Ecological Economics 145 (2018) 420–429

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Estimating the Economic Impact of Stormwater Runoff in the Allen Creek Watershed

Kelly Hellman[a,*], Jeffrey Wagner[b], Daniel Lass[a], Karl Korfmacher[c], Bríd Gleeson Hanna[b]

[a] *Department of Resource Economics, University of Massachusetts Amherst, United States*
[b] *Department of Economics, Rochester Institute of Technology, United States*
[c] *Environmental Science Program, Rochester Institute of Technology, United States*

ARTICLE INFO

Keywords:
Hedonic model
Marginal damage
Stormwater management
Urban runoff
Water quantity implicit prices
L-THIA

ABSTRACT

Stormwater runoff generated by increased landscape imperviousness results in flooding and degradation of aquatic systems. This paper proposes an economic model of stormwater runoff damage estimation. Using a hedonic property model that allows us to account for the heterogeneity in each parcel's generation of stormwater runoff, we estimate the marginal implicit cost of an additional 10,000 ft^3 of annual runoff (which represents about a 2% increase in the average annual runoff volume coming from each lot) to a downstream community in the Allen Creek watershed located in Rochester, NY. We estimate that an additional 10,000 ft^3 of runoff translates to nearly $12,000 (or $1.20 per cubic foot) of damages to downstream residences under current development conditions. Results can be compared with abatement cost estimates from other studies to help quantify one important part of the tradeoffs between the desirability of development versus the increase in environmental challenges and economic costs that may result.

1. Introduction

The management of urban stormwater runoff is of increasing policy concern as development, particularly the proliferation of impervious surfaces, increases. Stormwater runoff occurs naturally; however, like many natural processes, stormwater flow can be affected by human activities. Changes in land use, specifically the conversion of natural landscapes to urbanized areas, have been found to significantly impact stormwater flow. Increased impervious surface area (such as roofs and pavement) in watersheds has been linked to changes in both the type and magnitude of stormwater flow. Watersheds dominated by a subsurface stormflow regime prior to urbanization experience an increase in runoff generated by overland flow due to increased imperviousness. Overland flow occurs when the soil infiltration capacity and depression storage are exceeded. Increased overland flow results in greater and more rapidly forming peak flows, or large volumes of water being delivered to the stream channel over a short period of time, and lower baseflow, which is water that flows through the soil to sustain streams over time (Dunne and Leopold, 1978).

These changes to the natural system have implications for both the water quality and quantity in a receiving water body. The amplification of peak flows and creation of new peak events can lead to channel overflow, causing the surrounding land area to flood, especially downstream (Booth, 1991 and Paul and Meyer, 2001). Increased flooding can have detrimental effects on riparian areas that are not adapted to a high frequency of flooding. Increased peak flows alter the stream channel and cause visible physical degradation as a result of changes in sedimentation and erosion patterns, and decreased baseflow impacts aquatic organisms in the stream. Additionally, water quality may decline in urban streams due to the large quantity of incoming runoff carrying urban pollutants that may not experience the intense filtration that occurs during percolation through the soil (House et al., 1993 and Paul and Meyer, 2001).

In economic terms, the existence of damage from uncontrolled stormwater runoff implies that the privately optimal rate of runoff exceeds the socially efficient rate of runoff. In the absence of constraints, private parties that could abate runoff will only do so to the extent that they privately benefit from their abatement activities. Since runoff flows downstream, upstream developers and homeowners have little financial incentive to abate runoff that causes damage to downstream properties. The absence of constraints implies zero marginal costs for increases in runoff coming from one's property; hence, private parties tend to choose zero abatement investment in order to maximize the total private benefits of their economic activities (development) that increase runoff volumes.

While abating urban stormwater runoff has both ecological and

---

* Corresponding author.
E-mail address: khellman@resecon.umass.edu (K. Hellman).

https://doi.org/10.1016/j.ecolecon.2017.11.022
Received 7 April 2017; Received in revised form 13 September 2017; Accepted 19 November 2017
0921-8009/

economic aspects that must be considered in an optimal management strategy, our study focuses on the economic property damage aspects. We adapt the basic economic model for pollution control to stormwater management. This model indicates that the economically efficient volume of runoff to abate in a watershed is a level that equates the marginal property damage avoided to the marginal abatement cost. This model can be used to inform development decisions in a watershed. Given the optimal volume of runoff abatement, planners can determine whether the abatement burden required to mitigate additional development is both technically feasible and not so costly that it overwhelms the economic benefits of the development.

Stormwater runoff can be controlled using centralized methods, decentralized methods, or a combination of both. Centralized control methods include large-scale efforts that are typically built downstream, like the creation of wastewater treatment plants and city sewage or tunnel systems. In contrast, decentralized control methods, such as adoption of site-specific best management practices (BMPs), focus on smaller scale, dispersed mitigation efforts. BMPs help decrease the volume of stormwater runoff downstream via upstream stormwater retention, promoting soil infiltration and improving water quality by facilitating vegetative filtration. These technologies can also present a cost-effective solution to runoff abatement (Braden and Ando, 2012 and Cutter et al., 2008).

The costs associated with various abatement technologies include construction, operation, maintenance, and land costs. While the literature agrees the value of land will have the largest impact on the cost-effectiveness of various abatement technologies, many studies estimate only the construction, operation and maintenance costs of different BMPs (Thurston et al., 2003; Landphair, 2001; Weiss et al., 2012). Thurston et al. (2003) and Weiss et al. (2012) use Cobb-Douglas functional forms to determine construction costs as a function of volume of stormwater abated. For most of the BMPs considered, the marginal construction costs vary substantially and decrease as volume abated increases. However, when including an estimate for the opportunity cost of land, Thurston (2006) and Cutter et al. (2008) show that the cost-effectiveness of decentralized BMPs relative to centralized methods depends largely on the value of the land being used for abatement.

On the stormwater damages side of the ledger, multiple studies show that there are economic benefits from improving water quality. For example, Poor et al. (2007) use a hedonic model and estimate that reductions in water quality due to one milligram per liter increases in total suspended solids and dissolved inorganic nitrogen have respective negative impacts of 0.5% and 8% on home values. Using a similar hedonic model but correcting for spatial autocorrelation, Walsh et al. (2011) find that residential stormwater management and aquatic plant control programs can increase home values by 3–5%. An analysis by Netusil et al. (2014) is closely related to our study in that they investigate how water quality in creeks near residential property affects property values; using a hedonic price model, they find that water quality does affect residential property values and that the effect generally dissipates, as expected, with distance from the creek.

Consistent with the water quality literature, Streiner and Loomis (1995) and Sander et al. (2010) use hedonic models to estimate the value of stormwater quantity mitigation. While Streiner and Loomis (1995) find that the effect of flood control is positive and worth 5% of property values, Sander et al. (2010) find a much smaller positive impact on property values (0.29–0.48%) resulting from a 10% increase in vegetative cover within close proximity to homes. Similarly, Kadish and Netusil (2012) examine the relationship between land cover types – trees, shrubs, water and impervious surface areas – and sale prices of single-family residences in the areas surrounding these properties. With regard to tree canopy, they find that increasing canopy increases a home's sale value but this benefit is less than the discounted estimated cost of planting and caring for trees on a given property. They note, however, that consideration of additional benefits from each tree, such as stormwater mitigation, may result in incremental social benefits exceeding the incremental social costs. Finally, Braden and Johnston (2004) summarize existing estimates for the value of flood reduction and conclude that stormwater mitigation is worth 0–5% of property values depending on the home's location in the floodplain. Using these estimates from the aforementioned paper, Johnston et al. (2006) study the impact of reducing the size of the 100-year flood plain, ultimately determining that the downstream benefit to stormwater management is between \$40–\$620 per developed acre.

Our study extends the above literature in two dimensions. First, while others have examined residential economic property damage that arises from relatively infrequent floods (i.e. 100-year events), our study estimates property damage from exposure to regularly occurring stormwater quantity flows (average annual runoff). Second, we believe ours is the first study to model this relationship in a manner that takes into account the parcel-level potential to both attenuate upstream stormwater flow and contribute to downstream stormwater flow. That is, our measure of stormwater runoff is at the individual parcel level; it accounts for heterogeneity in each parcel's generation of stormwater runoff.[1] We estimate the marginal damage of runoff for a small urbanized watershed located primarily in the Town of Brighton, Rochester NY. The Town of Brighton is considering impacts that the development of a large area of green space (87 acres) would have downstream. Our results help to answer this question by providing an estimate for marginal property damage. Thus, our study helps quantify one important part of the tradeoffs communities face when evaluating the desirability of development (e.g., raising the tax base) versus the increase in environmental challenges and economic costs that may result (e.g., greater harm from stormwater runoff).

Our paper proceeds as follows. In Section 2, we present our theoretical economic model of urban stormwater runoff generation and its abatement. Our study area and data are presented in Section 3. We then estimate the empirical model in Section 4 and discuss the results. Section 5 presents an application of our results as we compare our marginal damage estimate to marginal abatement costs from previous literature. Finally, in Section 6 we discuss our conclusions and directions for future research.

2. The Economic Model

A fundamental economic challenge faced by urban planners is to balance the costs of abating stormwater runoff with the benefits of doing so. While the abatement cost and damage associated with urban stormwater runoff is a function of both quantity and quality, and watershed managers must consider both of these aspects of stormwater management, the model is simplified so that abatement cost and damage are functions of quantity only. In focusing on the quantity aspect, the model assumes that abating stormwater quantity will also indirectly mitigate stormwater quality effects (Laukkanen et al., 2009).

Let the volume of uncontrolled stormwater runoff in the watershed be denoted by $\overline{RO}$. The planner's objective is to determine the optimal volume $RO \leq \overline{RO}$. Suppose the abatement cost $A(RO)$ is a continuous and differentiable function with $\frac{\partial A}{\partial RO} < 0$ and $\frac{\partial^2 A}{\partial RO^2} \geq 0$.[2] We represent

---

[1] Rosen's (1974) seminal paper on hedonic modeling presents the theoretical underpinnings of first and second-stage hedonic analyses. The first stage model relates prices of homes to characteristics of those homes to estimate the implicit price functions, while the second-stage uses the marginal implicit prices determined in the first stage to trace out the household's compensated demand curve, or marginal bid curve. At the optimal level of consumption, the marginal implicit price is equal to the marginal bid (Taylor, 2003). In our study, we make the simplifying assumption that the marginal implicit price of runoff is equal to the marginal bid to interpret our first-stage hedonic regression results as estimates of damage.

[2] While we discuss the specific case of continuous abatement costs, complexities of stormwater management plans and differences in costs associated with installing BMPs on various types of land in a watershed could result in discontinuities. For instance, a stormwater management plan that uses various BMPs and extends widely across a watershed could see jumps in costs at specific volumes upon switching to new technologies to abate larger volumes or after the availability of less expensive land for BMP installation has been exhausted.