Underdrain Asset Rating, Asset Management, and Maintenance: A Post Construction Case Study

Alexander M. Hainen
Purdue University
550 Stadium Mall Drive, West Lafayette, IN 47907-2051
Phone: 765-496-7314 Fax: 765-494-0395
Email: ahainen@purdue.edu

Stephen M. Remias
Purdue University
550 Stadium Mall Drive, West Lafayette, IN 47907-2051
Phone: 765-496-7314 Fax: 765-494-0395
Email: sremias@purdue.edu

Richard S. Freije
Purdue University
550 Stadium Mall Drive, West Lafayette, IN 47907-2051
Phone: 765-496-7314 Fax: 765-494-0395
Email: rsfreije@purdue.edu

W. Benjamin Smith
Purdue University
550 Stadium Mall Drive, West Lafayette, IN 47907-2051
Phone: 765-496-7314 Fax: 765-494-0395
Email: smithwb@purdue.edu

Hayley T. Summers
Purdue University
550 Stadium Mall Drive, West Lafayette, IN 47907-2051
Phone: 765-496-7314 Fax: 765-494-0395
Email: hsummer@purdue.edu

Corresponding author:
Darcy M. Bullock
Purdue University
400 Centennial Mall Drive, West Lafayette, IN 47907
Phone: 765-496-2226 Fax: 765-494-0395
Email: darcy@purdue.edu

November 15, 2013

Word Count: 2,295 words + 9 x 250 words/Figure-Table = 2,295 + 2,250 = 4,545

TRB Paper 14-4443

TRB 2014 Annual Meeting

Paper revised from original submittal.
ABSTRACT
Properly draining pavement bases is important for longevity of pavements. Underdrain lateral discharge pipes are high-volume, low-cost assets which are critical for pavement maintenance. Historically, little attention has been paid to monitoring the health and performance of lateral discharge pipes and their ability to remove water from underdrain systems below pavements. After a few years, many underdrains can become filled, clogged, and non-functional. When these drains fail, the freeze/thaw cycle of moisture in the base contributes heavily to pavement degradation. However, the literature is silent on how often underdrains should be maintained and what that maintenance activity should be.

This paper reports on an empirical survey of an 8-mile section of new interstate and examines the condition of 400 lateral underdrain discharge pipes two years after construction was completed. Surprisingly, 20% of the lateral discharge pipes were substantially filled with sediment and in poor shape two years after construction was completed. The paper concludes by recommending underdrain maintenance, rarely performed earlier then on a 5 year cycle, may be more effective after the first or second year as a contract item to remove the bulk of the fines that accumulate in the underdrain systems. Further data collection and asset condition tracking is needed to develop definitive recommendations for subsequent maintenance intervals, but it is expected subsequent maintenance intervals would be on the order of 5 years or longer.
INTRODUCTION

Properly draining pavement bases is important for longevity of pavements (1). The freezing and thawing cycles of water below pavements is a major factor in pavement degradation. As such, proper drainage of pavement bases is required. Since the 1950s, the Indiana Department of Transportation has designed roads with underdrain systems to collect water and remove it from the cross section before it enters the base of the pavement. Since the 1960s, longitudinal drains have been typically placed at the edge of pavements below the surface (2). Lateral underdrain outlets at regular spacing are constructed that discharge the water from the longitudinal underdrains.

Historically, lateral outlets have been a few feet of PVC pipe extending out of the bank into the ditch. During mowing operations, these segments can be damaged by mowers or crushed by tractor tires pulling the mower. They often become overgrown, lost, and clogged with debris or sediment. At this point, the lateral discharge pipe is no longer functional and the water in the longitudinal underdrains remains stored below the pavement, thus no longer effectively draining the roads. Ideally, maintenance crews could go back to the field construction reports and trace the location, but this isn’t very effective and often the drains still cannot be located. One way to keep track of the lateral discharge locations is by placing marker posts for each location. However, mowers and vehicles in run-off-road crashes often hit these markers (see Figure 1a showing a bent marker) and all indication of the underdrain is lost. Figure 1b shows a 2-year old outlet which has become significantly overgrown and could easily become completely overgrown before an initial 5-year cleaning. When this happens, the drain is either abandoned or more expensive location techniques (like ground penetrating radar) would have to be used (3).

More recently, construction details have included outlet protection to guard against overgrowth and to make locating easier. The most common type of outlet protection is a large concrete pad (Figure 2) in which the end of the lateral discharge pipe sits flush. This prevents mowers from breaking off the end of the lateral discharge pipe as well as keeping grass and shrubs from growing around (and into) the end of the drain.

There has been limited literature published on underdrain maintenance. Larrahando et al. have demonstrated that ground penetrating radar and other technologies can be used to measure and assess the performance of buried drains (3). Video inspection is another alternative that has since been recommended by the Indiana Design Manual assessing the need for more frequent underdrain maintenance (4). However, very little is published on how quickly these assets deteriorate.

MOTIVATION

Although substantial progress has been made in improving underdrain designs to prevent mowing damage (5), the motivation for this paper is to show that, despite having outlet protection, there is still substantial degradation of the underdrain condition that warrants routine maintenance. Figure 1c shows substantial growth in the lateral outlet. Furthermore, the alarming level of debris and sediment in some of the underdrains (see Figure 1d) was quite surprising. This emphasizes the need for cleaning and tracking the health of the underdrain systems.

UNDERDRAIN COSTS

The Indiana Department of Transportation expenditures on underdrains for the 5-year period between 2008-2012 were $38 million. A breakdown for 2012 is reported in Table 1, showing that over $6 million was spent on underdrains. Nearly half of this was spent on aggregates, but almost 30% was cost associated with the lateral outlet protection. Also, it’s noteworthy that the
cleanout, outlet inspection, and outlet cleaning were well under 1% of spending. While this is, at first, quite surprising, these numbers are contract expenditures. Most of the cleaning and inspection happens at the district level and likely is not effectively represented in these costs (the costs in the table are primarily for new underdrain installations). The takeaway point from this is that with so much spent on the newer style outlet protection, maintaining the outlets instead of having them buried should help crews during cleaning.

FIELD DATA COLLECTION 2 YEARS POST CONSTRUCTION
An 8-mile stretch of interstate northwest of Indianapolis was reconstructed and opened in the summer of 2011. In the spring of 2013, researchers traversed both sides of the road to evaluate the condition of lateral discharge pipes. No lateral discharge pipes were in the median and all were along the side of the road discharging into the outer ditches. Over the 8-mile segment, 400 lateral discharge pipes were observed. An attempt was made to observe every drain, but it is conceivable that a few were missed as the markers for many of the drains were already bent, broken, or missing, presumably from mower or vehicle strikes. The secondary objective of the field inspection was to obtain GPS locations for the outlets. This is analogous to building information systems, where conduits, ducts, and other hidden components are documented during construction.

The data collection process is shown in Figure 3. A wide angle picture was taken (Figure 3a) to note the outlet protection and number of outlets (Figure 3b). The lateral outlet locations were then logged with a handheld GPS receiver (Figure 3c) where the exact location was recorded for later records (Figure 3d). Finally, a close picture of each drain was taken to observe the condition of each outlet.

EMPIRICAL RANKINGS AND RESULTS OF FIELD OBSERVATIONS
Field notes and pictures of each outlet were gathered into a geo-database (Figure 4). Two users then went through and rated each drain on the perceived condition based on several attributes observed in the field and in the pictures. The condition rating of the underdrain was based on a 1-5 integer scale. Attributes of the rating included:

Sediment Fill Level
Since these drains were relatively new, it was hypothesized that vegetation would not be a major issue and that fill from sediment would be more of a concern. Behind many of the rodent screens, there was, in fact, much fine sediment that had accumulated. After construction, it would be expected that several cycles of hydraulic loading will transport fine sediment. This emphasizes the importance of an early cleaning as opposed to waiting 5 years. Not only might sediment be accumulating in the outlets, but segments of the longitudinal drains could also have significant amounts of sediment.

Vegetation Inside and Outside the Underdrain
Once sediment accumulates, the moisture from underdrains provides a perfect environment for vegetation to grow. Vegetation (grass and other sprouts) can grow both behind the rodent screen and also in front of the rodent screen. Once vegetation starts to grow, it continues to expand and accumulate sediment and debris. Decaying vegetation such as sticks and leaves can also breakdown and facilitate overgrowth of the drains.
Trash Inside and Outside the Underdrain

Similar to vegetative debris, trash and other non-vegetative debris can also reduce the ability of lateral outlets to discharge water. Loose plastic bags and corrugated cardboard were particularly noted for trapping sediment and water. Cups and bottles also found their ways into the outlets.

Composite Rating

Using the above factors, subjective ratings were established between 1 and 5 with a rating of “1” being poor and rating of “5” being pristine.

- Figure 5a and Figure 5b show an example of a drain with a 1-rating which is in poor shape as the outlets are almost completely filled with vegetation, keeping in mind this is only 2 years after being installed. By year 5, this drain would certainly be completely failed.
- Figure 5c and Figure 5d show a drain with a rating of 2. In Figure 5b, there is considerable vegetative debris, loose sediment, and aggregate inside the drain and vegetative overgrowth outside on the outlet protector.
- Figure 5e and Figure 5f show an underdrain with a 3-rating. The drain is in decent shape (especially inside the drain), but does have some vegetative overgrowth.
- Figure 5g and Figure 5h shows a drain with a 4-rating clear of external debris. There is some sediment in the bottom of the drain and on the rodent screen. This drain would likely perform well until an initial 5-year cleaning.
- Figure 5i and Figure 5j show a 5-rating drain which is pristine. It should be noted that while a 5-rating drain seems ideal, this could be an indicator that the longitudinal drains might be clogged. As such, video confirmation would be useful to assess if the lateral drain condition is correlated with the entire drainage system rating.

Once the ratings for the drains were compiled, histograms of the ratings were assembled for observer 1 (Figure 6a) and for observer 2 (Figure 6b). While each observer has different biases with rating and different averages and standard deviations, the important observation is that about 20% of the drains in each histogram are a 2-rating or worse. This portion of the drains receiving low ratings after only 2 years of being installed is quite significant.

Spatial Mapping of Condition

Another interesting and informative factor is the geospatial distribution of the ratings. Figure 7 shows a map of the locations colored by the rating with red representing a 1-rating (poor) and green representing a 5-rating (good). At the south end of the study area, callout “i” shows a cluster of locations with a 1-rating (red). While the whole study area is level grade with little change in elevation of the road, low spots in the ditch or variations in grade of the underdrain structure might be important (6). Also, the 1-rated drains are on the same side of the road. This might suggest a problem with that specific ditch and its design or capacity. Similarly, callout “ii” notes a section of drains with 2-ratings (orange). The difference from the first example is that these marginally-rated drains are on both sides of the road and perhaps a different mode of failure (geotechnical, geochemical, environmental, etc.) might be occurring (7). Both of these regions are shown in Figure 8 and would be target locations for further investigation. Also, the road surface may be monitored for degradation, particularly if high water level is a factor in the ratings.
CONCLUSIONS
Underdrains are important assets that may not be receiving the necessary attention they deserve. Pavement life expectancy is very dependent on proper drainage. Cleaning and maintenance of the underdrain system may be more necessary than many DOTs currently judge. The important finding from this paper is that fine sediment from 1 or 2 years after construction may be quite important to clean early in the service life rather than waiting for an initial 5-year cleaning when many of the drains could be overgrown. Although outlet strainers are important to keep rodents out, during the first couple of years it is important to clean the inside of these strainers to keep them from plugging with early construction debris.

Even with outlet protection and markers, some GIS/GPS asset management should be utilized (especially if outlet protection is not used). Future research should include more thorough examination (video inspection, ground penetrating radar) to expand on the rating system, while also including more advanced rating analysis (such as analytical hierarchy process or other controlled subjective rating regimes).

ACKNOWLEDGEMENT
This work was supported by the Indiana Department of Transportation. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the sponsoring organizations. These contents do not constitute a standard, specification, or regulation.
WORKS CITED


LIST OF TABLES
Table 1 Breakdown of 2012 underdrain Expenditures ................................................................. 11

LIST OF FIGURES
Figure 1 Motivation for monitoring underdrain condition, both with and without outlet protection .......................................................................................................................... 9
Figure 2 Standard drawing of an outlet protector ................................................................................ 10
Figure 3 Data collection process on I-65 ............................................................................................. 12
Figure 4 Geodatabase showing underdrain locations and pictures, with a link for more detailed information ......................................................................................................................... 13
Figure 5 Example underdrains for each condition rating ...................................................................... 14
Figure 6 Histograms of ratings for the 400 observed underdrains ............................................................. 15
Figure 7 Underdrain locations colorized by rating .................................................................................. 16
Figure 8 Close up maps showing areas of concern .................................................................................. 17
a) Bent underdrain marker. Once broken, the drain will be nearly impossible to locate.

b) No outlet protection and the drain is being overgrown.

c) Heavy vegetation (clover growth) in the drain.

d) High amount of sediment trapped behind the rodent screen.

Figure 1  Motivation for monitoring underdrain condition, both with and without outlet protection
Figure 2  Standard drawing of an outlet protector
### Table 1 Breakdown of 2012 underdrain Expenditures

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>LOW PRICE</th>
<th>HIGH PRICE</th>
<th>WGT AVG</th>
<th>NO ITEMS</th>
<th>TOTAL</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>718-03277</td>
<td>PIPE, UNDERDRAIN, CORRUGATED PLASTIC, PERFORATED, 6 IN. CLEANOUT</td>
<td>LFT</td>
<td>$2.80</td>
<td>$84.50</td>
<td>$6.25</td>
<td>14,734.00</td>
<td>$92,136.35</td>
<td>1.5%</td>
</tr>
<tr>
<td>718-04986</td>
<td>CLEANOUT</td>
<td>EACH</td>
<td>$240.00</td>
<td>$1,350.00</td>
<td>$445.26</td>
<td>19</td>
<td>$8,460.00</td>
<td>0.1%</td>
</tr>
<tr>
<td>718-06526</td>
<td>HMA FOR UNDERDRAINS</td>
<td>TON</td>
<td>$80.00</td>
<td>$777.65</td>
<td>$156.53</td>
<td>544.5</td>
<td>$85,231.85</td>
<td>1.4%</td>
</tr>
<tr>
<td>718-06528</td>
<td>OUTLET PROTECTOR, 1</td>
<td>EACH</td>
<td>$0.00</td>
<td>$980.00</td>
<td>$513.96</td>
<td>1,830.00</td>
<td>$940,539.77</td>
<td>15.6%</td>
</tr>
<tr>
<td>718-06529</td>
<td>OUTLET PROTECTOR, 2</td>
<td>EACH</td>
<td>$400.00</td>
<td>$1,200.00</td>
<td>$511.45</td>
<td>1,358.00</td>
<td>$694,546.36</td>
<td>11.5%</td>
</tr>
<tr>
<td>718-06531</td>
<td>OUTLET PROTECTOR, 3</td>
<td>EACH</td>
<td>$325.00</td>
<td>$810.00</td>
<td>$468.84</td>
<td>307</td>
<td>$143,934.06</td>
<td>2.4%</td>
</tr>
<tr>
<td>718-06532</td>
<td>VIDEO INSPECTION FOR UNDERDRAINS</td>
<td>LFT</td>
<td>$0.55</td>
<td>$3.50</td>
<td>$0.96</td>
<td>186,722.00</td>
<td>$180,031.70</td>
<td>3.0%</td>
</tr>
<tr>
<td>718-08308</td>
<td>UNDERDRAIN, PATCHING</td>
<td>LFT</td>
<td>$19.00</td>
<td>$19.00</td>
<td>$19.00</td>
<td>1,240.00</td>
<td>$23,560.00</td>
<td>0.4%</td>
</tr>
<tr>
<td>718-09978</td>
<td>UNDERDRAIN OUTLET INSPECTION</td>
<td>EACH</td>
<td>$150.00</td>
<td>$500.00</td>
<td>$325.00</td>
<td>2</td>
<td>$650.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>718-09979</td>
<td>UNDERDRAIN OUTLET CLEANING</td>
<td>EACH</td>
<td>$150.00</td>
<td>$150.00</td>
<td>$150.00</td>
<td>1</td>
<td>$150.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>718-34000</td>
<td>PIPE, UNDERDRAIN, PERFORATED, 0.052 IN., 6 IN.</td>
<td>LFT</td>
<td>$10.00</td>
<td>$10.00</td>
<td>$10.00</td>
<td>2,828.00</td>
<td>$28,280.00</td>
<td>0.5%</td>
</tr>
<tr>
<td>718-52610</td>
<td>AGGREGATE FOR UNDERDRAINS</td>
<td>CYS</td>
<td>$0.00</td>
<td>$150.00</td>
<td>$28.03</td>
<td>105,466.50</td>
<td>$2,956,714.32</td>
<td>49.0%</td>
</tr>
<tr>
<td>718-99153</td>
<td>GEOTEXTILES FOR UNDERDRAIN</td>
<td>SYS</td>
<td>$0.00</td>
<td>$10.00</td>
<td>$0.72</td>
<td>1,230,339.50</td>
<td>$880,680.44</td>
<td>14.6%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$6,034,914.85</td>
<td></td>
</tr>
</tbody>
</table>
a) Taking a wide-angle picture of the drains and outlet protector

b) Wide-angle picture of the drains and outlet protector

c) Geo-locating the underdrain

d) Recording the latitude and longitude and ID of the drain

e) Taking a close-up detail picture of the lateral discharge outlet

f) Close-up detail picture of the lateral discharge outlet

Figure 3 Data collection process on I-65
Figure 4  Geodatabase showing underdrain locations and pictures, with a link for more detailed information
a) 1-rating w/heavy vegetation in the outlet  
b) 1-rating w/heavy vegetation in the outlet (grass/debris)
c) 2-rating w/heavy vegetation around the outlet protector  
d) 2-rating w/some sediment in the bottom of the lateral discharge  
e) 3-rating w/vegetation around the outlet and debris in the outlet  
f) 3-rating with debris and aggregate in the bottom of the outlet  
g) 4-rating w/fine sediment in the bottom of the outlet  
h) 4-rating w/fine sediment in the bottom of the outlet  
i) 5-rating of pristine outlet  
j) 5-rating of pristine outlet

**Figure 5** Example underdrains for each condition rating
a) Histogram of observer 1 ratings

b) Histogram of observer 2 ratings

Figure 6  Histograms of ratings for the 400 observed underdrains
Figure 7  Underdrain locations \((n = 400)\) colorized by rating
a) Area of concern with three red icons on one side of the road

b) Another area of concern with orange icons on both sides of the road

Figure 8 Close up maps showing areas of concern