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Short communication

Ecological assessment of a transitioned stormwater infiltration basin

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ABSTRACT

Infiltration basins are stormwater control measures (SCMs) widely employed for urban stormwater management. A transitioned infiltration basin is a failed infiltration basin that has gradually transformed into a wetland- or wetpond-like practice. The transitioned basin was found to effectively control the storm runoff flows and volumes, and improve the discharge water quality, thereby reducing the downstream hydrologic and pollutant loads on most occasions. Qualitative assessment of the site showed presence of wetland and non-wetland vegetation, small animals, and some potential for cultural benefit. The ecological evaluation demonstrated that runoff management and habitat provision in a sub-urban setting enhance the overall functionality of this new type of SCM ecosystem. A functionality assessment guide was developed for assessing infiltration basins considered to have failed. The Level-1 assessment includes visual criteria such as hydrophytic vegetation, hydric soils, hydrologic regime modification, and design check. The rapid assessment plans developed in this study can be applied to determine the ecological and stormwater management functions and benefits of failed/transitioning/transitioned basins, and may be adapted for other similar SCMs.

1. Introduction

The increased impervious surface footprint induced by urbanization and highway construction has resulted in higher stormwater runoff flows and volumes, faster routing of runoff, frequent flooding, reduced infiltration and evapotranspiration, and lower baseflow in nearby streams (Paul and Meyer, 2001; Walsh et al., 2005). Impervious surfaces collect assorted pollutants that are washed off by stormwater runoff and ultimately delivered into the proximate surface water body (Davis and McCuen, 2005). As a result of the modified rate, timing and delivery of flow and elevated contaminant levels, the physical, chemical, and biological conditions of receiving waters become impaired (Paul and Meyer, 2001; Walsh et al., 2005).

Stormwater control measures (SCMs) have been widely implemented to control the non-point pollution contributed by urban stormwater runoff and reduce runoff volume. Infiltration basins are SCMs that capture, temporarily store, and gradually infiltrate runoff into the ground, thereby reducing the net volume of runoff leaving the site, and can provide moderate to high removal of some pollutants in runoff (U.S. EPA, 1999; Birch et al., 2005; Dechesne et al., 2005).

However, the condition and infiltration performance of infiltration basins can progressively decline due to sediment deposition, irregular maintenance, improper siting, and poor design. Infiltration basins surveyed and monitored 2–15 years after construction have exhibited slower infiltration, inappropriate ponding of water (characterized by permanent ponding and/or increased frequency and duration of wetness), excessive sediment or debris accumulation, and clogging (Lindsey et al., 1992; Dechesne et al., 2005; Le Coustumer and Barraud, 2007; Emerson et al., 2010; Lassabatere et al., 2010; Bergman et al., 2011). At some point, the infiltration basin is considered to have “failed” to hydrologically function as designed and intended.

Nonetheless, for some designs a failed infiltration basin can gradually evolve or “transition” into a wetland- or wetpond-like practice and begin (or continue) to provide stormwater management benefits due to other processes related to the new features. In an intensive three-year field-scale research and monitoring study, the transitional performances of a failed infiltration basin, managing highway runoff in Maryland, USA, were systematically quantified during storm and inter-storm periods (Natarajan and Davis, 2015a,b, 2016). Although the infiltration component was diminished, the transitioned infiltration basin provided effective runoff control by detention, retention and evapotranspiration (Natarajan and Davis, 2015a), and runoff treatment by a combination of

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physical, chemical and biological processes (Natarajan and Davis, 2015b, 2016). The wetland and wetpond features resulted in modified, yet, successful operation of the transitioned infiltration basin.

Runoff water quality and hydrologic management are primary ecosystem services provided by effective SCMs. Only a few studies have focused on qualifying or quantifying the ancillary SCM ecosystem services; as engineered ecosystems, constructed stormwater wetlands and wetponds have been shown to provide wildlife habitat, vegetation biodiversity, carbon sequestration, and cultural services (Knight, 1997; Bishop et al., 2000; Brand and Snodgrass, 2010; Van Meter et al., 2011b; Le Viol et al., 2012; Moore and Hunt, 2012). Given its unique transformed nature, it can be hypothesized that a transitioned infiltration basin could also provide a range of ecosystem services.

The first objective of this work was to assess the ecological functions and benefits of the transitioned infiltration basin. Two traditional SCM performance metrics, i.e., runoff flow and water quality management (previously quantified in Natarajan and Davis, 2015a,b, 2016), and two ancillary functions namely, habitat for wildlife and vegetation, and cultural services (recreational and educational opportunities) were considered. Ecological evaluation of SCMs is relevant given the recent increase in incorporating features of natural ecosystems like wetlands into the design of SCMs (Welker et al., 2013), and the limited research that currently exists on assessing the ecosystem services of SCMs and integrating them into the management of SCMs (Brand and Snodgrass, 2010; Moore and Hunt, 2012).

The second objective of this work was to develop a simple, but principal-based ecological framework for substantiating the functionality of infiltration basins and similar facilities considered to have failed. The framework employs hydrology, soil, and vegetation as primary indices of functionality since they are readily measurable, can detect wetland/wetpond attributes, and can be used to identify the functions most likely to be performed by the facility under investigation. In other words, if ecological evidence of a transitioned (or transitioning) nature can be found and appropriately documented, the facility can be assumed to be performing adequately as a SCM. Accordingly, it can be more intensively studied for SCM functionality or allowed to exist in its current state, which could potentially free funds designated for rehabilitating the failed facility, for use in other environmental improvement programs.

The intended users of the ecological evaluation plan and functionality assessment guide presented in this work are those directly responsible for stormwater management at the municipal-, watershed-, or state-scale. The ecological evaluation plan can serve as a template for assessing the ecosystem services of any SCM. The functionality guide will be a useful addition to existing SCM inspection toolboxes that evaluate the proper functioning, operational problems and maintenance needs of SCMs, and could be employed as a decision-making tool for future SCM assessments.

2. Site description and monitoring method

The transitioned infiltration basin site is located in Columbia (Howard County), Maryland, USA. The infiltration basin manages stormwater runoff from a 2.9 ha drainage area consisting of 0.96 ha impervious cover (MD 175 highway) and 1.9 ha of grass cover. There is no baseflow to the site. The infiltration basin is 71 m long, 5.8 m wide (average bottom width), and 0.91 m deep and has an approximate storage volume of 600 m^3. The actual infiltration basin had been classified by the Maryland State Highway Administration (SHA) as "requiring retrofit due to existence of several issues or indication of failure" six years after construction. Sediment deposition and permanent inundation in the infiltration basin indicated its failure from an engineering perspective.

The study site was monitored from August 2009 to August 2012. Runoff inflows, outflows from the transitioned basin, and rainfall depths were recorded during multiple storm events. Water quality samples of inflow and outflow were collected using automated water samplers during the course of selected storm events and the concentrations of various pollutants (total suspended solids (TSS), nitrogen species, phosphorus species, heavy metals and chloride) determined. The basin water was sampled during interstorm periods. The data collected were used along with the water level, temperature, pH, and oxidation–reduction potential (ORP) measurements in the basin to understand the water balance and pollutant separations/transformations within the facility. Detailed description of the study site and measurement methods are provided in Natarajan and Davis (2015a,b, 2016).

The type of vegetation and wildlife at the site were recorded by direct observation. Field notes and photographs were taken during each site visit (approximately monthly except during very cold periods) that typically lasted 1–2 h during non-rainy daylight hours. The major plant communities growing within, in the periphery, and in the upland area of the transitioned basin were noted. The plant species were identified with the help of Prof. Andrew Baldwin at University of Maryland, College Park, MD 20742 (personal communication, June 2012). Characterization as wetland or non-wetland species was done using the *2012 National Wetland Plant List* (http://rsgisias.crrel.usace.army.mil/NWPL/). While walking around the infiltration basin, animals encountered in the basin periphery and terrestrial area were noted, although focus was not limited to a specific animal type. Clues on wildlife presence (i.e., nests, feces, burrows, footprints) were noted if found. Due to the qualitative scope of the habitat assessment aspect of this study and the desire to produce a screening tool that did not involve extensive commitment of resources, visual survey was primarily employed and a comprehensive biosampling was not performed.

The cultural services of recreational and educational opportunities were also qualitatively assessed. The evaluation criteria were selected from existing studies (Knight, 1997; Moore and Hunt, 2012): presence or absence of recreational facilities (public accessibility, walking trails, wildlife-viewing area) and opportunities for education and research activities.

3. Results and discussion

3.1. Summary of hydrology and water quality performances

The infiltration basin was continuously wet and inundated following and between storm events, and did not dry out even during the warmest and driest periods. Overall, the transitioned basin was found to effectively manage the highway runoff. The inflow runoff was largely attenuated, observed in the form of reduced outflow rates, volumes (4–100% reduction; mean = 64%), and frequency for the 120 storm events monitored (Natarajan and Davis, 2015a). The 38 water quality events demonstrated statistically significant decreases in inflow event mean concentrations (EMCs) and mass loads for all pollutants. The mean pollutant mass reductions were 95% TSS, 86% copper (Cu), 76% lead (Pb), 81% zinc (Zn), 82% total phosphorus (TP), 76% dissolved phosphorus (DP), 88% NOx (nitrite + nitrate), 77% total Kjeldahl nitrogen (TKN), 66% organic nitrogen (ON), and 65% chloride (Natarajan and Davis, 2015b, 2016). The basin water contained average concentrations of 20 mg/L TSS, 0.15 mg/L TP, 0.05 mg/L DP, 0.08 mg/L NOx, 1.3 mg/L TKN, <2 μg/L Cu, <5 μg/L Pb, <25 μg/L Zn, and 152 mg/L chloride during the dry periods between storms. Sedimentation, adsorption, denitrification, vegetative uptake, and dilution combined with volume reduction in the transitioned basin were the mechanisms of pollutant abatement. However, during the largest and extreme storms