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# Impact Assessment of Stormwater Alternatives on Generated Runoff in Cities Experiencing Urban Decline

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**Abstract**

Shrinking cities have experienced substantial, chronic population decline resulting in the inundation of impervious, vacant or abandoned properties that contribute to the runoff entering the stormwater systems. These cities have the potential to shift land uses, selectively transition excess land to pervious surfaces, or implement green infrastructure to treat stormwater onsite, reducing the runoff and pollutants entering the stormwater systems. This study evaluated the impact on the generated runoff due to: (1) decommissioning impervious surfaces, (2) transitioning land uses, and (3) incorporating bioretention cells at the neighborhood level in vacant lots. Hydrology-hydraulic modeling was used to evaluate the alternatives in two Midwestern shrinking cities, each operating on different stormwater systems (combined and separate) using city-provided and publicly available data. Historic precipitation; short-duration, high-intensity storms; and long-duration, low-intensity storms were assessed. Implementing the alternatives can reduce runoff between 10% and 98% depending upon the alternative and precipitation/storm.


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*Keywords:* Shrinking cities; Stormwater management; Runoff; Green infrastucture; Combined sewer systems; Land use

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## 1. Introduction

Shrinking cities are cities that have experienced substantial, chronic decline in their populations over multiple decades (e.g., Detroit, MI; Gary, IN) and decreasing demands for infrastructure services [18]. In spite of decreasing demand arising from fewer consumers, the cost to maintain the aging and decaying infrastructure remains, as the infrastructure footprint is relatively stable, not contracting with the declining populations [28, 6, 11].

Two types of stormwater infrastructures are of particular interest to this study: separate sewer systems and combined sewer systems (CSSs). Separate sewer systems collect generated runoff, typically transporting the runoff to open water sources, with limited, if any, treatment. CSSs that transport stormwater runoff and wastewater flows in the same infrastructure system operate in approximately 770 communities that are home to around 40 million people in the US [36]. These CSSs are characteristic of older communities, many of which are Midwestern shrinking cities. CSSs may exceed capacity, discharging untreated flows into surrounding receiving water sources with precipitation events as little as 0.1 inches [22]. Untreated overflows introduce pollutants and pathogens into the water sources, degrading the water quality and potentially causing public health threats and environmental degradation [37]. CSSs can also pose challenges during dry periods, when solids settle due to low flows and the solids are discharged during overflow events at a later time.

Contributing to the generated runoff entering either the separate stormwater system or the CSSs are the vacant and abandoned impervious surfaces in shrinking cities that impede water infiltration to the groundwater system [18]. Additionally, non-point source pollutants and debris accumulate in the generated runoff [3]. This runoff entering the infrastructure systems may result in the increasing frequency of discharges as the system exceeds capacity. The Clean Water Act established in the 1970s created environmental programs such as the National Pollutant Discharge Elimination System (NPDES) permit program, to regulate pollutant discharges [35]. Methods to reduce these discharges and aid cities in compliance include increasing the capacity of the underground stormwater collection system or separating the stormwater collection to be separate from the wastewater system in CSSs. Implementing stormwater management practices to either reduce generated runoff or treat stormwater onsite, as opposed to entering the underground infrastructure, are other suggested approaches to reduce strain on the wastewater treatment plant or increase available capacity in the stormwater collection infrastructure system.

The application of stormwater management to reduce generated runoff has been explored in literature and in practice. Philadelphia, PA has invested in stormwater onsite management with green infrastructures, such as bioswales and rain gardens, in attempt to reduce overflows prior to financially investing in an overflow tunnel [4]. Carter and Jackson [12] consider implementing stormwater management in urbanized areas, evaluating the most effective practices with limited land use. Montalto et al. [23] presents a low impact development (LID) rapid assessment tool to estimate the cost-effectiveness of various forms of LID practices in densely, urbanized areas. Jia et al. [21] proposes a decision-making tool using ArcGIS and optimization evaluating the potential of alternatives to coexist with proposed/existing developments. Another alternative explored is the impact of permeable pavements on water quality and runoff (e.g., [5, 14]). This alternative is unlikely to be implemented in a fiscally strained, shrinking city due to the large-scale repaving effort necessary in the severely declining areas considered in this study.

This paper explores integrating stormwater management methods within shrinking cities where there is an abundance of underutilized, vacant land and limited opportunity for lot-level investment due to the high vacancy rates. Researchers and planners are now focusing on stabilizing growth in shrinking cities and resizing the city footprint to meet the needs of the smaller population (e.g., [8, 1, 27, 10, 7, 34]). These cities have the potential to shift land uses, selectively transition excess land uses, or implement LID practices that treat stormwater onsite, to reduce the quantity of runoff and pollutants entering the infrastructure system. Stormwater retooling alternatives in this study refer to physical changes to the surface infrastructure in shrinking cities (e.g., abandoned/vacant parcels, sidewalks), to improve the performance of stormwater/wastewater system. This study evaluates the impact of three stormwater retooling alternatives on the generated runoff:

- **Decommissioning vacant/abandoned impervious surfaces** to allow onsite infiltration**.**
- **Transitioning land uses** post decommissioning impervious surfaces, such as a wooded or grass area.
- **Incorporating bioretention cells** at the neighborhood level to treat water onsite.