EVALUATION OF

IMS - SWEDISH LASER ROAD TESTER

Final Report

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Report FHWA-88-072-008, "Evaluation of the Laser Road Surface Tester for Measuring Pavement Roughness and Rut Depth," may be consulted for a thorough discussion of equipment functioning and measuring provisions.

16. Abstract

A test of the IMS - Swedish Laser road tester was conducted in September 1988. The vehicle mounted laser equipment was used to survey pavement conditions on sections of Oregon's Interstate and non-interstate highway system.

The IMS laser equipment performed in the manner expected, but deficiencies were noted in groundpoint/mile marker location recording and in travel lane positioning.

The IMS equipment is able to gather large amounts of roadway data simultaneously. The lack of present need for much of the data, however, does not make this method of data gathering cost effective for use on Oregon's highway system.

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INTRODUCTION

Vehicle mounted electronic data gathering equipment offers the possibility of rapid "objective" multi-element roadway condition data gathering.

This document reports on a test of an IMS - Swedish Laser Road Tester. This test was conducted during September 1988 to gather specific surface condition information. Other data gathering techniques were used to check the accuracy of the data collected by the IMS equipment.

Results indicate that the IMS equipment, in the form used, is not cost effective. Improvements in equipment and technique may well make such equipment cost effective for future data gathering.

Evaluation of IMS Swedish Laser Road Tester

Final Report - September 1990

BACKGROUND

The Swedish Laser Road Tester marketed in the U.S. by Infrastructure Management Systems (IMS) is one of several machines available to gather large amounts of roadway data simultaneously. These machines use a number of different technologies, notably: lasers, video, and ultrasonics.

In Early 1988, IMS made a presentation to the Pavement Management Steering Committee. As a result of that presentation, an offer was made to the Highway Division to survey 1,000 miles of highway for $25 per mile. The Research Unit of Materials and Research Section and the Pavement Management Unit of the Planning Section decided to accept the IMS offer for the following reasons:

1. The Research Unit needed to calibrate it´s Mays ride trailer to the International Roughness Index (IRI). This was required by FHWA in its latest requirements for HPMS reporting. This work was budgeted for FY 1989 on the basis of rod-and-level surveys of selected sites. The estimated cost of the field work was about $20,000.

2. The Proposed Pavement Management Policy of FHWA, since modified, included some requirements for large-scale ´objective´ data gathering.

3. Oregon had no first-hand experience with any of these multi-element data gathering systems. It was felt that, until we had some experience with these systems, it would be hard to write requirements for this type of service in the future.

4. Oregon would be better able to evaluate any future requirements for this type of data gathering, should it be either mandated or recommended by FHWA.

5. There was a need to evaluate the value of the various data elements being collected to determine if this type of collection was cost efficient.

For these reasons, Oregon entered into a $25,000 contract with IMS to survey selected sections of various highways.

THE SURVEY

The survey was done in September of 1988 over a 7 day period. The following is a summary of the survey period:

Equipment

The equipment was a Ford Van with the necessary electronics and laser bar installed. Mechanically, the van was in relatively poor shape and later required immediate repair. This repair delayed the survey by a day and a half.

Personnel

The crew of three people were not as experienced as was expected. This may, or may not, have had an effect on the conduct of the survey.

Operations

The advance operations manager for IMS met with personnel from Research, Pavement Management, and Surfacing Design Units to coordinate the survey parameters. These parameters included:

1. Horizontal control and distance measurement.
2. Classification of cracking by sizes.
3. Surface profile classification by wavelength.
4. Surface texture classification.
5. Switch setting criteria for visual data.

Problems

As the survey progressed, several problems were identified:

1. The driver, while maintaining proper placement within the travel lane, was also required to evaluate the pavement conditions and operate the auxiliary switches. This may have had an effect on the data represented by the switch settings.
2. Pavement Management personnel observed the machine in operation and reported that the horizontal placement within the travel lane was definitely erratic, especially on the narrower roadway sections. This may have been because of driver inexperience, or of asking him to do too much. This concern was passed along to the crew.

3. Mechanical failure delayed the whole survey by a day and a half.

SURVEY RESULTS

The results of the survey were delivered in mid November on floppy disks in both 'text' and 'archive' formats. The archive format was necessary because of the size of some of the files. Research Unit has analyzed the data and has been able to characterize a number of data elements.

Horizontal Control

The horizontal control system measures in meters from a beginning point. While the overall accuracy was relatively good, less than 1% error, the ability to match checkpoints was poor.

Because the distance counters were reset at each check point and the summary points measured from that checkpoint, the duplication of any individual section was difficult.

One problem was that there was no provision to insert check points in the running mileage without resetting the counters to zero. This made the handling of mile point equations extremely difficult.

This inability to exactly locate individual sections in the field hampered the overall effort to verify the data and calibrate the results.

The conclusion is, that in the future, any data system using the Highway Division's mileage control must be able to update the mileage counters on a random access basis. Alternatively, it must be possible to overlay mileage checkpoints in a form that is a permanent part of the data. The system must also be able to summarize on any selected criteria, without respect to where the survey starts.

Rutting

Field checks of the rutting figures were performed. The results indicate that the rut measurement was reasonably accurate, given the difficulty of locating given points with reasonable precision.

When the problem of lateral lane placement was discussed, Mr. Novak of IMS could not tell us how the rut calculation system would react. Field measurements did not yield any clues to how the system would react.

The conclusion is that any future automated rut measuring system should be tolerant of variation in lateral placement and account for such in the calculation of average rut depth.

Ride

We were not able to verify ride data by field measurements, primarily because of winter weather. The IMS machine is recognized to be a standard for IRI measurements.

The Mays trailer duplicated most of the route of the IMS machine. The data obtained with the Mays trailer was compared with the IMS results for correlation and errors. The SHRP K. J. Law Profilometer was also used over some of the same areas.

The only problem with the ride portion of the data is the difficulty of verifying ground-point location.

Cracking

We were unable to evaluate this element because of the difficulty of identifying exact ground location and because of expected variations resulting from the 1988 - 89 winter weather season.

Other Data

The data from the switch settings was verified as much as possible.

There was little or no correlation between surface texture measurements and measured friction. While there have been significant efforts, by a number of researchers, to establish this relationship, the results are not encouraging.

OBSERVATIONS

1. The IMS system, as configured for the Oregon test run, had a number of significant shortcomings. Specifically, horizontal mileage control and a high dependency on the operator´s skill levels. These problems have been corrected, according to IMS.

2. The informal quote of $250,000 to do a one-time survey of all Oregon Highways is probably more than can be justified by the possible results.

3. If the IMS system is representative of the present state of development for this type of equipment, it may be prudent to await further developments on this area. Generally, we can expect both greater accuracy, versatility, and reliability, as well as lower costs in the future.

CONCLUSION

The IMS machine, with the above noted exceptions, was able to perform as advertised and provided relatively accurate data. If the problems noted above have been corrected, it should be able to meet the needs of future pavement management systems.

The cost of gathering this much data must be justified by the need for each data element. Presently, systems simpler than IMS can provide the needed data for Oregon's system at a much lower cost.

Expansion of pavement management technology will probably allow us to use more and more of the data elements gathered by IMS or similar machines. When the need for data justifies the cost of gathering the data, Oregon should consider the IMS, or similar, machines for pavement data gathering.

IMS Swedish Laser Road Tester
Final Report - September 1990

APPENDICES

A. IMS data gathering proposal

B. Outline of data elements to be gathered

C. Map of IMS test route

D. Narrative of field gathering on control sections

E. Control section data summaries

F. IMS computer file descriptions

G. Printout of Inventry file for Highway 30

H. Printout of Object file for Highway 30

I. IMS test interim report comments

PROPOSAL

FOR

OREGON DEPARTMENT OF TRANSPORTATION

(01-8195A00)

MAY 12, 1988

We are pleased to submit the following proposal for a surface condition survey on 1,000 lane miles of your highway system.

For the Oregon Department of Transportation, we propose to undertake a surface condition survey which would include the following:

1. <u>Surface Condition Survey:</u> This survey will be conducted using the Laser Road Surface Tester. Using this equipment, the Oregon Department of Transportation will receive a continuous, objective, and accurate survey of the surface condition of the Interstate system. The information to be gathered in this survey includes roughness (with both quarter-car and MO values), rut depth, cracking, and macrotexture. The survey will be carried out on a tenth of a mile basis. All the information will be recorded in the tenth of a mile segments. Mean values will be provided for one mile or other lengths as desired.

2. <u>Data Transfer:</u> All the data collected in the surface condition survey will be placed on disks. Information will be loaded onto an Oregon Department of Transportation IBM PC, IBM XT, IBM AT, or compatible microcomputer. We will furnish the necessary software for the transfer of the data and will supply editing programs to ensure that the data transferred is accurate and that the location data will properly interface with the other collected data.

3. <u>Timing:</u> The surface condition survey using the Laser RST will require approximately 10 days. Within 15 days of the completion of the tests, all the data will be transferred to the Oregon Department of Transportation's microcomputer.

APPENDIX B

DATA ELEMENTS TO BE GATHERED

On Tuesday Sept. 6, the previously mentioned people with the addition of Msrs. Sorensen and Carter of FHWA along with the IMS operations crew and a representative from Mileage Control Unit of Planning Section met in the Materials Lab conference room to finalize the data to be gathered.

The elements and parameters were as follows:

ELEMENT	Parameters	COMMENT
RUTTING	> 1/2" (12mm.) > 3/4" (18mm.)	Average by reported section. Less than 1/2" to be calculated.
CRACKING	1/16" - 1/8" (1.5mm - 3.0mm) 1/8" - 1/4" (3.0mm - 6.0mm) 1/4" - 1/2" (6.0mm - 12.0mm) 1/2" - 2" (12.0mm - 50.0mm)	Densities on cracking are also reported by section.
PROFILE	IRI index 15 Meter Wavelength 45 Meter Wavelength	Quarter car simulation.
MICROTEXTURE	Machine standard wave lengths.	
DRAINAGE	* C & G w/Storm Sewers * > 3' Ditch * > 3' Ditch	Switch Selected Switch Selected Switch Selected
SHOULDER TYPE	* C & G or > 8' Paved * 2' - 8' Paved * < 2' Paved	Switch Selected Switch Selected Switch Selected
FLUSHING	* None * Wheel Tracks Only * Entire Lane	Switch Selected Switch Selected Switch Selected
ALLIGATOR CRACKING	* None * Small Patches (<33%) * > 33% Cracked	Switch Selected Switch Selected Switch Selected

DATA ELEMENTS TO BE GATHERED Cont.

ELEMENT	Parameters	COMMENTS
EDGE CRACKS	* None or Single < 1/4"	Switch Selected
	* Multiple >2' or < 3' from edge of Pvmnt.	Switch Selected
	* Multiple > 3' from EP or Alligatored.	Switch Selected
LONGITUDINAL CRACKING	* None in or near Wheel tracks.	Switch Selected
	* On edge of Wheel track	Switch Selected
	* Within Wheel track	Switch Selected
TRANSVERSE CRACKING	* None	Switch Selected
	* Intermittent	Switch Selected
	* Uniform	Switch Selected
PATCHING	* None	Switch Selected
	* Occasional	Switch Selected
	* Frequent	Switch Selected

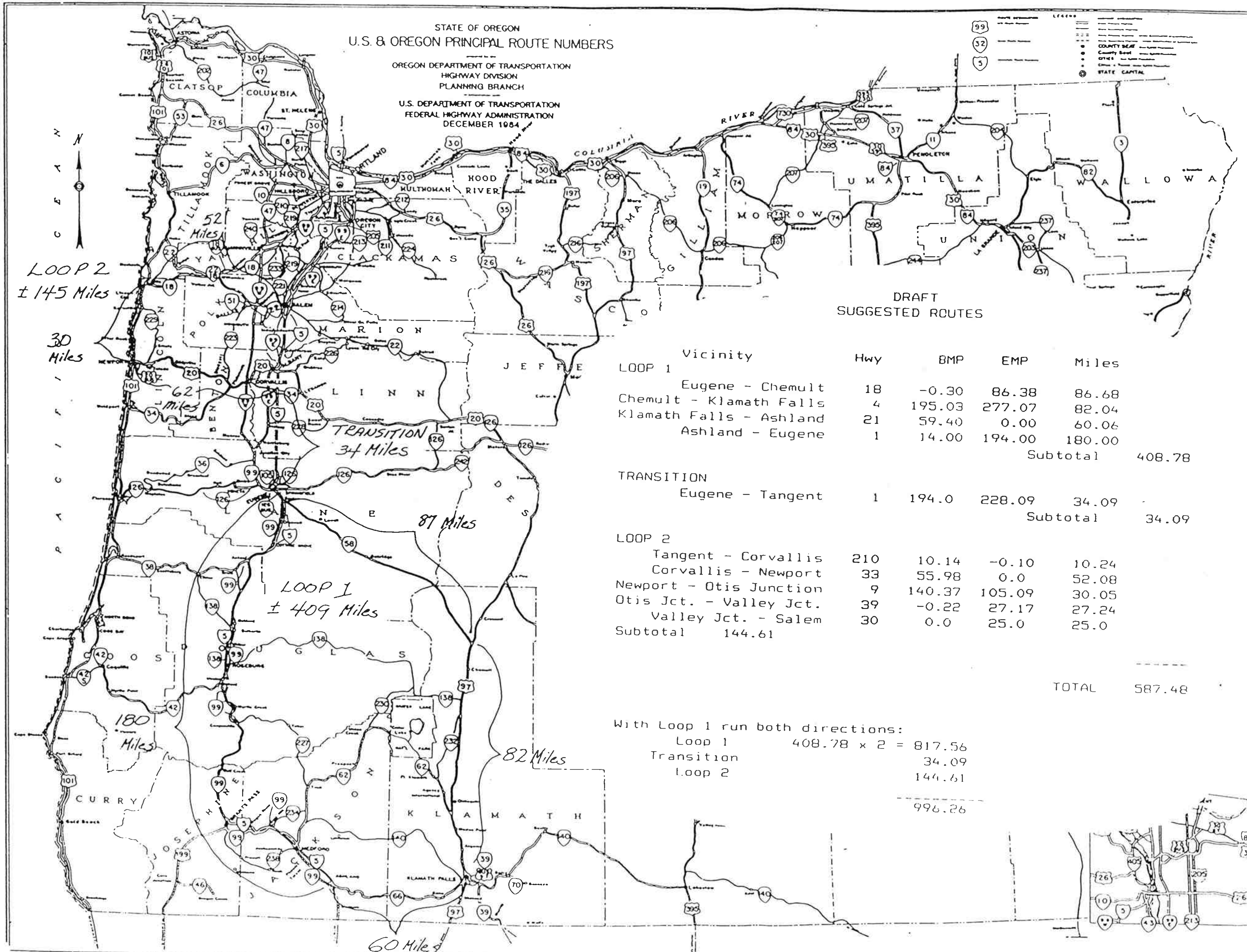
The Switch Selected items will be reported as percent of reported section having that attribute.

REPORTING and DATA FORMAT

The data will be summarized by 0.1 miles with a complete summary by 1 mile sections.

The data will be delivered to Research Unit on # 1/2" IBM-compatible floppy disks in an ASCII, delimited, flat format.

APPENDIX C



DRAFT
SUGGESTED ROUTES

Vicinity	Hwy	BMP	EMP	Miles	
LOOP 1					
Eugene - Chemult	18	-0.30	86.38	86.68	
Chemult - Klamath Falls	4	195.03	277.07	82.04	
Klamath Falls - Ashland	21	59.40	0.00	60.06	
Ashland - Eugene	1	14.00	194.00	180.00	
				Subtotal	408.78
TRANSITION					
Eugene - Tangent	1	194.0	228.09	34.09	
				Subtotal	34.09
LOOP 2					
Tangent - Corvallis	210	10.14	-0.10	10.24	
Corvallis - Newport	33	55.98	0.0	52.08	
Newport - Otis Junction	9	140.37	105.09	30.05	
Otis Jct. - Valley Jct.	39	-0.22	27.17	27.24	
Valley Jct. - Salem	30	0.0	25.0	25.0	
Subtotal 144.61					
				TOTAL	587.48

With Loop 1 run both directions:

Loop 1	408.78 x 2 = 817.56
Transition	34.09
Loop 2	144.61
	996.26

EVALUATION NARRATIVE
IMS LASER ROAD SURFACE TESTING
PAVEMENT MANAGEMENT UNIT

Willamina - Salem Highway
OSHD Highway Number: 30
Posted Route Number: 22
Beginning Milepost: 19.43
Ending Milepost: 18.43

All measurements refer to the right lane westbound. There was light flushing over most of the length of the right lane wheelpaths. There were occasional spots of light ravelling where there was no flushing. Most cracks were filled. The shoulder was clean and quite free of loose gravel.

The section started at a bicycle trail undercrossing and continued to the centerline of the Basket Slough bridge. Only the first mile of the section is reported here. This is one of the IMS control sections.

The pavement condition of this section was 3 in the fall 1988 report.

Kings Valley Highway
OSHD Highway Number: 191
Posted Route Number: 223
Beginning Milepost: 0.97
Ending Milepost: 0.07

All data refer to the northbound lane. The road had been chip sealed between milepoint 0.97 and milepoint 0.94. The chip seal was in place before IMS evaluated the road using the laser road testing equipment.

There were occasional patches of combined longitudinal and transverse cracking. These might be considered too widely spaced to be called alligator cracking but were too close together and too limited in area to be considered independent groups of cracks. There were occasional patches of heavy bleeding.

This was a control section for the IMS testing. The section began at the centerline of Oak Villa Road and ended at the centerline of Oregon Route 22. Only the first .9 miles are reported. We deemed it unsafe to try to gather information in the intersection of two state highways at the crest of a hill.

The pavement condition of this section was 3 in the fall 1988 report.

Corvallis - Newport Highway
OSHD Highway Number: 33
Posted Route Number: 20
Beginning Milepost: 51.31
Ending Milepost: 52.11

All data refer to the Eastbound lane.

This section had been blade patched for nearly the entire section. The blade patching was in place when IMS tested the section.

The shoulders were badly alligatored in several spots. The alligatoring was most prominent in the gore area between the main route and the weigh station alongside this section. Most cracking in the travelled way appeared to be reflective cracking. Most segments of the shoulder were covered with loose gravel.

The section began at Newton Creek Culvert in the town of Philomath. There is a log yard beside this section, with heavy log truck traffic in and out of the yard.

Data was gathered only for the first 0.8 miles of this section. A maintenance crew destroyed all evidence of alligatoring and cracks by patching at the end of the section after we started gathering the data at the beginning of the section.

The pavement condition of this section was 4 in the fall 1988 report.

Oregon Coast Highway
OSHD Highway Number: 9
Posted Route Number: US 101
Beginning Milepost: 137.86
Ending Milepost: 138.86

All data refer to the southbound lane. This section began at the Lucky Gap Creek culvert and ended 1.0 miles later at the driveway to the Newport.Hotel.

The only crack on this section was 29 inches long. There were occasional very small patches of stripping. The only other blemishes in the pavement looked as though they were imperfections made by construction equipment while the AC was still soft.

There was very little loose gravel on the shoulder, although the storm sewer was full of gravel.

The pavement condition of this section was 2 in the fall 1988 report.

4/17/89
P. Spring

APPENDIX E

Evaluation Summary
IMS Laser Road Surface Testing
Pavement Management Unit

Willamina - Salem Highway
OSHD Highway Number: 30
Posted Route Number: 22
Beginning Milepost: 19.43
Ending Milepost: 18.43

Switch Settings

Switch Number	1	2	3	4	5	6	7	8
Switch Designation M.P.	Drainage	Shoulder Type	Flushing	Alligator Cracking	Edge Cracking	Longitudinal Cracking	Transverse Cracking	Patching
19.43	1	1	1	1	1	1	3	1
19.33	3	1	1	1	1	1	3	1
19.23	3	1	1	1	1	2	3	1
19.13	3	1	2	1	1	2	2	1
19.03	2	1	2	1	1	2	2	1
18.93	2	2	2	1	1	2	2	1
18.83	3	1	1	1	1	2	2	1
18.73	3	1	1	1	1	2	3	1
18.63	3	1	1	1	1	2	3	1
18.53	2	1	1	1	1	2	3	1
18.43	3	1	1	1	1	2	2	1

Rut and Crack Measurements

				Crack Sizes (mm)			
M.P.	Left Rut Depth (mm)	Right Rut Depth (mm)	Average Rut Depth (mm)	<3	3 - 6	6 - 12	12 - 50
19.43	9	8	8				X
19.33	15	6	11				X
19.23	12	12	12				X
19.13	12	6	9			X	X
19.03	11	6	8		X	X	
18.93	9	9	9		X	X	
18.83	14	8	9		X	X	
18.73	9	5	7		X	X	
18.63	15	11	13		X	X	
18.53	12	11	11		X	X	
18.43	14	9	11		X	X	

4/18/89
P. Spring

Evaluation Summary
IMS Laser Road Surface Testing
Pavement Management Unit

Kings Valley Highway
OSHD Highway Number: 191
Posted Route Number: 223
Beginning Milepost: 0.97
Ending Milepost: 0.07

Switch Settings

Switch Number	1	2	3	4	5	6	7	8
Switch Designation M.P. \ Setting	Drainage	Shoulder Type	Flushing	Alligator Cracking	Edge Cracking	Longitudinal Cracking	Transverse Cracking	Patching
0.97	3	2	2	3	1	1	1	3
0.94	3	2	1	2	1	3	2	1
0.87	3	2	1	2	1	3	2	1
0.77	3	2	1	2	1	3	2	1
0.67	2	2	1	1	1	3	2	1
0.57	3	2	2	1	1	3	2	1
0.47	3	2	1	1	1	3	2	1
0.37	3	2	1	1	1	3	2	1
0.27	3	2	1	2	1	3	2	1
0.17	3	2	1	2	1	3	2	1
0.07	3	2	1	1	1	3	2	1

Rut and Crack Measurements

M.P.	Left Rut Depth (mm)	Right Rut Depth (mm)	Average Rut Depth (mm)	Crack Sizes (mm) <3	3 - 6	6 - 12	12 - 50
0.97	5	5	5				
0.94	6	6	6		X		
0.87	5	3	4		X		
0.77	3	5	4		X		
0.67	3	3	3		X		
0.57	3	3	3		X		
0.47	5	3	4				
0.37	3	3	3		X		
0.27	3	2	2		X		
0.17	5	5	5		X		
0.07	3	3	3		X		

4/18/89
P. Spring

Evaluation Summary
IMS Laser Road Surface Testing
Pavement Management Unit

Corvallis - Newport highway
OSHD Highway Number: 33
Posted Route Number: 20
Beginning Milepost: 51.31
Ending Milepost: 52.31

Switch Settings

Switch Number	1	2	3	4	5	6	7	8
Switch Designation MP \ Setting	Drainage	Shoulder Type	Flushing	Alligator Cracking	Edge Cracking	Longitudinal Cracking	Transverse Cracking	Patching
51.31	3	2	1	2	1	1	1	3
51.41	3	2	1	2	2	3	2	3
51.51	3	2	1	2	2	3	2	3
51.61	N/A	1	1	2	3	3	2	3
51.71	3	2	1	1	1	1	1	3
51.81	3	2	1	2	2	2	2	3
51.91	3	2	1	2	2	3	1	3
52.01	3	2	1	2	2	2	1	3
52.11	2	2	1	2	1	3	1	3
52.21	Not Available for Inspection.							
52.31	Under Repair by OSHD Maintenance Crews.							

Rut and Crack Measurements

MP	Left Rut Depth (mm)	Right Rut Depth (mm)	Average Rut Depth (mm)	Crack Sizes (mm) <3	3 - 6	6 - 12	12 - 50
51.31	6	6	6			X	
51.41	6	6	6			X	
51.51	9	11	10			X	
51.61	0	2	1			X	
51.71	6	0	3				
51.81	3	2	2			X	
51.91	5	3	4				
52.01	6	6	6			X	
52.11	3	9	6			X	
52.21	N/A	N/A	N/A				
52.31	N/A	N/A	N/A				

4/18/89
P. Spring

Evaluation Summary
IMS Laser Road Surface Testing
Pavement Management Unit

Oregon Coast Highway
OSHD Highway Number. 9
Posted Route Number: US 101
Beginning Milepost: 137.87
Ending Milepost: 138.87

Switch Settings

Switch Number	1	2	3	4	5	6	7	8
Switch Designation M P \ Setting	Drainage	Shoulder Type	Flushing	Alligator Cracking	Edge Cracking	Longitudinal Cracking	Transverse Cracking	Patching
137.86	2	2	1	1	1	1	1	3
137.96	2	2	1	1	1	1	1	1
138.06	2	2	1	1	1	1	1	1
138.16	2	2	1	1	1	1	1	1
138.26	2	2	1	1	1	1	1	1
138.36	2	2	1	1	1	1	1	1
138.46	1	1	1	1	1	1	1	1
138.56	1	1	1	1	1	1	1	1
138.66	2	2	1	1	1	1	1	1
138.76	1	1	1	1	1	1	1	1
138.86	1	1	1	1	1	3	1	1

Rut and Crack Measurements

				Crack Sizes (mm)			
M P	Left Rut Depth (mm)	Right Rut Depth (mm)	Average Rut Depth (mm)	<3	3 - 6	6 - 12	12 - 50
137.86	5	2	3				
137.96	5	3	4				
138.06	5	5	5				
138.16	3	5	4				
138.26	2	0	1				
138.36	6	3	5				
138.46	5	0	2				
138.56	6	3	5				
138.66	3	3	3				
138.76	6	2	4				
138.86	5	2	3			x	

4/18/89
P. Spring

APPENDIX F

The Data collected using the Road Surface Tester (RST) appears in several files. The files appear on 7 disks. The data on the disks is as follows:

Inventory FIles. The inventory files appear on 1 disk. The inventory data is a listing of sections that were tested. Each section is given an rst number denoted at RSTNUM. This rst number is used to relate the object, and mean data to the physical section. The section information includes the name of the route tested (using the State Numbering Code rather than the Actual route number). The inventory also includes the starting and ending landmarks, and other information including surface type, and direction of travel during the test. A discription of the fields in the inventory files appears in a file named inventry.doc.

Object Files. The object files appear on 2 disks. The data contained in these files is marked in one mile sections. Each section has a distinct RST NUMBER (RSTNUM) which will tie the data to the inventory. A definition of the fields appears in a file named object.doc.

Mean Files. The mean files appear on 4 disks. The data contained in these files is marked in one tenth of a mile sections. Therefore there are as many as ten mean records with the same rst number. To distinguish between the sections it is necessary to look at the field marked start. This field marks how many meters have passed from the beginning of the section. A discription of the fields appears in a file named MEAN.DOC on this disk.

File Naming Convention: Files are named in the following mannor YXXX.ZZZ

Where Y has 1 of 3 meanings. it can be either

- I - Inventory
- O - Object
- M - Mean

XXX is the route number. It can be any of the routes tested.

- 001 - Route 1
- 004 - Route 4
- 009 - Route 9
- 018 - Route 18
- 021 - Route 21
- 030 - Route 30
- 033 - Route 33
- 039 - Route 39
- 210 - Route 210

ZZZ is the file type. There are two files types that you will find on the disks. Data files with an extention DAT, and archive with an extention of ARC. The data files need no further processing, however the archive files do need some processing.

*** NOTE ***

There should be 3 files for each route number:

IXXX.ZZZ, OXXX.ZZZ, AND MXXX.ZZZ.

Due to the extreme size of the mean files it was necessary to process the files with an archiving utility which reduced the amount of space required to store the data. The data was archived using a public domain program named ARC.EXE. In order to retrieve the data from the archive follow the instructions.

1) Copy the ARC.EXE program to the hard disk
2) copy the archive file to the hard disk.
3) At the DOS prompt type: ARC E MXXX MXXX.DAT
4) Repeate steps 2 and 3 until all of the files have been extracted, replacing the XXX with the number in the archived files file name.

NOTE

In order to extract the file you will need approximatly 4 to 5 times more space than the size of the file. For example if a file requirês 100 K-Bytes of disk space, in order to extract the file from the archive you will need a mimimum of 500 K-Bytes of free disk space.

The archive files are named in the following manor.

MXXX.ARC -> MXXX.DAT

Where the file contained in the archive is identical to the name of the archive.

WARNING

All of the files together will take up approximatly 4.0 MegaBytes of disk space.

WARNING

do not try to use data in the archived format, or the integrity of the data may be destroyed.

Definition of INVENTORY File

Files named IXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
STREET	C	15	0	Name of Route tested
FROM	C	15	0	Starting Landmark
TO	C	15	0	Ending Landmark
ROUTE	C	3	0	State Highway Code
RSTNUM	N	4	0	Section Number
DIR	C	1	0	Direction of travel during test
LANE	N	2	0	Lane tested (1 = leftmost)
CLASS	C	3	0	Traffic Classification -- (HWY - HIGHWAY
SURFACE	C	2	0	Surface Type (AC - Asphalt, PC - Concrete)

Definition of OBJECT File
(1 Mile Sections)
Files named OXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
RSTNUM	N	5	0	Section Number
START	N	5	0	Starting Position (Usually 0 for all objects)
LEN1	N	5	0	Length of section in meters
LEN2	N	5	0	Actual length of test (Machine Can be turned off for part)
SPEED	N	4	0	Speed in Km per Hour
IRI	N	6	2	Quarter Car
MO	N	6	2	Mays Equivalent
RMS1	N	6	2	RMS value of wavelengths from 0 - 15 meters
RMS2	N	6	2	RMS value of wavelengths from 0 - 45 meters
RUT	N	6	2	Average rut depth
RUTG10	N	3	0	Percent of rut depth > 12mm
RUTG20	N	3	0	Percent of rut depth > 18mm
BUTT1	N	3	0	NOT USED
BUTT2	N	3	0	NOT USED
BUTT3	N	3	0	NOT USED
BUTT4	N	3	0	NOT USED
BUTT5	N	3	0	NOT USED
BUT1	N	3	0	NOT USED
BUT2	N	3	0	NOT USED
BUT3	N	3	0	NOT USED
SW1	N	1	0	As described in the preimplimentation meeting
SW2	N	1	0	As described in the preimplimentation meeting
SW3	N	1	0	As described in the preimplimentation meeting
SW4	N	1	0	As described in the preimplimentation meeting
SW5	N	1	0	As described in the preimplimentation meeting
SW6	N	1	0	As described in the preimplimentation meeting
SW7	N	1	0	As described in the preimplimentation meeting
SW8	N	1	0	As described in the preimplimentation meeting
MTP1	N	5	1	Mean of transverse profile: (mm)
MTP2	N	5	1	Cameras 1 and 11 are 0
MTP3	N	5	1	markers. All of the other
MTP4	N	5	1	cameras are measured from
MTP5	N	5	1	this 0. Thus the mean of
MTP6	N	5	1	the camera data over the
MTP7	N	5	1	entire length of the
MTP8	N	5	1	section.
MTP9	N	5	1	
DTP1	N	5	1	Deviation of the transverse profile: (mm)
DTP2	N	5	1	This is the same as the mean
DTP3	N	5	1	except that the data
DTP4	N	5	1	reported is the standard
DTP5	N	5	1	deviation of each camera
DTP6	N	5	1	over the entire length of
DTP7	N	5	1	the section.
DTP8	N	5	1	
DTP9	N	5	1	

Definition of OBJECT File
(1 Mile Sections)
Files named OXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
MRMS1	N	5	2	Megatexture mean RMS for the left texture camera
RRMS1	N	5	2	Rough macrotexture mean RMS for the left texture camera
FRMS1	N	5	2	Fine macrotexture mean RMS for the left texture camera
R11	N	4	0	Inside Wheel path rough macrotexture % 0.15mm - 0.30mm
R12	N	4	0	% 0.30mm - 0.40mm
R13	N	4	0	% 0.40mm - 0.60mm
R14	N	4	0	% 0.60mm - 0.90mm
R15	N	4	0	% 0.90mm - 1.30mm
R16	N	4	0	% 1.30mm - 2.00mm
R17	N	4	0	% 2.00mm - 3.00mm
R18	N	4	0	% 3.00mm - 5.00mm
F11	N	4	0	Inside Wheel Path fine macrotexture % 0.15mm - 0.30mm
F12	N	4	0	% 0.30mm - 0.40mm
F13	N	4	0	% 0.40mm - 0.60mm
F14	N	4	0	% 0.60mm - 0.90mm
F15	N	4	0	% 0.90mm - 1.30mm
F16	N	4	0	% 1.30mm - 2.00mm
F17	N	4	0	% 2.00mm - 3.00mm
F18	N	4	0	% 3.00mm - 5.00mm
MRMS4	N	5	2	Megatexture mean RMS for the right texture camera
RRMS4	N	5	2	Rough macrotexture mean RMS for the right texture camera
FRMS4	N	5	2	Fine macrotexture mean RMS for the right texture camera
R41	N	4	0	Outside wheel path rough macrotexture % 0.15mm - 0.30mm
R42	N	4	0	% 0.30mm - 0.40mm
R43	N	4	0	% 0.40mm - 0.60mm
R44	N	4	0	% 0.60mm - 0.90mm
R45	N	4	0	% 0.90mm - 1.30mm
R46	N	4	0	% 1.30mm - 2.00mm
R47	N	4	0	% 2.00mm - 3.00mm
R48	N	4	0	% 3.00mm - 5.00mm
F41	N	4	0	Outside wheel path fine macrotexture % 0.15mm - 0.30mm
F42	N	4	0	% 0.30mm - 0.40mm
F43	N	4	0	% 0.40mm - 0.60mm
F44	N	4	0	% 0.60mm - 0.90mm
F45	N	4	0	% 0.90mm - 1.30mm
F46	N	4	0	% 1.30mm - 2.00mm
F47	N	4	0	% 2.00mm - 3.00mm
F48	N	4	0	% 3.00mm - 5.00mm
CRACK11	N	4	0	Camera 1 crack < 3.0mm deep, 1.5mm - 3.0mm wide
CRACK12	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK13	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK14	N	4	0	3.0mm deep, 12.0-50.0mm wide
CRACK15	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK16	N	4	0	6.0mm deep, 6.0-12.0mm wide
CRACK21	N	4	0	Camera 2 crack < 3.0mm deep, 1.5mm - 3.0mm wide
CRACK22	N	4	0	3.0mm deep, 3.0mm-6.0mm wide

Definition of OBJECT File
(1 Mile Sections)
Files named OXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
CRACK23	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK24	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK25	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK26	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
BOTH12	N	5	0	Crack in camera 1 and 2 within 4 inches
CRKDENS11	N	8	2	Density camera 1 (% Length with > 2 SHALLOW CRACKS/.5 meter)
CRKDENS12	N	8	2	Density camera 1 (% Length with > 2 DEEP CRACKS/.5 meter)
CRACK31	N	4	0	Camera 3 crack 3.0mm deep, 1.5mm-3.0mm wide
CRACK32	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK33	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK34	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK35	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK36	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
CRACK41	N	4	0	Camera 4 crack 3.0mm deep, 1.5mm-3.0mm wide
CRACK42	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK43	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK44	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK45	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK46	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
BOTH34	N	5	0	Crack in camera 3 and 4 within 4 inches
CRKDENS41	N	8	2	Density camera 4 (% Length with > 2 SHALOW CRACKS/.5 meter)
CRKDENS42	N	8	2	Density camera 4 (% Length with > 2 DEEP CRACKS/.5 meter)

Definition of MEAN File
(0.1 Mile Sections)
Files named MXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
RSTNUM	N	5	0	Section Number
START	N	5	0	Starting Position (Usually 0 for all objects)
LEN1	N	5	0	Length of section in meters
LEN2	N	5	0	Actual length of test (Machine Can be turned off for part)
SPEED	N	4	0	Speed in Km per Hour
IRI	N	6	2	Quarter Car
MO	N	6	2	Mays Equivalent
RMS1	N	6	2	RMS value of wavelengths from 0 - 15 meters
RMS2	N	6	2	RMS value of wavelengths from 0 - 45 meters
RUT	N	6	2	Average rut depth
RUTG10	N	3	0	Percent of rut depth > 12mm
RUTG20	N	3	0	Percent of rut depth > 18mm
BUTT1	N	3	0	NOT USED
BUTT2	N	3	0	NOT USED
BUTT3	N	3	0	NOT USED
BUTT4	N	3	0	NOT USED
BUTT5	N	3	0	NOT USED
BUT1	N	3	0	NOT USED
BUT2	N	3	0	NOT USED
BUT3	N	3	0	NOT USED
SW1	N	1	0	As described in the preimplimentation meeting
SW2	N	1	0	As described in the preimplimentation meeting
SW3	N	1	0	As described in the preimplimentation meeting
SW4	N	1	0	As described in the preimplimentation meeting
SW5	N	1	0	As described in the preimplimentation meeting
SW6	N	1	0	As described in the preimplimentation meeting
SW7	N	1	0	As described in the preimplimentation meeting
SW8	N	1	0	As described in the proimplimentation meeting
MTP1	N	5	1	Mean of transverse profile: (mm)
MTP2	N	5	1	Cameras 1 and 11 are 0
MTP3	N	5	1	markers. All of the other
MTP4	N	5	1	cameras are measured from
MTP5	N	5	1	this 0. Thus the mean of
MTP6	N	5	1	the camera data over the
MTP7	N	5	1	entire length of the
MTP8	N	5	1	section.
MTP9	N	5	1	
DTP1	N	5	1	Deviation of the transverse profile: (mm)
DTP2	N	5	1	This is the same as the mean
DTP3	N	5	1	except that the data
DTP4	N	5	1	reported is the standard
DTP5	N	5	1	deviation of each camera
DTP6	N	5	1	over the entire length of
DTP7	N	5	1	the section.
DTP8	N	5	1	

Definition of MEAN File
(0.1 Mile Sections)
Files named MXXX.DAT
where XXX is the route number

FIELD NAME	FIELD TYPE	LENGTH OF FIELD	DECIMAL PLACES	DESCRIPTION
DTP9	N	5	1	
MRMS1	N	5	2	Megatexture mean RMS for the left texture camera
RRMS1	N	5	2	Rough macrotexture mean RMS for the left texture camera
FRMS1	N	5	2	Fine macrotexture mean RMS for the left texture camera
MRMS4	N	5	2	Megatexture mean RMS for the right texture camera
RRMS4	N	5	2	Rough macrotexture mean RMS for the right texture camera
FRMS4	N	5	2	Fine macrotexture mean RMS for the right texture camera
CRACK11	N	4	0	Camera 1 crack < 3.0mm deep, 1.5mm - 3.0mm wide
CRACK12	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK13	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK14	N	4	0	3.0mm deep, 12.0-50.0mm wide
CRACK15	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK16	N	4	0	6.0mm deep, 6.0-12.0mm wide
CRACK21	N	4	0	Camera 2 crack < 3.0mm deep, 1.5mm - 3.0mm wide
CRACK22	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK23	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK24	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK25	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK26	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
BOTH12	N	5	0	Crack in camera 1 and 2 within 4 inches
CRKDENS11	N	5	0	Density camera 1 (% Length with > 2 SHALLOW CRACKS/.5 meter)
CRKDENS12	N	5	0	Density camera 1 (% Length with > 2 DEEP CRACKS/.5 meter)
CRACK31	N	4	0	Camera 3 crack 3.0mm deep, 1.5mm-3.0mm wide
CRACK32	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK33	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK34	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK35	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK36	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
CRACK41	N	4	0	Camera 4 crack 3.0mm deep, 1.5mm-3.0mm wide
CRACK42	N	4	0	3.0mm deep, 3.0mm-6.0mm wide
CRACK43	N	4	0	3.0mm deep, 6.0mm-12.0mm wide
CRACK44	N	4	0	3.0mm deep, 12.0mm-50.0mm wide
CRACK45	N	4	0	6.0mm deep, 3.0mm-6.0mm wide
CRACK46	N	4	0	6.0mm deep, 6.0mm-12.0mm wide
BOTH34	N	5	0	Crack in camera 3 and 4 within 4 inches
CRKDENS41	N	5	0	Density camera 4 (% Length with > 2 SHALOW CRACKS/.5 meter)
CRKDENS42	N	5	0	Density camera 4 (% Length with > 2 DEEP CRACKS/.5 meter)

APPENDIX G

HWY 30	MRN BRDG 26.18	END BRDG 25.66	030	1W	1HWYAC
HWY 30	E[illegible]DG 25.66	1 MILE	030	2W	1HWYAC
HWY 30	1 MILE	OXNG ACS 24.53	030	3W	1HWYAC
HWY 30	OXNG ACS 24.53	1 MILE	030	4W	1HWYAC
HWY 30	1 MILE	2 MILE	030	5W	1HWYAC
HWY 30	2 MILE	3 MILE	030	6W	1HWYAC
HWY 30	3 MILE	4 MILE	030	7W	1HWYAC
HWY 30	4 MILE	U/XNG BK 19.43	030	8W	1HWYAC
HWY 30	U/XNG BK 19.43	1 MILE	030	9W	1HWYAC
HWY 30	1 MILE	2 MILE	030	10W	1HWYAC
HWY 30	2 MILE	DRRY OXNG 16.94	030	11W	1HWYAC
HWY 30	DRRY OXNG 16.94	1 MILE	030	12W	1HWYAC
HWY 30	1 MILE	2 MILE	030	13W	1HWYAC
HWY 30	2 MILE	3 MILE	030	14W	1HWYAC
HWY 30	3 MILE	4 MILE	030	15W	1HWYAC
HWY 30	4 MILE	KGN VLLY 12.83	030	16W	1HWYAC
HWY 30	KGN VLLY 12.83	1 MILE	030	17W	1HWYAC
HWY 30	1 MILE	2 MILE	030	18W	1HWYAC
HWY 30	2 MILE	3 MILE	030	19W	1HWYAC
HWY 30	3 MILE	4 MILE	030	20W	1HWYAC
HWY 30	4 MILE	SLT CRK 8.38	030	21W	1HWYAC
HWY 30	SLT CRK 8.38	1 MILE	030	22W	1HWYAC
HWY 30	1 MILE	2 MILE	030	23W	1HWYAC
HWY 30	2 MILE	3 MILE	030	24W	1HWYAC
HWY 30	3 MILE	MLL CRK 4.71	030	25W	1HWYAC
HWY 30	MLL CRK 4.71	GSNCK CRK 3.97	030	26W	1HWYAC
HWY 30	GSNCK CRK 3.97	1 MILE	030	27W	1HWYAC
HWY 30	1 MILE	2 MILE	030	28W	1HWYAC
HWY 30	2 MILE	3 MILE	030	29W	1HWYAC
HWY 30	3 MILE	YMHLL RVR .02	030	30W	1HWYAC

APPENDIX H

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0001 0080
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

1	0	910	910	65	2.62	2.08	3.06	13.38	5.40	3	0	0	0	0	0	0	0
2	0	1610	1610	79	1.40	0.81	1.14	5.60	8.50	11	0	0	0	0	0	0	0
3	0	140	140	71	1.59	1.06	1.26	6.62	6.40	0	0	0	0	0	0	0	0
4	0	1610	1610	70	1.69	1.05	1.54	5.94	7.40	10	0	0	0	0	0	0	0
5	0	1610	1610	76	1.59	0.91	1.36	4.80	3.70	1	0	0	0	0	0	0	0
6	0	1610	1610	75	1.60	0.96	1.40	5.52	6.10	1	0	0	0	0	0	0	0
7	0	1610	1610	77	1.49	0.83	1.20	5.44	6.00	7	0	0	0	0	0	0	0
8	0	1545	1545	81	1.38	0.80	1.34	5.14	9.60	10	0	0	0	0	0	0	0
– 9	0	1610	1610	76	1.10	0.50	0.98	3.18	9.20	5	0	0	0	0	0	0	0
– 10	0	1610	1610	73	1.36	0.73	1.44	3.94	8.90	3	0	0	0	0	0	0	0
11	0	825	825	74	1.84	1.20	1.86	5.16	8.50	12	1	0	0	0	0	0	0
12	0	1610	1605	60	1.67	1.23	2.18	9.44	7.30	4	1	0	0	0	0	0	0
13	0	1610	1610	75	1.46	0.79	1.30	4.68	4.60	3	0	0	0	0	0	0	0
14	0	1610	1610	82	1.32	0.67	1.18	4.78	1.90	0	0	0	0	0	0	0	0
15	0	1610	1610	83	1.33	0.65	1.26	4.60	1.70	0	0	0	0	0	0	0	0
16	0	425	425	83	1.43	0.76	1.44	6.20	1.70	0	0	0	0	0	0	0	0
17	0	1610	1610	83	1.36	0.70	1.22	5.42	1.70	0	0	0	0	0	0	0	0
18	0	1610	1610	79	1.44	0.84	1.52	5.18	8.60	12	0	0	0	0	0	0	0
19	0	1610	1610	77	1.13	0.57	1.18	3.96	8.00	0	0	0	0	0	0	0	0
20	0	1610	1610	75	1.01	0.49	0.98	3.72	8.50	1	0	5	5	5	5	2	0
21	0	630	630	76	1.17	0.68	1.24	6.08	8.20	0	0	0	0	0	0	0	0
22	0	1610	1610	71	1.79	1.26	2.12	8.70	4.70	2	0	0	0	0	0	0	0
23	0	1610	1610	72	1.60	1.10	1.94	9.02	4.00	0	0	0	0	0	0	0	0
24	0	1610	1610	80	1.07	0.57	1.12	5.94	2.30	0	0	0	0	0	0	0	0
25	0	1100	1100	79	1.14	0.80	1.22	9.18	2.30	0	0	0	0	0	0	0	0
26	0	1205	1205	78	1.21	0.74	1.42	6.46	2.30	0	0	0	0	0	0	0	0
27	0	1610	1610	77	1.21	0.77	1.46	7.74	2.20	0	0	0	0	0	0	0	0
28	0	1610	1610	79	1.29	0.86	1.56	8.00	3.20	0	0	0	0	0	0	0	0
29	0	1610	1610	78	1.12	0.65	1.30	7.96	1.90	0	0	0	0	0	0	0	0
30	0	1575	1575	76	1.27	0.81	1.36	8.06	2.40	0	0	0	0	0	0	0	0

****************************** BOTTOM OF DATA ******************************

172 K AVAIL L 02 C

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0081 0160
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

0	012111111	1.0	0.9	2.3	2.7	1.9	0.8	-0.7	-1.3	-1.8	5.1	4.9	5.3	4.9	4
0	012111111	-2.6	-3.6	-1.5	0.8	4.1	6.0	4.9	3.3	-0.3	4.1	4.8	5.3	5.6	5
0	012111111	2.2	0.8	1.1	1.8	4.4	8.3	8.6	5.5	0.3	4.0	4.0	4.3	5.0	6
0	012121111	-2.5	-3.6	-1.6	0.7	2.3	2.9	1.1	-1.4	-3.2	4.2	4.9	5.3	5.0	4
0	011111111	4.9	6.8	9.0	9.8	10.2	11.2	10.1	8.1	3.3	3.8	4.6	5.7	5.7	5
0	012121111	0.8	0.1	1.5	2.4	2.8	3.8	2.5	0.8	-1.7	4.6	5.3	5.5	5.1	4
0	012121111	3.6	4.3	5.0	5.2	5.4	6.9	6.4	5.1	1.4	5.4	6.7	7.2	6.8	6
0	012121111	-5.8	-7.1	-4.3	-0.9	1.4	1.8	-0.8	-3.0	-5.1	4.0	3.3	3.5	3.2	2
0	012121111	-3.5	-6.0	-4.0	-1.1	2.2	4.1	2.2	-0.7	-3.7	4.0	3.5	3.3	2.9	2
0	012121111	-3.7	-4.7	-2.6	-0.3	1.2	2.0	-0.1	-2.3	-4.4	4.1	3.9	3.7	3.1	2
0	011121112	-3.1	-3.7	-1.2	1.2	2.5	3.5	1.8	-0.2	-2.6	4.9	5.0	5.1	4.9	5
0	011111112	-2.5	-4.1	-2.9	-0.8	1.7	4.1	3.1	1.0	-2.0	3.4	3.2	3.2	2.8	2
0	011111112	0.3	0.7	3.1	5.0	5.9	6.3	4.7	3.3	1.1	2.6	3.2	3.8	4.0	4
0	011111111	4.8	5.6	7.5	9.4	10.1	11.0	9.9	8.3	4.7	4.3	3.9	3.9	3.5	3
0	012111111	4.3	5.8	8.2	9.4	9.3	10.1	9.0	7.6	4.1	3.3	3.1	3.1	2.6	2
0	012111111	5.8	6.8	8.6	9.8	9.6	10.4	9.5	8.0	4.0	2.3	2.3	2.5	1.9	2
0	012111111	5.2	6.3	8.1	9.5	10.5	10.5	9.3	7.5	3.9	2.3	2.6	2.9	2.7	2
0	012211111	-2.5	-4.4	-3.5	-1.5	0.9	2.2	1.2	-0.2	-3.0	3.6	3.9	3.7	3.0	2
0	012111111	-1.9	-4.5	-4.2	-2.2	1.3	3.9	3.4	2.2	-1.0	2.5	2.4	2.2	2.1	1
0	012111111	-1.7	-4.5	-4.3	-2.3	1.1	3.7	3.1	2.1	-0.8	2.3	2.4	2.2	1.8	1
0	012111111	-0.9	-3.3	-2.8	-0.9	2.1	4.3	3.9	2.7	-0.6	4.5	4.6	3.4	2.3	1
0	012111111	5.3	5.2	5.9	7.2	8.8	10.6	9.9	8.3	3.7	4.9	6.2	6.6	6.8	6
0	012111222	4.4	5.7	7.4	9.1	10.6	12.1	11.0	8.8	4.1	4.2	4.7	5.1	6.7	7
0	012111111	2.9	3.8	5.7	6.7	7.7	8.5	7.5	5.5	2.0	2.2	2.4	2.8	2.6	2
0	012111111	3.0	4.3	6.6	7.4	8.0	7.7	6.7	4.8	1.9	3.5	3.6	3.4	3.0	2
0	012111111	6.5	7.6	8.7	9.0	8.6	8.7	7.7	6.6	3.2	5.0	4.3	4.1	3.8	3
0	012112111	5.5	6.5	8.3	9.5	10.1	10.6	9.1	7.0	2.9	2.7	2.5	2.7	2.4	2
0	012111112	2.5	3.1	4.9	6.5	8.2	9.0	7.7	5.7	1.7	3.4	3.4	3.8	3.8	3
0	012112111	5.5	6.9	8.5	9.3	9.9	10.2	9.2	7.4	3.6	3.7	3.0	2.9	2.5	2
0	012111111	4.0	5.7	7.5	8.2	8.0	7.8	6.7	5.5	2.6	2.8	2.5	2.6	2.3	2

****************************** BOTTOM OF DATA ******************************

172 K AVAIL L 02 C

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0161 0240
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

.9	4.7	4.5	4.0	3.0	0.43	0.58	0.40	0	5	13	41	36	1	0	0	2	50	
.5	5.0	5.1	4.8	4.0	0.46	0.68	0.52	0	1	2	33	54	7	0	0	0	1	
.5	8.0	8.7	6.4	3.0	0.36	0.61	0.50	0	2	6	43	45	2	0	0	0	2	1
.6	4.5	4.6	4.4	3.9	0.42	0.58	0.40	0	5	17	43	29	4	0	0	1	55	
.6	5.4	4.8	4.4	3.8	0.25	0.39	0.26	0	31	33	31	2	0	0	0	1	85	1
.7	4.5	4.5	4.5	3.9	0.33	0.48	0.31	0	16	26	41	12	2	0	0	3	58	2
.0	5.7	6.0	5.8	4.6	0.26	0.45	0.31	0	17	28	42	10	0	0	0	4	58	2
.6	3.3	4.0	3.6	2.5	0.22	0.41	0.21	3	42	22	21	10	0	0	0	11	84	
.5	2.7	3.3	3.1	2.3	0.26	0.49	0.23	0	15	24	37	21	0	0	0	3	93	
.7	3.3	3.4	3.2	2.8	0.24	0.44	0.22	0	27	28	29	14	0	0	0	6	90	
.0	4.7	5.1	5.1	4.2	0.33	0.54	0.29	0	13	18	34	31	1	0	0	3	66	2
.3	2.4	2.8	2.7	2.5	0.27	0.50	0.25	2	9	20	47	19	0	0	0	5	88	
.3	4.1	3.7	3.3	2.6	0.20	0.43	0.25	1	35	23	28	11	0	0	0	0	90	
.1	2.8	2.5	2.2	1.7	0.15	0.38	0.29	0	36	27	33	1	0	0	0	0	70	2
.4	2.0	1.8	1.6	1.2	0.17	0.41	0.30	0	22	32	41	3	0	0	0	0	63	3
.0	2.3	2.4	2.5	2.3	0.14	0.34	0.27	2	36	47	13	0	0	0	0	2	83	1
.9	2.1	2.1	1.9	1.7	0.14	0.34	0.25	5	39	37	16	1	0	0	0	4	86	
.6	2.6	3.0	3.2	2.6	0.48	0.80	0.37	0	5	4	3	62	22	0	0	0	24	5
.9	1.5	1.8	2.0	1.9	0.42	0.75	0.35	0	0	0	6	85	7	0	0	0	28	6
.9	1.9	2.1	2.4	2.2	0.49	0.86	0.38	0	0	0	7	58	34	0	0	0	19	5
.9	2.1	3.0	3.3	2.7	0.39	0.74	0.34	0	0	2	19	66	11	0	0	0	37	5
.7	6.0	6.0	5.8	5.1	0.37	0.70	0.34	0	4	7	21	58	8	0	0	0	35	5
.1	8.0	7.8	7.5	4.8	0.25	0.55	0.33	0	7	16	45	28	2	0	0	0	50	3
.8	2.4	2.5	2.1	1.7	0.24	0.54	0.27	0	3	18	54	21	2	0	0	0	85	1
.6	2.2	2.1	2.0	1.7	0.29	0.62	0.32	0	2	5	45	43	2	0	0	0	62	3
.7	3.4	3.1	2.7	2.3	0.24	0.56	0.30	0	2	16	50	28	1	0	0	0	67	2
.3	2.5	2.7	2.5	2.1	0.21	0.50	0.26	0	3	22	58	15	0	0	0	0	90	
.8	3.2	3.2	2.8	2.4	0.22	0.51	0.27	0	6	16	57	17	1	0	0	0	86	1
.3	2.4	2.7	2.8	2.5	0.27	0.60	0.28	0	0	6	55	33	4	0	0	0	83	1
.3	2.4	2.5	2.4	2.3	0.31	0.60	0.28	0	0	13	49	30	5	0	0	0	76	2

****************************** BOTTOM OF DATA ******************************

172 K AVAIL L 02 C

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0241 0320
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

6	32	7	0	0	0	0.44	0.61	0.46	0	3	8	37	49	1	0	0	0	30	19
7	80	9	1	0	0	0.44	0.68	0.55	0	0	0	20	76	2	0	0	0	0	1
2	78	6	1	0	0	0.37	0.60	0.49	0	0	0	56	42	1	0	0	0	0	9
5	27	9	0	0	0	0.45	0.56	0.40	0	8	18	36	34	1	0	0	0	53	7
1	1	0	0	0	0	0.29	0.42	0.29	0	26	35	30	6	0	0	0	0	80	15
6	10	0	0	0	0	0.34	0.48	0.31	0	20	23	38	15	1	0	0	0	66	27
7	8	0	0	0	0	0.28	0.44	0.30	0	14	32	47	6	0	0	0	0	74	22
2	0	0	0	0	0	0.27	0.45	0.27	0	22	27	37	12	0	0	0	0	86	11
3	0	0	0	0	0	0.31	0.50	0.26	0	4	16	62	16	0	0	0	0	94	5
2	0	0	0	0	0	0.27	0.47	0.26	0	7	29	51	10	0	0	0	0	93	5
2	6	0	0	0	0	0.38	0.54	0.30	0	6	16	48	24	1	0	0	0	73	18
5	0	0	0	0	0	0.27	0.44	0.27	3	17	26	44	8	0	0	0	4	83	11
7	0	0	0	0	0	0.19	0.39	0.25	3	44	19	24	8	0	0	0	0	90	8
7	1	0	0	0	0	0.14	0.29	0.25	2	67	24	5	0	0	0	0	0	95	4
1	4	0	0	0	0	0.15	0.32	0.27	1	47	39	11	0	0	0	0	0	86	13
2	1	0	0	0	0	0.13	0.29	0.27	1	70	26	1	0	0	0	0	0	91	7
6	1	0	0	0	0	0.13	0.28	0.25	5	71	20	3	0	0	0	0	0	94	5
4	18	1	0	0	0	0.43	0.72	0.35	0	8	4	9	62	13	0	0	0	30	54
4	6	0	0	0	0	0.37	0.67	0.33	0	0	2	27	64	4	0	0	0	38	54
8	21	0	0	0	0	0.41	0.72	0.34	0	0	2	21	66	9	0	0	0	30	65
5	6	0	0	0	0	0.34	0.64	0.32	0	2	4	34	55	3	0	0	0	45	52
5	7	0	0	0	0	0.37	0.62	0.33	0	11	10	25	46	4	0	0	0	46	46
6	11	1	0	0	0	0.24	0.45	0.33	0	20	26	41	10	0	0	0	0	54	34
2	1	0	0	0	0	0.20	0.42	0.25	0	25	39	27	6	0	0	0	0	92	6
2	4	0	0	0	0	0.25	0.55	0.31	0	~2	12	59	23	1	0	0	0	66	28
5	6	0	0	0	0	0.23	0.47	0.28	2	7	26	52	10	0	0	0	0	82	15
9	0	0	0	0	0	0.18	0.41	0.25	0	24	40	28	5	0	0	0	0	92	6
1	1	0	0	0	0	0.24	0.50	0.27	0	11	20	48	16	1	0	0	0	84	14
3	2	0	0	0	0	0.25	0.53	0.27	0	2	21	54	19	1	0	0	0	88	10
1	1	0	0	0	0	0.28	0.52	0.28	0	4	25	48	20	1	0	0	0	77	19

****************************** BOTTOM OF DATA ******************************

172 K AVAIL L 02 C

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0321 0400
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

35	13	1	0	0	11	5	3	1	0	1	9	4	1	0	0	0	2	0.00
83	13	1	0	0	8	2	0	0	0	0	4	2	0	0	0	0	0	0.00
85	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34	3	0	0	0	74	46	17	3	1	0	78	61	15	3	1	0	14	0.00
2	0	0	0	0	38	15	1	0	2	0	64	23	4	1	0	1	2	0.00
5	0	0	0	0	61	32	6	1	0	1	68	30	9	2	0	0	4	0.00
2	0	0	0	0	57	26	5	2	0	0	74	36	6	0	0	0	2	0.00
1	0	0	0	0	41	15	9	2	0	0	27	20	7	0	0	0	0	0.00
0	0	0	0	0	45	35	8	0	1	0	35	33	4	0	0	0	1	0.00
0	0	0		0	46	35	7	0	1	1	51	46	9	3	1	0	2	0.00
6	1	0		0	33	21	10	0	1	0	33	30	4	1	2	0	3	0.00
0	0	0	0	0	89	48	14	1	1	2	73	37	15	0	2	0	13	0.00
0	0	0	0	0	55	26	5	2	0	1	36	21	3	0	0	0	2	0.00
0	0	0	0	0	68	14	1	0	0	0	35	12	0	0	0	0	0	0.00
0	0	0	0	0	85	20	2	0	0	0	108	27	3	0	0	0	6	0.00
0	0	0	0	0	11	3	0	0	0	0	9	2	0	0	0	0	0	0.00
0	0	0	0	0	31	9	1	0	1	0	29	8	2	0	0	0	1	0.00
15	0	0	0	0	92	57	22	0	0	1	69	45	10	1	1	0	3	0.00
7	0	0	0	0	132	65	20	1	0	0	125	81	9	0	0	0	8	0.00
4	0	0	0	0	71	45	5	0	0	1	87	38	6	0	0	0	3	0.00
1	0	0	0	0	24	23	2	0	0	0	31	12	2	0	0	0	1	0.00
6	0	0	0	0	65	48	13	3	0	1	82	47	14	6	0	0	5	0.00
10	0	0	0	0	78	24	11	0	1	0	49	33	8	3	2	0	4	0.00
0	0	0	0	0	85	86	31	3	1	0	93	74	27	1	0	0	8	0.00
4	0	0	0	0	37	25	6	2	2	2	39	48	20	1	0	1	1	0.00
2	0	0	0	0	55	56	30	1	1	1	72	68	34	4	1	2	13	0.00
0	0	0	0	0	86	60	22	2	0	1	70	64	29	1	0	1	2	0.00
1	0	0	0	0	70	52	17	3	2	1	63	57	24	3	0	0	6	0.00
0	0	0	0	0	52	65	24	0	0	0	58	55	22	3	0	1	5	0.00
3	0	0	0	0	52	39	15	2	0	0	45	43	19	4	1	0	4	0.00

****************************** BOTTOM OF DATA ******************************

172 K AVAIL L 02 C

BROWSE1 B:\O030.SDF LINE -000000 COLUMNS 0399 0478
COMMAND ===
SCROLL === HALF

****************************** TOP OF DATA ******************************

0.00	4	6	0	0	0	1	6	3	0	1	0	0	2	0.00	0.00
0.00	4	0	1	0	0	0	10	3	0	0	0	0	1	0.00	0.00
0.00	1	0	0	0	0	0	1	1	0	0	0	0	0	0.00	0.00
0.00	46	34	16	5	1	0	62	67	18	4	0	1	3	0.00	0.00
0.00	28	20	1	0	2	0	49	50	17	6	0	1	0	0.00	0.00
0.00	60	52	14	3	3	1	48	62	21	10	0	2	3	0.00	0.00
0.00	51	24	5	0	1	1	27	24	11	3	0	0	3	0.00	0.00
0.00	33	32	14	2	1	1	27	15	14	3	0	0	0	0.00	0.00
0.00	33	42	7	4	0	0	21	31	12	1	0	2	1	0.00	0.00
0.00	49	46	13	2	0	0	30	20	5	0	0	2	1	0.00	0.00
0.00	31	27	10	1	4	1	24	27	15	2	2	4	7	0.00	0.00
0.00	73	35	24	0	4	2	54	18	6	2	0	2	5	0.00	0.00
0.00	33	27	8	4	3	0	38	17	5	0	2	1	3	0.00	0.00
0.00	42	13	0	0	0	0	20	4	2	0	0	0	0	0.00	0.00
0.00	46	20	1	0	0	0	24	10	0	0	0	0	1	0.00	0.00
0.00	19	3	0	0	0	0	1	0	0	0	0	0	0	0.00	0.00
0.00	29	13	2	0	0	0	15	3	1	0	0	0	0	0.00	0.00
0.00	32	32	4	1	0	0	60	37	5	0	0	0	2	0.00	0.00
0.00	46	35	13	1	0	0	50	34	3	0	0	0	0	0.00	0.00
0.00	21	19	7	0	0	0	38	31	3	0	0	0	0	0.00	0.00
0.00	23	23	1	0	0	0	19	14	4	0	0	0	1	0.00	0.00
0.00	66	49	13	2	0	0	56	36	11	4	0	0	3	0.00	0.00
0.00	31	13	5	0	1	0	33	22	18	4	0	3	1	0.00	0.00
0.00	58	53	24	1	0	1	36	28	16	3	0	1	3	0.00	0.00
0.00	38	41	13	1	1	0	29	36	14	2	0	0	3	0.00	0.00
0.00	78	74	24	2	0	2	46	54	20	2	1	1	12	0.00	0.00
0.00	41	66	17	5	0	2	42	31	10	1	0	0	2	0.00	0.00
0.00	60	54	18	3	0	0	55	61	27	0	0	1	3	0.00	0.00
0.00	49	59	32	2	0	1	41	50	27	2	0	0	2	0.00	0.00
0.00	15	39	12	2	0	0	42	37	16	3	0	1	1	0.00	0.00

****************************** BOTTOM OF DATA ******************************

72 K AVAIL L 02 C

IMS Infrastructure Management Services

April 6, 1990

Mr. W.J. Quinn, P.E.
Engineer of Materials and Research
Oregon Department of Transportation
Highway Division
Materials & Research Section
800 Airport Road Southeast
Salem, Oregon 97310

Dear Mr. Quinn:

I want to thank you for sending me a copy of Dick Parker's Interim Report entitled "Evaluation of IMS-Swedish Laser Road Tester". You indicated in your covering letter that a final report will be issued that is not too different from the interim report.

I have read the interim report and would like to comment on some of the statements that were made and some of the conclusions that were reached from that report. There were a number of criticisms of the Laser RST and the performance of IMS on the project performed in September of 1988. These were in the following areas:

1. Mechanical condition of the Laser RST.
2. Inexperience of the IMS crew.
3. Erratic driving and its effect on test results.
4. Horizontal control
5. Delivery of data.

I would like to comment on these and also on the following:

6. Correlation between data obtained by the Laser RST and Oregon Department of Transportation.
7. Observation on the equipment that should be used by the Oregon Department of Transportation.

MECHANICAL PROBLEMS - LASER RST

In the section entitled "Equipment", the report stated that mechanically the van was in relatively poor shape, required immediate repair and that this delayed the survey by a day and a half.

Prior to the survey for the Oregon DOT, the Laser RST was performing a study for the Ministry of Transportation/Highways, in British Columbia. The week of August 28, 1989, the rear main seal on the Laser RST started to leak. Because the RST was scheduled to start working for the Oregon DOT on September 4th, it was decided to hold up on the repair of the rear main seal until such a time as the Oregon DOT job was concluded or until rain might cause a delay in the project.

3350 SALT CREEK LANE SUITE 117 ARLINGTON HEIGHTS, ILLINOIS 60005
(708) 506-1500
Fax (708) 255-2938

The survey for the Oregon DOT began on Monday afternoon and proceeded through to Tuesday morning, at which time the project was stopped because of rain. On Wednesday testing proceeded. Our crew was advised that it was going to rain all day Thursday. It was therefore decided to repair the rear main seal. The repair took all day Thursday, a rain day, and part of Friday morning. The equipment was picked up at 10:00 a.m. that morning and it was again raining so no surveying occurred on Friday. Thereafter, surveying was performed on Saturday through Tuesday, at which time the project was completed. Please note that the repair of the equipment was done during a rain delay and therefore, had only a marginal effect on the RST productivity.

The RST continued to operate for another 60,000 miles without any major breakdowns. In November, 1989 we replaced the engine. The unit is still operating today in good condition.

During the testing at the Oregon DOT we had no problems with the lasers, the electronic system, or the computer. The statement that the vehicle was in poor repair because of the need for rear main seal, and the statement that mechanical failure delayed the whole survey by a day and a half, when in fact it rained in that period of time, were perhaps a little misleading.

INEXPERIENCE OF THE IMS CREW

Four people were involved in the IMS survey. These were: Roger Speicher, Pete Johnson, Matt Holden, and Dan Ballard. Roger Speicher visited the Oregon DOT and met with Dick Parker on the Friday before the survey was to commence. His function was to coordinate the survey. The other three personnel were members of the Laser RST survey crew.

The forerunner to IMS was Novak-Dempsey & Associates. Roger joined Novak-Dempsey & Associates on August 1, 1977. He has been actively engaged in pavement management in field surveys and later in a supervisory coordinating capacity. At the time of the survey, Roger had eleven years of experience in pavement management field surveys and coordination.

Pete Johnson joined IMS in July, 1986. In the summer of 1987, he spent two months in Sweden, where he underwent extensive training in the operation and maintenance of the RST. This included driving with the VTI Laser RST survey crews. It should be noted that VTI is the developer of the Laser RST. At the time of the survey he had been with IMS for two years and had served as crew chief on a number of RST surveys.

Matt Holden joined IMS in July, 1987. He had been a Laser RST crew member during the entire period prior to the Oregon test. At the time of the Oregon test he had been with IMS in excess of one year.

Dan Ballard had joined IMS in August, 1988. He had undergone indoctrination and had been a crew member for a 1000 km project in British Columbia. He was working under the direct supervision of Pete Johnson. He is the only member of the crew that had been with the RST a short period of time. It should be noted however, that he had worked successfully on a large project just prior to the Oregon DOT survey.

ERRATIC DRIVING AND ITS EFFECT ON TEST RESULTS

I am enclosing herewith a sheet from the Laser Road Surface Tester brochure. This sheet is entitled "Measurement of Rut Depth" and it shows the RST laser array. Please note that there are eleven lasers. The two outside lasers are mounted at a 45 degree angle. Since the laser bar is approximately 16 inches above the roadway surface, the measurements from the angled lasers are approximately one foot outside the laser bar.

Care must be exercised to make sure that all lasers are measuring on the pavement surface. If the laser measurement is outside the pavement edge, then it will create a false reading and affect the rut depth measurement. It was desired, in this case, that the rut depth be measured to approximately one foot inside the pavement edge. This meant that the right wheel of the vehicle could be approximately two and one half feet from the pavement edge and still result in a good rut depth reading. On a narrow road, it would always appear as if the right wheel was inside of the right wheelpath.

Please note from the attached sheet that there are six lasers from the mid-point of the laser bar to the outside edge. Therefore, on a narrow road instead of the third laser from the right reading the right rut depth, the second laser from the right might read that position. This is the advantage of an eleven sensor bar as opposed to a three or a five sensor bar. There is less effect from the lateral positioning of the laser array. Also since our program is based on the wire method and not the straightedge method, the outside laser does not necessarily need to be at the top of the rut in all cases. This makes the Laser RST less sensitive than most other equipment to driving exactly in the wheelpath. In some cases it appears as if the vehicle wheels are properly positioned even though it is not the case. It is the drivers responsibility to make sure that the outside lasers are measuring within the pavement section.

The South Dakota Profilometer, which is now being constructed by the Oregon Department of Transportation to measure rut depth has, in its normal configuration, three sonic sensors or if specially ordered, five sonic sensors - one in the center and one in each wheelpath. The South Dakota Profilometer has a much higher sensitivity to lateral positioning than the eleven sensor Laser RST. It should also be noted that the lasers have a much higher resolution than the South Dakota Profilometer sonic sensors. This makes Statement #3 in the Observations (Pg. #4) curious in that the suggestion is made that a delay in choosing equipment should be made until greater accuracy, versatility and reliability are obtained from sensing equipment.

HORIZONTAL CONTROL

At the meeting that Roger Speicher had with Dick Parker, a rather lengthy discussion was held regarding the horizontal control for this project. It was indicated that Ms. Geraldine Pierce would join the RST crew as an observer. Since she had been surveying these particular roads she knew the beginning and end points and would so indicate them to our crew. Ms. Geraldine Pierce was with the crew during the whole survey. One of the functions was that she had with her the maps and would indicate exactly where to start testing and when to stop and would give us the section numbers. The starting and ending positions were input from her voice commands.

The present horizontal control program in the Laser RST allows for the insertion of checkpoints without resetting the counter to zero. This was put into the program approximately 30 days after the Oregon Department of Transportation project. It was actually developed prior to the project but because of the checking of the software, it was not inserted until October, 1988. It should be noted that the location of the test sections could easily be observed on the ground since Ms. Pierce was able to determine the beginning and starting position from the map and by observing the terrain features.

The RST program can now update the milage count on a random access basis, also the survey can now give the running distance as well as the relationship to any given point.

DELIVERY OF DATA

The original contract indicated that we would complete the work on September 30. We in fact, did not deliver the completed data until November 1st. We apologize for this delay. We take complete responsibility for the delay in getting the information to you.

CORRELATION BETWEEN DATA OBTAINED BY LASER AND OREGON DEPARTMENT OF TRANSPORTATION

It was our understanding that at the time we were performing our survey, a parallel survey would be performed by the Oregon Department of Transportation so the data could be correlated and checked. As of the writing of your interim report on evaluation of the IMS-Swedish Laser Road Tester, February 1989, some of the parallel measurements had not been undertaken. That is unfortunate because we would anticipate that rut depth and roughness and even surface distress patterns could change over a winter season. This could make it impossible for you to ascertain the accuracy of our survey and therefore, not be able to judge it on its merits or if, in fact, driving patterns affected the results.

OBSERVATION ON EQUIPMENT THAT SHOULD BE USED BY THE OREGON DEPARTMENT OF TRANSPORTATION

As I indicated in the section on erratic driving and its effect on test results, the Oregon Department of Transportation is now building a South Dakota Profilometer. Although it is less expensive than the Laser RST,(note the Laser RST in fact, costs us approximately ten times the cost of the South Dakota Profilometer), it is not capable of performing all the RST functions. Also it should be noted that because of the lesser number or sensors the South Dakota Profilometer is extremely more sensitive to driver error than the Laser RST. This will effect not only the values obtained but long term repeatability, particularly with different operators using the equipment.

CONCLUSIONS

Although some of the statements in the interim report are true, I do not feel the Laser RST performed to the degree of disatisfaction that the tone of this interim report would indicate. I would like to apologize for any inconvenience that the leak in the rear main seal may have created, the delay in submitting the data, and any inconvenience in your correlations of the horizontal control.

I want to thank you for allowing me to take the liberty to both comment on this report and to express my concerns about some of its content.

Very truly yours,

IMS INFRASTRUCTURE MANAGEMENT SERVICES

Robert L. Novak
Director of Engineering

Encl.

RLN/bjv

Ref: 01-1212A00

MEASUREMENT OF RUT DEPTH

All eleven lasers supply signals to a special rut depth measuring card. The rut depth measuring card plots a transverse profile of the pavement and records the deepest rut every 10cm.

At the end of the test section, an average rut depth is reported and a percentage of distance where the rutting was greater than two operator selected limits (normally 1/2" and 1") is reported. The data is reported in real time. Rut depth is measured by the wire method (see figure 2).

SAMPLE TRANSVERSE LASER ARRAY AND RUT PLOT

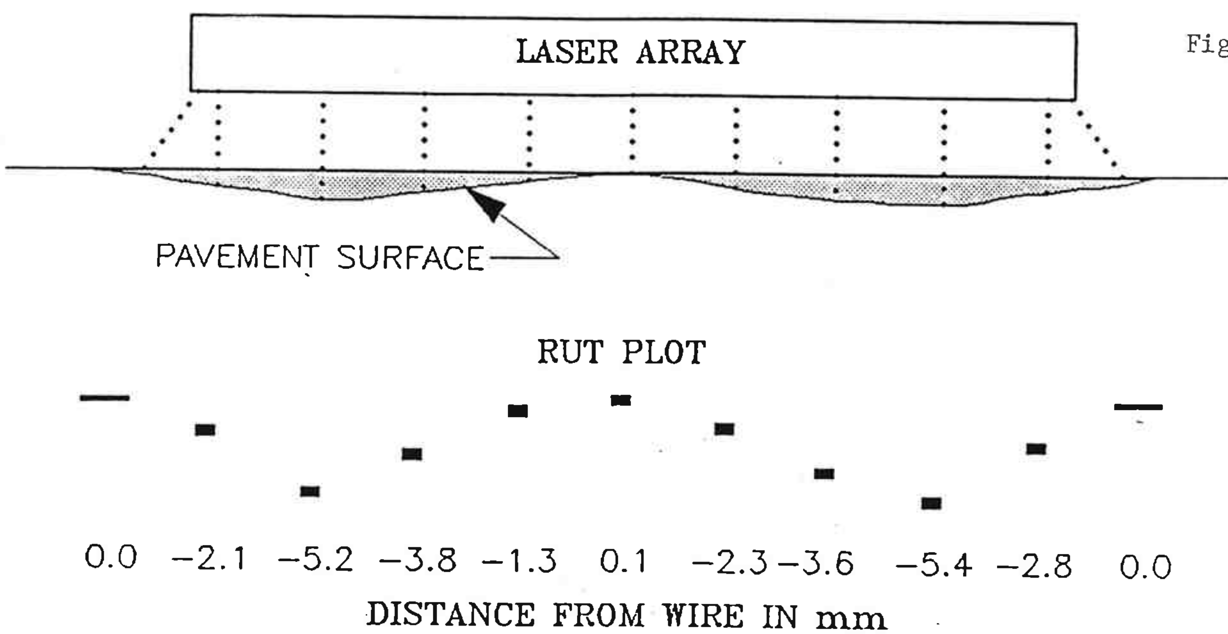


Figure 2