Porous Asphalt Pavement Performance In Cold Regions

LRRB INV 878

Task 6 report

Submitted by:

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CHAPTER 1 INTRODUCTION

1.1 Background

Porous asphalt pavement consists of bituminous asphalt pavement with greatly reduced fine aggregate particles and a relatively high (20%) void content. The surface permeability and high porosity allows water to pass directly into the base material underneath the pavement. The base material aggregate typically used is clean, uniformly graded, and deep enough to allow sufficient water storage while allowing infiltration into the subgrade soils.

Environmental permits from Minnesota Pollution Control Agency [1] and Capital Region Watershed District [2] that require stormwater runoff to be treated will be including requirements to retain, at a minimum, the first ½ inch of runoff. Practices include the direct infiltration of stormwater. This portion of the porous pavement research is to monitor and measure the environmental effects of stormwater runoff as it passes through the pavement profile and into the subgrade soils. Monitoring and measuring will be done both electronically (capturing rainfall and temperatures) and manually (collecting water samples and temperatures). Outcomes from the data gathering and water sampling will help provide tools to meeting Best Management Practices for stormwater treatment prior to discharge to resource waters. Using information from research in other countries will help confirm and add to our data to developing good practices. This information will be provided in the final report.

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 be measured thru electronic monitoring and at the outfall when water samples are taken. For comparison, the adjacent nonporous, impermeable pavement section will have the same water testing and monitoring protocol.

Water sampling plan is to take samples after 1 inch or greater rain events. The water quality samples are taken by Mn/DOT personnel and sent to a laboratory for 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, and
- total Mercury

Adjustments to the sampling plan can be made to reduce the amount of samples taken in a given year to spread the costs of the tests over time rather getting all test don in a given year. Samples from some ports could not be taken since there was no water to take samples. We have limited our sampling to these ports this next year and modified the time to take samples to during a storm event which will rely on Mn/ROAD staff to get the samples.

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.

CHAPTER 2 SITE CONDITIONS

2.1 Site Description

Research is taking place at MnDOT's MnROAD facility located in Central Minnesota. The site is along Interstate 94 near Albertville and Monticello Minnesota. Our test sections are located on the low volume loop road adjacent to the westbound lanes of Interstate 94. **(Figure 2.1)**

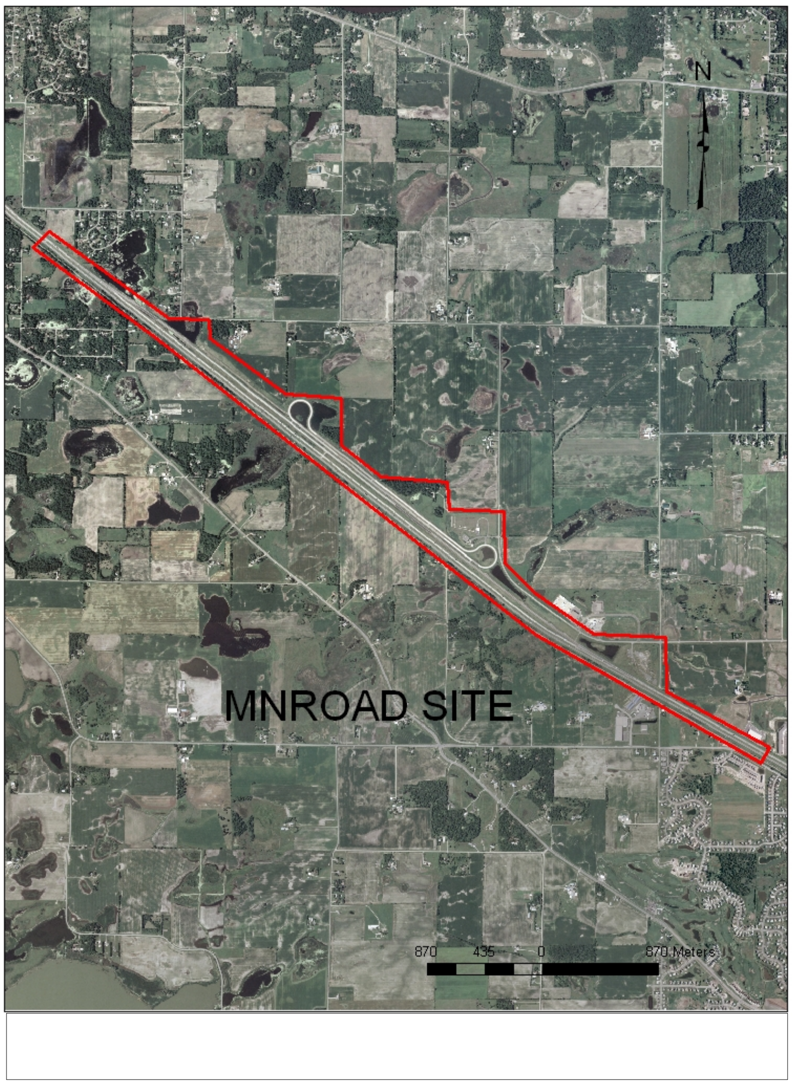


Figure 2.1
MnROAD Site Location

Weather information gages are located at each end of the MnROAD facility and data is electronically provided every 15 minutes. Data helpful for our use include air temps and rainfall. The test sections are located at the western end of the loop road and about 1 mile from each of the weather stations. The cells are numbered from west to east; porous asphalt cell number 86 is the western most of the cells and has sand as the subgrade. Cell 87 is the nonporous bituminous pavement, and is the control section. Porous asphalt cell 88 has clay as the sbgrade. **Figure 2.2** provides the layout view. **Appendix A** provides a cross sectional view of each section and the location of the cells on the Low volume road.

Figure 2.2
Porous Cell Location

Each test section is equipped with a tipping bucket that captures surface runoff. Each tip of the bucket is electronically collected and has a monitoring port to collect water samples. **Figure 2.3** and **Figure 2.4** shows the tipping bucket assembly and installation.

Figure 2.3
Tipping Bucket Assembly

Figure 2.4
Tipping Bucket Installation

The original plan provided for lysimeters to capture runoff as it passes thru each of the porous sections to measure volume and also provide an opportunity to obtain water samples. During construction of the sections the lysimeters were not installed due to some constructability issues. To provide opportunity to gather storm water runoff as it filters through the porous pavement, water sample ports were installed at the end of each porous pavement section. These are labeled Port 86 and Port 87. These were used to take samples of water for water quality testing. **Figure 2.5** provides the relative location of each of the porous pavement sections along with the tipping bucket and water sampling ports. **Figure 2.6** shows the field location of the sample port for cell 86. **Figure 2.7** provides the field location of the tipping bucket for cell 88.

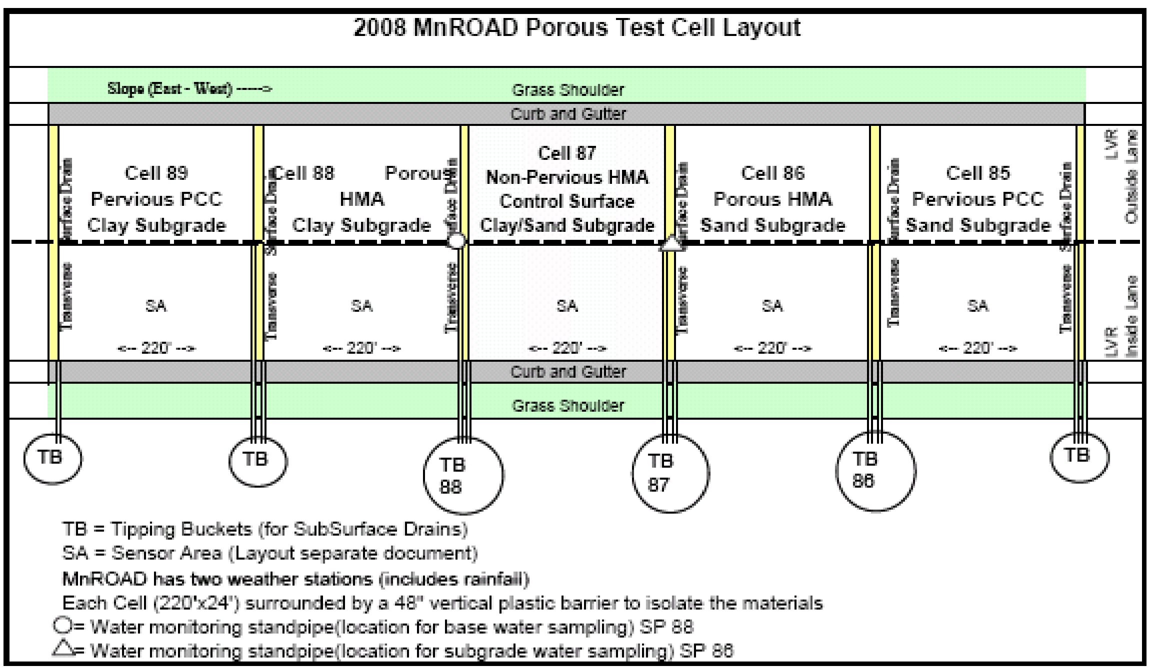


Figure 2.5
Cells & Tipping Bucket Locations

Figure 2.6
Cell 86 Sample Port

Figure 2.7
Cell 88 Tipping Bucket Sample Port

Ground water wells are located on the project to provide background data. These are labeled T3MW (Well Number 1) and T4MW (Well Number 2) in **Figure 2.8**.

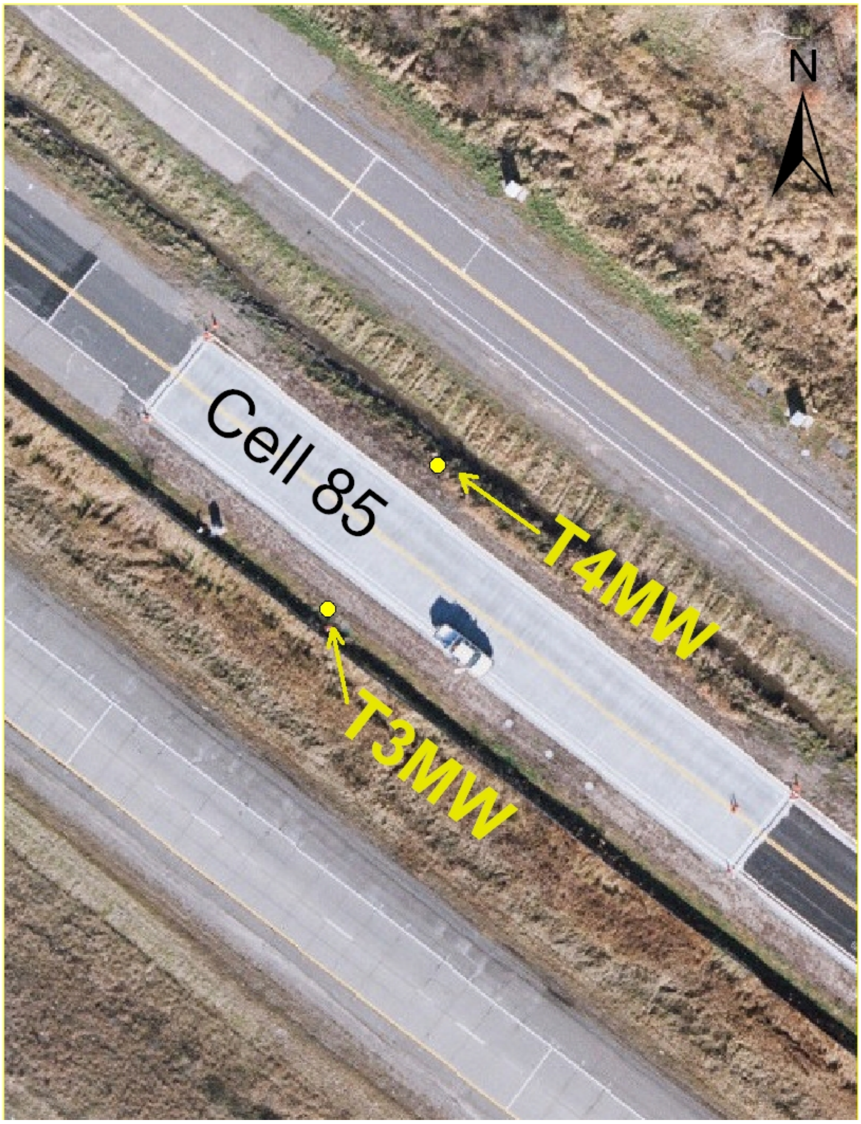


Figure 2.8

Groundwater Monitor Wells

The last of the instruments for monitoring environmental effects are thermocouples to measure pavement temperature. Cell 19 is the baseline section. Cells 86 and 88 also have these installed. **Table 2-1** provides the label and depth of each thermocouple sensor in each of the cells.

Table 2-1
Thermocouple Sensor Locations

Cell 19	Cell 86	Cell 88	Depth from surface (in)
101	SEQ 17	SEQ 1	0.5
102	SEQ 18	SEQ 2	1.5
103	SEQ 18	SEQ 3	2.5
104	SEQ 20	SEQ 4	3.5
105	SEQ 21	SEQ 5	4.5
106	SEQ 22	SEQ 6	6
107	SEQ 23	SEQ 7	9
108	SEQ 24	SEQ 8	12
109	SEQ 25	SEQ 9	15
110	SEQ 26	SEQ 10	18
111	SEQ 27	SEQ 11	24
112	SEQ 28	SEQ 12	30
113	SEQ 29	SEQ 13	36
114	SEQ 30	SEQ 14	48
115	SEQ 31	SEQ 15	60
116	SEQ 32	SEQ 16	72

Changes that occurred from our initial scope found in task report 1 and 2 are as follows:

- Locations of the test cells were moved further away from the baseline ground water wells, therefore further analysis will be needed to determine direct correlation to contaminants into the ground water. However we can still provide information of the contaminant levels of each cell.
- Demonstrations of porous asphalt pavement vacuuming were performed on November 9, 2009 and September 6, 2010. Porosity tests were conducted before and after vacuuming. Since vacuuming was done at prescribed times, further analysis will be needed to determine maintenance intervals for vacuuming.
- Lysimeters were not installed as planned due to constructability issues. These were going to be used to determine infiltration rates and provide water sampling to determine filtration capabilities of the pavement or leaching of chemicals from the pavement. However using the porosity tests before and after vacuuming will allow us to analyze the infiltration rates.
- Sampling ports were installed at the end of each section. Installing these sampling ports provided us with the water sampling capabilities.

CHAPTER 3 ENVIRONMENTAL CONDITIONS

3.1 Introduction

Data obtained from this research will provide more information regarding the environmental benefits of porous pavement roads in cold climates both for structural and water quality purposes. The Mn/Road facility provides excellent opportunities to meet these goals.

3.2 Rainfall

Total rainfall for 2009 was 26.5 inches and for 2010 the rainfall total was 27.7 inches. The months that had more significant rainfalls were June, August, October of 2009; and May, June, July, August of 2010. Rain events of 1 inch or greater in a 24 hour period were used for analysis. During the 2009 and 2010 there were **10** events that met this criterion. Rainfall information taken from the weather station measurements will also be used to calculate the expected volume runoff of the porous sections. These events will be compared to the tipping bucket volumes in the same 24 hour events. Comparing these results will help determine when porous sections start to clog. Water samples were also taken to compare water quality. **Figure 3.1** shows the October 2, 2009 event which had 1.2 inches in a 24 hour event.

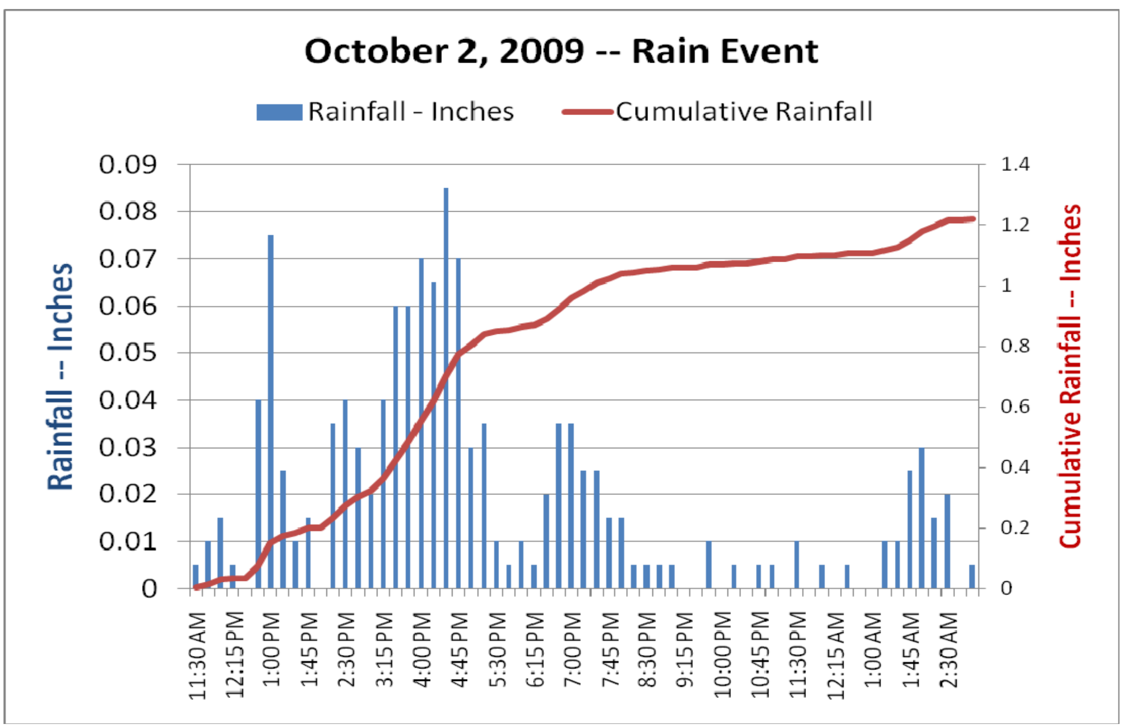


Figure 3.1
Rainfall Event

Figure 3.2 shows the same rain event triggering tipping bucket for Cell 86 (porous over sand), Cell 87 (standard pavement), and Cell 88 (porous over clay).

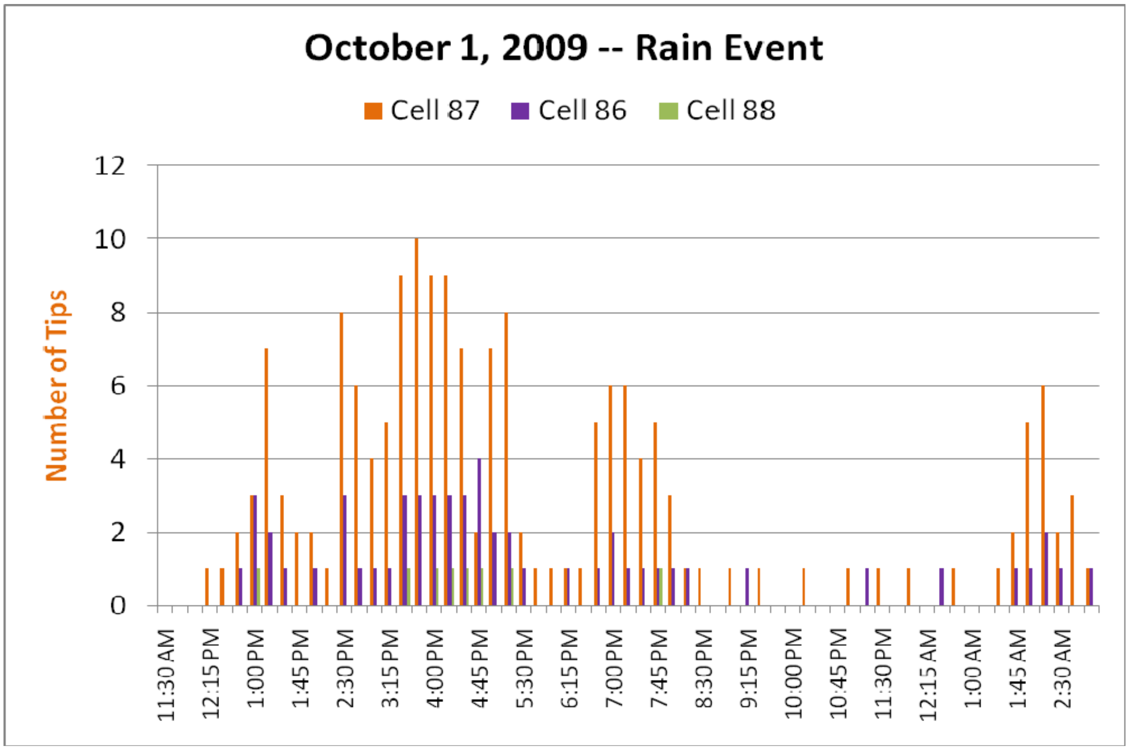


Figure 3.2
Tipping Bucket Event

3.3 Groundwater

The groundwater elevations were measured for Well Number 1 at 951.35 feet and Well Number 2 at 940.15 feet. This is a quite large gradient since the distance between the wells is 30 feet. Further investigation will be needed to determine the differences. Ground water elevations taken from cell 86 will be compared to see if there are changes to ground water elevations under pavements and to help determine ground water flow. Samples were also taken for water quality.

3.4 Overland flow

Drainage areas of each cell will be from the rain falling on each section with no other overland flow occurring from adjacent areas. Runoff volumes were measured from the surface of each test section, including the control section which is an impervious dense graded bituminous surface.

Runoff data was calculated two ways and comparisons made. The expected volume of water for each cell was calculated using the rainfall events and the surface areas of each cell. The actual runoff volume of water from each cell was calculated from the tipping buckets. **Table 3-1** shows the area of each cell, both porous and non porous. **Table 3-2** shows the capacity of each tipping bucket.

Table 3-1 Cell Areas								
AREA (ft^2)				**Percentage Area**		**Acreage**		
Cell	**Porous**	**Non Porous**	**Total**	**Porous**	**Non Porous**	**Porous**	**Non Porous**	**Total**
86	5824	1408	7232	80.5%	19.5%	0.1337	0.0323	0.1660
87	0	7232	7232	0.0%	100.0%	0.0000	0.1660	0.1660
88	5824	1408	7232	80.5%	19.5%	0.1337	0.0323	0.1660

Table 3-2

Capacity of each bucket:

Gallons per tip	
Gallons	Tip
16	1

As shown in **Appendix B** there are some inconsistencies with the outcome of the data. For the non porous pavement, cell 87, expected and actual should match up more closely than shown. February 2010 shows no readings for the tipping buckets when there was actual rainfall that occurred. To make a more complete analysis we will need to physically check that the tipping buckets work on a weekly basis in order to get consistent data and to make conclusions regarding runoff verses infiltration volumes. Also we will need to calibrate each of the tipping buckets to verify the volume of each tip.

For purposes of this report we have selected October 2, 2009 rainfall event to compare data gathered as shown in **Table 3-3** and **Figure 3.1** and **Figure 3.2**.

Table 3-3 Runoff Volumes (gallons)										
Day	Rainfall	Cell 86 surface runoff			Cell 87 surface runoff			Cell 88 surface runoff		
		Expected	tips	Actual	Expected	Tips	Actual	Expected	Tips	Actual
Oct 2, 2009	1.22	1070	56	896	5500	170	2720	1070	8	128

CHAPTER 4 WATER QUALITY

4.1 Introduction

Minnesota waters are broken up into beneficial use categories and there are different water quality standards for each of these categories. The beneficial uses of waters are taken from Minnesota Rules Chapter 7050 and are grouped into 7 classes. Below are general definitions of each class:

- Drinking water - Class 1
- Aquatic life and recreation - Class 2 (sometimes shortened to “fishing and swimming”)
- Industrial use and cooling - Class 3
- Agricultural use, irrigation - Class 4A
- Agricultural use, livestock and wildlife watering - Class 4B
- Aesthetics and navigation - Class 5
- Other uses - Class 6
- Limited Resource Value Waters - Class 7

Each of the classes may be broken into subclasses and each has specific water quality standards. For our purposes results will be compared to Class 2a and 2b waters.

4.2 Sampling Methods

Water quality samples were taken based in the sampling and analysis plan. Samples were taken from ground water wells; Well 1 and Well 2, tipping buckets; TB86, TB88, and Sample Ports; SP86, SP88. Samples were taken using an ISCO well pump **(Figure 4.1**). Four water samples were taken from each sampling tube; 1 liter for general, 250 ml for nutrients, 250 ml metals, and 125 ml mercury. Mn/DOT water quality and testing unit personnel measured water temperature, turbidity, dissolved oxygen, pH, and specific conductance. Samples were also sent to the Department of Health for additional tests. The Department of Health tests include: turbidity, conductivity, suspended volatile solids, suspended solids, total volatile solids, total solids, chloride, nitrogen, phosphorous, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc.

Figure 4.1
Sampling for port 86 (SP86)

4.2.1 Groundwater Test Results

Baseline groundwater samples were taken at 3 different dates during 2008. Comparing test samples with water quality standards for class 2 waters, the ground water was above standards for copper, lead, and suspended solid. This data will be compared to runoff and groundwater sampling of the test sections to measure the effectiveness of the porous surface system and underlying soils. Surface runoff samples from the control section will need to be taken to be used as baseline information. The groundwater testing results and water quality standards are attached in **Appendix E**. These results will be used to monitor concentrations in the surface water runoff, how the porous pavement system filters these contaminants and if, or how, they impact the groundwater levels. Preliminary results show that background concentration levels fall within the water quality standards. Runoff from the pavement is typically lower in concentrations of the tested parameters than the ground water. The data is inconclusive for filtering capabilities of the porous pavement of the tested parameters.

4.2.2 Surface Water Testing

Water quality samples were taken from the tipping buckets from cell 86 and 88. These are labeled TB86 and TB88 in **Figure 2.5.** We will need to collect surface runoff for cell 87 (TB87) to make final conclusions. Preliminary results show that surface runoff has no measurable impacts to ground water. Test data is shown in **Appendix E.**

4.3 Filtration Testing

Originally the samples were going to be taken from lysimeters but due to construction issues these could not be installed. Instead sampling tubes were installed at the end sections of each cell. Water quality samples were taken at cell 86 and 88 but only two samples were taken in cell 88 since there was no water observed at the other times. Sampling methods need to be adjusted at cell 88 to provide proper analysis. We will need to take samples from cell 88 immediately after rainfall events happen. This data will give us better opportunity to analyze and develop conclusions.

Since Cell 86 sampling port is in ground water directly below the porous pavement we can make some good comparisons with the background tests for Well 1 & Well 2. Test samples taken for Cell 86 (SP86) shows that the turbidity, copper and lead are higher than water quality standards for class 2 waters and background levels in Well 1 and Well 2. Surprisingly the concentrations of chlorides increased with each sample. These were below water quality standard for chlorides but did generate some concerns as to why the increase. Further monitoring and investigation will be completed this next year to help answer the high concentrations of these parameters. Test data is attached in **Appendix E**

4.4 Temperature Monitoring

Temperature probes are located in Cell 86 (porous over sand), Cell 23 (standard pavement), and Cell 88 (porous over clay). The probes range in depth from 0.5 inches to 72 inches. Electronic conductance measurements were taken at 15 minute intervals and these measurements were translated to temperatures. These are temperatures of the ground and not the storm water as it flows through the soil, but one can assume that as the water passes thru these layers of soil that the water will be approaching these temperatures. For these purposes we will look at the temperatures for August and October 2009. **Figure 4.1** and **Figure 4.2** shows the pavement temperatures 0.5 inches below the surface for cell 23 and cell 88 for August and October of 2009. Note that the porous surface shows more moderate temps vs. the non porous surface. **Figure 4.3 and Figure 4.4** show temperatures of October 6, 2009 during a storm event that had 1.41 inches of rainfall in a 24 hour period. Comparing the air temperatures to the pavement sections shows that the porous sections are consistently higher than conventional pavements. We would like to include similar comparisons for warmer months with similar rain events but did not have that for 2009 since some of the instrumentation was not working properly. This will be added in the final report. We would like to assume that the underlying depths of the porous pavement are cooler than air temps and surface temps. This would show that the air voids in the porous sections act as a thermal layer providing warmer temps in cooler climate conditions and cooler temps in warmer climate conditions.   During summer months the porous pavement sections could be used as part of a treatment train to cool storm water prior to discharge to resource waters. This theory will be proven or dismissed after further study.

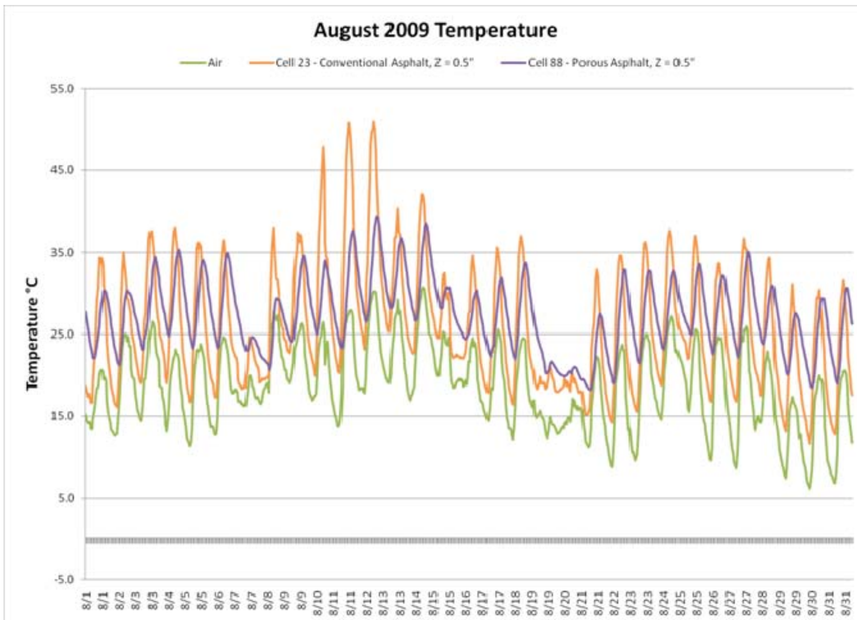


Figure 4.2
August 2009 Air & Pavement Temperatures

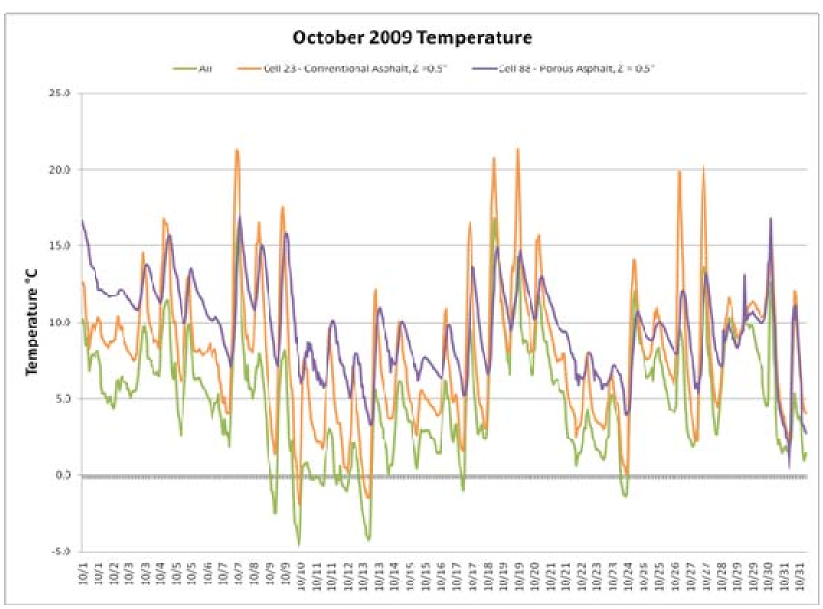


Figure 4.3
October 2009 Air & Pavement Temperatures

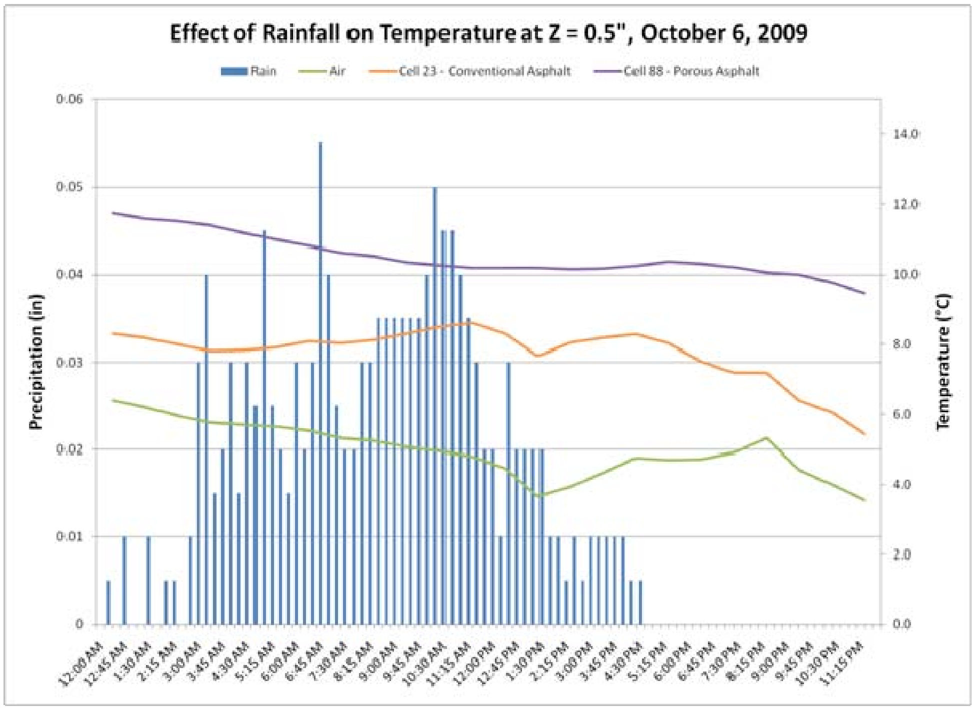


Figure 4.4
October 6, 2009 Temperatures

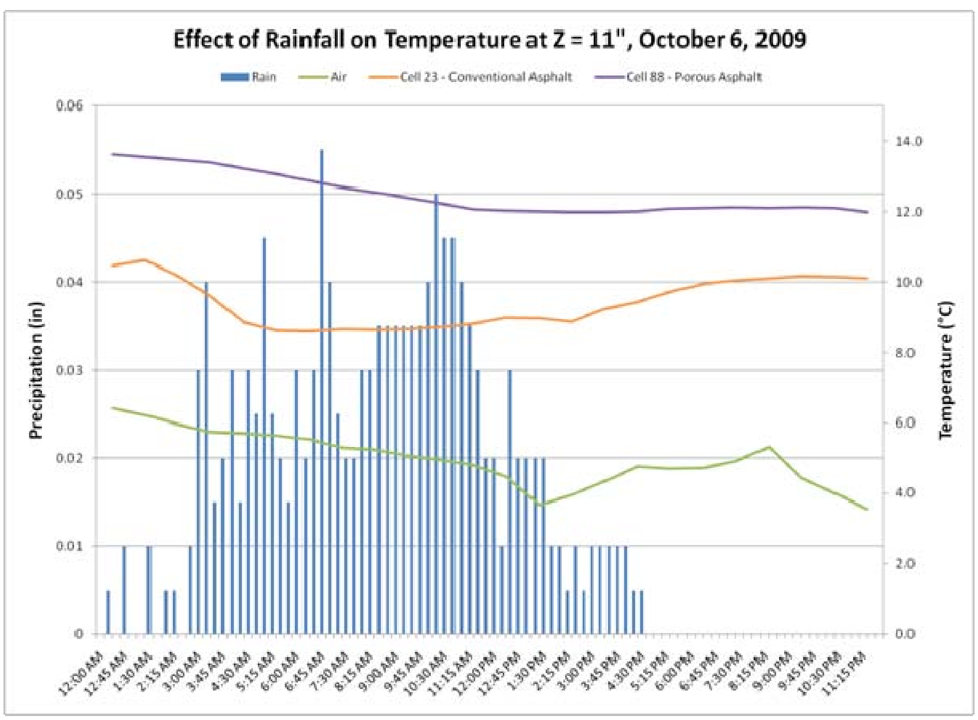


Figure 4.5
October 6, 2009 Temperatures

CHAPTER 5 CONCLUSIONS

5.1 Filtration

- We will need to take samples from cell 88 immediately after rainfall event happens.

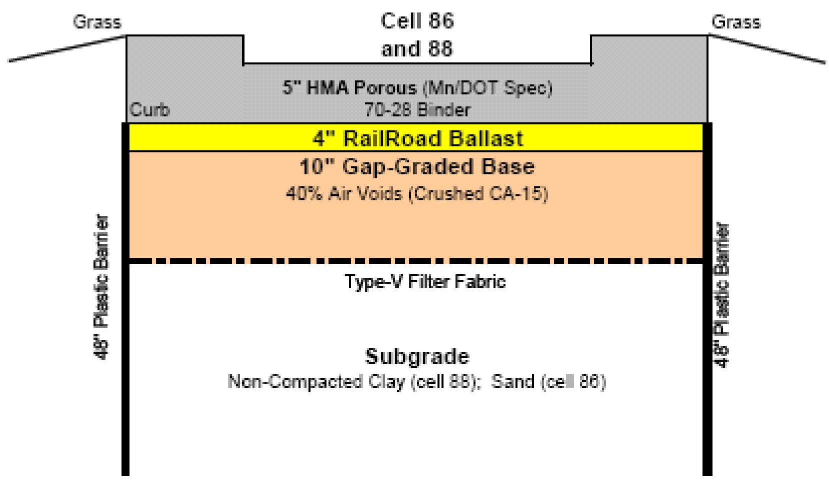
5.2 Water Quality

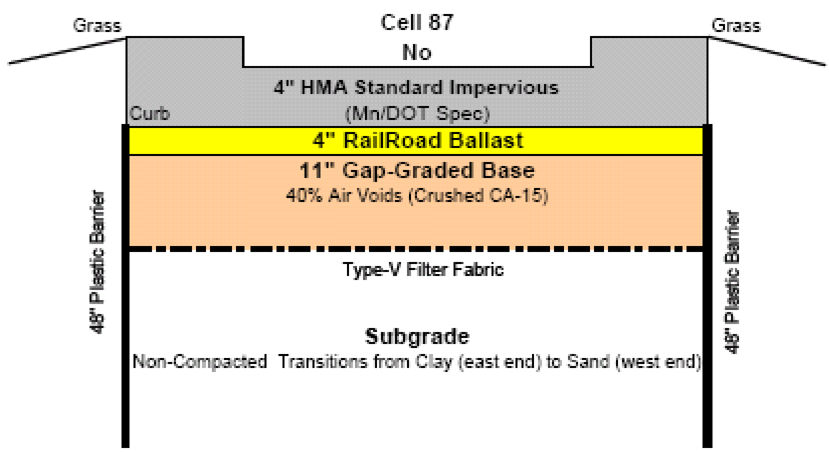
- Concentrations of Chlorides were of concern. Since the runoff concentrations were around .5 mg/l and the concentrations were increasing in the ground water at cell 86 and at levels in of 70 mg/l and higher. Further monitoring and investigation will need to be completed this next year to help answer the high and increasing concentrations.
- Surface runoff samples from the control section will need to be taken. This data will be used as baseline information.
- Water depths in SP 88 will need to be monitored soon after a storm event and samples taken when there is sufficient water depth to take samples.

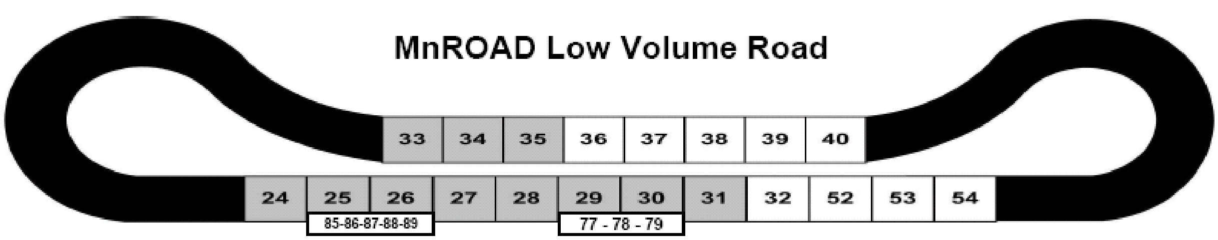
5.3 Tipping Buckets

- The expected vs actual stormwater runoff indicates a significant discrepancy in measurement. We will need to physically check that the tipping buckets work on a weekly basis in order to get consistent data and to make conclusions regarding runoff verses infiltration volumes.
- We will need to calibrate each of the tipping buckets to verify the volume of each tip.

Appendix A
Pervious Cells Cross Section & Layout



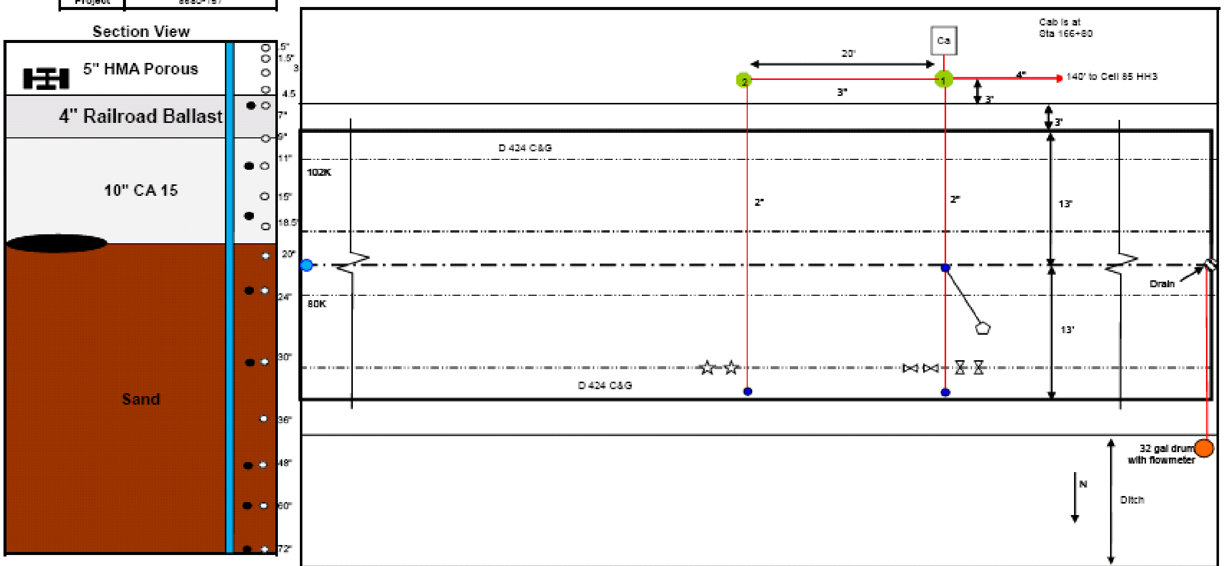




Porous Cell Sample Wells

MnROAD Instumentation Summary, Porous HMA over Sand

Cell	86
Project	8680-157



Sensor Requirement

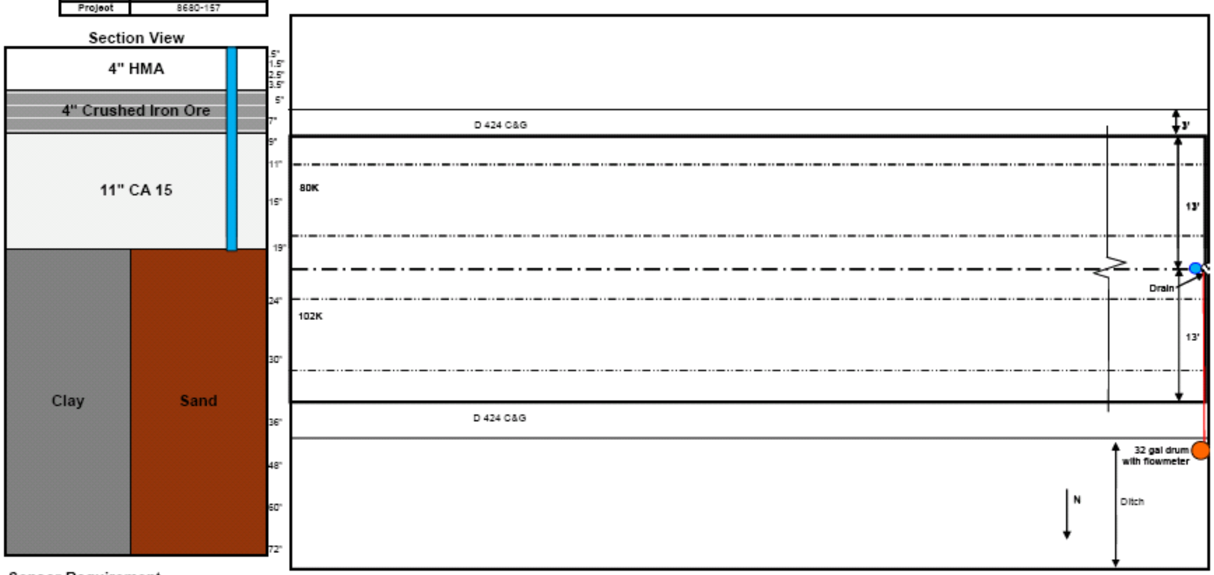
Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Decagon ECH_2O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitdinal (LE) strain gauge-measures longitdinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend

	Risers		Wheelpath (9.5' offset from CL)
	Centerline		Chain Link Fence
	LE Sensors		Conduit
	TE Sensors		TC Sensors
	PG Sensor		EC Sensors
	TC/ M Sensors		
	Handhole		Groundwater sampling standpipe

MnROAD Instumentation Summary, Pervious/Porous Control Section

Cell	87
Project	8680-157



Sensor Requirement

Code	Number	Sensor	Description
TC	0	ThermoCouple (Temperature	Measures Temperature - installed in a Thermal Couple Tree to a depth of 8' from the surface
EC	0	EcH2O-TE (Moisture)	Measure volmetric moisture content, temperature, electric conductivity
TE	0	TE Sensor	Embedded transverse strain gauge-measures transverse strain at the bottom of bound layers
LE	0	LE Sensor	Embedded longitdinal strain gauge-measures longitdinal strain at the bottom of bound layers
PG	0	PG Sensor	Measures normal stress at base/subgrade interface

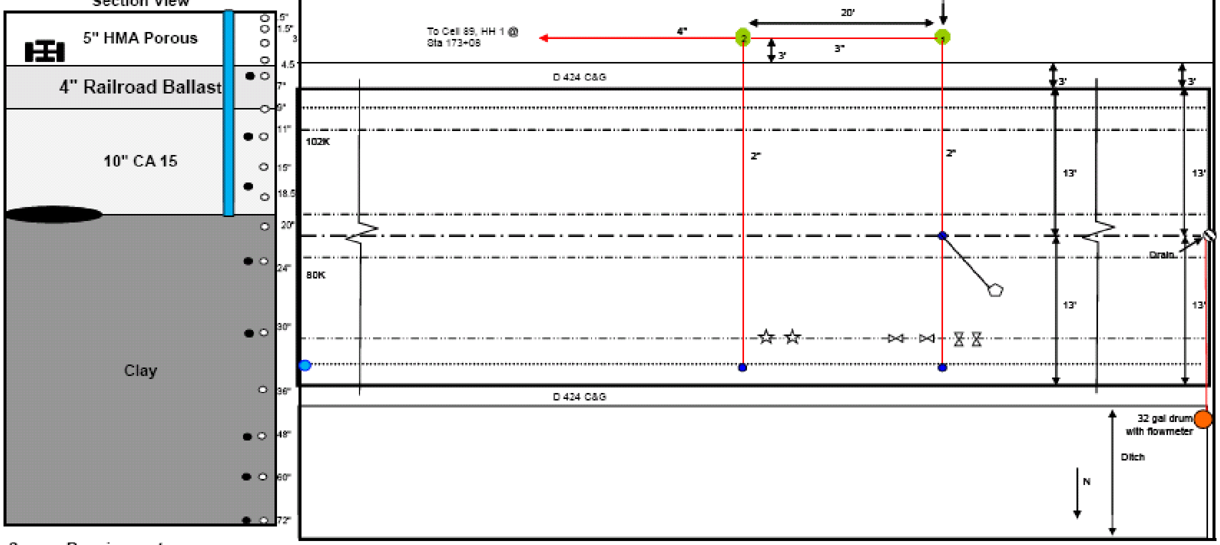
Legend

	Risers		Wheelpath (9.5' offset from CL)
	Centerline		Chain Link Fence
	LE Sensors		Conduit
	TE Sensors		TC Sensors
	PG Sensor		EC Sensors
	TC/ M Sensors		
	Handhole		base water sampling tube

MnROAD Instumentation Summary, Porous HMA over Clay

Cell	88
Project	8680-157

Section View



Sensor Requirement

Code	Number	Sensor	Description
TC	16	ThermoCouple (Temperature)	Measures Temperature - Installed in a Thermal Couple Tree to a depth of 6' from the surface
EC	8	Dedcagon ECH_2O-TE (Moisture)	Measures volmetric moisture content, temperature, electric conductivity
TE	2	CTL Strain Gauge, TE	Embedded transverse (TE) strain gauge-measures transverse strain at the bottom of bound layers
LE	2	CTL Strain Gauge, LE	Embedded longitidinal (LE) strain gauge-measures longitidinal strain at the bottom of bound layers
PG	2	Geokon Pressure Cell, PG	Measures normal stress at base/subgrade interface

Legend			
	Risers		Wheelpath (9.5' offset from CL)
	Centerline		Chain Link Fence
	LE		Conduit
	TE		TC Sensors
	PG Sensor		EC Sensors
	TC/ M Sensor		
	Handhole		base water sampling tube

Appendix B
Rainfall and Tipping Bucket Data for 2009-2010

Month	Rainfall	Cell 86 surface runoff			Cell 87 surface runoff			Cell 88 surface runoff		
		Expected	tips	Actual	Expected	Tips	Actual	Expected	Tips	Actual
Jan09	0.17	149			766			149		
Feb09	0.81	711			3651			711		
Mar09	2.4	2106			10819			2106		
Apr09	0.98	860			4418			860		
May09	0.67	588			3020			588		
Jun09	3.455	3032			15575			3032		
Jul09	3.72	3265			16770			3265		
Aug09	6.29	5520			28355			5520		
Sep09	0.765	671	6	96	3449	45	720	671	12	192
Oct 09	**5.4**	**4739**	**179**	**2864**	**24343**	**1007**	**16112**	**4739**	**33**	**528**
Nov09	0.555	487	10	160	2502	126	2016	487	1	16
Dec09	1.365	1198	1	16	6153	146	2336	1198	4	64
Jan10	0.425	373	3	48	1916	19	304	373	38	608
Feb10	0.24	210	0	0	1082	0	0	210	0	0
Mar10	1.18	1036	149	2384	5319	0	0	1036	1	16
Apr10	1.865	1637	82	1312	8407	107	1712	1637	50	800
May10	2.685	2356	114	1824	12104	11	176	2356	55	880
Jun10	**6.83**	**5994**	**208**	**3328**	**30789**	**30**	**480**	**5994**	**94**	**1504**
Jul10	3.14	2756	56	896	14155	14	224	2756	107	1712
Aug10	**3.67**	**3221**	**78**	**1248**	**16544**	**2**	**32**	**3221**	**39**	**624**
Sep10	5.87	5152	249	3984	26462	3	48	5152	109	1744
Oct10	1.875	1646			8452			1646		

APPENDIX C
Water Quality Testing Results

Sample Ports (SP 86 & SP 88)

Well #	Cell 86 (East end in middle) SP 86								Cell 88W (West end in middle) SP88	
Sample date	05/11/09	06/10/09	06/17/09	07/21/09	08/17/09	08/20/09	10/02/09	8/13/2010	06/10/09	07/21/09
Time	10:57	12:22	10:41	12:17	11:00	10:05	9:00	11:00	12:38	12:30
Pre-sample depth to water (ft.)	2.6	3	4.12	2.86	N/A	2.15	4.18		1.45	1.51
Conductivity (umhos/cm)	680	650	740	780	750	810	880	1100	440	360
Turbidity (NTU)	3900	260	98	12	4.9	16	19	62	93	63
Suspended Vol. Solids (mg/L)	300	25	10	2.8	1.6	1.6	2.4	7.6	5.3	2.8
Suspended Solids (mg/L)	4600	350	140	25	11	27	20	130	81	37
Solids, Total Volatile (mg/L)	320	110	130	93	82	87	190	170	67	79
Solids, Total (mg/L)	4900	780	600	490	470	520	600	760	400	330
Nitrate+Nitrite Nitrogen, Total (mg/L as N)	2.1	2.3	2.3	2.5	2.8	4	2.5	2.5	1.1	1.1
Kjeldahl Nitrogen, Total (mg/L)	3.19	0.54	0.3	0.42	0.66	0.35	0.24	0.36	0.92	0.65
Phosphorus Total, LL (mg/L as P)	2.95	0.46	0.173	0.213	0.089	0.088	0.075	0.149	0.321	0.305
Chloride, Total (mg/L)	72.9	70	80.7	82.5	96.7	115	127	182	50	21.8
Cadmium LL (ug/L)	4	0.5	0.17	0.18	<0.10	0.15	0.12	0.21	<0.10	<0.10
Chromium LL (ug/L)	150	25	9.2	10	4.1	6.6	6.7	9.17	11	10
Copper (ug/L)	290	41	10	17	37	18	8.4	16.8	39	17
Iron HL, Tot (ug/L)	190000	23000	4500	6300	830	490	1700	4220	3500	3500
Lead (ug/L)	89	10	2.1	3	<1.0	<1.0	1	2.46	1.6	1.8
Mercury (ug/L)	N/A	0.04	0.02	0.02	<0.01	<0.01	0.08	0.024	0.03	0.03
Nickel LL (ug/L)	210	31	9.6	12	4.5	2.7	6.6	10.3	6.3	5
Zinc HL (ug/L)	260	41	11	15	<10	<10	<10	11.8	10	<10
Temp (deg C)	13.49	17.62	19.09	22.09	21.52	21.74	19.72		16.82	24.69
PH	6.73	7.18	7.53	7.37	7.04	7.25	6.74		9.11	9.12

Runoff Water Quality

Sample Port #	TB Cells 88 & 89		TB Cells 86 & 87	
Sample date	6/9/2010	8/13/2010	6/9/2010	8/13/2010
Time	10:10	11:30	10:15	11:20
Pre-sample depth to water (ft.)				
Conductivity (umhos/cm)	56	49	96	71
Turbidity (NTU)	1.4	7	2.9	3.8
Suspended Vol. Solids (mg/L)	1.2	2.4	<1.0	2.8
Suspended Solids (mg/L)	2	10	1.2	12
Solids, Total Volatile (mg/L)	<10	11	18	21
Solids, Total (mg/L)	52	44	80	64
Nitrate+Nitrite Nitrogen, Total (mg/L as N)	0.18	0.2	0.78	0.29
Kjeldahl Nitrogen, Total (mg/L)	<0.20	0.34	0.43	0.55
Phosphorus Total, LL (mg/L as P)	0.032	0.071	0.037	0.05
Chloride, Total (mg/L)	<0.500	0.548	0.911	0.964
Cadmium LL (ug/L)	<0.10	<0.10	<0.10	<0.10
Chromium LL (ug/L)	0.76	1.17	0.9	1.25
Copper (ug/L)	<1.00	<10.0	1.79	<10.0
Iron HL, Tot (ug/L)	40.8	365	85.3	253
Lead (ug/L)	<1.0	<1.0	<1.0	1.18
Mercury (ug/L)	0.011	0.02	<0.010	0.025
Nickel LL (ug/L)	<1.0	<1.0	1.74	1.57
Zinc HL (ug/L)	46.2	18.4	75.6	30.2

Groundwater Water Quality

Well #	Well 1 (T3MW Cell 25)			Well 2 (T4MW Cell 25)		
Sample date	03/04/08	06/18/08	11/20/08	03/04/08	06/18/08	11/20/08
Time	11:45	12:00	12:20	13:15	12:45	13:00
Pre-sample depth to water (ft.)	9.55	6.75	8.4	21.45	10.65	12.42
Conductivity (umhos/cm)	710	730	740	1100	1500	1400
Turbidity (NTU)	78	92.4	na	100.3	7.9	178.1
Suspended Vol. Solids (mg/L)	6.7	16	32	4.7	5.2	3.3
Suspended Solids (mg/L)	75	240	540	68	90	80
Solids, Total Volatile (mg/L)	120	130	140	180	250	200
Solids, Total (mg/L)	560	930	1100	820	1200	1100
Nitrate+Nitrite Nitrogen, Total (mg/L as N)	<0.05	<0.05	<0.05	2.4	<0.05	0.55
Kjeldahl Nitrogen, Total (mg/L)	1.06	1.66	0.43	1.81	1.45	0.57
Phosphorus Total, LL (mg/L as P)	0.095	0.372	0.142	0.139	0.152	0.212
Chloride, Total (mg/L)	21	23	25	42	84	34
Cadmium LL (ug/L)	<0.10	0.7	0.24	<0.10	0.23	0.16
Chromium LL (ug/L)	4.7	14	7.2	4.4	4.2	2.9
Copper (ug/L)	53	21	9.6	65	66	6.9
Iron HL, Tot (ug/L)	3300	N/A	6300	3200	N/A	2600
Lead (ug/L)	2.2	12	3.8	1.6	2.5	1.3
Mercury (ug/L)	0.03	0.04	<0.01	0.05	0.03	0.01
Nickel LL (ug/L)	7.9	16	13	8.7	13	15
Zinc HL (ug/L)	15	36	19	14	<10	<10
Temp (deg C)	8.35	15.58	10.7	10.47	14.22	12.53
PH	6.67	6.83	6.03	6.08	6.85	6.73

Appendix D
Minnesota Water Quality Standards

Water Quality standards taken from Minnesota Rules 7050								
	class 1		class 2A			Class 2b		
	min	max	CS	MS	FAV	CS	MS	FAV
Turbidity (NTU)			10			25		
Suspended Vol. Solids (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA
Suspended Solids (mg/L)			See below					
Solids, Total Volatile (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA
Solids, Total (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate+Nitrite Nitrogen, Total (mg/L as N)		10						
Kjeldahl Nitrogen, Total (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA
Phosphorus Total, LL (mg/L as P)			12			30		
Chloride, Total (mg/L)		250	230	860		230	860	
***Cadmium LL (ug/L)**		5	0.66	1.8		0.66	15	
***Chromium LL (ug/L)**			117	984		117	984	
***Copper (ug/L)**		1000	6.4	9.2		6.4	9.2	
Iron HL, Tot (ug/L)		300						
Lead (ug/L)			1.3	34		1.3	34	
Mercury (ug/L)		2000	6.9			6.9		
***Nickel LL (ug/L)**			88	789		88	789	
***Zinc HL (ug/L)**		5000	59	65		59	65	
Temp (deg centigrade above for stream				0		5		
Temp (deg centigrade above for lake)				0		3		
PH	6.5	8.5	6.5	8.5		6.5	8.5	
"CS" means the highest water concentration of a toxicant to which organisms can be exposed indefinitely without causing chronic toxicity								
MS" means the highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality.								
FAV = final acute value (96 hour) The FAV equals twice the MS value								

TSS water Quality Standards Criteria Table

Regional water quality criteria (Total Suspended Solids [TSS] mg/L)	Reference/least impacted	Biology	**Combined**
All Class 2A waters (Trout Streams)	10		**10**
Northern River Nutrient Region	16	14	**15**
Central River Nutrient Region	31	24	**30**
Southern River Nutrient Region	60	66	**65**
Red River mainstem – Headwaters to border		100	**100**
(Concentrations can be exceeded no more than 10% over a ten year data window; the assessment season is April through September)			
Lower Mississippi River – Pools 2 through 4 [through the Lower Mississippi River SAV draft SS WQS]		**32**	**32**
Lower Mississippi River main stem below Lake Pepin [UMRCC criteria report]		**25**	**25**
[summer average TSS concentration met in at least half of the summers, defined as June-September]			

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