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EVALUATION OF THE LONG TERM IMPACTS OF AN INFILTRATION BMP

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ABSTRACT

The natural hydrologic cycle is severely disrupted by development because the water that used to infiltrate into the ground is now running off into nearby streams. The negative impact of development on streams includes increased stream bank erosion, pollutant levels, and decreased base flow. Best management practices (BMPs) are recommended by regulatory agencies because they can mitigate peak flow, provide treatment, and partially restore the natural hydrologic cycle. BMP is a broad term used to describe a host of structures and activities; they are classified as structural (e.g. infiltration basin) or non structural (e.g. street cleaning). While infiltration BMPs are gaining acceptance, there is a concern that infiltrating stormwater has solved one problem by improving stream quality, but has caused another by contaminating the groundwater. To date, there have not been many opportunities to study the long term effects of infiltration. However, two 85 to 100 year old infiltration pits were discovered on the campus of Villanova University. Soil samples were collected from these pits and were tested for copper. Copper was selected based on the contaminants seen in the stormwater at other Villanova BMP sites. One of the pits has low infiltration rates and a plan to restore its infiltration capacity is described. This restored infiltration pit will serve as a permanent demonstration and research site, joining a collection of BMPs at Villanova University.

1. INTRODUCTION

Storm water runoff, flooding, and pollution elements associated with runoff have become increasing problems for urban areas throughout the United States (e.g. Schueler 1994; Schueler 1995; Schueler 1997; Paul and Meyer 2001; and Wang et al. 2001, US EPA 2005). As properties throughout an urban area are developed and create more impervious surfaces, stormwater runoff and the elements associated with impervious surfaces (including fossil fuels, nitrates, phosphorous, and metals like copper) continue to raise threats to urban infrastructure (bridges, roads, buildings), groundwater, surface waters, wastewater treatment facilities. To combat this increasing problem, engineers are investing time, money and research in many concepts associated with Best Management Practices (BMPs). In the past, many urban developments used detention and retention basins. While these devices do decrease the peak flow allowed into a stream system, they do not decrease the total volume of runoff (Traver and Chadderton 1983; McCuen and Moglen 1998; and US EPA 2005). Thus, flash flooding, erosion, and pollutant transport are not well controlled by these devices.

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Infiltration BMPs hold keys to solving the problems listed above for detention and retention basins. These devices decrease runoff and improve water quality, along with providing higher base flow in urban streams during dry weather. One such infiltration BMP is a seepage/infiltration pit. When properly installed and maintained, a seepage pit will divert significant portions of runoff into the soil via storage pits. By diverting runoff into the soil, seepage pits can recharge groundwater, augment low flows and preserve base flow in streams, protect local downstream biota, and help minimize erosion and flooding. Information on the long-term impacts of infiltration BMPs is rare as is information on how to restore functionality if adequate infiltration capacity is lost. Thus, the Villanova University seepage pits described in this paper provide a great opportunity for study due to their age.

2. SITE HISTORY

The seepage pits are located on the campus of Villanova University in Radnor Township, an eastern suburb of Philadelphia in South Eastern Pennsylvania. The site is located at the headwaters of Ithan Creek and Valley Run, which are part of the Darby Creek watershed. As such, the site has importance in maintaining healthy waters at the start of this urban watershed. Any contamination imposed at the headwaters will deteriorate the downstream waters of the watershed.

An extensive review of all available university documentation was performed to determine the history of the pits. From this research we determined that the structures were built circa 1899 around the time Tolentine Hall, at the time called College Hall, was built. While investigating the location of pipes connected to the pits, bricks that had sustained fire damage were found. This provides confirmation that the construction of the pits preceded the fire that occurred in 1928.

Originally, four pits existed in the area to collect and infiltrate storm water off of Tolentine Hall (building to the left in Figure 1) and St. Thomas Monastery (building to the right in Figure 1). We found through our investigations that two of the pits had been replaced by large box culverts and no longer function as seepage pits. Currently, all stormwater is being routed to these two box culverts. The locations of the two remaining pits are indicated by arrows on Figure 1. To facilitate our discussion, the pits have been named based on their proximity to the Monastery and Tolentine and will here in after be referred to as either the Monastery or Tolentine pits.

The pits are below ground located on the hill side that descends off the driveway in front of Tolentine Hall and the Monastery and onto the open field between the aforementioned buildings and Lancaster Avenue (US. 30). Figure 2 shows a top view of the site.

As we began our investigation of this site we discovered that a sewage line from Tolentine Hall had been mistakenly connected to the Monastery pit. Our evidence suggests this mistake occurred at the time of construction for the driveway in front of Tolentine in the 1960's. The sewer line was disconnected approximately 8 months prior to the research project beginning. Due to the connection of a sewer line to the pits, an investigation into the bacterial counts was performed.

Both of the remaining pits were constructed in a similar fashion. The pits are brick cylinders with sandy bottoms. The stability of these brick lined walls is a concern that will need to be addressed as we consider restoring functionality to the pits. The Monastery pit is approximately 4 m deep and the Tolentine pit is approximately 1.5 m deep. Both pits are estimated to be 2 m in diameter. Due to safety concerns no one has entered the pits at this point.

A pipe camera was used to map the locations of the pipes connected to the pits. We found an extensive set of terracotta pipes that extend to and from the pits. The two pits in the research project have connected outlets that release overflow into the large grass field in front of Tolentine that runs along Lancaster Avenue.

Figure 1 Photograph of the Site Facing North from Lancaster Avenue

Figure 2 Top View of Site

3. TESTING AND METHODS

A drilling contractor, SITE-Blauvelt, was hired to drill test borings at the site. This drilling program required a great deal of coordination because the drillers would be on the front lawn of Villanova, which is a national arboretum, and because of the close proximity of the Monastery pit to a rare Dawn Redwood. Three borings were drilled: one in each of the pits and one control boring in between the two pits (dubbed the "null" boring). The borings went to a depth of 6 m or bedrock. Split spoon samples were obtained and the blow counts were recorded. Samples were taken at 15, 30, 46, 61, 76, 91, and 183 cm for testing of bacteria and copper concentration.

Research performed on a more recent infiltration BMP on Villanova's campus indicated that copper would be the constituent of most concern (Kwiatkowski, et al. 2006). The elevated copper concentrations are a result of the copper from the sheathing beneath the slate roofs, gutters, and downspouts. Other researchers have found a first flush effect from copper (e.g. Forster 1996 and Zobrist, et al. 2000); however, once infiltrated, the copper present in the roof runoff is removed through the process of adsorption (Mason, et al., 1999; Blaszczyk, 1997; and Mikkelsen, et al., 1996). The bacterium testing was performed because of the mistakenly connected sewage line described previously.

3.1 Bacteria Testing

The bacteria testing performed was a variation of the membrane filtration method in Standard Methods for the Examination of Water and Wastewater, Section 9222. A known weight of sample was extracted with sterile phosphate buffer. A specific volume of the extracted buffer was then passed through a millipore filter unit. The filter was placed on the m-coli blue agar and incubated at the temperature specified by the manufacturer. The plates were incubated for at least a week, and often longer, because the colonies were very slow to grow.

We were not concerned about extraction efficiency or absolute numbers of bacteria in each sample. The goal of the tests was to show relative differences in bacterial growth between samples obtained from the null site and the two pits. Specifically, we wanted to compare the total coliform and e-coli counts.

3.2 Chemical Testing

To determine the levels of copper in the soil in each pit, the samples taken at 15, 30, 46, 61, 76, 91, and 183 cm were tested using the DTPA extraction solution method. Ten g of soil from each depth were placed in a 50 mL Erlenmeyer flask. Twenty mL of DTPA extracting solution was added and each sample was shaken at 180 rpm for 2 hours. The samples were removed from the shaker and the solution was filtered through Whatman 42 filter paper. The resulting extracted liquid was tested using a graphite furnace and/or flame AA, depending on initial results from the graphite furnace. Blanks for these tests consisted of DTPA, not water.

Along with the copper testing, the pH and cation exchange capacity were also tested. Cation exchange capacity (CEC) was performed using ammonium acetate procedure described by Chapman (1965). Currently, soil samples are being tested to determine total carbon and total phosphorus.

4. RESULTS

The soils in the vicinity of the pits consist of silty sands (SM according to the Unified Soil Classification System). Encountering bricks buried near the pit is common due to the dumping of bricks after the 1923 fire in Tolentine Hall. Standard Penetration Testing at the time of drilling yielded blow counts of 6-15 with the blow count increasing with depth. Increasing blow counts are correlated to increasing densities, and thus decreasing infiltration rates. The Monastery pit also contained a high amount of organic matter caused by the sewer line being connected in the past. We believe that this organic matter has formed a mat that has decreased the infiltration rate.

For the bacteria testing, it was found that there were counts of e-coli in the soil, but nothing of major concern. For most of the depths tested, the counts for coliforms were much greater than e-coli counts (Table 1). In addition, to obtain any readings at all, the samples were concentrated, thus the values in the table are for comparison purposed only. At first glance, the coliform counts may appear high; however, many bacteria that are naturally found in soils can create false positives for this test. Because similar numbers of total coliforms were found for all the borings, including the null boring, it is presumed that the bacterial found in soil is naturally occurring.

The results of the copper testing are presented in Figure 3. The copper concentrations peak at a depth of 46 cm with a maximum value of 364 ppm. Although we did detect elevated levels of copper in the soil beneath the pits as compared to the null site, these levels are still well below the maximum levels acceptable to the PA DEP for residential soils. The PA DEP limits copper concentrations for residential fill to 8200 ppm (PA DEP 2000). The copper found in the soils were a result of copper coming off of the roof. The increase in copper concentrations found in the soils, while not alarming, is a factor that must be considered by BMP designers.

The CEC and pH levels are displayed in Table 2. These results show that the soil does not have any peculiar CEC and/or pH levels that would indicate the soil has a higher or lower tendency to hold onto copper particles.

Table 1 Bacteria Counts at 15 cm of depth

	Coliform	e-coli	Total bacteria
Monastery	150	7	157
Tolentine	212	11	224
Null	147	0	147

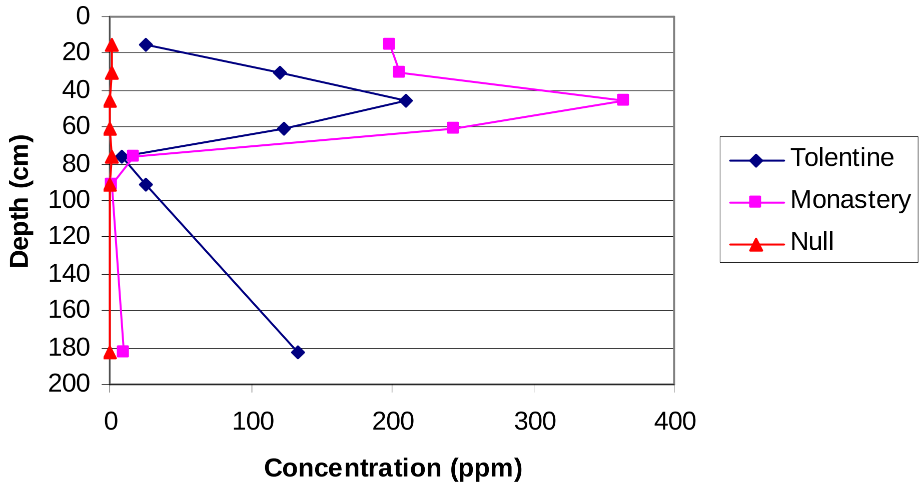

Figure 3 Copper Concentrations versus Depth

Table 2 Cation Exchange Capacity (CEC) and pH

CEC (meq/100 g)			
Depth (cm)	Tolentine	Monastery	Null
15	17.1	20.8	13.3
76	16.1	17.0	13.3
183	15.4	9.3	12.0
pH			
	5.7	6.2	6.0

5. RESTORATION PLANS

The next step in this project is to restore functionality to the pits. The Monastery Pit is the easiest pit to reconnect to existing storm sewers. Unfortunately, the infiltration capacity of this pit is quite poor at 5 cm/day. We attribute this reduction in infiltration capacity to the bacteria mat from the sewage. Consequently, we have developed a plan to install four prefabricated earthquake drains to a depth of

3.5 m. These drains are composed of an inner plastic core wrapped by a nonwoven geotextile. They are called earthquake drains because they are used to reduce excess pore water pressures that are created during earthquakes and have not been used for this purpose to date. The Tolentine pit displays excellent infiltration capacity and we are still exploring opportunities to reconnect it.

6. CONCLUSIONS

Two infiltration pits on the campus of Villanova University that were at least 85 years old were studied. The pits provided a unique opportunity to ascertain the impact of an infiltration BMP over many years of service. After many years of accepting stormwater runoff from the roofs of Tolentine Hall and the Monastery, the soil in the pits displayed increased levels of copper as compared to the soil where the rooftop runoff was not directed. However, the elevated levels of copper were far below the threshold used by the PA DEP to describe fill acceptable for residential uses where direct contact is expected.

The infiltration rates of the two pits varied dramatically. The Monastery pit's infiltration capacity is inadequate and we are currently in the process of installing a geosynthetic product to restore its infiltration capacity. We are hopeful that the Tolentine pit, which has excellent infiltration capacity, will be reconnected to the storm sewer system in the near future.

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