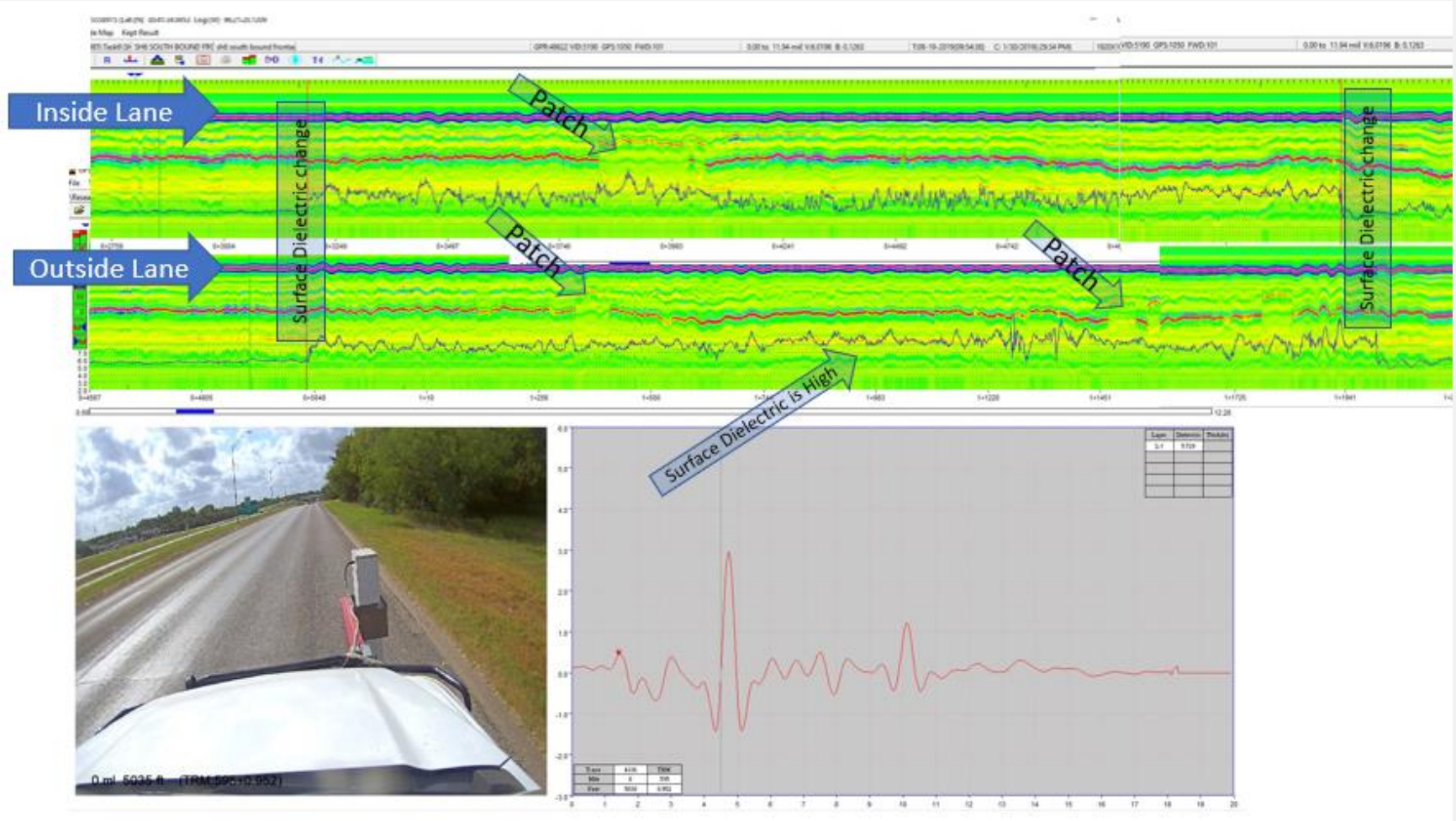
Specific Location Testing → Develop a testing plan for field → Preliminary laboratory testing plan → Estimate quantity and type of materials sampled

- Methods
  - GPR: all thru lanes, right wheelpath
  - Falling weight deflectometer:
    - All frontage roads outside lane
    - Outside ML and shoulders from SH 40 to BS6R
  - TPAD, ML outside lane US 190 to BS6R
  - Field sampling and testing – FR, southbound (west side FR) from US 190 to FM 158
    - Coring
    - Dynamic cone penetrometer

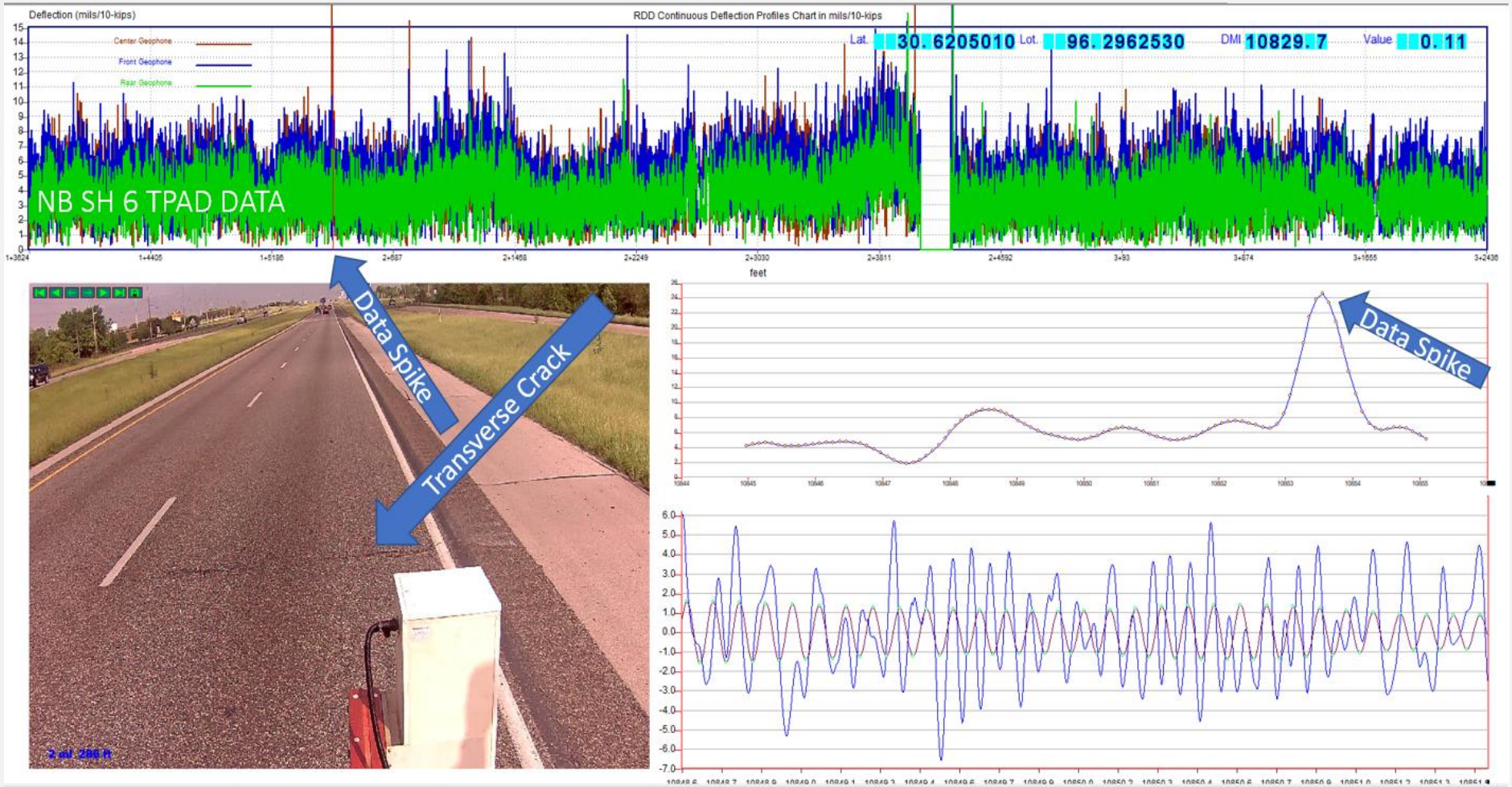


SH 6 Case Study: GPR

SB FR repair areas



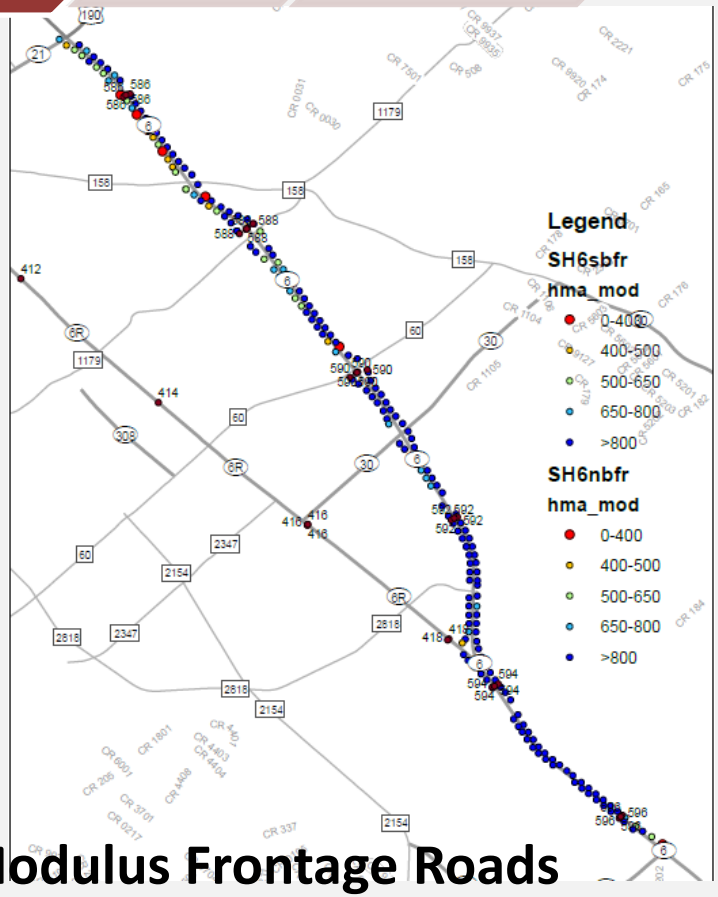
SH 6 Case Study Example TPAD Data



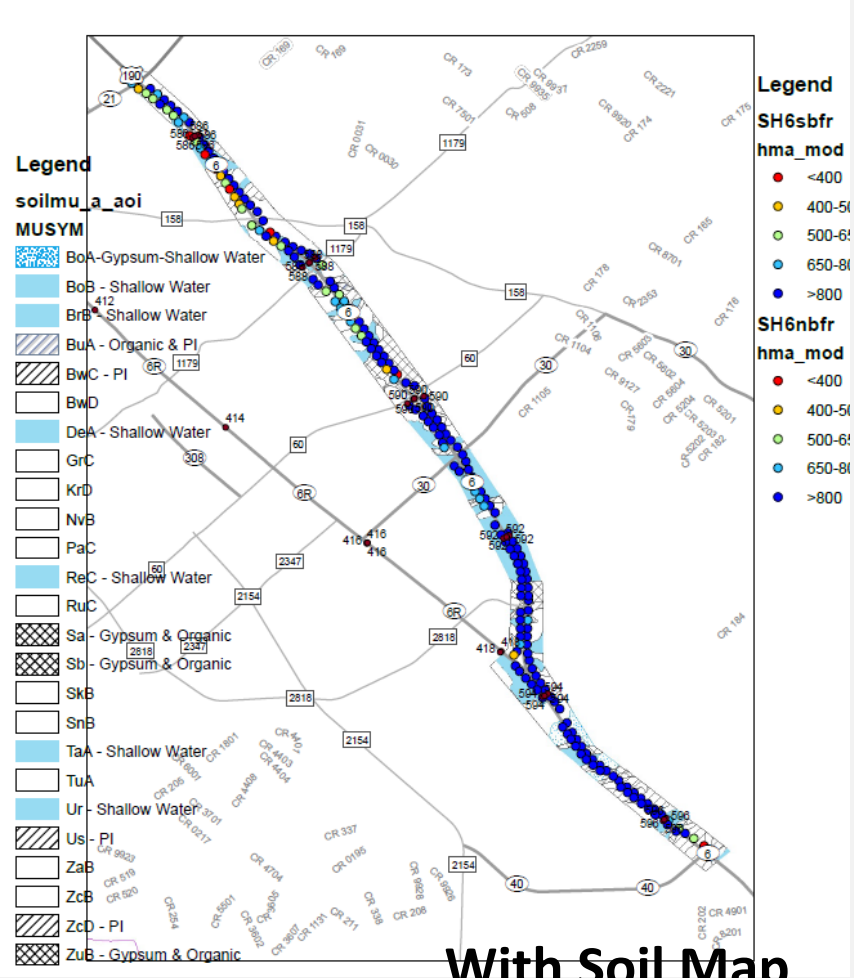
SH 6 Case Study Combined information – FWD & Soil Data

Sampling and Testing → Pavement coring → Subgrade sampling → Pavement sampling → DCP

Laboratory Testing → Material testing → Stabilization designs



HMA Modulus Frontage Roads



With Soil Map

SH 6 Case Study – FWD Summary

ML 2: ~ BS6-R to SH 40	SBOL		SBOshld		NBOL		NBOshld	
	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)
Pavement:	8.00	1060	8.00	1580	8.00	1258	8.00	1085
Base:	10.00	724	10.00	163	10.00	611	10.00	229
Subgrade:	111.57	17.3	104.55	12.8	99.25	15.7	113.04	14.7
Sections:	SB 1		SB 2		SB 3		SB 4	
SB Frontage Road	SB FR SH 30 to SH 21		SBFR-Water Locust to FM 158		SBFR SH 30 to SH 40		SBFR Tx Ave. to Rock Pr.	
	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)
Pavement:	12.00	943	5.00	763	8.00	1245	2.00	708
Base:			6.00	103	8.00	136	10.00	1143
Subbase:			6.00	2000				
Subgrade:	125.55	9.3	111.5	10.2	111.31	10	284.38	21.9
Sections:	NB 1		NB 2					
NB Frontage Road	NBFR SH 40 to SH 30		NBFR SH 30 to SH 21					
	Thickness (in)	Mod (ksi)	Thickness (in)	Mod (ksi)				
Pavement:	8.00	1750	12.00	1623				
Base:	10.00	58						
Subbase:								
Subgrade:	284.38	10.9	111.31	7.1				

Notes: Pavement Manual, Ch 5, for dense-graded mixes recommends:
Combined HMA thickness:
≤ 4 in. use 500 ksi
4.0 in. < T ≤ 8 in. use 650 ksi and
≥ 8 in. use 850 ksi
- Will use default design values if field tested values are greater. Used DCP results for SB2 base.

SH 6 Case Study

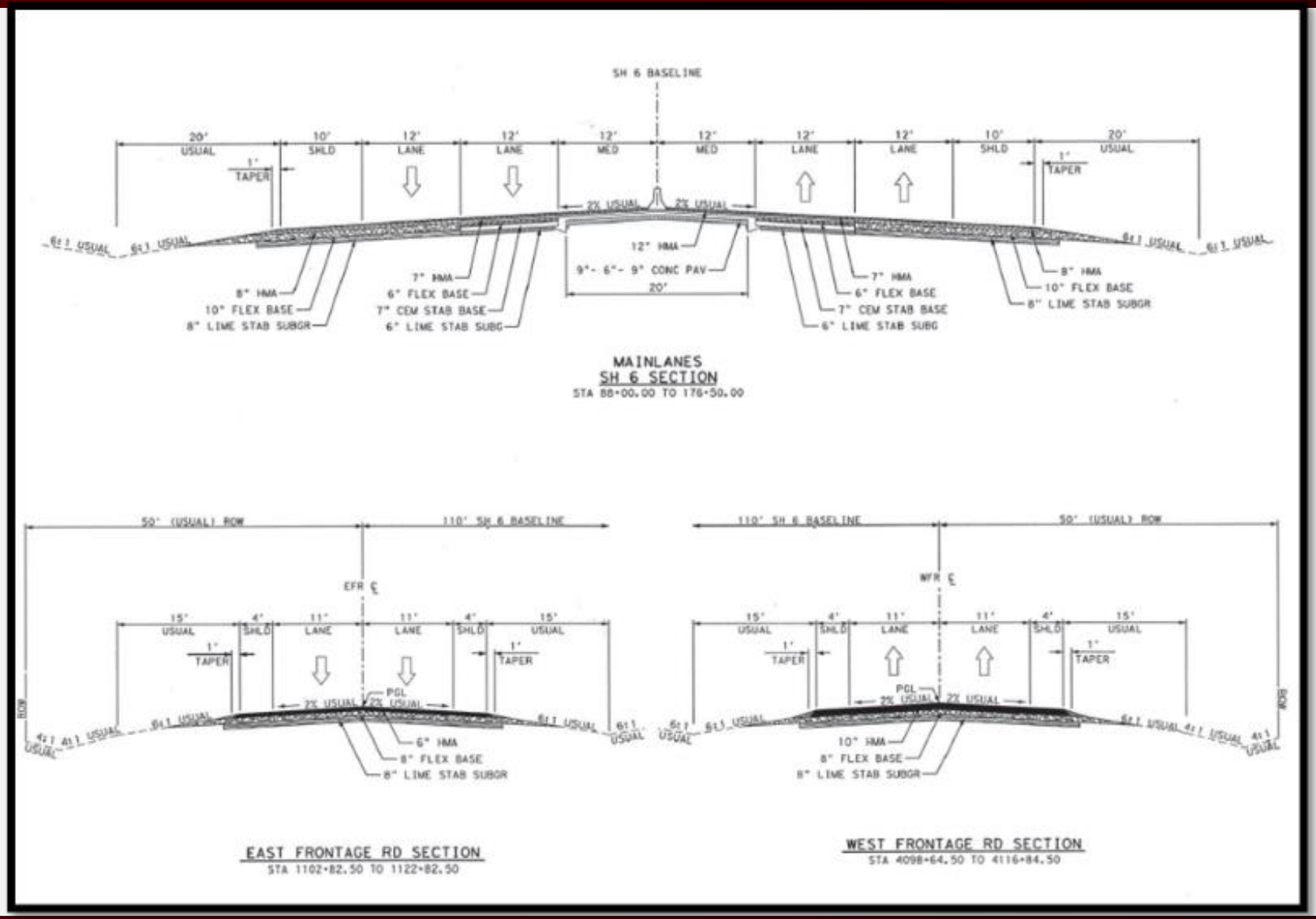
Sampling and Testing → Pavement coring → Subgrade sampling → Pavement sampling → DCP

Laboratory Testing → Material testing → Stabilization designs

Pavement Design

- Pavement designs
  - Modulus
  - Flexible: FPS-21 pavement design
  - Rigid: TxCRCP-ME

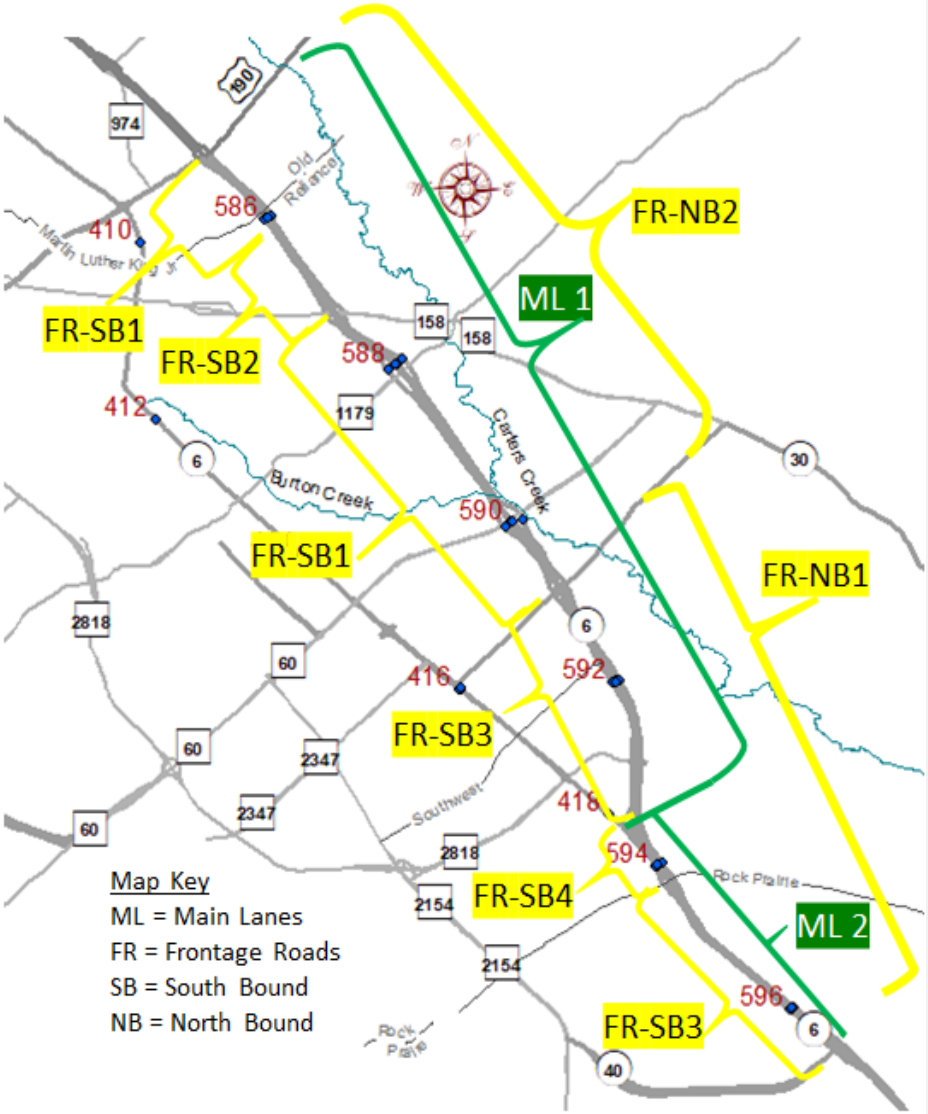
SH 6 Case Study – BS6R to SH 40 (South End Project)



SH 6 Case Study – Pavement Designs

Section	Notes	Widening	Estimated Pavement Cost
M1	Remove PFC. Use remaining existing pavement as subbase. Raises profile 13".	*Widen to Inside.* Widen to match existing pavement layers. Shoulder will have to be reconstructed or cement treated in place.	On existing $79.60/sy Widen $108.00/sy
M2	Remove PFC. 3" Overlay	*Widen to Outside.* Widen to match existing pavement layers. CTB plant mixed is preferred.	On existing $24.90/sy Widen $91.35/sy
FR- SB2, SB3 & NB1	2" overlay with underseal	*Widen to the inside* towards mainlanes since most is already close to the ROW line. Match pavement section. Widening cost will be similar to the FDH repair cost.	$15.70/sy
FR-SB1, SB4 & NB2	No additional structure is required. Replace Surface Layer.		$18.10/sy
FR-SB1 Spot Repairs	FDR raises profile or Full Depth HMA (FDH) can match profile.		FDR = $54.35/sy FDH = $90.70/sy

Any reconstruction or new construction, consider rigid section since it will minimize the traffic impacts of future work and LCCA is approximately the same for the Frontage Roads (Rigid LCCA = $112.95 and Flexible LCCA = $111.10) and the rigid is more cost effect for the mainlanes (ML Rigid LCCA = $128.80 and Flexible LCCA = $140.40).



SH 6 Case Study – Innovative Tool Summary

- Structural properties
  - Pavement layer thickness and deterioration
    - GPR
  - Structural condition
    - FWD
    - TPAD
    - DCP
  - Traffic data
    - Statewide planning map
    - p-WIM data
- Functional properties
  - Subgrade properties
    - USDA Web Soil Survey
  - Geometry
    - LiDAR
      - Bridge clearances (horizontal and vertical)
      - Widening potential
  - Visual check
    - HDV

SH 6 Case Study

- ML1 from US 190 to BS 6R is an 8.5-mile section with a proposed CRCP pavement
  - The project duration and traffic delay are highly interdependent
  - The agency can find a balanced tradeoff on the weekend option
    - Reduces traffic disruption at an acceptable range (24 minutes) while accelerating construction time (5230 closure hours) and road user costs ($80,000 daily) compared to the 24/7 option, which has 4,216 closure hours and road user costs of $138,000 per day
- ML2 from BS 6R to SH 40 is a 3.4-mile section
  - The integrated tradeoff analysis shows that all four options will produce a minimal level of traffic delay if the resurfacing work can be executed after the widening project is first completed

	ML 1	ML2	ML1 + ML2
Keep ($/sy)	$ 79.60	$ 24.90	
Build New ($/sy)	$ 128.80	$ 140.40	
Savings ($/sy)	$ 40.68	$ 88.78	
SY	378,987	175,531	
Total Savings	$15,417,177.60	$15,583,612.59	$31,000,790.19
Estimated Time Savings			19 months

SH6 Traffic Control Strategies

SH-6 BCS Project

Schedule-Cost-Traffic Integrated Tradeoff Analysis

Texas A&M Transportation Institute

Project Analysts: Darlene Goehl & Kunhee Choi

Alternatives

	Nighttime	Weekend	Weekdays	24/7
Construction Staging	M-F 9PM-5AM 8 Hrs per closure	F 8PM- M 6AM 58 Hrs per closure	T 8AM- R 8AM 72 Hrs per closure	M-Sun 24 hrs/d 168 Hrs per closure
ML1 CRCP Widening 17 lane-miles	Schedule 1,860 Closure | 14,880 Hours Road User Cost $1.4k Closure | $1.4k Days Peak Delay 2.6 Min	Schedule 90 Closure | 5,230 Hours Road User Cost $194k Closure | $80k Days Peak Delay 23.6 Min	Schedule 68 Closure | 4,886 Hours Road User Cost $481k Closure | $160k Days Peak Delay 57.3 Min	Schedule 25 Closure | 4,216 Hours Road User Cost $966k Closure | $138k Days Peak Delay 57.5 Min
ML1 CRCP Resurfacing 34 lane-miles	Schedule 2,488 Closure | 19,902 Hours Road User Cost $0.5k Closure | $0.5k Days Peak Delay 0.2 Min	Schedule 148 Closure | 8,554 Hours Road User Cost $8.8k Closure | $3.1k Days Peak Delay 0.2 Min	Schedule 112 Closure | 8,008 Hours Road User Cost $11.4k Closure | $3.8k Days Peak Delay 0.2 Min	Schedule 42 Closure | 6,959 Hours Road User Cost $34.4k Closure | $4.9k Days Peak Delay 0.4 Min
ML2 HMA Widening 6 lane-miles	Schedule N/A Closure | N/A Hours Road User Cost N/A Closure | N/A Days Peak Delay N/A Min	Schedule 11 Closure | 627 Hours Road User Cost $195k Closure | $81k Days Peak Delay 23.6 Min	Schedule 8 Closure | 575 Hours Road User Cost $483k Closure | $161k Days Peak Delay 57.5 Min	Schedule 3 Closure | 481 Hours Road User Cost $978k Closure | $140k Days Peak Delay 57.7 Min
ML2 HMA Resurfacing 12 lane-miles	Schedule 68 Closure | 538 Hours Road User Cost $1.6k Closure | $1.6k Days Peak Delay 0.2 Min	Schedule 6 Closure | 343 Hours Road User Cost $21.1k Closure | $8.7k Days Peak Delay 0.5 Min	Schedule 5 Closure | 337 Hours Road User Cost $29.5k Closure | $9.8k Days Peak Delay 0.6 Min	Schedule 2 Closure | 330 Hours Road User Cost $75.6k Closure | $10.8k Days Peak Delay 0.6 Min

SH 6 – ML1 Widening CA4RPS Example

Schedule/Cost/Traffic Tradeoff Analysis

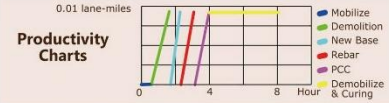
Alternative	Schedule (Calendar Days)		Road User Cost (US Dollar)		Peak Delay (Min)
Nighttime Single-lane Closure, M-F 9PM-5AM, 8 Hrs per Closure	1,860 Closure	14,880 Working Hours	$1,423 Closure	$1,423 Daily	2.6 Min Peak Delay
Weekend Single-lane Closure, F 8PM- M 6AM, 58 Hrs per closure	90 Closure	5,230 Working Hours	$194,012 Closure	$80,171 Daily	23.6 Min Peak Delay
Weekdays Single-lane Closure, T 8AM- R 8AM, 72 Hrs per closure	68 Closure	4,886 Working Hours	$480,608 Closure	$160,202 Daily	57.3 Min Peak Delay
24/7 Single-lane Closure, M-Sun 24 hrs/d, 168 Hrs per closure	25 Closure	4,216 Working Hours	$965,456 Closure	$137,923 Daily	57.5 Min Peak Delay

Summary of Production Rates and Traffic Delays

Nighttime
Single-lane Closure
M-F 9PM-5AM
8 Hrs per Closure

Production Profile:
Production Per Closure: *0.009 lane-miles*
Closure Needed: *1860.1*
Working Method: *Sequential Single Lane*
Demolition/Paving Hrs: *1.0/0.4*
Curing Time: *4 Hours*

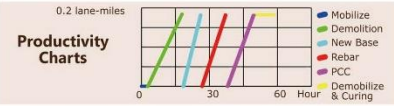
Resource Profile:
Hauling Truck: *9 Trucks/hour*
Rebar Installation: *170 sq. yd/hour*
Batch Plant: *90 cu. yd/hour*
Concrete Per Closure: *20.9 cu. yd*
Paver Speed: *2.0 ft/min*



Weekend
Single-lane Closure
F 8PM- M 6AM
58 Hrs per closure

Production Profile:
Production Per Closure: *0.189 lane-miles*
Closure Needed: *90.2*
Working Method: *Sequential Single Lane*
Demolition/Paving Hrs: *21.2/8.3*
Curing Time: *12 Hours*

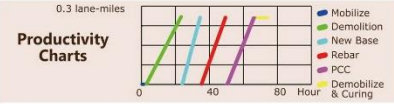
Resource Profile:
Hauling Truck: *9 Trucks/hour*
Rebar Installation: *170 sq. yd/hour*
Batch Plant: *90 cu. yd/hour*
Concrete Per Closure: *430.2 cu. yd*
Paver Speed: *2.0 ft/min*



Weekdays
Single-lane Closure
T 8AM- R 8AM
72 Hrs per closure

Production Profile:
Production Per Closure: *0.251 lane-miles*
Closure Needed: *67.9*
Working Method: *Sequential Single Lane*
Demolition/Paving Hrs: *28.1/11.0*
Curing Time: *12 Hours*

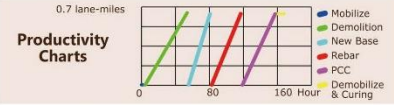
Resource Profile:
Hauling Truck: *9 Trucks/hour*
Rebar Installation: *170 sq. yd/hour*
Batch Plant: *90 cu. yd/hour*
Concrete Per Closure: *571.6 cu. yd*
Paver Speed: *2.0 ft/min*



24/7
Single-lane Closure
M-Sun 24 hrs/d
168 Hrs per closure

Production Profile:
Production Per Closure: *0.678 lane-miles*
Closure Needed: *25.1*
Working Method: *Sequential Single Lane*
Demolition/Paving Hrs: *76.0/29.8*
Curing Time: *12 Hours*

Resource Profile:
Hauling Truck: *9 Trucks/hour*
Rebar Installation: *170 sq. yd/hour*
Batch Plant: *90 cu. yd/hour*
Concrete Per Closure: *1545.8 cu. yd*
Paver Speed: *2.0 ft/min*



Conclusion

- Using innovative tools and techniques has the potential to save time and money
  - Method to evaluate traffic control strategies
    - User delay cost
    - Delay time impacts
  - Keep existing pavement
    - Saves resources (new materials)
      - Helps the environment
    - Saves removal and disposal costs
    - Saves time by not removing and reconstructing layers