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16. Abstract <p>This study was undertaken by the Texas DOT to nondestructively detect stripping in the asphalt surfacing on IH45 in the Bryan District. This highway was constructed in the 1960s and 1970s, with an initial concrete slab thickness of 200 mm (8 in). Since then several asphalt overlays have been applied. Maintenance of this highway is a recurring headache, and it is known that in several locations, moderate to severe areas of subsurface stripping are present.</p> <p>In order to plan the future rehabilitation of this important highway, the Bryan District investigated the ability of ground-penetrating radar (GPR) to provide subsurface condition information. A GPR survey was conducted at close to highway speeds, and the data was interpreted prior to taking validation cores. The GPR was used to provide information on the following: 1) the section breaks along the highway based on asphalt layer thickness and condition, 2) the average thickness of the asphalt layer within each section, and 3) the extent and severity of any defect in the asphalt layer.</p> <p>Over 60 cores were taken to validate the GPR interpretation. The comparison of GPR results and ground truth cores are given in this report. In general, the comparisons were good. The GPR equipment and interpretation schemes used were found to provide information of sufficient quality and accuracy to permit the district to make programming decisions.</p> <p>GPR is now being used on several additional projects in the Bryan District. The best use appears to be for both defect detection and thickness estimation prior to deflection testing and coring. GPR will not eliminate coring or deflection testing, but by using all three in a coordinated approach the pavement designer will have more confidence in his or her design decisions.</p>					
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**DETECTING STRIPPING IN ASPHALT CONCRETE LAYERS  
USING GROUND-PENETRATING RADAR**

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Research Report 2964-S  
Research Study Number 7-2964  
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of Asphalt Layers on Interstate Pavements

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College Station, Texas 77843-3135



## **IMPLEMENTATION STATEMENT**

The results collected in this study indicate that GPR is a useful tool for detecting subsurface deterioration in asphalt layers. To implement this technology:

1. TxDOT should identify upcoming major flexible pavement rehabilitation projects in which defects such as stripping are suspected, or projects which have performed poorly.
2. A GPR survey should be taken and predictions made by extent, depth, and severity of problem.
3. TxDOT should core the suspected problem locations.

To obtain the most benefit from this technology TxDOT's Area Engineers should be introduced to its potential benefits. This could best be achieved by describing successful case studies in the Technical Quarterly.



## **DISCLAIMER**

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration. This report does not constitute a standard, specifications, or regulations, nor is it intended for construction, bidding or permit purposes. The engineer in charge of the project was Tom Scullion, P.E. #62683.

There is no invention or discovery conceived or reduced to practice in the course of or under this contract; including any art, method, process, machine, manufacture, design, or composition of matter; or any new and useful improvement thereof; or any variety of plant which is or may be patentable under the patent law of the United States of America or any foreign country.

## **ACKNOWLEDGMENT**

The Texas Department of Transportation provided the funding to complete this study. Yiqing Chen and Lok Lau of Texas Transportation Institute collected the GPR data, and the laboratory testing personnel from the Bryan District laboratory performed the validation cores.



## TABLE OF CONTENTS

	Page
LIST OF FIGURES .....	x
SUMMARY .....	xi
I. INTRODUCTION .....	1
II. BASICS OF GPR TESTING .....	3
III. RESULTS FROM THE IH45 SURVEY .....	9
IV. VALIDATION OF GPR INTERPRETATION .....	15
V. TxDOT'S USE OF GPR SURVEY RESULTS .....	21
VI. CONCLUSIONS AND RECOMMENDATIONS .....	23
REFERENCES .....	25

## LIST OF FIGURES

	Page
1. GPR Equipment and Principles of Operation . . . . .	4
2. Typical GPR Waveform. Peaks A, B, and C Are Reflections from the Surface, Top of the Base, and Top of the Subgrade, Respectively . . . . .	5
3. GPR Return from a Pavement with a Defect in the Hot Mix Surfacing. Reflections A and B Are from the Top of the Hot Mix and the Top of Base. Reflection C Is from the Top of the Unstable Stripped Layer . . . . .	6
4. COLORMAP Displays of Sections of IH45 (Grey Scale Version) . . . . .	10
5. Section Breakdown of IH45, Based on GPR Interpretation . . . . .	12
6. Graphical Display of Asphalt Condition. Priority 1 Is Worst Condition . . . . .	13
7. GPR Trace and Validation Core from “Good Quality” Homogeneous Asphalt . .	16
8. GPR Trace and Validation Core from an Area Where Stripping Was Found at the Bottom of the Asphalt Layer . . . . .	17
9. GPR Trace and Validation Core from an Area Where Stripping Was Found at Middepth in the Asphalt Layer . . . . .	18
10. GPR Trace and Validation Core from an Area Where the Stripped Layer Is Close to the Surface . . . . .	19

## SUMMARY

The Texas DOT and TTI undertook this study as a nondestructive means of detecting stripping in the asphalt surfacing on IH45 in the Bryan District. This highway was constructed in the 1960s and 1970s, with an initial concrete slab thickness of 200 mm. Since then several asphalt overlays have been applied. Maintenance of this highway is a recurring headache and it is known that in several locations moderate to severe areas of subsurface stripping are present.

In order to plan the future rehabilitation of this important highway the Bryan District investigated the ability of ground-penetrating radar (GPR) to provide subsurface condition information. The research team conducted a GPR survey at close to highway speeds and interpreted the data prior to taking validation cores. The GPR was used to provide information on the following; 1) the section breaks along the highway based on asphalt layer thickness and condition, 2) the average thickness of the asphalt layer within each section, and 3) the extent and severity of any defect in the asphalt layer.

Over 60 cores were taken to validate the GPR interpretation. This report gives the comparison of GPR results and ground truth cores. In general, the comparisons were good. The GPR equipment and interpretation schemes provide information of sufficient quality and accuracy to permit the district to make programming decisions.

GPR is now being used on several additional projects in the Bryan District. The best use appears to be for both defect detection and thickness estimation prior to deflection testing and coring. GPR will not eliminate coring or deflection testing, but by using all three in a coordinated approach the pavement designer will have more confidence in his or her design decisions.



# **CHAPTER I**

## **INTRODUCTION**

Many miles of highways in Texas contain aggregates now known to be moisture susceptible and prone to stripping; the rounded river gravels used in the 1970s and early 1980s are often classified “strippers.” Stripping is accelerated by repeated wetting and drying cycles, and in the advanced stage it is observed as the total failure of the aggregate and asphalt bond which leaves a weak unstable layer. Over time these weak layers are often buried beneath overlays. Continuing to resurface pavements containing buried stripped layers is usually not cost effective; surface cracking often reappears within a short period of time. Recent changes to the Texas Department of Transportation (TxDOT) specifications, including specifying the number of crushed faces, the use of anti-stripping agents, and the introduction of stripping tests have greatly reduced the likelihood of future problems. However, there remain many miles of pavement with severely deteriorated lower asphalt layers.

In an attempt to identify these layers for future rehabilitation, the Bryan District solicited proposals to implement a quick, cost effective, and safe technology to detect stripping in asphalt concrete layers. Several proposals were submitted. The district elected to implement the ground-penetrating radar (GPR) technology proposed by the Texas Transportation Institute (TTI).

This report presents how the GPR technology was used to detect stripping in asphalt concrete layers on Interstate 45 (IH45) in the Bryan District. This project is four-lane divided highway, 110 miles long, constructed between 1960 and 1970. The original construction of the main lanes consisted of 150 mm of lime stabilized subgrade, 100 mm of asphalt stabilized subbase, and 200 mm of portland cement concrete (PCC) surface mostly continuously reinforced. The shoulders consisted of 150 mm of lime stabilized subgrade and 300 mm of asphalt concrete. Over the years, all but 13 miles of this project were overlaid with asphalt concrete (AC). The overlay thickness varies from 50 mm to 300 mm depending on traffic, soil type, and safety considerations.

In several locations, fatigue (alligator) cracking started showing up and eventually became potholes. This type of cracking is unusual for asphalt concrete over portland cement concrete pavement. To determine the cause, several cores were taken, leading to the conclusion that the initial overlays were constructed using rounded river gravel, which is prone to stripping in the presence of water and traffic loading. Coring 176 km and all four lanes to detect and locate stripping is costly, destructive, hit and miss, and dangerous to the workers.

The objective of the study was to use the GPR technology to detect and identify sections of IH45 with stripped AC layers for future programming. When detecting stripping, the following items were pursued:

- a. at what depth the stripping was present;
- b. how severe the stripping was; and
- c. how widespread the problem was throughout the section.

For the deterioration concentrated in a small area, limited milling and patching may be sufficient. However, if the problem occurs throughout the section, then the question is whether to mill and totally remove the problem areas or to apply a temporary repair until the required rehabilitation funds become available.

## CHAPTER II

### BASICS OF GPR TESTING

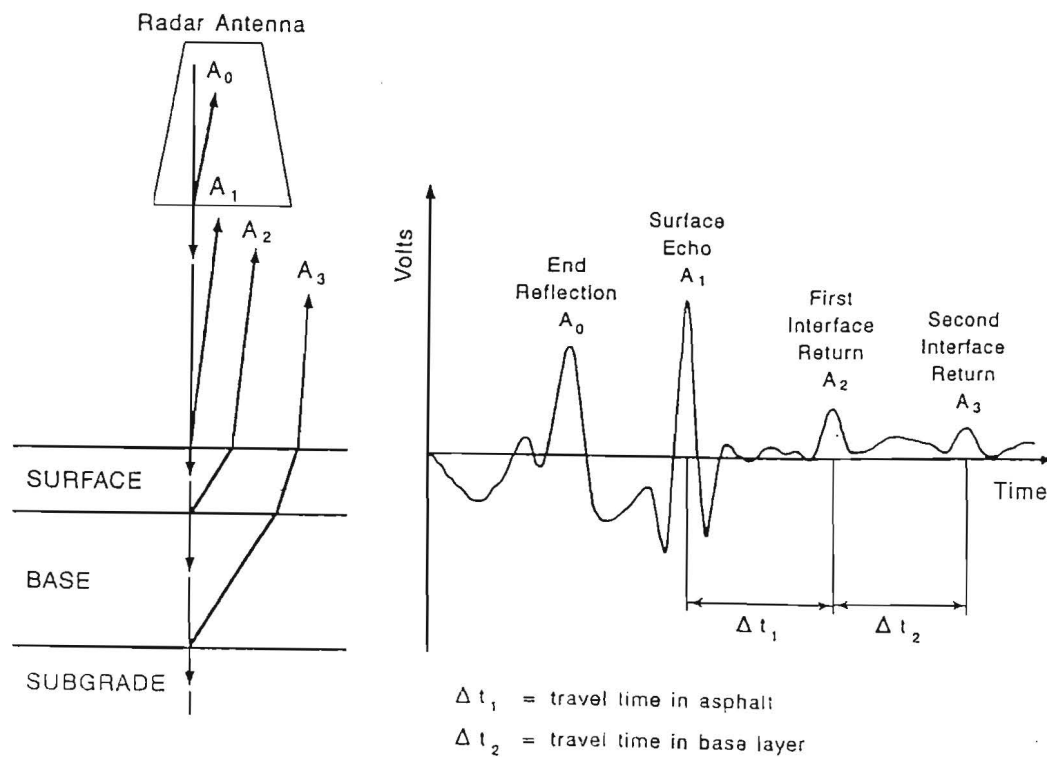
Figure 1a shows the TTI ground-penetrating radar vehicle with a Pulse Radar Inc. antenna. The antenna transmits pulses of radar energy, with a central frequency 1 GHz, into the pavement. The waves are reflected at significant layer interfaces in the pavement. The system captures these reflected waves and displays them as a plot of return voltage versus arrival time. As shown in Figure 1b, the largest peak is the reflection from the pavement surface. The amplitudes before (to the left of) the surface reflection are internally generated noise and of little significance. The reflections of interest to pavement engineers are those that occur after the surface echo. These are significant reflections from subsurface interfaces within the pavement, and the measured travel time between peaks is related to the thickness of the layer. For example, the time between the surface echo  $A_1$  and  $A_2$  is related to the thickness of the top layer.

The GPR return waveform from a pavement with a homogeneous surface layer in “good” condition is shown in Figure 2. Peaks A, B and C are reflections from the top of the surface, base, and subgrade, respectively. The hot mix surfacing is classified as “homogeneous with no defects” because there are no significant peaks between A and B. If the asphalt layer consisted of several thin layers placed at different times with different aggregates, then there may be small positive reflections at each asphalt layer interface.

This trace for a “good” asphalt should be contrasted with the trace shown in Figure 3. In this figure a negative peak C occurs between major peaks A and B. This signifies a layer of lower dielectric properties. Lower dielectrics can be naturally occurring, for example, due to layers constructed of lightweight aggregates or sand asphalts. They can also be caused by overlapping reflections from several thin layers. However, based on our experience in Texas, when there are intermittent negative peaks within the surfacing layer, these are usually related to the presence of a stripped layer within the asphalt layer. Given that all the Texas studies have been conducted at least 2 days after any significant rainfall, the stripped layer appears to GPR as a dry, very low density layer within the asphalt layer.



a. TTI GPR Equipment.



b. Principles of Ground-Penetrating Radar. The Incident Wave is Reflected at Each Layer Interface and Plotted as Return Voltage Against Time of Arrival in Nanoseconds.

Figure 1. GPR Equipment and Principles of Operation.



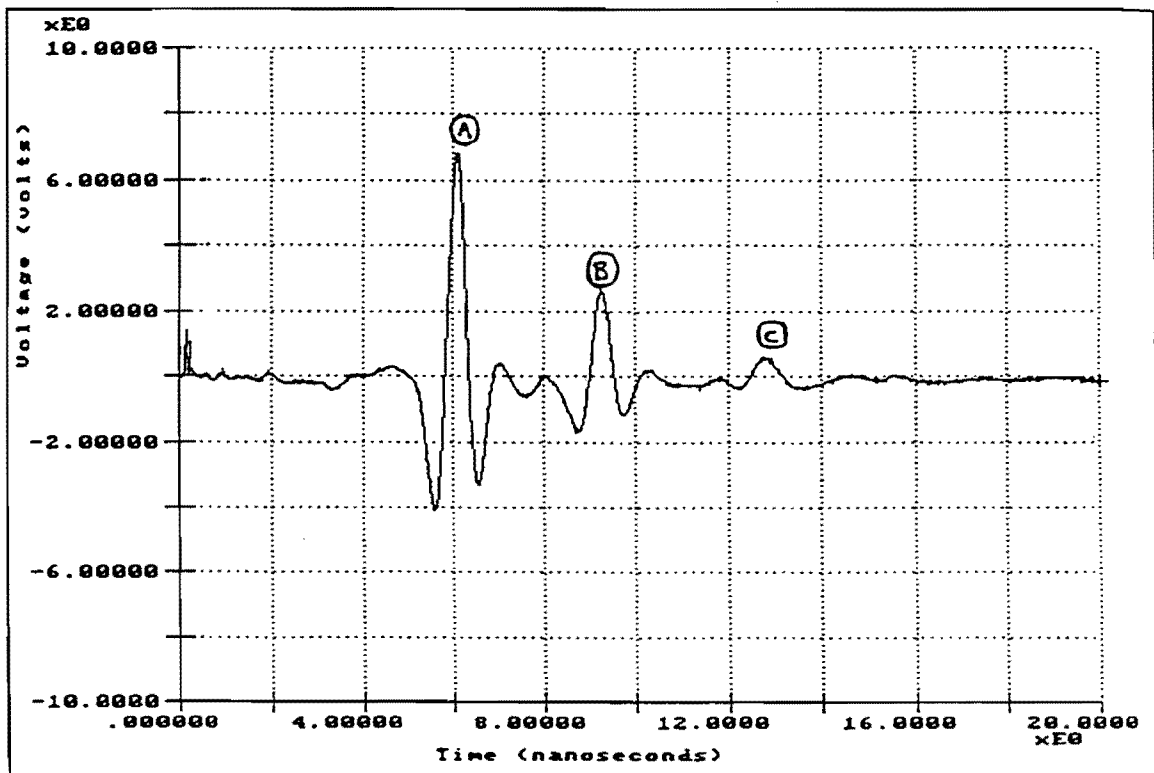


Figure 2. Typical GPR Waveform. Peaks A, B, and C Are Reflections from the Surface, Top of the Base, and Top of the Subgrade, Respectively.

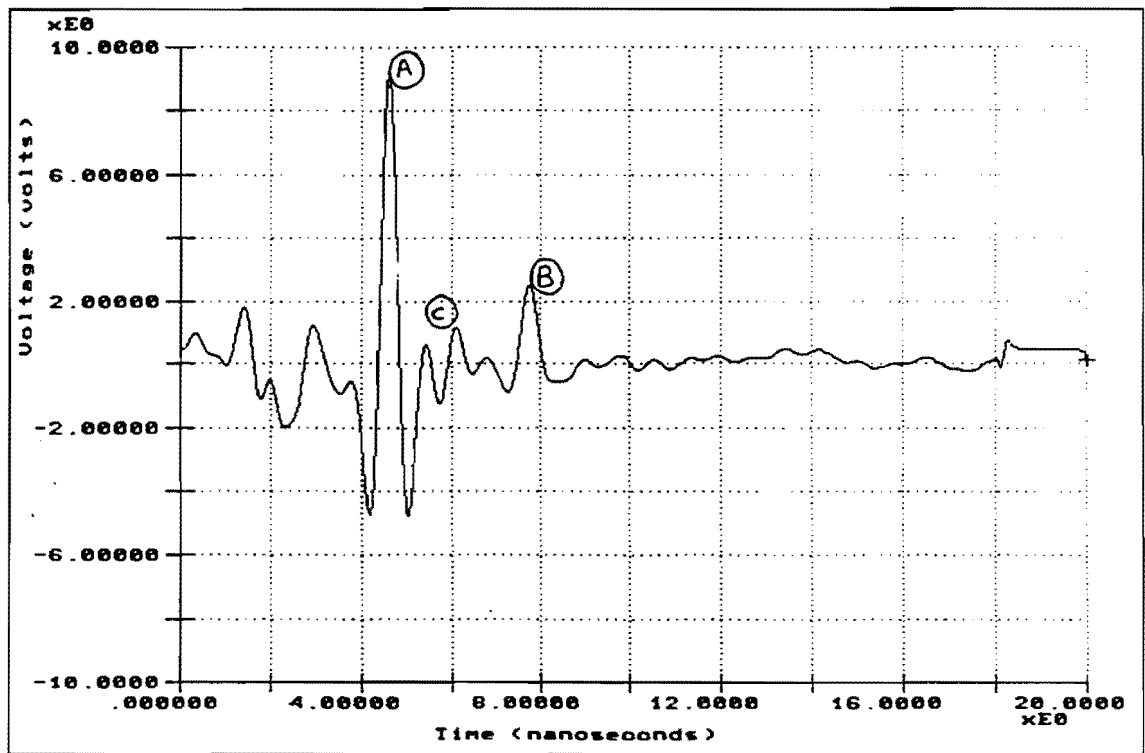


Figure 3. GPR Return from a Pavement with a Defect in the Hot Mix Surfacing. Reflections A and B Are from the Top of the Hot Mix and the Top of Base. Reflection C Is from the Top of the Unstable Stripped Layer.

The amplitude of reflection from any layer is a function of the contrast in dielectrics between layers. The main factor which influences the dielectric properties of pavement materials is the moisture content of the material. As the moisture content of the layer increases, its layer dielectric will also increase. If the base moisture increases then the amplitude of reflection from the top of the wave base will increase. In Figure 1 this would be observed as increase in the amplitude for peak  $A_2$ . The secondary factor influencing dielectrics is density. If the density of a layer increases then the dielectric for the layer will also increase, and the amplitude of reflection will increase. Conversely, if the density of the second layer is less than that of the surfacing (with no change in moisture content) then a negative reflection will be generated from the interface between layers.

When conducting GPR surveys, traces such as those shown in Figures 2 and 3 are collected at regular intervals along the highway. In most instances several thousand traces will be collected on any particular job. In order to process such a massive amount of data, in a timely fashion, TTI employs several innovative data processing techniques. To assist in reviewing the GPR data, each individual trace is color coded into a single line scan as described in TTI report 1341-1 (3). This report is a user's manual for TTI's COLORMAP signal processing system which was used extensively in this study. In this system the strong positive reflections (+ voltages) are colored "red" and the high negative reflections (- voltages) are colored "blue." Each individual trace therefore becomes a single vertical line containing several colors. These lines are then stacked side by side so that several hundred traces can be displayed on a single computer screen. Examples of these color coded stacked traces are shown in Figure 4. The benefit of this approach is that it permits the user to quickly and easily identify section breaks, obtain approximate layer thicknesses and locate anomalies within layers.

The second data processing approach used by TTI is the automated signal processing where the software measures amplitudes of reflections and time delays between reflections and converts these into layer dielectric and thicknesses. Earlier reports on this project explain the equations used in these computations (1, 2).



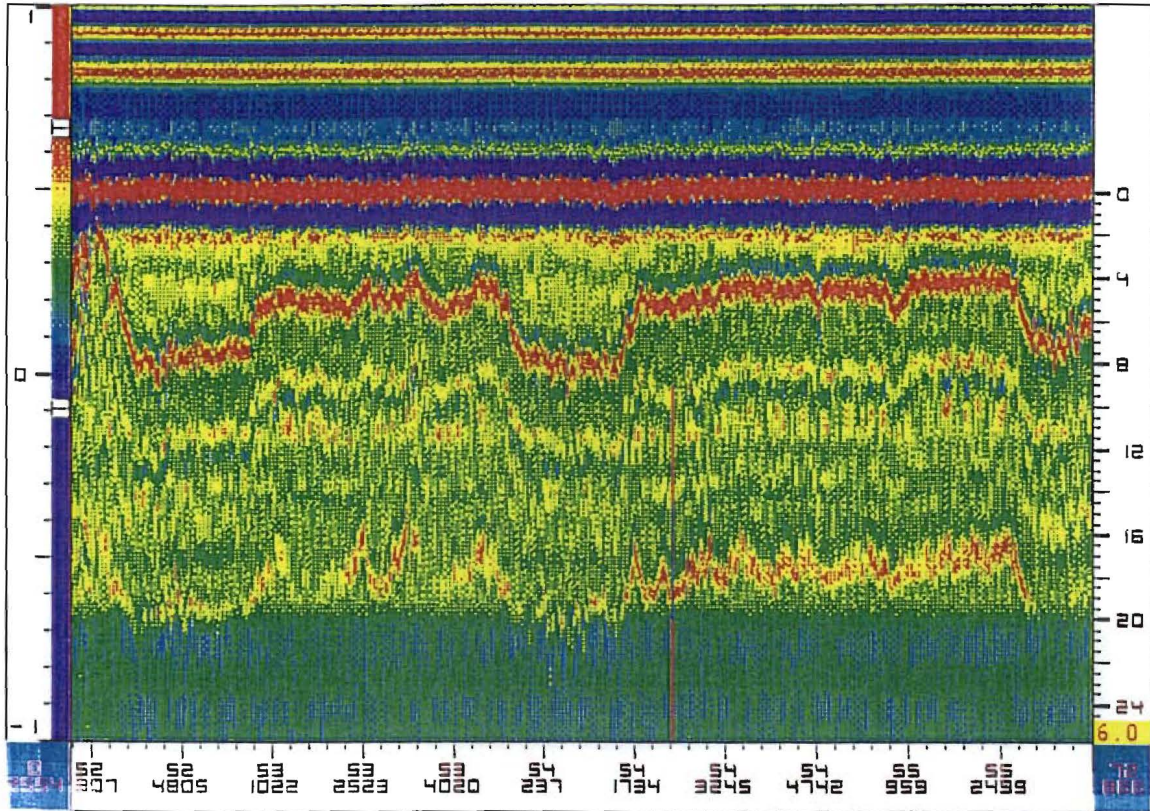
## **CHAPTER III**

### **RESULTS FROM THE IH45 SURVEY**

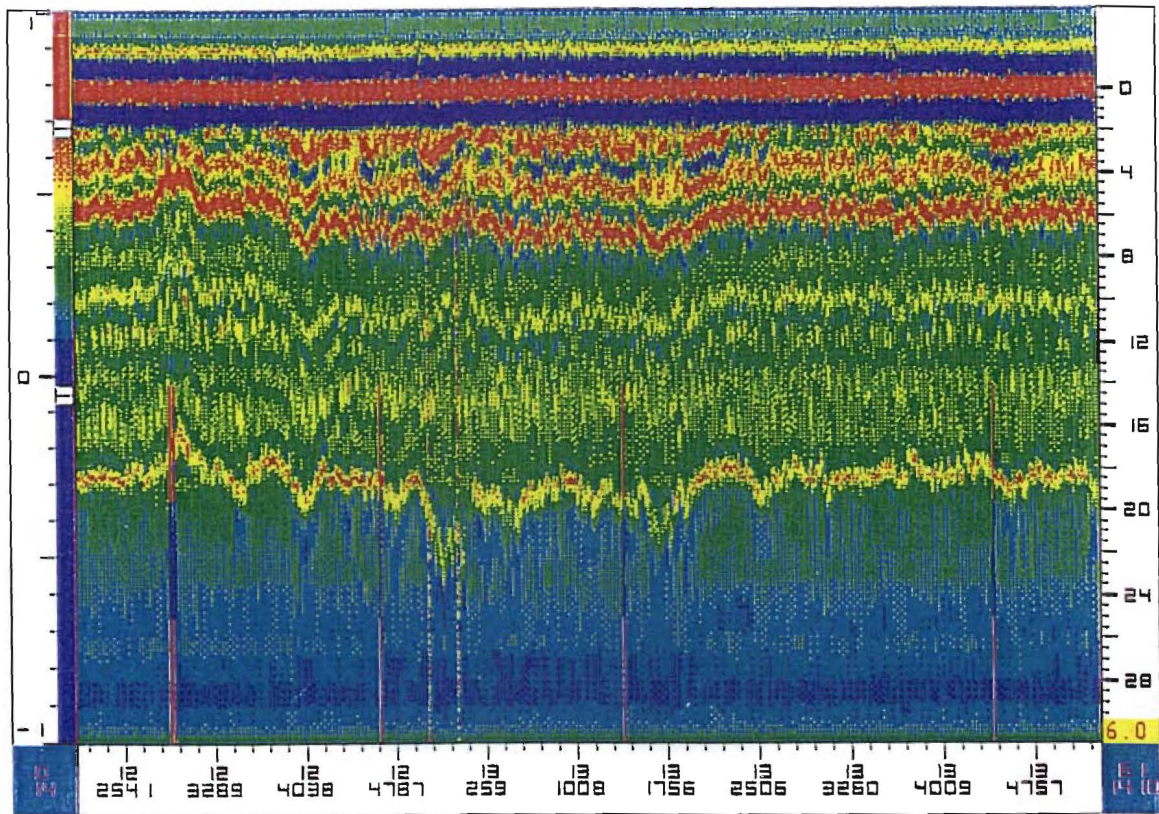
The GPR survey was completed using the Pulse Radar Inc. antenna shown in Figure 1. The data acquisition and processing system were developed by TTI (3). Both the northbound and southbound outer lanes were tested, a total survey length of 350 km (220 miles). The GPR data were collected at 80 kph (50 mph) with one trace collected every 1.5 m (5 ft). Testing was restricted to the outside wheel path of the outside lane.

The first step in data processing was to use the color display feature of TTI's COLORMAP software. This feature presents the GPR waves in either a color display or grey scale display (black/white only). The color display is better for locating defects. Two sections from IH45 are shown in Figure 4 , where the lower axis is distance along the highway and the axis on the right of the figure is the depth below the surface in inches. The zero depth is at the center of a solid red line, which is the reflection from the pavement surface. In Figure 4a, the variable line at a depth of 100 to 200 mm (4 to 8 inches) is the reflection from the top of the concrete. The lower faint line is the reflection from the bottom of the concrete. The upper section is from an area where the asphalt surfacing is relatively new and in good condition. In Figure 4a indicates there are no strong reflections between the surface reflection and the reflection from the top of the concrete. It is therefore concluded that this layer is homogeneous and relatively free of any defects.

Figure 4a should be contrasted with the GPR display from the other section of IH45 where the asphalt surface, top of concrete (150 mm or 6 inches below the surface) and the top of the subgrade reflections are still present, however this time there are several strong reflections within the asphalt surfacing layer. Of special interest are the dark blue areas at approximately middepth within the asphalt layer. These dark areas are associated with a reflection from a low dielectric layer, which as discussed earlier is associated with low densities and in Texas these types of patterns are often caused by the presence of a severely stripped layer. (See reference 3 for details.)



(a) Good Quality Hot Mix



(b) Areas with Stripping

Figure 4. COLORMAP Displays of Sections of IH45.

Based on the above discussion it is possible to interpret the two color displays shown in Figure 4 as follows; for Figure 4a the interpretation would be “variable thickness asphalt layer between 100 and 200 mm (4 to 8 ins) thick, good condition no apparent subsurface deterioration”; for Figure 4b a different interpretation would have been given “relatively uniform thickness asphalt surface 125 to 150 mm thick with moderate to severe levels of deterioration starting at a depth of 75 mm beneath the surface. To validate the presence of stripping, take a core at mile post 13 + 2000 feet which appears to be one of the worst areas.”

Interpretations such as these were made for the entire project. The intent was to use the GPR to define sections and evaluate the subsurface conditions. The tabular listing of sections as recommended from the GPR data interpretation is given in Figure 5. These data were also developed into a map as shown in Figure 6. The assigned priorities were arbitrarily defined as follows:

- Priority 1 · GPR data indicated significant widespread stripping problems within the asphalt surfacing. These should be the top priority for repair.
- Priority 2 GPR data were not clear, no clear interfaces were found. The GPR signature was not what would have been expected from a good quality hot mix. Probable deterioration at the asphalt/concrete interface. Coring required to confirm potential problem.
- Priority 3 Hot mix looks good, no significant problem areas were identified.

### Evaluation of IH45 in the Bryan District

Sect	County	Mile Posts	Length	Southbound		Northbound		Action
				GPR Interpretation	Priority	GPR Interpretation	Priority	
1	Freestone	212-197.5	14.5	<ul style="list-style-type: none"> <li>•AC thickness 6-7"</li> <li>•Good clear interfaces</li> <li>•No bad spots</li> </ul>	3	<ul style="list-style-type: none"> <li>•AC thickness 4-6"</li> <li>•Good interfaces</li> </ul>	3	•Hot mix looks good
2	Freestone	197.5-180.9	16.6	<ul style="list-style-type: none"> <li>•AC thickness 4-5"</li> <li>•No clear AC interfaces</li> <li>•Check for deterioration at AC/PCC interface</li> </ul>	2	<ul style="list-style-type: none"> <li>•AC thickness 4-5"</li> <li>•Minor trouble with interfaces</li> <li>•No major problems</li> </ul>	2	•Core section to check condition of hot mix
3	Leon	180.9-168.0	12.9	•Concrete section not analyzed	3	<ul style="list-style-type: none"> <li>•Concrete section</li> <li>•No interfaces</li> </ul>	3	•Maintenance and patching
4	Leon	168.0-152.10	16.0	<ul style="list-style-type: none"> <li>•AC thickness 4-5"</li> <li>•No bad spots</li> <li>•Clear interfaces</li> </ul>	3	<ul style="list-style-type: none"> <li>•AC thickness 4-5"</li> <li>•Good interfaces</li> <li>•No bad spots</li> </ul>	3	•Hot mix looks good
5	Madison	152.0-146.8	5.2	<ul style="list-style-type: none"> <li>•AC thickness 6"</li> <li>•Good clear traces</li> <li>•No bad spots</li> </ul>	3	<ul style="list-style-type: none"> <li>•AC thickness 5-6"</li> <li>•Good interfaces</li> </ul>	3	•Hot mix looks good
6	Madison	146.8-142.1	4.7	<ul style="list-style-type: none"> <li>•AC thickness 5-6"</li> <li>•Intermittent stripping 2" below surface throughout project</li> <li>•Recent 1.5-2" overlay at MP 144.7-143.6</li> </ul>	1	<ul style="list-style-type: none"> <li>•Bad section</li> <li>•AC thickness 6-8"</li> <li>•Intermittant stripping 2-3" down</li> <li>•Recent repairs around MP 142</li> <li>•Wet subgrade</li> </ul>	1	<ul style="list-style-type: none"> <li>•Core to confirm stripping and condition of hot mix</li> <li>•Future milling project</li> <li>•Core at following locations: SB 143.9-144.1 SB 142.5-142.7 These are potential bad spots</li> </ul>
7	Madison Walker	142.14-132.32	9.82	<ul style="list-style-type: none"> <li>•AC thickness 5-7.5"</li> <li>•Multiple layers</li> <li>•Many bad spots at 3-4" depth throughout section</li> <li>•Stripping suspected</li> <li>•Worst: 142.1-136.9</li> <li>•Bad: 132.7-132.9</li> <li>•New overlay: 137-135.8</li> </ul>	1	<ul style="list-style-type: none"> <li>•AC thickness 6-8"</li> <li>•Many Layers</li> <li>•Intermittant problem at middepth, worst 141.5</li> <li>•Strong Reflections from subgrade</li> <li>•Wet subgrade</li> </ul>	1	<ul style="list-style-type: none"> <li>•Worst section on highway</li> <li>•Consider milling entire AC at MP 142.1-137 (SB)</li> <li>•Remainder of section will require similar treatment</li> </ul>

Figure 5. Section Breakdown of IH45, Based on GPR Interpretation.

(1 inch = 25.4 mm)



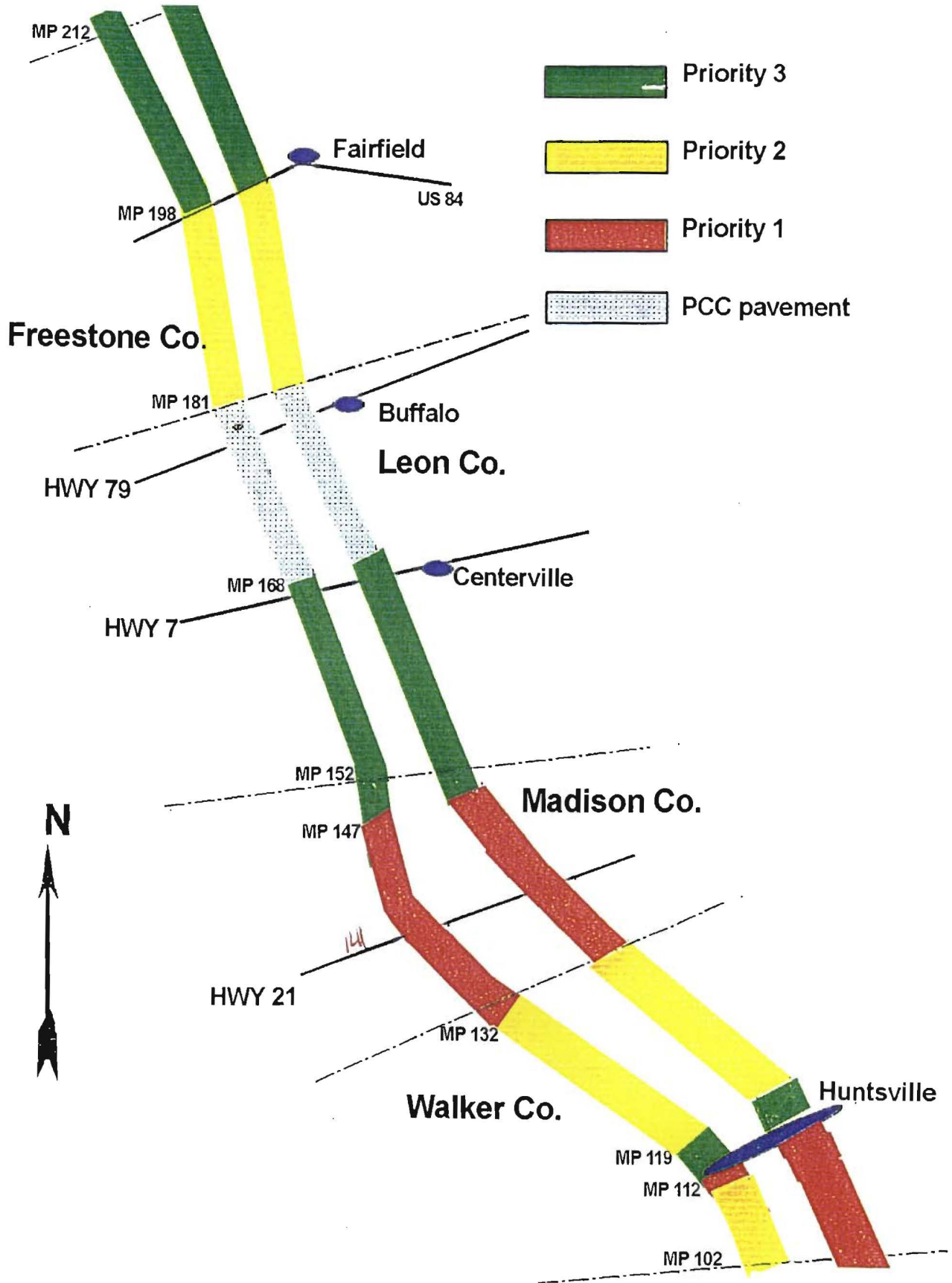


Figure 6. Graphical Display of Asphalt Condition. Priority 1 Is Worst Condition.



## CHAPTER IV

### VALIDATION OF GPR INTERPRETATION

In order to validate the GPR interpretation, researchers took a series of 60 cores at one-mile intervals in both the north and southbound directions. They compared the cores with the individual GPR traces collected at the approximate core locations. Each milepost was marked in the GPR data during data acquisition. The team found that the section breaks identified by the GPR matched the breaks found during coring and that the thickness estimates and depth to defects were reasonable. In several areas 100 to 150 mm (4 to 6 ins) of good quality asphalt was found to be covering very low strength, old, deteriorated asphalt layers. Where substantial subsurface stripping was found the calculated depths to the problem area were good but the thickness of the stripped layer was difficult to estimate. This was because at these locations the lower layer was variable causing numerous small GPR reflections and difficult data processing. The levels of deterioration were so severe that in many cases the subsurface layer totally disintegrated during coring and the total asphalt layer thickness could only be determined by measuring the depth of the core hole.

To demonstrate typical comparisons between the GPR traces and field cores four sets of results are given in Figures 7 through 10. Each shows the GPR trace and a photograph of the asphalt core removed from this location.

Figure 7 shows a GPR trace and a core from an area where the hot mix was classified as homogenous and free of defects. The trace shows a large surface reflection followed by a peak from the top of the concrete layer. Both reflections are similar in shape although different in size. There are no significant reflections between the surface and the top of the concrete. The small peaks after the concrete reflection are from the steel and lower layer interfaces. The extracted core shows no deterioration and is uniform with depth. The thickness estimates from the GPR data are close to the actual core thicknesses. The (+) signs on the traces are user inputs to provide information for the automated thickness calculation routines.

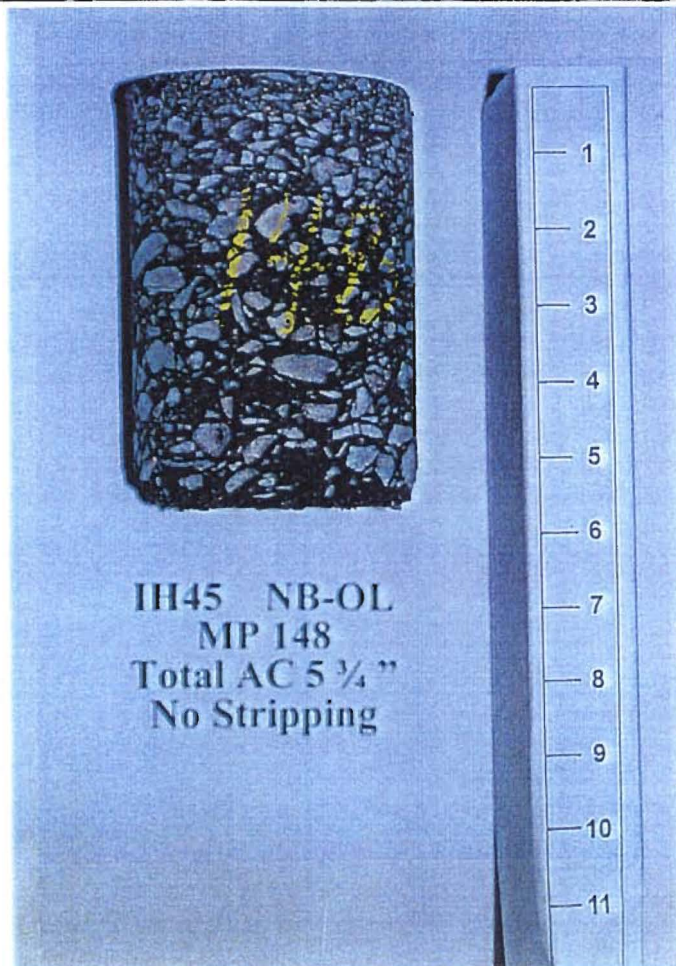
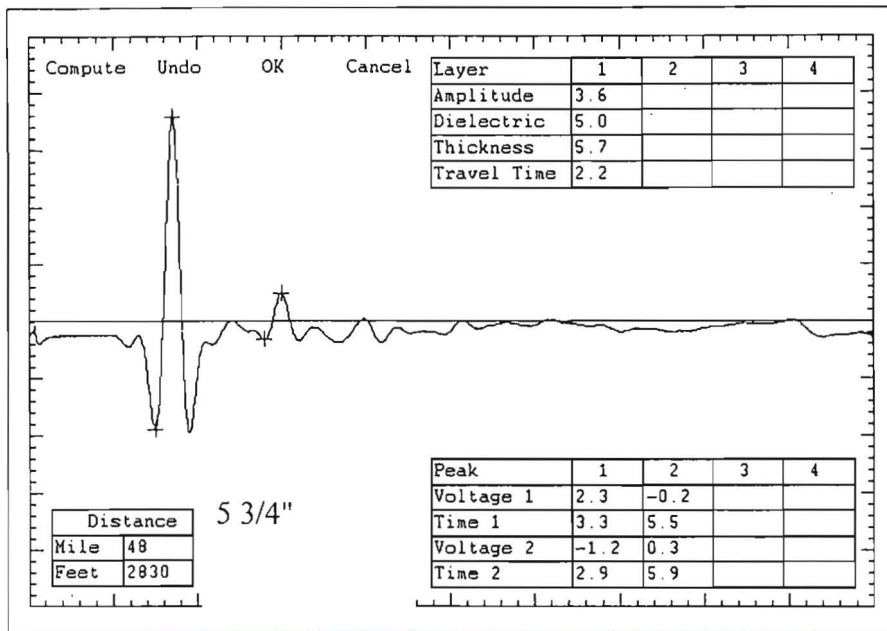


Figure 7. GPR Trace and Validation Core from "Good Quality" Homogeneous Asphalt.

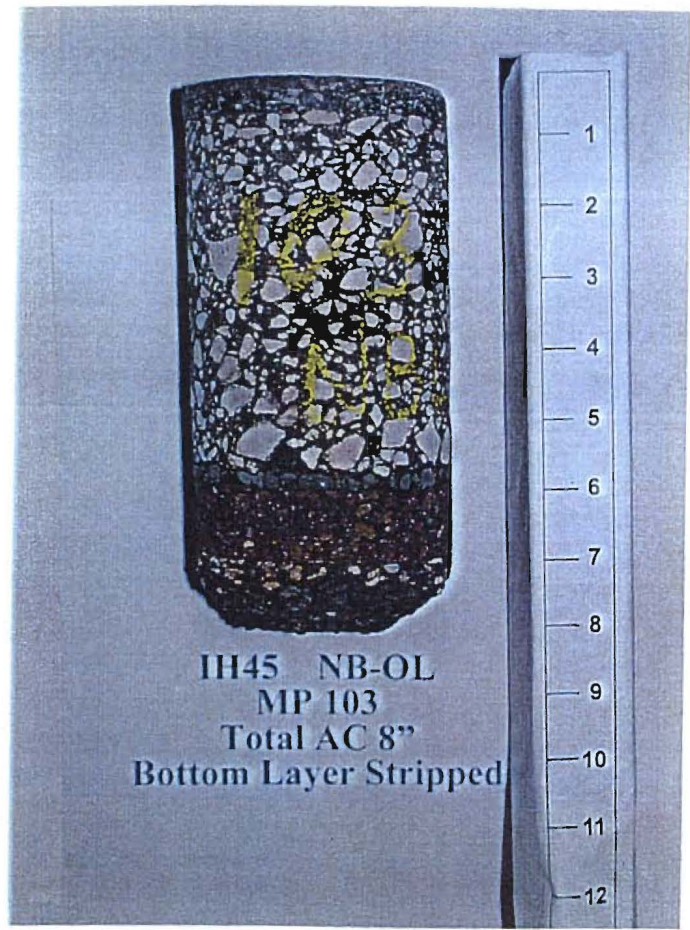
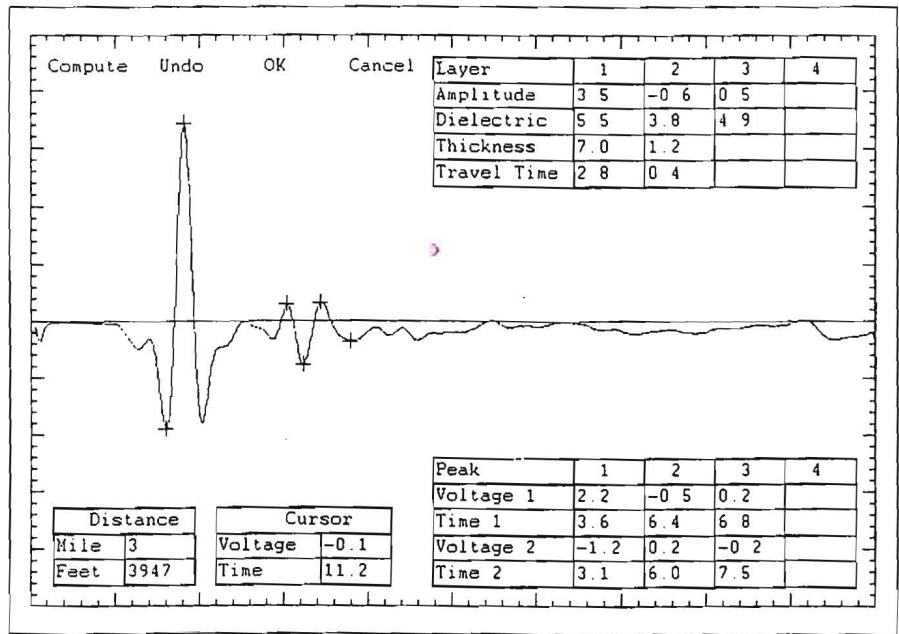


Figure 8. GPR Trace and Validation Core from an Area Where Stripping Was Found at the Bottom of the Asphalt Layer.

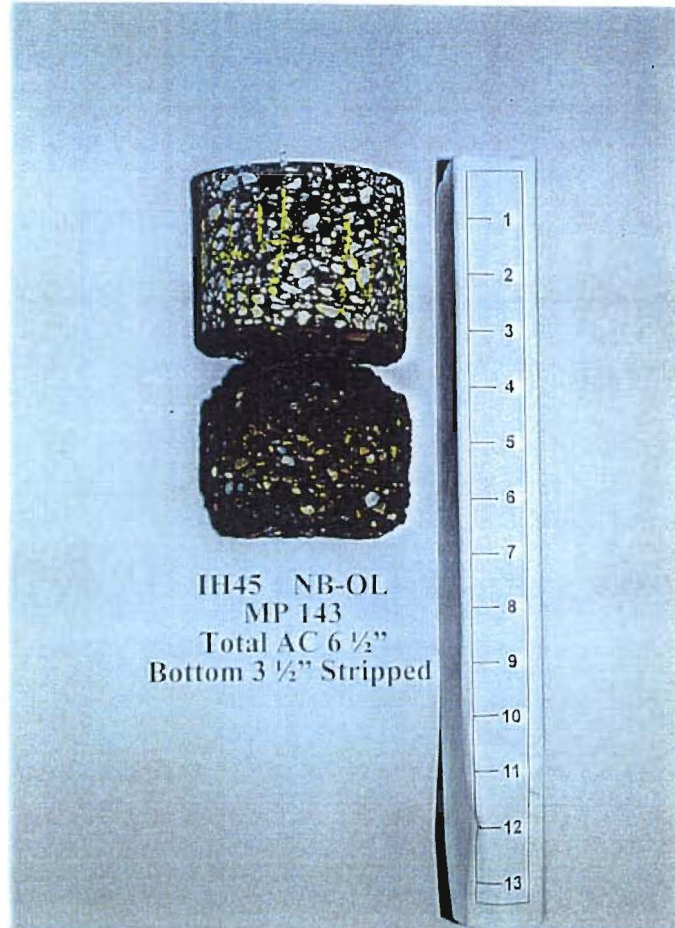
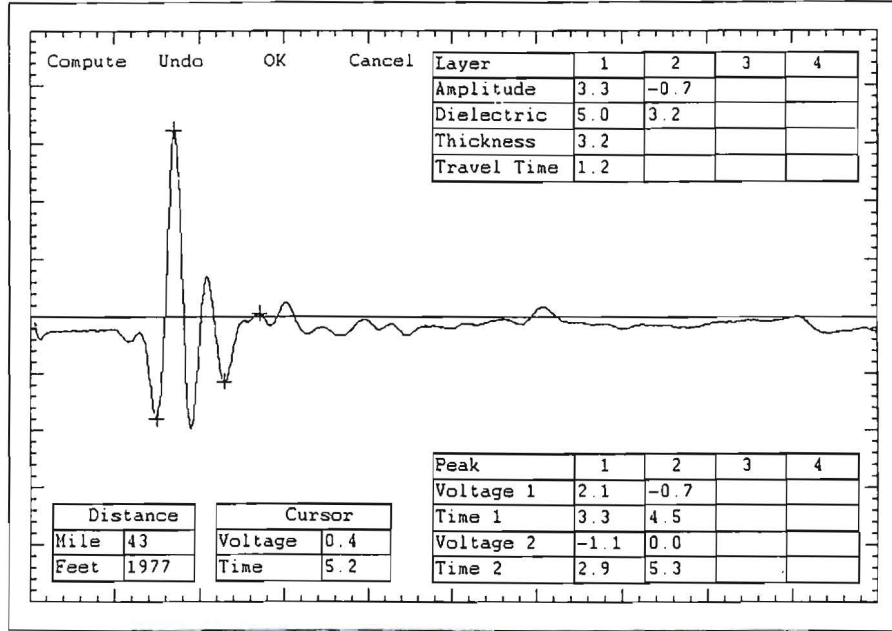


Figure 9. GPR Trace and Validation Core from an Area Where Stripping Was Found at Middeth in the Asphalt Layer.

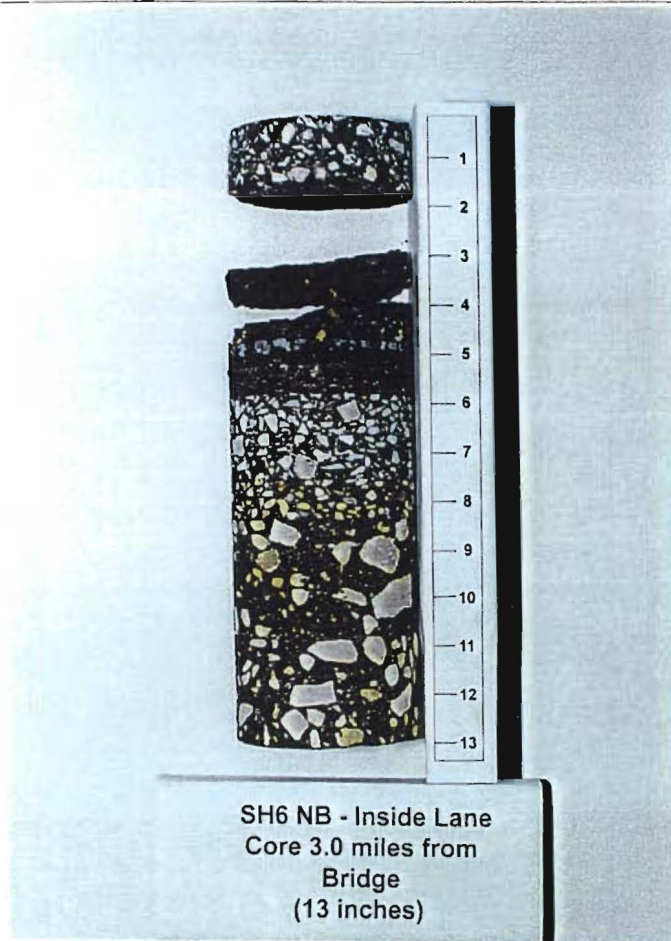
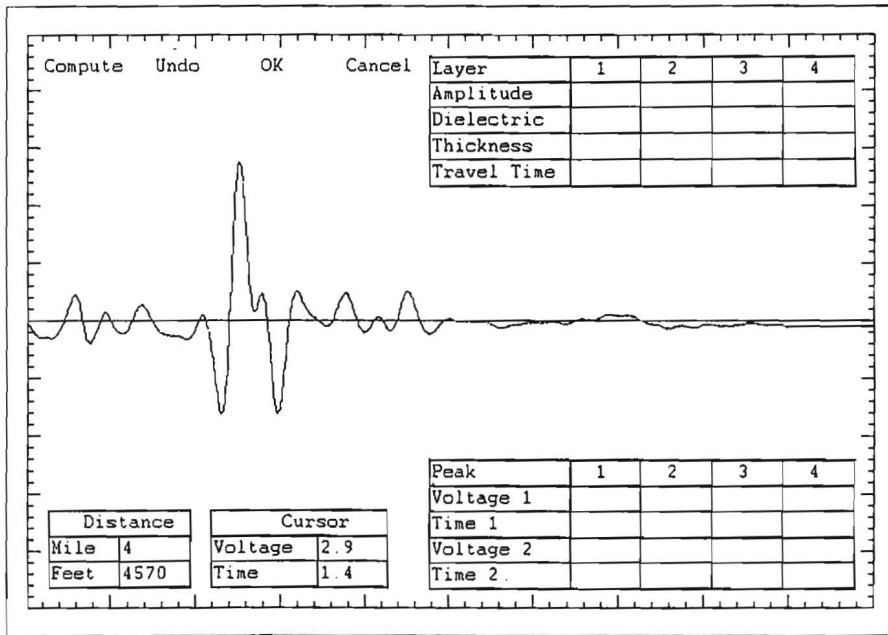


Figure 10. GPR Trace and Validation Core from an Area Where the Stripped Layer Is Close to the Surface.

Figure 8 shows a trace where the surface reflection is similar to that in Figure 7, but the reflection from the top of the concrete is different. In this trace the single peak is replaced by two overlapping reflections, one possibly negative and the other positive. Positive peaks are normal and associated with the reflection when moving to a layer of higher dielectric. This is normally associated with an increase in layer moisture content with depth. A substantial negative peak is associated with a transition from a high to a lower dielectric material which is normally a lower density material. In asphalt this transition to a lower dielectric is usually attributed to advanced stripping. This discussion illustrates one of the challenges in interpreting, GPR data processing: that of overlapping reflections from thin layers. The best the analyst can do at the moment is make the interpretation and validate it with field coring. In this case there appears to be a negative reflection closely followed by a positive reflection. This would represent a deteriorated layer at the bottom of the hot mix layer. In this study the deterioration was verified during the coring where a 175 mm (7 ins) core was removed from a 200 mm (8 ins) deep core hole. The bottom 25 mm (1 in) had disintegrated during the coring process.

Figure 9 shows a reasonably shaped surface echo which is closely followed by a positive and large negative reflection. The interpretation is that the defect is moving closer to the surface. In the computation, the depth to the stripped layer was estimated to be 80 mm (3.2 ins). The stripping was found during coring as shown in the photograph of the core, shown in Figure 9. The peak later in this trace is from the top of the concrete.

The results shown in Figure 10 are not from IH45 but from another highway in the Bryan District. It was included to demonstrate what happens when the stripped layer is very close to the surface. In this case the large negative reflection overlaps with the positive surface reflection causing a distorted shape. As shown in the photograph the depth of quality asphalt above the severely stripped layer in this case was only 35 mm (1.5 ins).



## **CHAPTER V**

### **TxDOT's USE OF GPR SURVEY RESULTS**

Based on the results of the GPR testing and analysis, the IH45 project was broken into sections depending on the asphalt concrete thickness and condition. Understanding the condition of the entire project, four rehabilitation projects were selected for fiscal year 1997 based on the amount of money allocated.

Project 1 is 27 km (15.6 mi) long, 150 mm (6 ins) AC surface over PCC. The surface is cracking and rutting. The GPR data showed that the deterioration is limited to the top 25 mm (1 in). The rehabilitation strategy consisted of removing and replacing the top 25 mm (1 in).

Project 2 is 22 km (12.7 mi) long, 75 mm (3 ins) AC surface over PCC. The surface is dry and cracking. Both the GPR and coring showed that the AC is not stripping. The rehabilitation strategy consisted of seal coat and 50 mm (2 in) AC overlay.

Project 3 is 7 km (4 mi) long, 50 mm (2 ins) AC over PCC. The surface is cracking. Both the GPR and coring showed that the AC is deteriorated. The rehabilitation strategy consisted of milling the entire AC, placing asphalt rubber seal coat on PCC, and 100 mm (4 ins) AC overlay.

Project 4 is 10 km (5.8 mi) long, 175 mm (7 in) of AC over PCC. The surface is beginning to show cracking. Both the GPR and coring showed that the bottom 75 mm (3 ins) of the AC is completely stripped. The rehabilitation strategy consisted of milling the entire AC layer, placing asphalt rubber seal coat, and 100 mm (4 ins) AC surface.

In addition to selecting rehabilitation projects for fiscal year 97, TxDOT now knows the condition of the entire project and has a good understanding of how much money we need for the next three years to rehabilitate and maintain this important project. The four projects described were completed in the 1996/1997 fiscal year.



## **CHAPTER VI**

### **CONCLUSIONS AND RECOMMENDATIONS**

On this project, GPR technology was found to be an effective way to detect stripping in asphalt concrete layers. Data collected at near highway speed provide a continuous measurement of the condition and thickness of the AC. Collecting, processing, and analyzing the data currently require experienced personnel; however, efforts are underway to implement the COLORMAP software in selected TxDOT Districts. With continuing improvements to the signal processing software it is hoped that future GPR interpretation will be made by pavement engineers. Also, this technology is best used in conjunction with limited coring to verify the reading.

On this project GPR appeared to work well in detecting the location and extent of subsurface stripping. However it must be remembered that the deterioration was at either a moderate or advanced stage. Cores taken from these locations were either badly eroded or disintegrated altogether. How GPR would perform at locating problems in their early stages of deterioration has not been established. GPR only works if there are differences in electrical properties between layers. Otherwise, there may not be sufficient contrast of the electrical properties.

TxDOT has currently funded two research projects to continue the development, improvement, and implementation of GPR technology. One of the improvements will be to develop and implement a miniature GPR antenna system for use and integration with TxDOT's 13 Falling Weight Deflectometers (FWD). In the future it is hoped that the new GPR system will provide surface layer information such as thickness and condition at the same location as the FWD readings.



## REFERENCES

1. Maser, K. R., and Scullion, T., "Automated Pavement Subsurface Profiling Using Radar - Case Studies of Four Experimental Field Sites," TRB Paper, January 1991.
2. Scullion, T., Lau, C. L., and Chen, Y., "Implementation of The Texas Ground-Penetrating Radar System," TTI Report 1233-1, April 1994.
3. Scullion, T., Chen Y., and Lau, C. L., "COLORMAP - User's Manual with Case Studies," TTI Report 1341-1, November 1995.



