Bridge Deck Condition Survey Using Ground Penetrating Radar (GPR) on the I-295 Corridor, Portland, ME

Final Report

submitted to

Maine Department of Transportation
16 State House Station
Augusta, Maine 04333

by

INFRASENSE, Inc.
14 Kensington Road
Arlington, MA 02476

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1. Introduction

This report describes a Ground Penetrating Radar (GPR) survey of seven bridges along the I-295 corridor in Portland (see Table 1). The objective of this survey is to provide subsurface bridge deck condition information so that the Maine Department of Transportation can better determine whether to rehabilitate or replace these decks. These decks are all reinforced concrete supported by girders. All the decks have been overlaid with asphalt except the Veranda St. Bridge, which is bare concrete. These bridges carry multiple lanes of traffic with the northbound and southbound traffic separated by a median.

Table 1 – Bridge List

BRIDGE NO.	MUNICIPALITY	FEATURE ON	FEATURE UNDER	ROADWAY AREA (SF)
5933	Portland	I-295	Veranda St & US 1	12,200
5618	Portland	US 1 & I-295	Kensington Street	5,300
5616	Portland	US1 & I-295	CNRR	15,680
5617	Portland	US1 & I-295	Sherwood Street	4,400
3088	Portland	I-295, 1A	Back Bay	48,480
6292	Portland	I-295 & 2 Ramps	Westbrook Arterial	14,276
6281	South Portland	I-295	Fore River	50,988

A detailed description of GPR principles, data collection, analysis and results are provided in the following sections.

2. Principles of GPR for Bridge Deck Evaluation

Ground penetrating radar operates by transmitting short pulses of electromagnetic energy into the pavement using an antenna attached to a survey vehicle (see Figures 1 and 2). These pulses are reflected back to the antenna with an arrival time and amplitude that is related to the location and nature of dielectric discontinuities in the material (air/asphalt or asphalt/concrete, reinforcing steel, etc). The reflected energy is captured and may be displayed on an oscilloscope to form a series of pulses that are referred to as the radar waveform. The waveform contains a record of the properties and thicknesses of the layers within the slab, as shown schematically in Figure 1.

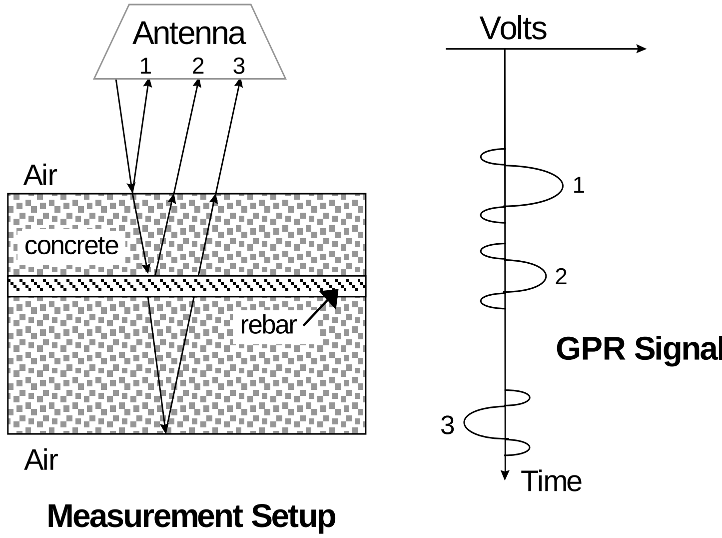


Figure 1 – Structure of the GPR Signal for Concrete Slabs

Deterioration of a slab can be inferred from changes in the dielectric properties and attenuation of the concrete (see Maser and Roddis, 1990; SHRP C-101, ASTM D 6087-08). The variation of the dielectric constant of the concrete is used as one measure of deterioration (Maser, 1990). Concrete with high moisture and chloride content, as associated with scaled concrete, will produce highly variable reflections at the overlay/concrete or concrete surface boundary. This reflection is related to the higher dielectric permittivity produced by the moisture and chloride.

The attenuation (loss of signal strength) of the radar signal, as measured from the top rebar reflection and/or the bottom of the slab, is used as an additional measure of concrete deterioration. Contaminated and delaminated concrete will cause the GPR signal to dissipate and lose strength as it travels through the slab and reflects back from the rebar and the bottom.

The analytical techniques described above serve as the basis for data analysis carried out during this project, as described in Section 4.

3. Data Collection

The GPR survey was conducted on October 2, 2009. The GPR equipment was a dual 1 GHz air coupled horn antenna system manufactured by GSSI, Inc. of Salem, NH and is shown in Figure 2. The vehicle was equipped with an electronic distance-measuring instrument (DMI) mounted to the rear wheel of the survey vehicle, providing distance data as the GPR data was collected. The data collection and recording was controlled by the SIR-20 GPR system operated from within the survey vehicle. Data was digitized and stored to hard disk as the survey progressed. The DMI distance data was synchronously recorded into each GPR record, so that each GPR data scan had an associated distance.

The GPR data was collected with a series of longitudinal passes, each spaced 3 feet transversely across the width of the deck. The GPR survey was carried out at normal driving speeds followed by a shadow vehicle provided by the Maine Department of Transportation.

Figure 2 – GPR Survey Vehicle using Air Coupled Antenna System

4. GPR Data Analysis

The bridge deck analysis was carried out according to ASTM D6087-08 with Infrasense's proprietary software, *win*DECAR®, using the following steps:

(1) Identification of the beginning and the end of the deck in each radar file, and check of the radar distance measurement against the known length and other features within the deck;

(2) Identification of features (bottom of asphalt, top rebar, bottom of deck) that appear as dielectric discontinuities in the GPR data (see example data, Figure 3);

(3) Setup of the analysis for all of the passes for a given deck, computation of concrete dielectric constant, rebar depth, and concrete attenuation; and

(4) Mapping the results and calculating quantities.

Figure 3 shows a sample of the raw GPR data. The figure represents a cross section through the deck, where the time axis is equivalent to depth. The asphalt overlay, top mat of rebar and bottom deck are distinct throughout. There was radio noise in GPR data collected on the Veranda St. Bridge, which required more extensive processing techniques to obtain useful data.

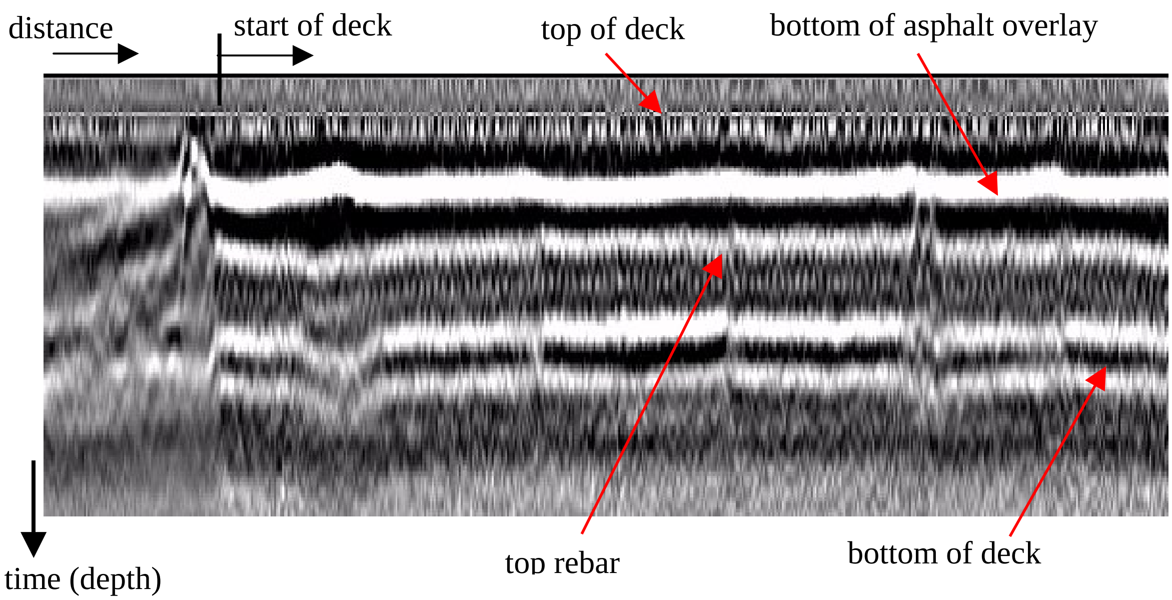


Figure 3 – GPR Data Sample: Tukey Bridge, Southbound

The Ground Penetrating Radar (GPR) results are presented for each bridge deck as a plan area contour map, with a separate map for each direction. These maps are presented in Attachment A. The probable areas of deteriorated concrete are shown in a blue to magenta color scale. The color scale indicates "severity", which is related to the degree of chloride contamination and rebar corrosion, but does not distinguish the depth of required repairs. The quantity of deterioration found by the GPR evaluation has been summarized in Table 2.

Table 2 – Summary of Deterioration Quantities

BRIDGE	NORTHBOUND	SOUTHBOUND
Veranda Street	6.4%	7.3%
Kensington Street	3.7%	4.7%
CNR Crossing	9.7%	18.6%
Sherwood St.	11.0%	7.7%
Tukey Bridge	7.6%	4.1%
Westbrook Arterial	7.4%	1.8%
Fore River	8.2%	2.2%

The condition of the Tukey Bridge was examined in more depth. It was widened around 1985, producing two distinct sections: an original one and a new one. Based on the original bridge drawings and a visual observation of the current geometry, the outside fascia of the original deck occurs at 12 ft from the outside edge of the existing deck in the northbound direction, and 16 ft in the southbound direction. The appearance of the rebar in the GPR data also confirms this.

The GPR data shows intermittent deterioration along the joint between the original and new deck. For the northbound Tukey bridge deck, it occurs along about 20% of this joint. On the southbound deck it occurs along about 10% of this joint. The quantity of deterioration found by the GPR evaluation in the original and new sections of the Tukey deck is presented in Table 3.

Table 3 – Tukey Bridge Deterioration Quantities

DIRECTION	ORIGINAL	NEW
Northbound	5.5%	15.4%
Southbound	3.5%	5.8%

5. References

ASTM *"Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar"*, Designation D 6087-08, ASTM International, West Conshohocken, PA, 2008.

Maser, K.R. and Rawson, A. *"Network Bridge Deck Surveys Using High Speed Radar: Case Studies of 44 Decks"*, Transportation Research Record No. 1347. Transportation Research Board. National Research Council, 1992.

Maser, K.R. *"Bridge Deck Condition Surveys Using Radar: Case Studies Of 28 New England Decks. Transportation Research Record No. 1304"*, Transportation Research Board. National Research Council, 1991.

Maser, K.R. *"New Technology for Bridge Deck Assessment"*, Phase I and II Final Report prepared for the New England Transportation Consortium, Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1990.

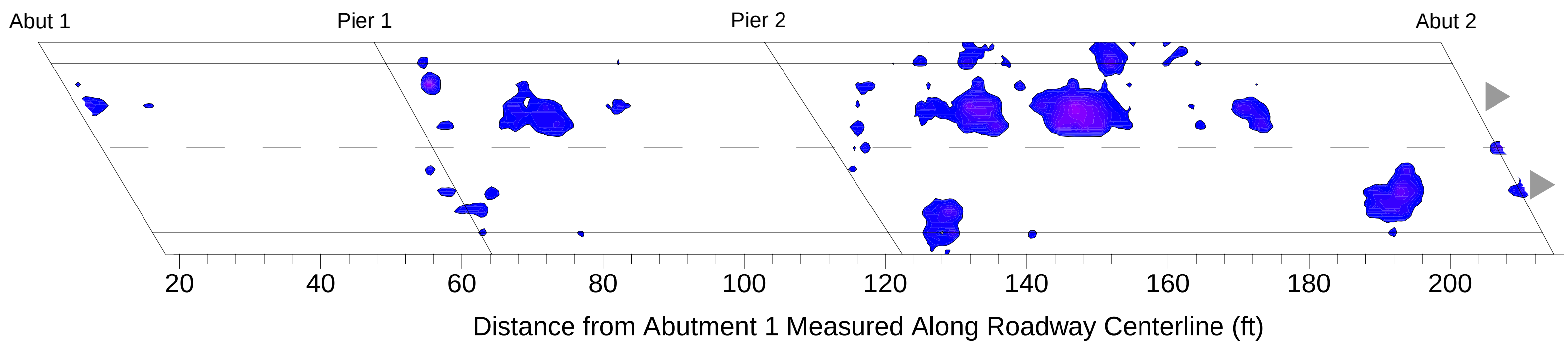
Maser, K.R., and Roddis, W.M.K., *"Principles of Radar and Thermography for Bridge Deck Assessment"*, ASCE Journal of Transportation Engineering, Vol. 116, No. 5, Sept/Oct, 1990.

Carter, C.R., Chung T., Holt, F.B., Manning D., *"An Automated Signal Processing System for the Signature Analysis of Radar Waveforms from Bridge Decks"*, Canadian Electrical Engineering Journal, Vol. 11, No. 3, pp. 128-137, 1986.

SHRP C-101 *"Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion – Volume 3: Method of Evaluating the Condition of Asphalt-Covered Decks"*, Strategic Highway Research Program Report SHRP-S-325, Washington, DC, 1993.

ATTACHMENT A

DETERIORATION MAPS



Predicted deterioration

Increasing severity -->

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5933 NB

I-295 OVER VERANDA ST.

analyzed by:	AJC	date:	10/22/09
checked by:	BCM	date:	11/13/09

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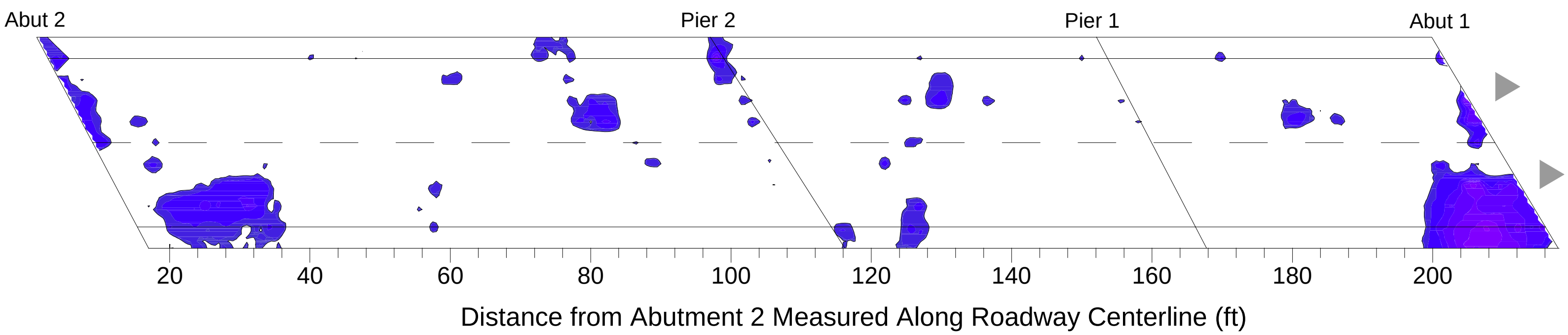
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5933 SB

I-295 OVER VERANDA ST.

analyzed by: AJC date: 10/22/09

checked by: BCM date: 11/13/09

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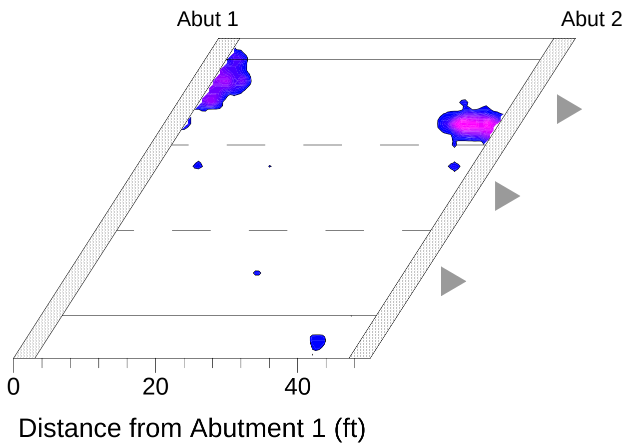
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5618 NB

KENSINGTON STREET

analyzed by: AJC date: 10/21/09

checked by: BCM date: 11/10/09

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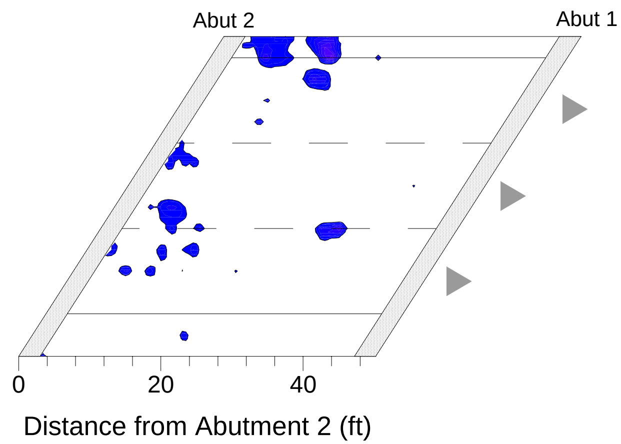
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5618 SB

KENSINGTON STREET

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checked by:	BCM	date:	11/10/09

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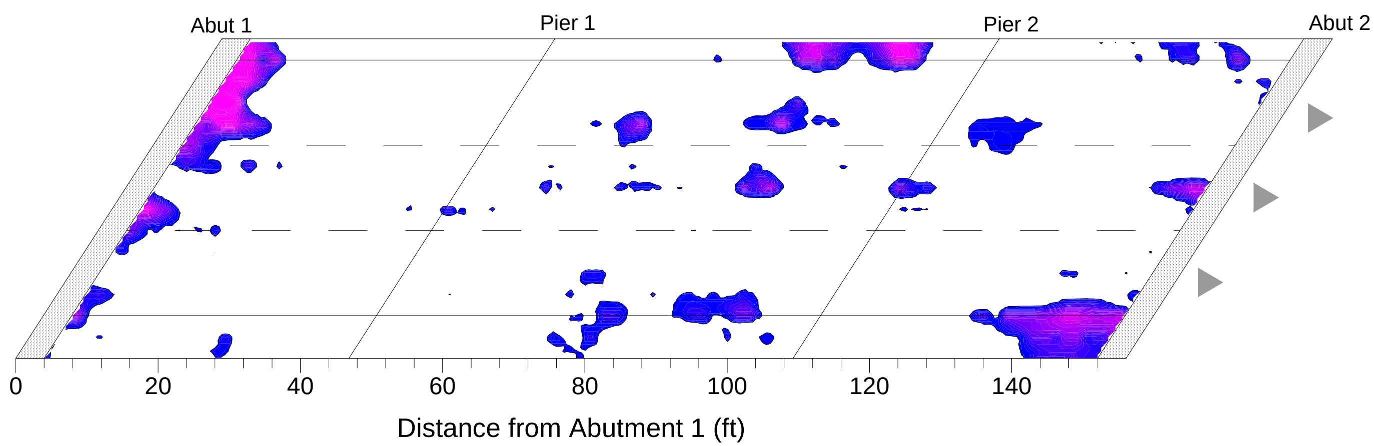
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5616 NB

CNR CROSSING

analyzed by: AJC date: 11/2/09

checked by: BCM date: 11/10/09

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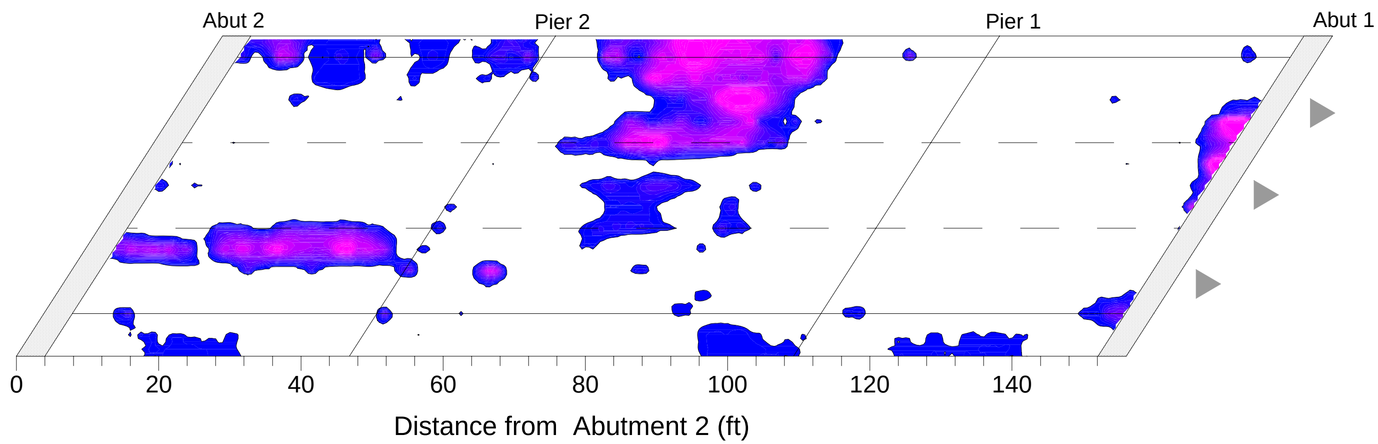
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

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Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5616 SB

CNR CROSSING

analyzed by: AJC date: 11/2/09

checked by: BCM date: 11/10/09

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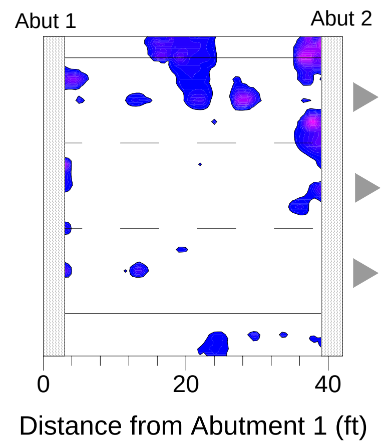
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5617 NB

SHERWOOD ST.

analyzed by: AJC date: 10/21/09
checked by: BCM date: 11/10/09

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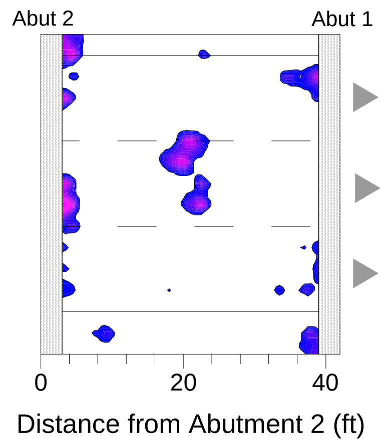
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 5617 SB

SHERWOOD ST.

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checked by:	BCM	date:	11/10/09

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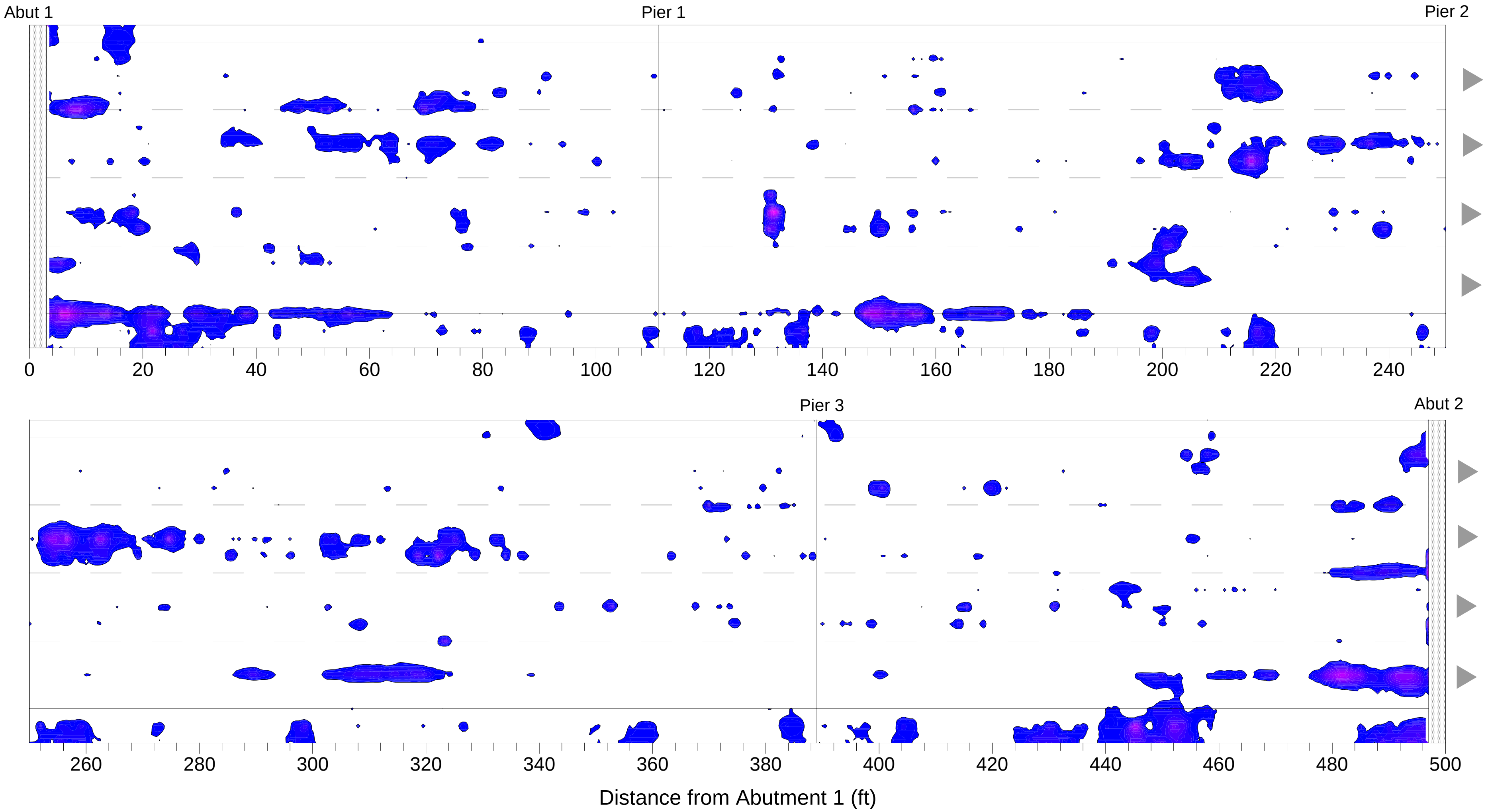
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 3088 NB

TUKEY BRIDGE

analyzed by: AJC date: 10/19/09

checked by: BCM date: 11/11/09

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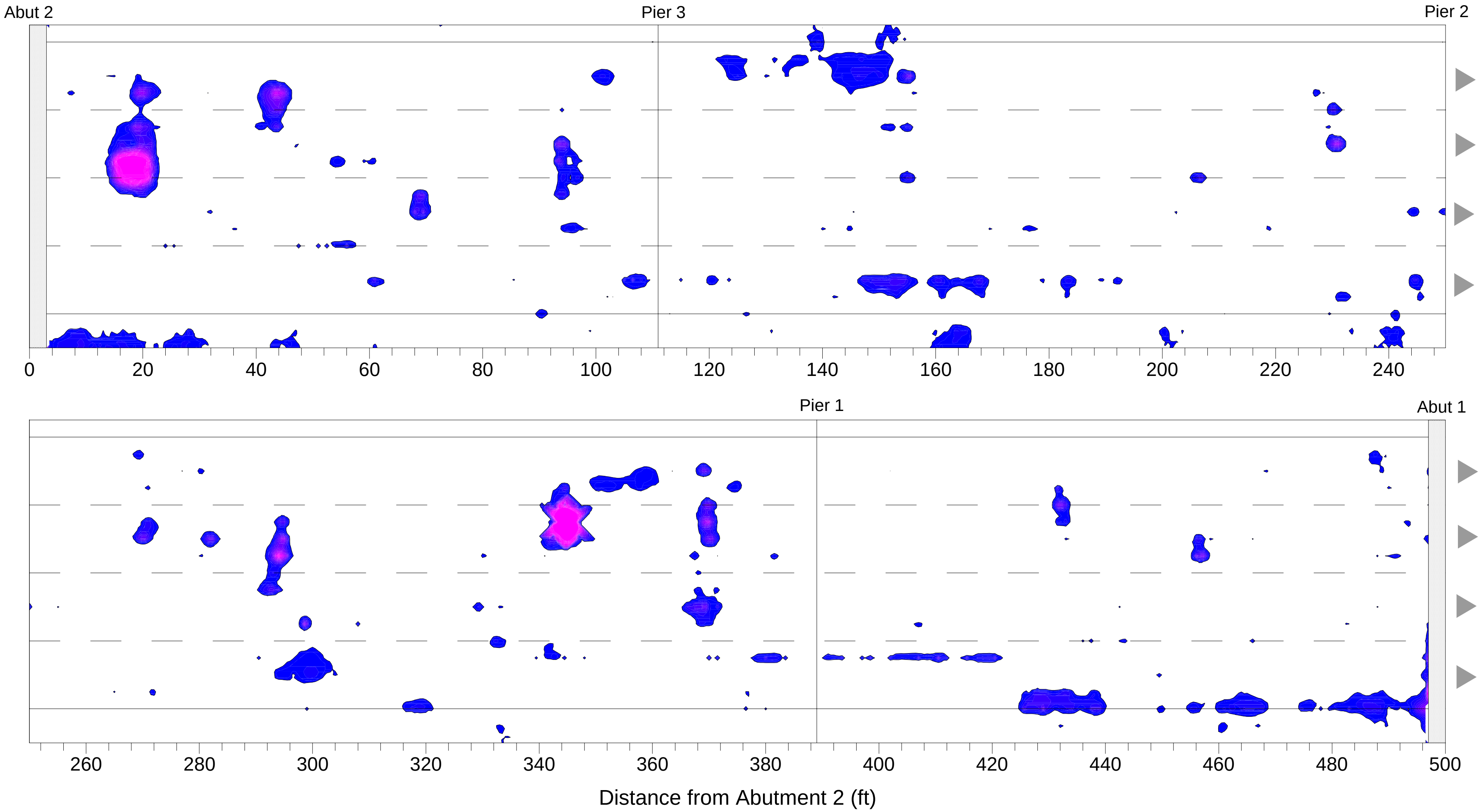
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 3088 SB

TUKEY BRIDGE

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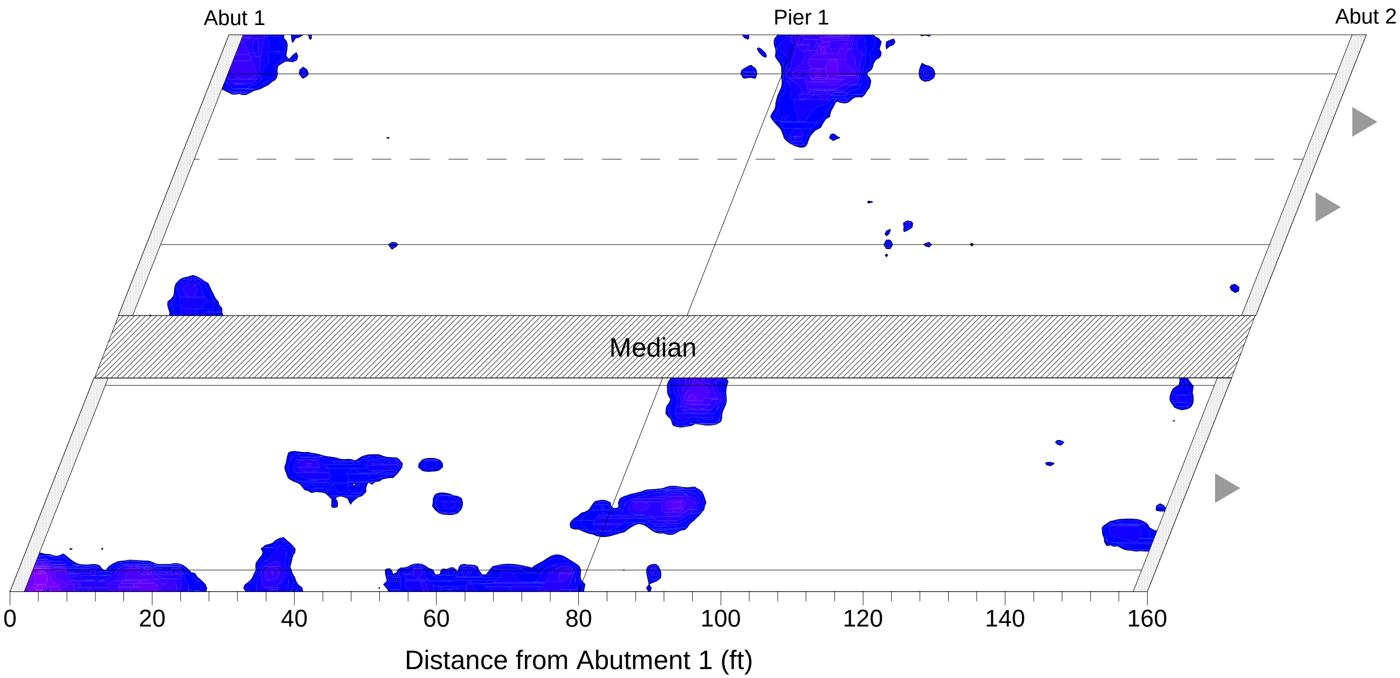
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 6292 NB

WESTBROOK ARTERIAL

analyzed by: LM date: 10/20/09

checked by: BCM date: 10/30/09

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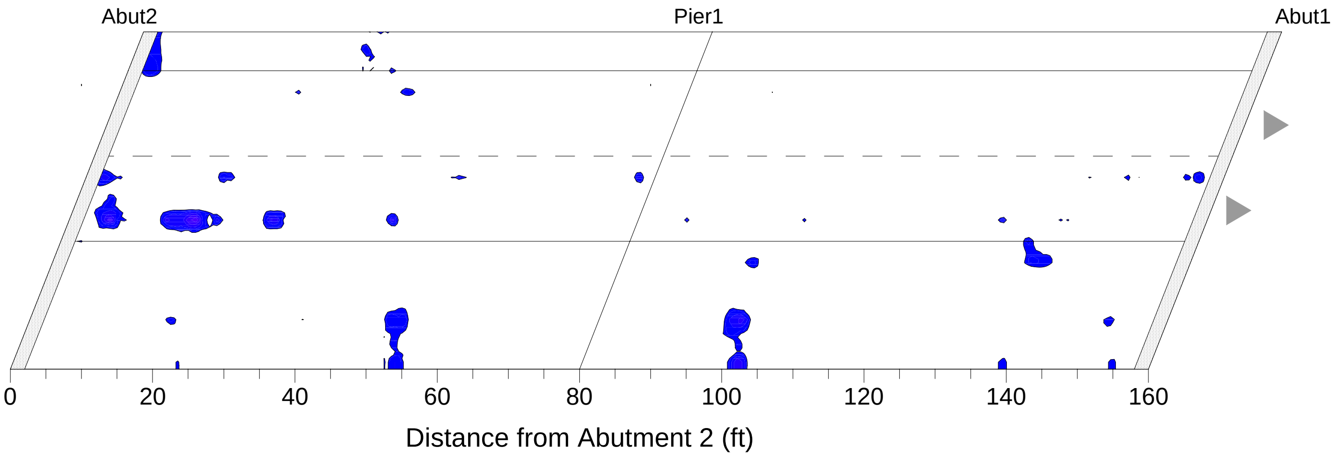
sheet 1 of 1



Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Direction of traffic

Bridge Deck Condition Evaluation using GPR

ME Bridge # 6292 SB

WESTBROOK ARTERIAL

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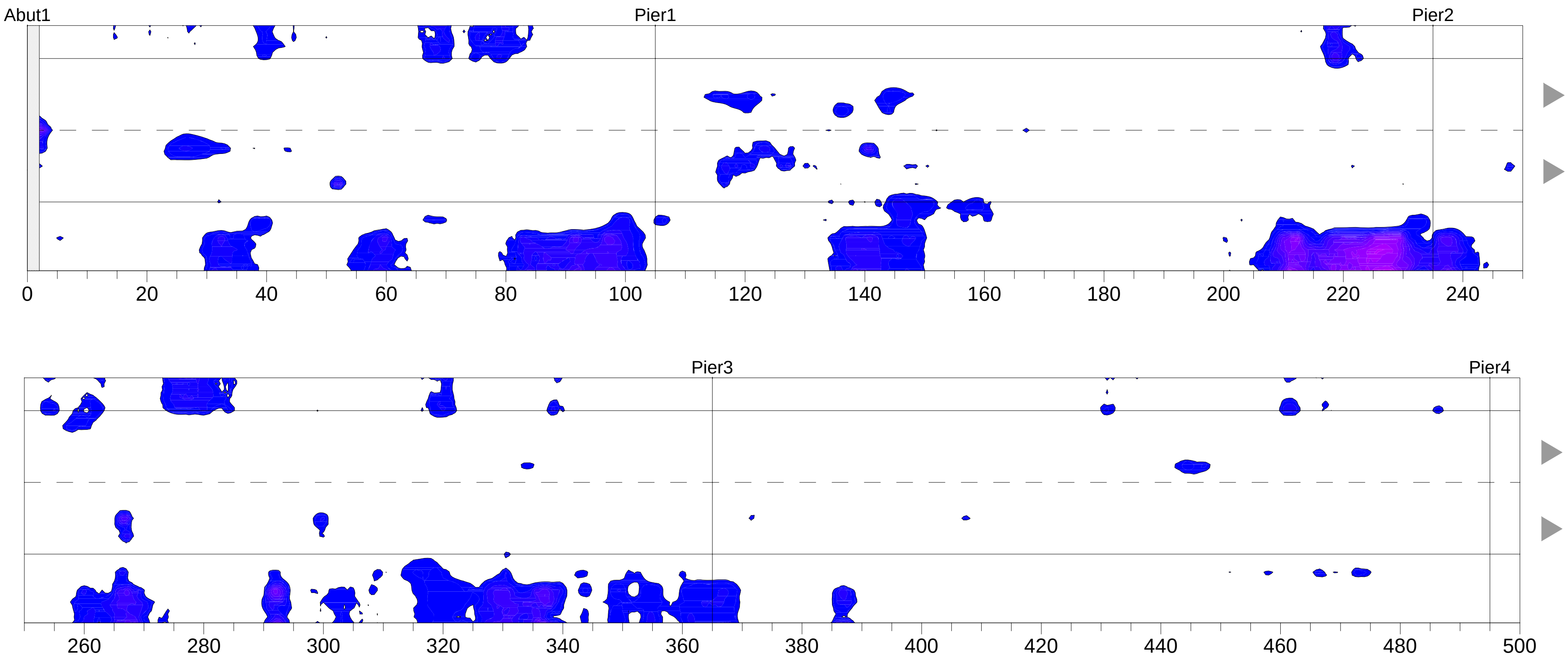

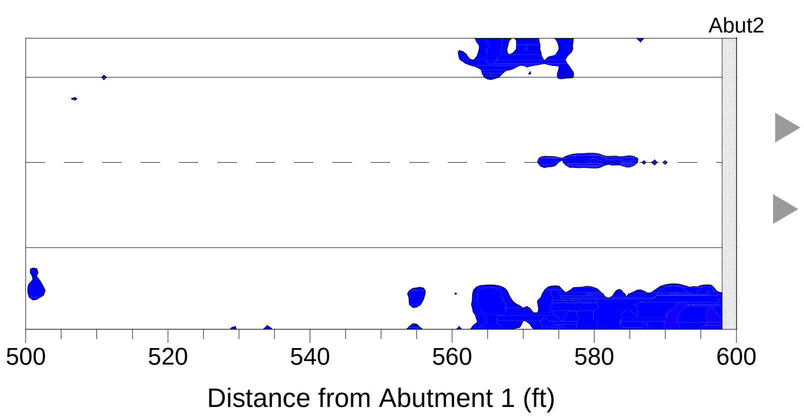

Direction of traffic

Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Bridge Deck Condition Evaluation using GPR

ME Bridge # 6281 NB

I 295 / FORE RIVER

analyzed by: LM date: 10/20/09

checked by: BCM date: 10/30/09

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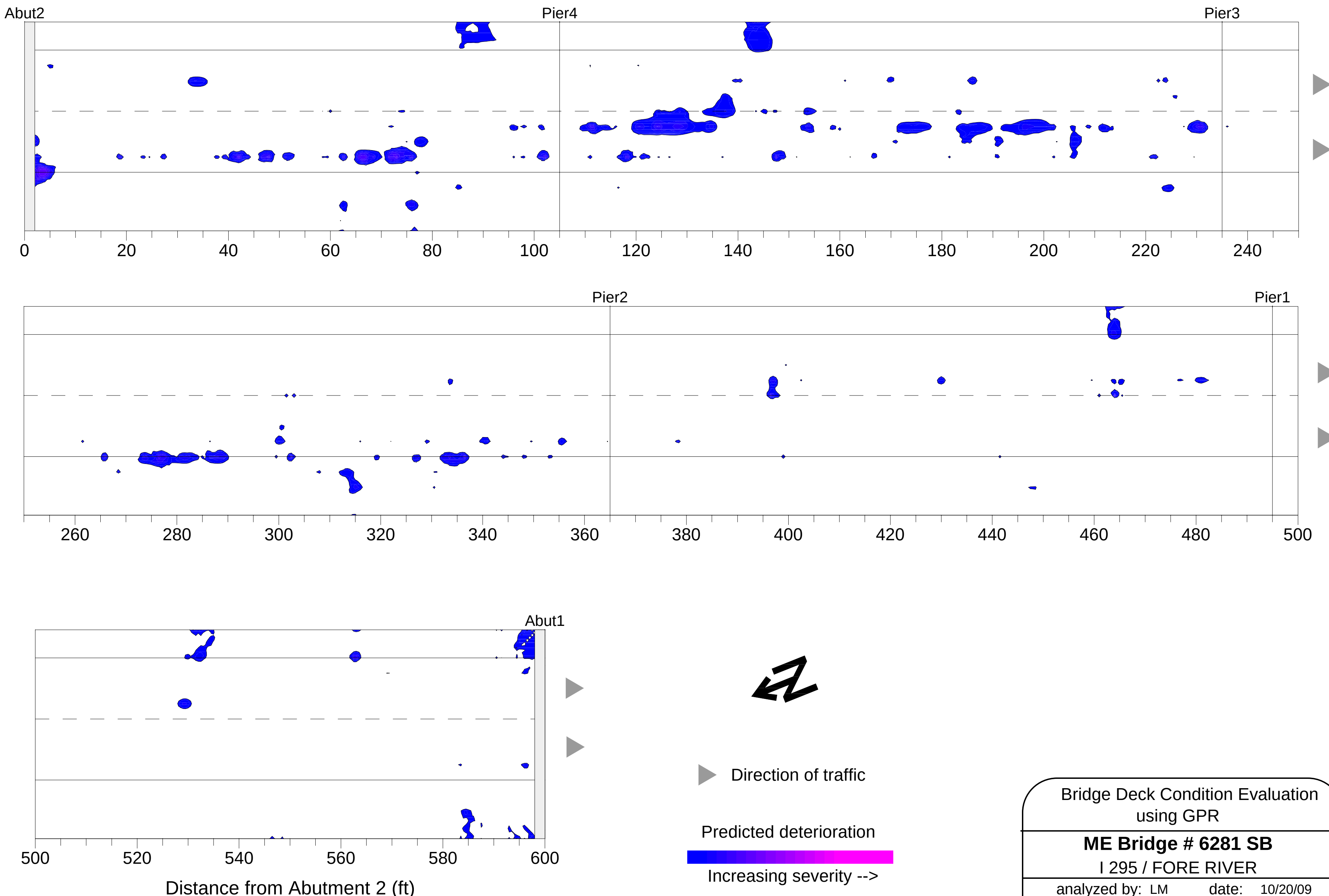
sheet 1 of 1



Direction of traffic

Predicted deterioration

Increasing severity -->

Conditions not detectable with GPR

Bridge Deck Condition Evaluation using GPR

ME Bridge # 6281 SB

I 295 / FORE RIVER

analyzed by: LM date: 10/20/09

checked by: BCM date: 10/30/09

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sheet 1 of 1