MATERIALS AND ROAD RESEARCH SECTION **RESEARCH PROJECT WORK PLAN**	INV. No. 878
TITLE OF PROJECT: Porous Asphalt Pavement Performance in Cold Regions	
IS THIS A RESPONSE TO A PROBLEM STATEMENT? ☐ NO ☒ YES IF YES, STATE NAME OF CONTACT PERSON. Bob Lisi	
PRINCIPAL INVESTIGATORS: Matthew Lebens and Brett Troyer	
POSITION TITLE/DEGREES	
MAILING ADDRESSES: Matthew Lebens, P.E. Research Engineer 1400 Gervais Ave, Maplewood, MN 55109-2044 Brett Troyer, P.E. Erosion Control Engineer 395 John Ireland Blvd, St Paul, MN 55155-1899	TELEPHONE AND FAX (AREA CODE, NUMBER, EXT.): TEL: 651-366-5526 FAX: 651-366-5461 E-MAIL: matthew.lebens@dot.state.mn.us TEL: 651-366-3629 FAX: 651-366-3603 E-MAIL: brett.troyer@dot.state.mn.us
TOTAL BUDGET: FUNDING SOURCE — AMOUNT LRRB — $82,400	TOTAL BUDGET PERIOD: START DATE: 2007 END DATE: 2010 PROJECT LENGTH (MONTHS): 36
KEY PERSONNEL OTHER THAN PRINCIPAL INVESTIGATOR.	
NAME Greg Larson POSITION TITLE Transportation Specialist ORGANIZATION Mn/DOT Office of Materials ROLE ON THE PROJECT Certified Technician	NAME Buffy Peterson POSITION TITLE Transportation Program Specialist ORGANIZATION Mn/DOT Environmental Services ROLE ON THE PROJECT Environmental Testing
PROJECT LIAISONS	
TECHNICAL LIAISON: NAME Larry Matsumoto ORGANIZATION City of Minneapolis, Street Construction ADDRESS 1858 E 27th St Minneapolis, MN 55407 612-919-1148	ADMINISTRATIVE LIAISON: NAME Bruce Holdhusen ORGANIZATION Mn/DOT ADDRESS 395 John Ireland Blvd, St Paul MN 55155 651-366-3760
TECHNICAL LIAISON: (Check one - electronic approvals accepted) Work Plan Approved ☒ Work Plan Approved with Changes Noted ☐ Work Plan Not Approved ☐	[signature] PRINT NAME: Larry Matsumoto DATE: 28 Nov 2007
PRINCIPAL INVESTIGATORS: I agree to accept responsibility for the scientific conduct of this project and to provide the required progress reports.	SIGNATURES OF PRINCIPAL INVESTIGATORS: [signature] DATE: 3 DEC 2007 [signature] DATE: 5 DEC 2007

MANAGER, ROAD RESEARCH SECTION: I hereby certify sufficient staff time will be scheduled for the Principal Investigator to complete the research as outlined in the attached work plan.	SIGNATURE OF MANAGER ROAD RESEARCH SECTION: Maren Jenn DATE: 12/7/07
DIRECTOR OF RESEARCH SERVICES:	SIGNATURE OF DIRECTOR OF RESEARCH SERVICES: Sue Lodahl DATE: 12/10/07

RESEARCH PROJECT WORK PLAN

KEY WORDS
Porous asphalt, stormwater, runoff, infiltration

ABSTRACT

Porous asphalt pavement is an emergent technology in pavement design in the United States. It consists of standard bituminous asphalt with greatly reduced fine particles and high (20%) void content, allowing water to pass directly through the surface. Underneath the pavement, a clean, uniformly graded stone bed allows storage and slow infiltration of stormwater into the subgrade soils. Filter fabric installed between the stone bed and subgrade prevents migration of fines upward.

Recently, the Capital Region Watershed District is requiring higher level of water quality and quantity control, such as reducing 1 inch of rainfall runoff on any project disturbing over 1 acre of land. This type of pavement may offer an effective means of managing storm water runoff, with the potential to reduce or eliminate the need for water detention basins and their associated structures and right-of-way needs. Additionally, the potential environmental benefits of porous asphalt include decreased ground and surface water contamination, and noise attenuation.

However, prior research in the seasonally diverse Midwest climate is lacking. The purpose of this research is to study the durability, maintenance requirements, hydrologic benefits, and environmental considerations of a porous asphalt roadway in a cold climate.

The proposed research consists of the following:

1. Construct a porous asphalt test section on MnROAD Low Volume Road with instrumentation.
2. Monitor pavement performance on a regular basis in terms of low temperature cracking, rutting and ride. Compare pavement performance of subcells constructed over clay and sand subgrade materials.
3. Monitor the volume of stormwater runoff and infiltration for comparison to a standard impermeable asphalt roadway control section.
4. Document the porous pavement maintenance procedures and results, in terms of when to vacuum and / or sweep roads based on stormwater infiltration monitoring data.
5. Test for water quality, such as solids, pH, Chloride, Phosphorous, Nitrogen, heavy metals. Compare contaminate levels in both the control section runoff and the porous asphalt infiltration water.

IMPLEMENTATION

Coordination with Mn/DOT Pavement Design Unit to develop a rider in the Bituminous Pavement Specifications that would guide the design and installation of porous asphalt pavements.

Provide guidance to Cities and Counties interested in constructing porous asphalt facilities.

Use stormwater infiltration / runoff data to develop environmental and water resource policies for porous asphalt installations.

Compare maintenance strategies for porous asphalt and suggest best maintenance practices.

DETAILED BUDGET FOR ENTIRE PROJECT			
SALARY:	DOLLAR AMOUNT (OMIT CENTS)		
NAME/ROLE	YEAR 1	YEAR 2	
Matthew Lebens	8000	9000	
Brett Troyer	4000	7000	
Greg Larson	2500	4000	
Buffy Peterson	2500	4000	
TOTAL SALARIES (years 1 and 2)	**17000**	**24000**	
DIRECT COSTS:			
CONSULTANT/CONTRACTOR COSTS (See Note[(1)]) Water quality testing	5400 (MDH)	4000 (MDH)	
EQUIPMENT (ITEMIZE) Instrumentation			
SUPPLIES Environmental Testing Supplies	500	500	
TRAVEL (In-state only)	500	500	
OTHER EXPENSES (i.e., testing) Permeability testing Vacuum and sweeping maintenance	750	750	
TOTAL DIRECT COSTS (years 1 and 2)	**7150**	**5750**	

Note[(1)]: Contracts for consultants/contractors will be processed by P.I. through Consultant Services and encumbered directly from LRRB accounts. Requisition for contract is sent through Research Services for coding of accounting information

DETAILED BUDGET FOR ENTIRE PROJECT			
SALARY:	DOLLAR AMOUNT (OMIT CENTS)		
NAME/ROLE	YEAR 3		TOTALS
Matthew Lebens	8000		25000
Brett Troyer	6000		17000
Greg Larson	4000		10500
Buffy Peterson	4000		10500
TOTAL SALARIES (year 3)	**22000**		**63000**
DIRECT COSTS:			
CONSULTANT/CONTRACTOR COSTS (See Note[(1)]) Water quality testing	2000 (MDH)		11400 MN Dept. of Health (MDH)
EQUIPMENT (ITEMIZE) Repair/ Replacement of Instrumentation	1900		1900
SUPPLIES Environmental Testing Supplies	500		1500
TRAVEL (In-state only)	500		1500
OTHER EXPENSES (i.e., testing) Permeability testing Vacuum and sweeping maintenance Pavement distress evaluation	1600		3100
TOTAL DIRECT COSTS (year 3)	**6500**		**19400**
TOTAL PROJECT COSTS			**82400**

Note[(1)]: Contracts for consultants/contractors will be processed by P.I. through Consultant Services and encumbered directly from LRRB accounts. Requisition for contract is sent through Research Services for coding of accounting information

BUDGET BY TASK:

Task No.	Description	[Lab]	(OES)	Contractor
1	Information Collection and Subsurface Exploration	[$7000]	($4500)	
2	Pavement Mix Design and Instrumentation Layout	[$10200]		
3	Trail Mixing, Possible Mix Redesign	[$5200]		
4	Construction of Test Section			
5	Pavement and Environmental Monitoring and Maintenance - Continuous	[$9000]	($9000)	$11400
6	Midproject Hydrological and Environmental Report	[$6500]	($8000)	
7	Draft Final Report	[$3000]	($2000)	
8	Final Report and Technical Blurb	[$4000]	($2600)	
	TOTALS	[$44900]	($26100)	$11400

BACKGROUND

Porous asphalt pavement for low-volume road construction is relatively new in Minnesota. It has been used more extensively in parking lot construction to provide storm water runoff and groundwater infiltration solutions. In October 2005, the Washington-Ramsey Watershed district installed a porous asphalt parking lot at their new district office in Little Canada, Minnesota. Dupont used porous asphalt on their company's parking lot in Delaware. Ford Motor Company constructed a porous asphalt parking lot at their Rouge River plant.

The US Environmental Protection Agency conducted an evaluation of porous asphalt parking lots. They found that the use of porous asphalt systems dramatically reduced the surface runoff volume and attenuated the peak discharge.

A full-scale porous asphalt pavement was built in 1993/1994 in a residential area in Northern Sweden. It was found that porous pavements have the potential to reduce melt water runoff, avoid excessive surface water during the snowmelt period, and accomplish groundwater recharge by local disposal of water by infiltration directly through the pavement. The porous asphalt pavement was also found to be more resistant to freezing and frost heave than a comparable impermeable asphalt pavement.

OBJECTIVE

The objective of this research is to examine the durability, effectiveness, and maintenance requirements of porous asphalt pavement in a low temperature environment (the MnROAD low volume road). A direct comparison of pavement performance will be made to an adjacent, impermeable asphalt surface.

Traditional impermeable asphalt pavement roadways generate significant stormwater runoff, requiring secondary treatment and storage systems such as detention ponds and associated right-of-way acquisition. This project will also examine the potential benefits of stormwater management by infiltration through porous pavement.

Porous asphalt roadways also have the potential to deliver traditional pavement functions, while minimizing contamination and temperature elevation of groundwater and surface water sources used for recreation and drinking water. Continuous monitoring of environmental effects, with a comparison to the adjacent impermeable pavement, will be performed and documented.

Other potential benefits of this technology will also be examined. These include reduced water spray & ponding, decreased ice formation (including subsurface ice), faster snow melt, reduced deicing chemical use, increased skid resistance, and vehicle noise attenuation.

SCOPE

The proposed research consists of the following:

- Construct a porous asphalt test section on MnROAD Low Volume Road with instrumentation.
- Monitor pavement performance on a regular basis in terms of low temperature cracking, rutting and ride. Compare pavement performance of different porous subcells constructed over clay and sand subgrade materials.
- Observe and document secondary effects such as reduced water spray, snow & ice conditions, and noise attenuation.
- Document the maintenance procedures and results; develop a policy concerning when to vacuum and/or sweep roads based on stormwater infiltration monitoring data.
- Monitor the volume of stormwater runoff and infiltration for direct comparison to a traditional, impermeable asphalt roadway.
- Test quality of surface and infiltrated water, including parameters of solids, pH, Chloride, Phosphorous, Nitrogen, heavy metals.

TASKS

Task 1: Information Collection and Subsurface Exploration

This task will identify existing porous asphalt pavements constructed in cold climates, particularly in Minnesota and surrounding neighbor states. Also, information related to porous asphalt pavement projects such as mix design and performance data will be collected if available.

This task also includes taking strategic borings for soils conductivity evaluation, and developing a baseline for piezometer and environmental contaminant levels. In order to describe the subgrade soils and model the groundwater flow, six borings will be taken within on the overall study section. Of these 6 borings, two shall be taken on each of cells 24, 25, and 26. Each of the borings shall be equipped with piezometers and automated piezometric / resistivity meters that shall be linked to the data collection system for continuous monitoring.

Deliverables for Task 1: Summary report detailing the following:

a) A short synthesis of current trends and updates in porous asphalt pavement.
b) A Geotechnical report of the subsurface conditions: the original piezometric (potentiometric) levels and the hydraulic conductivity.
c) Baseline environmental contamination and conditions report.

Duration of Task: August 2007 to April 2008

Task 2: Design of Pavement base and Instrumentation

Perform a design of the open-graded stone base, based on structural capacity and stormwater storage requirements. The test sections will have a porous HMA layer over a uniform (open) graded stone base, and a filter fabric layer above uncompacted plastic subgrade clay and sand soils.

Also, instrumentation to monitor pavement response and storm water temperature, infiltration, runoff, and water treatment effectiveness will be provided. Strain gauges to measure pavement strain, thermocouples, piezometers, and frost depth measurement devices will be installed in the pavement system.

Instrumentation layout will be performed with the following considerations:

- Harmonious and optimal installation with the adjacent pervious concrete cells and optimal selection of instrumentation to maximize effect and facilitate uniform testing.
- Instrumentation type, frequency, and interval of installations will also be described.
- Structural / Mechanical instrumentation will include time domain reflectometers and embedment sensors.
- Hydrological instrumentation includes tension infiltrometers, lysometers, tipping buckets, piezometers and resistivity meters.

Deliverables for Task 2: Summary report detailing the following:

a) A design of the pavement thickness, base structure, filter fabric recommendations, and cell separation and drainage requirements.
b) Detailed Instrumentation Layout.

Duration of Task: September 2007 to April 2008

Task 3: Mix Design, Trial Mix Testing, And Possible Mix Redesign

The Contractor will provide to Mn/DOT a porous asphalt mix design at least 2 months before paving. The asphalt mix design will be performed according to the MnROAD construction plan special provisions. The Contractor will submit to Mn/DOT the results of their design, as well as sufficient materials to duplicate the trial mix and all other required tests.

Trial mixes using the Contractor's design will be repeated in the Mn/DOT materials lab. The asphalt mixtures will be tested to obtain dynamic modulus and tested under an Asphalt Pavement Analyzer (APA) to determine rutting susceptibility. In addition, freeze-thaw and voids tests will be conducted on the mixtures to study mixture durability. Mn/DOT will recreate the mix, prepare a separate trial mix report, and may submit recommendations for design changes to the contractor, who will incorporate any changes in the final mix design before paving.

Deliverables for Task 3:

a) A pavement mix design for the porous asphalt surfacing.
b) A brief report detailing the trial mix report and recommendations.

Duration of Task: September 2008 (or 2 months before paving)

Task 4: Construction of Test Sections

Two porous asphalt test sections with curb & gutter and surface drains will be constructed on the MnROAD low volume road loop. One section will be constructed over a sand subgrade, the other over a clay subgrade. Curb & gutter and surface drains will also be added to an existing adjacent impermeable section to be used as a direct comparison of hydraulic effectiveness, durability, and environmental effects. This work will coincide with construction of two similar pervious concrete sections in adjacent cells, to be installed and monitored by separate research project. Material samples will be collected during construction for laboratory testing.

A report will be generated to document the construction process and the materials used. The report will also record and discuss instrumentation types, installation process, and as-built layout. It also will record a description of environmental / storm water measurement devices; cross drains, lysometers and soil borings taken in the vicinity of the test sections. It will discuss the adjoining control test cell that will serve as a baseline for hydraulic conductivity measurements and mechanical properties. This report will document the initial pavement surface characteristics using the Mn/DOT laser-equipped ASTM Circular Track Meter.

Deliverable for Task 4:

A Draft Construction and Instrumentation Report.

Duration of Task 4: (8 weeks after date of Paving) October 2008

Task 5: Pavement and Environmental Monitoring and Maintenance - Continuous

Falling Weight Deflectometer (FWD) and pavement friction tests will be performed 2 times per year. Pavement noise testing and detailed pavement distress surveys will be conducted on the test section periodically. Also, pavement sensor data will be collected to study the response of this type of pavement under traffic loading.

Storm water retention, infiltration, and runoff rates will be monitored monthly, and after major rain events, as well as quality and extent of water treatment observed. Temperature of the rainfall as it flows through the filter layers and at the outfall. For comparison, the adjacent nonporous, impermeable pavement section will have the same water testing and monitoring protocol.

Water quality samples to be taken by Mn/DOT personnel and sent to a laboratory to testing. The tests to be done on all water samples are: total solids, suspended solids, suspended volume solids, PH, total Chloride, total Phosphorous, total Kjeldahl Nitrogen, Total Nitrates+nitrite, total Zink, total lead, total mercury.

Surface cleaning and/or vacuuming will be performed on the porous pavement periodically to maintain permeability. Comparison to the impermeable adjacent section will help define the required surface cleaning or vacuuming maintenance rate. The maintenance method used, and any resulting change in permeability will be documented.

Noise, ride and texture measurements and splash and spray visibility index will be conducted seasonally after the initial post construction testing. These will be analyzed independently and in comparison to the cells in the Pavement surface characteristics MnROAD Studies Construction and Pavement Surface Characteristics (Rehabilitation) MnROAD Study. Noise shall be measured with the on-Board Sound Intensity metric and ride will be measured with the Mn/DOT Light weight profiler. Texture will be measured with the laser-equipped device that can capture clogging by averaging lesser texture on account of reduced porosity.

Surface properties will be measured once a month and analyzed. A protocol for quantification of splash & spray and texture specification will be proposed. Tension Infiltrometers shall be used to monitor hydraulic conductivity once a week in the first 2 months, and once every 2 weeks until snow and ice operations begin, where the rate will once again be once a week. Direct measurement of two, 5-gallon water buckets shall be performed at the same rate of testing as with the tension Infiltrometers. Sensor data will be uploaded to the central data collection system, and available upon request. Maturity data loggers will be placed in the asphalt and a maturity function for porous asphalt will be utilized.

Deliverables for Task 5:
First year pavement performance report
A power point presentation
Data from Continuous Monitoring
Technical Brief (Addendum to First Year performance report)

Duration Of Task: October 2009 (with 24 months of Continuous Data Collection Ending June, 2010)

Task 6: Midpoint Hydrological and Environmental Report

This task is aimed at examining the hydraulic and hydrologic data mainly to provide a mid-project evaluation of the test methods and frequency. The hydrological report includes a description of monitoring devices and related parameters, hydraulic conductivity tracking, and water quality sampling.

Groundwater upstream versus downstream will be analyzed and compared. This involves controlled boring, screening, and sampling - paying attention to deicing salts if applied and noting any observed pollutants and contaminants.

Deliverables for Task 6: Preliminary hydrological report including a critical evaluation of the hydraulic data collection process, hydraulic conductivity data, and environmental evaluation.

Duration of Task: (12th months after paving to 14th months after paving) November 2009

Task 7: Draft Final Report

Deliverable for task 7:
A draft final report and power point presentation will be generated.

Duration Of Task: June 2010

Task 8: Final Report and Technical Blurb

Deliverable for task 7:

A final report will document the porous asphalt pavement performance and effectiveness in a cold weather environment, under low volume traffic loading. Additionally, the hydrologic and environmental benefits of the pavement system will be discussed. Maintenance recommendations and schedule will be included. A final technical blurb will be published (similar to the executive summary).

Duration Of Task: September 2010

Timeline Based On Spring Construction Of Porous Asphalt Pavement

TASK	DESCRIPTION Precedent network Contingent on assumed Pavement Construction Window	QTR → / COST ↓	1 Sept 07 - Nov 07	2 Dec 07 - Feb 08	3 Mar 08- May 08	BEGIN CELL CONSTRUCTION	4 June 08 - Aug 08	5 Sept 08 - Nov 08	6 Dec 08 - Feb 09	7 March 09- May 09	8 June 09 - Aug 09	9 Sept 09 - Nov 09	10 Dec 09 - Feb 10	11 March 10- May 10	12 June 10 - Aug 10	13 Sept 10 - Nov 10			
1	Information Collection and Subsurface Exploration	$11,500	X	X	X														
2	Pavement Base Design and Instrumentation Layout	$10,200	X	X	X														
3	Trial Mixing, possible Mix Redesign	$5,200			X	X	X	X											
4	Construction of Test Section					X	X	X											
5	Monitoring and maintenance - Continuous	$29,400			X	X	X	X	X	X	X	X	X	X					
6	Midproject Hydrological and Environmental Report	$14,500									X	X							
7	Draft Final Report	$5,000											X	X					
8	Final Report, Tech Blurb	$6,600												X	X				
		$82,400																	

LITERATURE SEARCH

A design, maintenance and construction guide for porous asphalt pavements has been published by the National Asphalt Pavement Association (NAPA) with the focus on low volume roads, parking lots and recreational areas such as tennis courts and bike paths. Design applications and pavement system design are treated in this publication, however the cold weather design considerations and maintenance information that is provided is minimal.

The United States Environmental Protection Agency (EPA) has published a Porous Pavement Technology Fact Sheet, citing advantages and disadvantages of the technology. Advantages described are Pollutant removal, aquifer recharge, reduced stormwater structures, and improved safety. Disadvantages noted are inexperience with the technology, poor durability, potential direct groundwater contamination, and special maintenance requirements. The paper discusses the lack of data concerning maintenance, snow & ice removal issues, and cold weather durability.

Thomas Cahill, et al, at Cahill Associates outlined the benefits of porous asphalt pavements and effectiveness of various uses. Also, several examples are given in their literature review. They pointed out that deicing salts or chemicals normally used on conventional pavements might be reduced or even eliminated on permeable pavements since the remaining snow melts faster and quickly drains through the pavement surface. Porous asphalt may provide the added benefit of reducing groundwater and soil contamination from deicing chemicals.

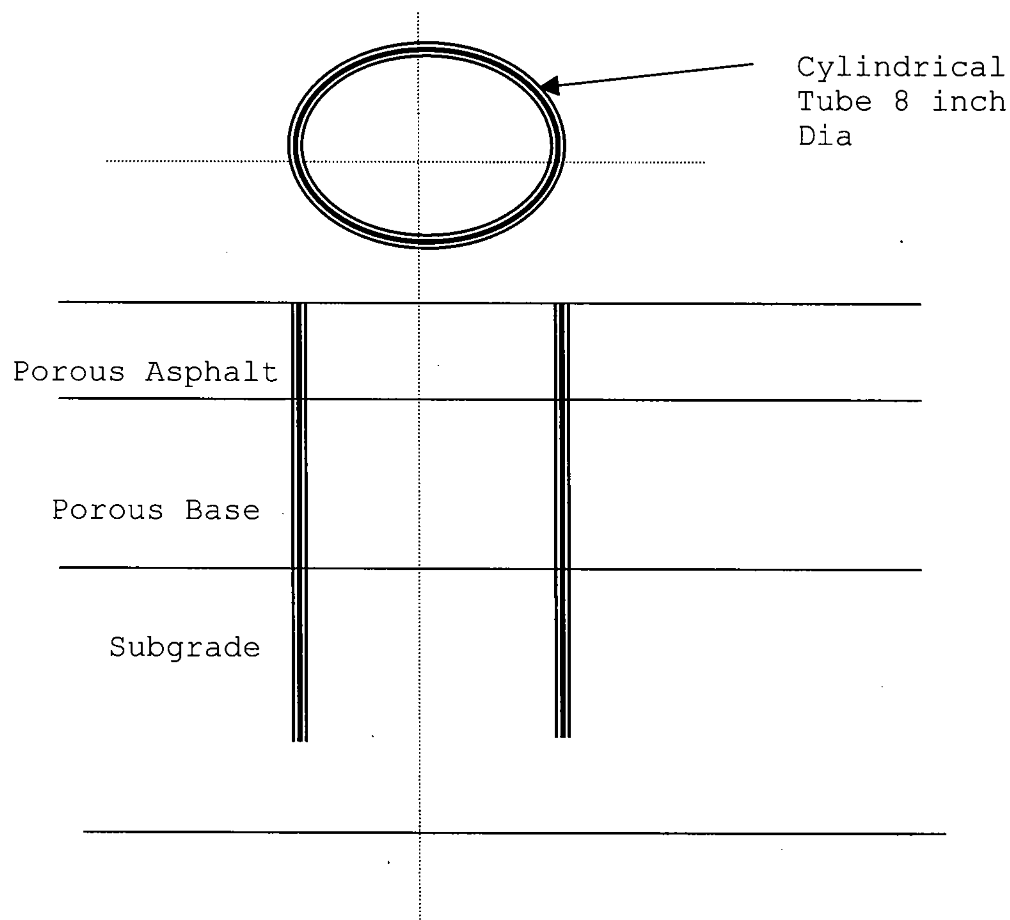
Several European countries have constructed porous asphalt roadways, and research has been performed in the Netherlands, France, United Kingdom, Italy, and Germany. The focus of most of the European research has been on durability, binder aging, polymers and fibers, and noise attenuation. In Japan, special polymer modified binders have been developed, and porous asphalt pavements are used extensively.

Magnus Backstrom PHD, of Lulea University, Lulea Sweden, documented the temperature variations and freeze-thaw resistance of the porous asphalt roadway section installed in Northern Sweden. His results indicate a higher resistance to freezing of the pavement and underlying base materials that impermeable asphalt, as well as more rapid thawing of the base materials in the porous asphalt. A decreased frost depth and shorter frost period demonstrated lower frost heave in the section as well.

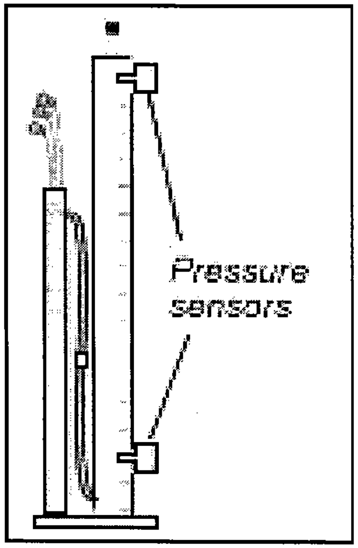
APPENDICES

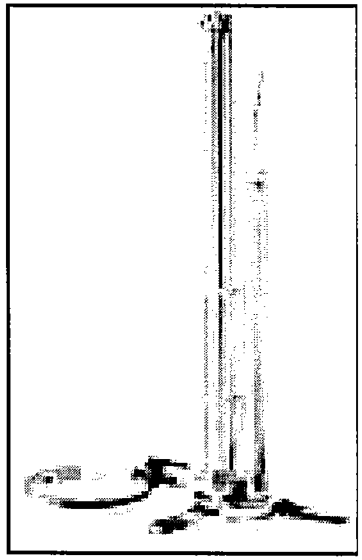
Appendix 1

Conceptual Instrumentation For Hydrologic evaluation
Frequency: 1 per porous HMA Sub-cell



Appendix 2 Pressure (Tension) Infiltrometers
One per porous HMA Subcell





Appendix 3

Conceptual Cell layout with various subgrade and pavement types but separated with transverse flow structures towards tipping buckets. This should be read in conjunction with a detailed instrumentation plan, which is a deliverable item.