AN EVALUATION OF THE
EFFECTIVENESS OF POROUS PAVEMENT
AND INFILTRATION TRENCH INSTALLATIONS AS
URBAN RUNOFF BEST MANAGEMENT PRACTICES

Mitchell C. Lathrop

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in Partial Fulfillment of the Requirements for the Degree of
Master of Science
Environmental Sciences and Engineering
Department of Civil and Environmental Engineering

Dr. Thomas Grizzard, Chair
Dr. Clifford Randall
Dr. Robert Hoehn

February 12, 1998
Blacksburg, Virginia

Keywords: Best Management Practices, porous pavement, infiltration trench
Copyright 1999, Mitchell C. Lathrop
AN EVALUATION OF THE EффЕCTIVENESS OF PорOUS PAВEMENT AND INFILTRATION TRENCH INSTALLATIONS AS URBAN RUNOFF BEST MANAGEMENT PRACTICES

Mitchell C. Lathrop

(Abstract)

The following study is a demonstration of the effectiveness of porous pavement and an infiltration trench as Best Management Practices (BMPs) in the reduction of stormwater and its constituents. The field work of the study was conducted from 1986 through 1988 and the report was written in 1990 and finalized in 1996. Results of the study show that porous pavement and the infiltration trench significantly reduced the volume of stormwater runoff as well as its constituents from an urban parking lot area. In addition, wetfall and dryfall were found to be the major contributors to the runoff loading and yet were not comparable to associated studies. Peak and total flow runoff volumes were reduced significantly thereby reducing the overall pollutant loading. Antecedent dry period was found to be related to pollutant loading but only up to about 5 days total.

Acknowledgements

The author would like to thank his Graduate Committee Members for their guidance and wisdom as well as the employees of Occoquan Watershed Monitoring Lab for their assistance in this effort. The author would also like to thank the members of his family for their support and assistance.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>Review of Literature</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Characterization of Urban Runoff</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Atmospheric Sources</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Direct Sources</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Soil Erosion</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Other Factors Affecting Urban Runoff</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Antecedent Dry Period Effects</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Constituents of Urban Runoff</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Phosphorus and Nitrogen</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Trace Metals</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Solids</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Infiltration BMPs</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Porous Pavement Design</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Infiltration Trench Design</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Infiltration Practices and Pollutant Removal Mechanisms</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Fate of Nitrogen Species in Soil</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Nitrogen Adsorption</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Fate of Phosphorus Species in Soil</td>
<td>48</td>
</tr>
<tr>
<td>III</td>
<td>Materials and Methods</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Site Description</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Field Monitoring Techniques</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Precipitation Measurement</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Wetfall/Dryfall Sampling</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Flow Measurement</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Sampling Methods</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Data Recording</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Groundwater Monitoring</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Laboratory Methods</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Quality Assurance</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Precision</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>76</td>
</tr>
<tr>
<td>IV</td>
<td>Study Results and Discussion</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Storm Event Sampling</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Wetfall/Dryfall Contribution</td>
<td>82</td>
</tr>
</tbody>
</table>

List of Figures: v
List of Tables: vii

On the page with the table of contents, the page numbers are consistently formatted in uppercase letters.
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal Aspects of Runoff Pollution</td>
<td>89</td>
</tr>
<tr>
<td>Antecedent Dry Period</td>
<td>93</td>
</tr>
<tr>
<td>Total Rain and Flow Balances</td>
<td>96</td>
</tr>
<tr>
<td>Peak and Total Flow Reductions</td>
<td>103</td>
</tr>
<tr>
<td>Stormwater Characteristics</td>
<td>109</td>
</tr>
<tr>
<td>Comparisons to Other Studies</td>
<td>109</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>113</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>114</td>
</tr>
<tr>
<td>Trace Metals</td>
<td>114</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>115</td>
</tr>
<tr>
<td>Determination of Pollutant Removal Efficiency</td>
<td>116</td>
</tr>
<tr>
<td>Chapter V Pollutant Removal Efficiency</td>
<td>123</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>123</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>128</td>
</tr>
<tr>
<td>Trace Metals</td>
<td>132</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>138</td>
</tr>
<tr>
<td>Lysimeter Collected Soil Pore Water</td>
<td>140</td>
</tr>
<tr>
<td>Phosphorus in Soil Pore Water</td>
<td>141</td>
</tr>
<tr>
<td>Nitrogen in Soil Pore Water</td>
<td>141</td>
</tr>
<tr>
<td>Chapter VI Summary and Conclusions</td>
<td>143</td>
</tr>
<tr>
<td>Conclusions</td>
<td>147</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Cross Section of Typical Porous Pavement Facility</td>
</tr>
<tr>
<td>2</td>
<td>Porous Asphalt Paving Typical Section</td>
</tr>
<tr>
<td>3</td>
<td>Schematic of an Infiltration Trench</td>
</tr>
<tr>
<td>4</td>
<td>Occoquan Watershed Location Map</td>
</tr>
<tr>
<td>5</td>
<td>Vicinity Map</td>
</tr>
<tr>
<td>6</td>
<td>Area Street Map</td>
</tr>
<tr>
<td>7</td>
<td>General Site Plan</td>
</tr>
<tr>
<td>8</td>
<td>Schematic Diagram of Flowmetering and Sampling Equipment</td>
</tr>
<tr>
<td>9</td>
<td>Schematic of Automated Flow Weighted Compositing Procedure</td>
</tr>
<tr>
<td>10</td>
<td>Diagram of Typical Lysimeter</td>
</tr>
<tr>
<td>11</td>
<td>Lysimeter Locations at PP-03</td>
</tr>
<tr>
<td>12</td>
<td>Typical Precision Control Chart</td>
</tr>
<tr>
<td>13</td>
<td>Median Dryfall Deposition Rates at the Davis Ford Project</td>
</tr>
<tr>
<td>14</td>
<td>Median Wetfall Deposition Rates at the Davis Ford Project</td>
</tr>
<tr>
<td>15</td>
<td>Seasonal Dryfall Contribution</td>
</tr>
<tr>
<td>16</td>
<td>Seasonal Wetfall Contribution</td>
</tr>
<tr>
<td>17</td>
<td>SKN Loading Versus Antecedent Dry Period</td>
</tr>
<tr>
<td>18</td>
<td>TKN Loading Versus Antecedent Dry Period</td>
</tr>
<tr>
<td>19</td>
<td>NH4_N Loading Versus Antecedent Dry Period</td>
</tr>
<tr>
<td>20</td>
<td>TP Loading Versus Antecedent Dry Period</td>
</tr>
<tr>
<td>21</td>
<td>Rainfall-Runoff Relationship at the Control Catchment</td>
</tr>
<tr>
<td>22</td>
<td>Rainfall-Runoff Relationship at the Porous Pavement Catchment</td>
</tr>
<tr>
<td>23</td>
<td>Rainfall-Runoff Relationship at the Infiltration Trench Catchment</td>
</tr>
<tr>
<td>24</td>
<td>Mean and Median Peak Flows at the Three Catchments</td>
</tr>
<tr>
<td>25</td>
<td>Reduction in Mean and Median Peak Flows at the BMP Catchments</td>
</tr>
<tr>
<td>26</td>
<td>Mean and Median Storm Duration in Hours for Each Catchment</td>
</tr>
<tr>
<td>27</td>
<td>Comparison of Event Mean Phosphorus Concentrations from Urban Runoff Field Studies</td>
</tr>
<tr>
<td>28</td>
<td>Comparison of Event Mean Phosphorus Concentrations from Urban Runoff Field Studies</td>
</tr>
<tr>
<td>29</td>
<td>Comparison of Event Mean Nitrogen Concentrations from Urban Runoff Field Studies</td>
</tr>
<tr>
<td>30</td>
<td>Comparison of Event Mean Trace Metal Concentrations from Urban Runoff Field Studies</td>
</tr>
<tr>
<td>31</td>
<td>Comparison of Event Mean TSS Concentrations from Urban Runoff Field Studies</td>
</tr>
<tr>
<td>32</td>
<td>Median Nutrient Event Mean Concentrations for the Three Catchments</td>
</tr>
<tr>
<td>33</td>
<td>Mean Nutrient Event Concentrations for the Three Catchments</td>
</tr>
<tr>
<td>34</td>
<td>Methods Used to Calculate the Pollutant Removal Efficiency of Urban BMPs</td>
</tr>
<tr>
<td>35</td>
<td>Phosphorus Removal Efficiencies at the Porous Pavement Catchment Based on Median and Long Term Load Reductions</td>
</tr>
<tr>
<td>36</td>
<td>Phosphorus Removal Efficiencies at the Infiltration Trench Catchment</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Based on Median and Long Term Load Reduction</td>
<td>126</td>
</tr>
<tr>
<td>37 Nitrogen Removal Efficiencies at Porous Pavement and Infiltration Trench Based on Reduction in Median EMCs</td>
<td>130</td>
</tr>
<tr>
<td>38 Nitrogen Removal Efficiencies at the Porous Pavement Catchment Based on Median and Long Term Load Reductions</td>
<td>134</td>
</tr>
<tr>
<td>39 Nitrogen Removal Efficiencies at the Infiltration Trench Catchment Based on Median and Long Term Load Reductions</td>
<td>135</td>
</tr>
<tr>
<td>40 TSS and Trace Metal Removal Efficiencies at the Porous Pavement Catchment Based on Median and Long Term Load Reductions</td>
<td>137</td>
</tr>
<tr>
<td>41 TSS and Trace Metal Removal Efficiencies at the Infiltration Trench Catchment Based on Median and Long Term Load Reductions</td>
<td>138</td>
</tr>
<tr>
<td>Table</td>
<td>Title</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Heavy Metals Export in Urban Runoff</td>
</tr>
<tr>
<td>2</td>
<td>Average Seasonal Loading Rates</td>
</tr>
<tr>
<td>3</td>
<td>Chemical Analyses Used in This Study</td>
</tr>
<tr>
<td>4</td>
<td>Wetfall and Dryfall Median Deposition Rates</td>
</tr>
<tr>
<td>5</td>
<td>Wetfall and Dryfall Median Yearly Loading Projections</td>
</tr>
<tr>
<td>6</td>
<td>Wetfall/dryfall percentage of PP-01 runoff</td>
</tr>
<tr>
<td>7</td>
<td>Seasonal Wetfall Contribution</td>
</tr>
<tr>
<td>8</td>
<td>Seasonal Dryfall Contribution</td>
</tr>
<tr>
<td>9</td>
<td>Seasonal Wetfall Contribution Based on Seasonal Distribution of Rainfall</td>
</tr>
<tr>
<td>10</td>
<td>Percent Reduction of Phosphorus Forms by BMPs Based on Median Load Reduction</td>
</tr>
<tr>
<td>11</td>
<td>Percent Reduction of Phosphorus EMCs of Entire Data Set</td>
</tr>
<tr>
<td>12</td>
<td>Percent Reduction of Phosphorus Forms by BMPs Based on Long Term Load Reductions</td>
</tr>
<tr>
<td>13</td>
<td>Reduction of Nitrogen Forms Based on Median EMCs of Entire Data Set</td>
</tr>
<tr>
<td>14</td>
<td>Reduction of Nitrogen Forms by BMPs Based on Median Load Reduction (lbs/acre)</td>
</tr>
<tr>
<td>15</td>
<td>Reduction Of Nitrogen Forms by BMPs Based on Long Term Load Reduction (lbs/acre)</td>
</tr>
<tr>
<td>16</td>
<td>Reduction of Trace Metal Forms by BMPs Based on Median Load Reduction (lbs/acre)</td>
</tr>
<tr>
<td>17</td>
<td>Reduction of Trace Metal Forms by BMPs Based on Long Term Load Reductions (lbs/acre)</td>
</tr>
<tr>
<td>18</td>
<td>Reduction of TSS Based on lbs/acre</td>
</tr>
<tr>
<td>19</td>
<td>Soil Pore Water EMC Comparisons</td>
</tr>
</tbody>
</table>