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Analysis

Do Stormwater Basins Generate co-Benefits? Evidence from Baltimore County, Maryland

Nicholas B. Irwin *, H. Allen Klaiber, Elena G. Irwin

The Ohio State University, 331 Ag Admin Bldg, 2120 Fyffe Rd, Columbus, OH 43212, United States

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ABSTRACT

An often-cited advantage of green infrastructure projects is the potential for "co-benefits" generated from its natural features, which depend on the generation of positive house price capitalization. Using housing transactions data and exploiting variation in placement and design, we examine the capitalization of stormwater retention basins, a common green infrastructure project in suburban housing developments. Results show adjacency causes decreases in housing prices between 13 and 14% for the average home. Additionally this negative effect exacerbates with basin age. Rather than providing co-benefits, we find that stormwater basins generate a cost for proximate households.

1. Introduction

Stormwater runoff poses multiple threats to the environment due to chemical and microbial contaminants that impair water quality and increase water velocity and volume, which degrade aquatic habitats and stream function (National Research Council, 2009). Current trends, including urbanization and increased intensity of storm events from climate change, underscore the critical and growing challenge that stormwater management poses for cities and urbanizing regions. Stormwater is especially problematic in urban areas with combined sewer systems, which are common in many parts of the United States. Combined sewer systems, with sanitary and stormwater passing through the same infrastructure, are prone to overflow when rain events exceed the capacity of the sewers or treatment facilities, leading to a discharge of untreated sewage into nearby waterways. These combined systems have received increasing attention from both regulatory agencies and urban policymakers, with the U.S. EPA prioritizing the issue and using civil penalties to force municipalities to comply with the National Pollutant Discharge Elimination System (NPDES) and mitigate overflows by installing additional infrastructure at a significant cost (EPA National Enforcements Initiative, 2015).

The installation of grey infrastructure, such as large underground storage tanks to collect rainfall or increases in treatment plant capacity, is the traditional means by which municipalities have proposed to comply with NPDES. To offset the high cost of grey infrastructure, urban areas have increasingly incorporated green infrastructure – such as green streets, green roofs, and stormwater retention basins[1] – into citywide comprehensive stormwater management plans. These green techniques have been noted to not only lower costs (Braden and Ando, 2012), but also to provide potential "co-benefits" to residents from the green space that is naturally produced by this type of development (Downing, 2015; LA Department of Public Works, 2016). However, the potential for green infrastructure projects to provide these co-benefits depends on the proximity of nearby households, the size of the project, and the nature of the green space. Small projects – such as green roofs or rain gardens – may be positively capitalized into the immediate house or lot with which they are associated, but are unlikely to provide co-benefits that extend beyond this. Larger projects, such as retention basins, are more likely to generate amenity benefits for multiple households, e.g., by creating a scenic view, providing recreational space, or preventing nearby development. On the other hand, it's possible that

[1] Green streets are curb extensions or sidewalk planters planted with vegetation that absorb stormwater. Green roofs are roofs with vegetation growing that utilizes stormwater. Retention basins are ponds that retain and filter stormwater before gradually releasing it into nearby waterways.

* Corresponding author.
E-mail address: irwin.114@osu.edu (N.B. Irwin).

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natural vegetation may create a disamenity, e.g., by appearing overgrown or attracting unwanted pests. Thus the value of green infrastructure to nearby residents, as capitalized into housing prices, is an empirical question.

A number of empirical studies have demonstrated the positive capitalization of heterogeneous open space into housing prices in urban settings (e.g., Geoghegan, 2002; Irwin, 2002; Anderson and West, 2006; Walsh, 2007; Abbott and Klaiber, 2010).[2] Other studies have found evidence of the positive influence of urban waterbodies, including large increases in housing prices based on proximity to coastal waterfront (e.g., Bond et al., 2002; Walsh et al., 2011), urban lakes (Abbott and Klaiber, 2013), wetlands (Mahan et al., 2000) and waterbodies (Cho et al., 2009). Water clarity and other measures of water quality associated with nearby waterbodies can also positively capitalize into housing values (Leggett and Bockstael, 2000; Poor et al., 2001). In contrast, far fewer studies have focused on the potential benefits from smaller, more distributed water features such as stormwater management infrastructure.

Cadavid and Ando (2013) find that survey respondents are willing-to-pay for reductions in flood frequency and improvements to the hydrological function in watersheds with stormwater infrastructure. While these results reveal a positive demand for the environmental benefits of stormwater management, they do not provide an estimate of the potential benefits from stormwater landscape features associated with basins. Using spatial regression, Lee and Li (2009) find significant correlation between stormwater basins and nearby housing prices in their study of two stormwater basins in a neighborhood in College Station, Texas. However, the positive house price correlation arises from a basin located within a park and raises potential endogeneity concerns. We take care to address potential time-constant unobservables in our research design and do so over a significantly larger dataset.

The purpose of this paper is to empirically identify the capitalization effect of stormwater basins on nearby housing prices and in so doing, investigate the potential for this particular type of green infrastructure to generate (dis)amenities that would augment or offset the intended environmental benefits of improved urban water management. We estimate this capitalization effect using data on the location of 2950 stormwater basins and over 90,000 observations of housing sales between 1996 and 2007 in a suburban county of the Baltimore, Maryland metropolitan region. We exploit spatial and temporal variation in the placement of basins, regulations on their design, and the occurrence of housing near basins of different vintages in close proximity to determine causally the capitalized value of stormwater basins into house prices.

Our results show that stormwater basin adjacency leads to housing prices that are consistently lower, with estimates between 13 and 14%, depending on model specification. For the mean house in our sample, this corresponds to a house price decrease between $28,185 and $30,579, a factor solely attributed to stormwater basin adjacency. Additionally, this negative capitalization effect accentuates as the basin ages. For the case of a house adjacent to a basin that is at least seven years old, we estimate it to have a compounding negative capitalization of approximately 17% when compared to an identical home not adjacent to such a basin. We do not find any significant effect on nearby houses that are not adjacent, suggesting that the effect is highly localized.

This paper is the first study to-date that identifies the causal effect of stormwater retention basins on housing values across a heterogeneous geographic area using revealed preference data on housing markets. Our approach controls for a number of sources of bias that could arise from the presence of unobservable landscape features, lending confidence that the estimated negative effect is robust. The results show that, in the absence of a purposeful approach to amenity creation, the stormwater regulations implemented in our Baltimore County, Maryland study region have resulted in stormwater basins that confer a substantial negative impact on adjacent houses and no significant effect on non-adjacent houses. Thus, households adjacent to stormwater basins bear a disproportionate share of the cost of providing green infrastructure that generates environmental benefits for all residents of the region. While this work does not consider the full costs and benefits of stormwater basins, including their costs of construction and maintenance and the value of the ecosystem services they deliver, it does imply that any ecological benefit further downstream should be sufficiently large to offset these losses in adjacent housing values in order to provide an overall net benefit to the region.

The remainder of the paper is as follows. The following section discusses state and local stormwater regulation in Maryland, with a focus on who bears the cost of compliance, followed by a discussion of data in Section 3 and methods in Section 4. We report results in Section 5 and conclude in the final section with a summary and discussion of implications.

2. Stormwater Policy and Compliance Burden

Stormwater management evolved out of concern for the impact of development on the natural hydrological cycles of the environment. When rainfall occurs in an undeveloped area, it infiltrates the ground surface or undergoes evapotranspiration by vegetation (National Research Council, 2009). In urban landscapes filled with impervious surfaces, the ability of the vegetation and soil to retain water is impaired, leading to stormwater flows that are concentrated and potentially devastating to the surrounding watershed (Thurston, 2012).

Since 1990, the NPDES Stormwater Permit Program, part of the larger Clean Water Act, has regulated water runoff from municipalities, construction activity, and industrial sources in the United States. Prior to 2003, each state had significant leeway in determining the threshold of land disturbance that required the issuance of an individual permit and creation of a stormwater site plan. Post 2003, the EPA set nationwide standards to be followed in each state for any development activity over one acre. The state of Maryland was a much earlier adopter, passing its first set of stormwater regulations in 1984, with the goal of protecting the Chesapeake Bay as a motivating factor. Maryland is much more stringent on stormwater management than the rest of the nation, requiring stormwater controls on every development that disturbs > 5000 square feet (0.11 acres) of land. From 1984 until 2001, all basins were required to hold the first flush of water from a rainfall event. From 2002 until 2008, basins were required to provide a water quality improvement of 20% from the pre-storm baseline through filtering occurring within the basin.

Maryland has also been the beneficiary of several U.S. EPA civil suits against housing developers found in repeated violation of stormwater regulations, with fines totaling over $6 million (EPA Office of Enforcement and Compliance, 2008; EPA National Enforcements Initiative, 2015). The bulk of these fines were due to poor stormwater practices during the construction portion of the homebuilding phase but this belies an important issue underlying stormwater regulations in suburban settings. Once the new development is finished and the initial stormwater infrastructure put into place by the developer, the cost of compliance and control of the infrastructure falls under the auspices of the households living near the stormwater basin, usually under the form of a local homeowner association (HOA) or equivalent. The HOA is responsible[3] for routine maintenance of the stormwater infrastructure, which includes ensuring all retention basin dams are intact, vegetative overgrowth is under control, outflow pipes are clean, and litter is collected. While the upkeep costs vary by basin size and need, the monetary funds required will come from the households who make up the HOA. In Baltimore County, all stormwater basins also require an inspection by the county every three years (Baltimore County Code, 2010).

[2] See McConnell and Walls (2005) for a review of the earlier literature.

[3] HOA's also occasionally arrange for maintenance and care of the stormwater infrastructure by nearby municipalities for a fee.

Due to the absence of rigorous empirical work on the effects stormwater compliance in a residential setting, we know very little on the effects of stormwater regulations on the resulting built environment and its effect on households.[4] Basins could provide an attractive amenity for proximate homeowners, as the grassy vegetation around the basins could be aesthetically pleasing and, when filled with water, serve as a point for wildlife observation. If this were true, then basins would capitalize positively into house prices. Basins could also be positively valued if households value the ecosystem services provided by it. However, if basins are unkempt, overgrown, or unsightly, they may capitalize negatively into house prices. We suspect the latter could be the case generally, as anecdotal evidence from speaking with stormwater inspectors in Maryland indicate that a large number of complaints regarding stormwater basins arise from nearby households who are concerned with the appearance or functionality of the basin. Inspections usually follow these complaints, with any remedies being the responsibility of the HOA under the threat of civil fines. These inspections are costly but more importantly, if they not adequately addressed by the HOA, additional basin degradation and the possibility of decreased effectiveness of basins is likely to occur. If homeowners initially valued the basin or services provided by it, the potential for deteriorating basin conditions over time could offset previously positive capitalization. In sum, the existence of any capitalization effect for basins generally is an empirical question.

3. Data

The focus of our study is the suburban Baltimore County, Maryland area and we show its location within Maryland in Fig. 1 as the highlighted area. This county contains both suburban and exurban areas located adjacent and to the north of the City of Baltimore. To evaluate the capitalization impact of stormwater retention basins on housing prices, we assemble data from a variety of sources that allow us to link housing transactions data with the exact location of stormwater retention basins using parcel GIS maps.

We obtain housing sale records from 1996 to 2007 from Maryland PropertyView, a database created by the Maryland Department of Planning that contains housing and parcel information as well as GIS parcel data. Stormwater basin information is from the Baltimore County GIS website, which provides the unique geolocation of every hydrological feature, including stormwater basins, located within the county. Fig. 2 shows the distribution of detached single-family house sales during the study period and the location and size of each of the 2950 stormwater basins identified within the county. As the figure shows, the majority of housing sales are located in the southern part of the county, which abuts the City of Baltimore. As the county surrounds the city, it contains numerous suburbs and housing subdivisions with many residents commuting to Baltimore for work. The spatial distribution of stormwater basins closely mirrors this transactions pattern, as one would expect given the regulatory requirements for stormwater mitigation associated with new housing development.

We limit our analysis to arms-length sales transactions and clean the housing transactions data by eliminating transactions missing key structural attributes. We exclude all transactions missing sale price, sale date, or a geographic identifier such as a block group number. We also drop all transactions missing key housing characteristic information such as housing square footage, parcel size, and number of bathrooms, all of which are important contributing factors to house prices. We also eliminate the extreme outliers in the housing transactions data resulting in the removal of all houses with sale prices less than \$10,000 or greater than \$3 million, all houses with under 500 ft^2, and houses on parcels greater than seven acres. We report summary statistics in Table 1. The median house size is approximately 1600 ft^2 and located on a quarter acre lot. The average price for a house sold during our study period is over \$218,000.

A key requirement of our identification strategy is the ability to precisely link houses to nearby stormwater basins, and therefore it is important that we have sufficient overlap in the location of housing tractions and nearby stormwater basins. In our sample, the average home is located 1300 ft from the nearest basin, suggesting that these basins are widespread in our study area, as shown in Table 2. Finally, 0.03% of our sample (2727 homes) consists of homes located adjacent to stormwater basins, meaning that the housing parcel abuts the stormwater basin, while 3.8% and 7.4% are located within 100- and 250-foot non-overlapping rings, respectively.

One limitation of the stormwater basin data is that it does not explicitly list a creation date for each stormwater basin nor contain specific attributes unique to each basin such as precise surrounding land cover. To partially overcome this limitation and obtain creation dates, we exploit local regulations that mandate the installation of basins in the approval process required for new subdivision development. Therefore, we can provide a reasonable approximation for the creation date of each stormwater basin by examining the houses surrounding each basin. To summarize this procedure, we examine the complete set of all houses located within 1000 ft of a stormwater basin and exploit the knowledge that these basins are built as part of the residential construction process. Stormwater site plans and practices are required by Maryland law to be in place as part of the initial construction activities (Baltimore County Code, 2010). We assign a creation date to each basin based on the oldest house located within this distance parameter but only if a sufficient cluster of houses of a similar age are present. For example, a basin may have six houses built in 2003 and one house built in 1960 nearby resulting in an assigned construction date of 2003.[5]

With this method, we identify the creation date for 1763 of the stormwater basins in the original data set, or approximately 60% of the total stormwater basins in the county and report the key statistics regarding these basins in Table 2. These basins have an average creation date of 1991 and have an average size of a little more than a third of an acre. The average year built of the basins falls right in the middle of the first period of stormwater basin regulation in Maryland. The basins for which we are unable to identify a creation date are all located at least 2500 ft from the nearest house, indicating their purpose is likely commercial or industrial and are located at a large enough distance that we would not expect any direct house price capitalization effect.

Using the creation date, we also create a variable to examine the aging process of basins and the influence of aging on the capitalized housing prices for surrounding homes. We calculate the age of the nearest basin at the time of each housing transaction by differencing the year sold and the basin creation date. This reveals a range of basin ages, reported in Table 2. Over 5% of houses in our sample were sold in the same year the basins were built with larger numbers in the one to three year, four to six, and seven-plus year groups. We also provide additional information on the percentage of homes sold and built after their nearest stormwater basin in Table 2. We find that at the subdivision scale, roughly 71% of houses were built and over 89% of house sales occurred after the creation date of their nearest basin.

4. Methods

We assume all households possess heterogeneous preferences for housing consumption including proximity to stormwater basins. This allows us to utilize a first-stage hedonic regression (Rosen, 1974) to uncover the capitalization of basins into surrounding homes. The literature is rich with advice for researchers on choosing the correct functional

[4] Gray and Shimshack (2011) provide an overview of the empirics of environmental compliance on industries and municipalities, some of which relate to NPDES compliance.

[5] To check against misidentification, we compare a random sample of our creation dates against a small list of known basin creation dates obtained from researchers affiliated with the Baltimore Ecosystem Study. We find that our identification method matches the creation date from the known list in most cases.

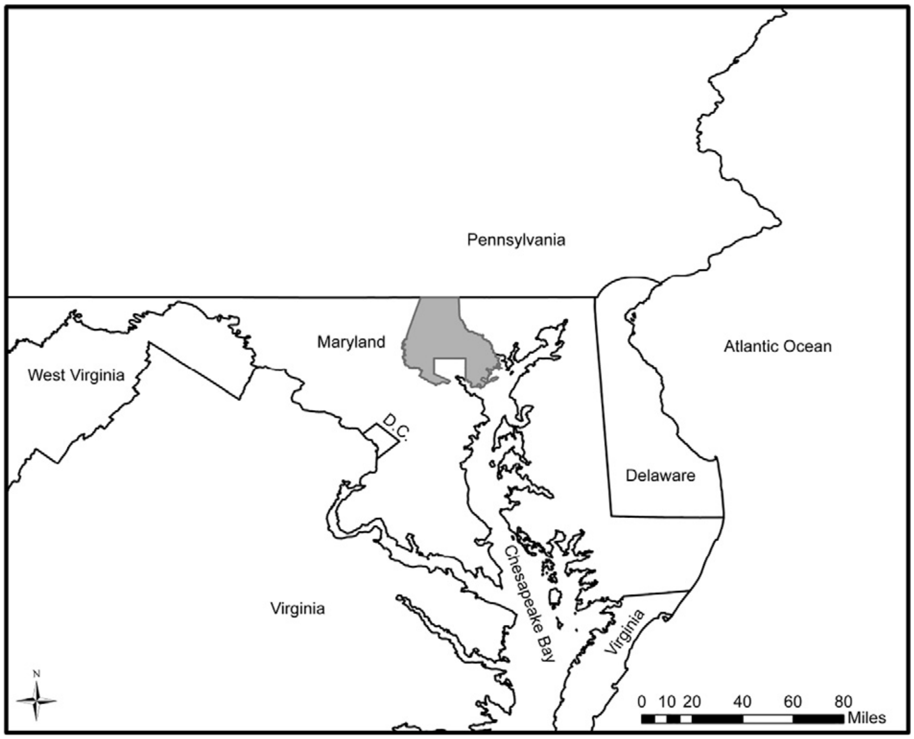

Fig. 1. Location of Baltimore County within Maryland.

form for a first-stage hedonic (Cropper et al., 1988; Kuminoff et al., 2010). Following previous research, we estimate a variety of functional forms,[6] before settling on a semi-log model as the basis for our subsequent regressions:

$$lnP_{ijt} = \beta_0 + \boldsymbol{\beta_X X_i} + \boldsymbol{\beta_N N_j} + \boldsymbol{\beta_Y Year_t} + \boldsymbol{\gamma_j Subd_j} + \beta_1 \boldsymbol{Ring_i} + \epsilon_{ijt} \quad (1)$$

The log price of house *i sold in year t located in neighborhood j* is determined by a vector of housing attributes $\boldsymbol{X_i}$, a vector of neighborhood characteristics $\boldsymbol{N_j}$, a year fixed effect, an indicator for location in one of several mutually exclusive distance rings near a stormwater basin, and an error term. In addition to the structural and neighborhood attributes included in this regression, we also include a variety of spatial fixed effects, $Subd_j$, to capture unobservable determinants of housing prices and allow the hedonic price gradient to shift across space. We use detailed subdivision identifiers in our data to include 5944 subdivision fixed effects, with each subdivision containing approximately 15 transactions.

In order to capture the capitalization of stormwater basins into surrounding housing prices, we use spatial heterogeneity in proximity to basins – the distance of each house to its nearest basin along with temporal variation in basin construction to estimate a difference-in-difference regression with heterogeneous treatment effects. Spatial heterogeneity arises from a series of non-overlapping rings around each basin with homes assigned a dummy variable value of one if located within a designated ring. We use this method to identify groups of houses adjacent to a basin, houses within 100 ft but not adjacent to a basin, and houses > 100 ft but <250 ft from a basin as we expect the influence of basins on housing prices likely varies across space.[7]

One identification challenge associated with the estimation presented in Eq. (1) is that we cannot be sure if the basin nearest the house is present prior to the housing sale. As written, we cannot distinguish between houses sold before or after basin construction. The latter group is the one of interest, as it would reflect the impact of the stormwater basin separately from potential capitalized open space premium associated with the location in which the stormwater basin is located. To identify each component separately, we modify (1) as follows

$$\begin{aligned} lnP_{ijt} = {} & \beta_0 + \boldsymbol{\beta_X X_i} + \boldsymbol{\beta_N N_j} + \boldsymbol{\beta_Y Year_t} + \boldsymbol{\gamma_j Subd_j} + \beta_1 \boldsymbol{Ring_i} \\ & + \beta_2 Post_{it} + \beta_3 Post_{it}{}^{*}\boldsymbol{Ring_i} + \epsilon_{ijt} \end{aligned} \quad (2)$$

In this specification, we include an additional indicator variable for a house selling after the creation date of the closest basin, labeled $Post_{it}$, using the same distance rings from Eq. (1), and an interaction term between these two variables, $Post_{it}{}^{*}\boldsymbol{Ring_i}$. The interaction term represents our treated group of interest – the set of all houses that are within a specified distance to a stormwater basin *and* sold after the creation date of the nearest basin—which allows us to separately identify the capitalization of the basin itself from the location on which the basin is situated.

If stormwater basins provide a positive capitalization effect and deliver on the promise of co-benefits, then we expect positive coefficients on distance rings near the basin and the treated group. Both variables would be an indication of an open space premium – via a development buffer preventing the building of nearby additional houses – directly attributable to stormwater basins with the treatment group identifying the sign and magnitude of any premium. We expect the relative capitalization effect to dissipate with distance as the open space premium is likely to take the form of a development buffer or localized open space, shown in much of the existing literature to impart a positive capitalized effect (see, e.g. Irwin, 2002 & Abbott and Klaiber, 2011) that is capitalized highest in houses closest to the buffer.

Our inclusion of fine-scale subdivision fixed effects ensures that identification of the basin effect is due to variation in proximity and attributes of the houses within each subdivision. Subdivision fixed effects control for capitalization differences that are time-constant across larger geographic areas and address the concern over time-invariant correlation between housing prices and the presence of open space (Irwin and

[6] We estimate a Box-Cox transformation of the main model (Eq. (2)) and find a theta value of 0.173 with the resulting tests indicating a semi-log model providing the best fit. As a final verification, we compare both the Akaike information criterion and the Bayesian information criterion from a liner, semi-log, and log-log models, which confirm the Box-Cox results.

[7] We also experiment with larger distance rings, which we do not report in this paper. The results with larger rings mirror the results of the 100 and 250 ft rings.

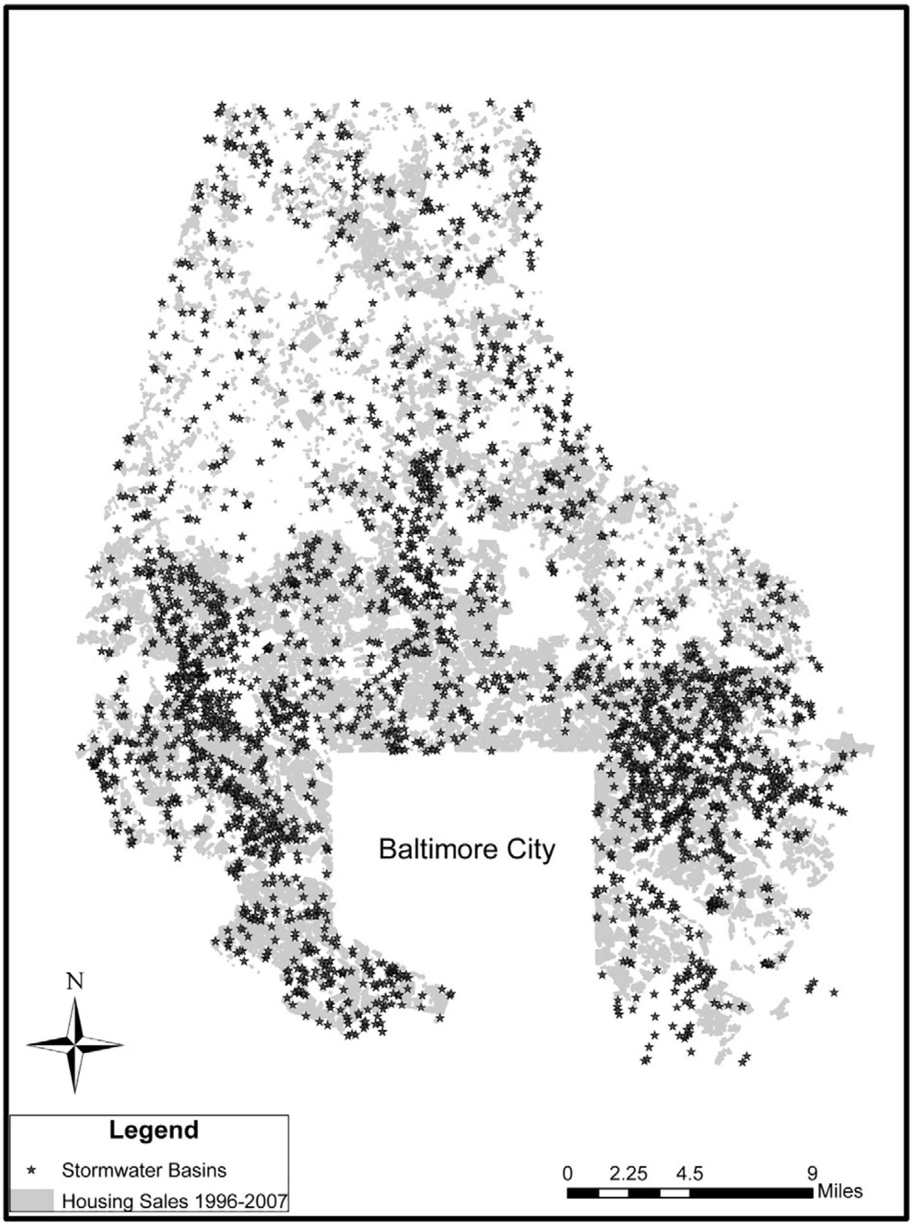

Fig. 2. Location of stormwater basins and housing sales in Baltimore County.

Bockstael, 2001). These basins are not recreational destination sites and we expect their influence on housing prices to be highly localized, thus motivating our use of fine-scale subdivision fixed effects. Despite the small spatial scale of these fixed effects, there remains substantial variation with respect to distance to stormwater basins within a single subdivision. Subdivision fixed effects also help mitigate the concern that we do not have maintenance records for each stormwater basin as the fixed effect will difference out the effect of routine, ongoing maintenance since all households in the same subdivision share a stormwater basin and the costs associated with maintenance. Finally, following Wooldridge (2003), we expect some correlation in the standard errors at the same spatial scale, so we cluster the standard errors at the subdivision level.

Our identification strategy relies on the assumption that houses in the same subdivision are similar after controlling for observable housing characteristics and time invariant subdivision level effects but vary in distance from the basin. As a robustness check to ensure there are no differences in house characteristics based on basin proximity, we compare the means of key characteristics and report them in Table 3. Within each subdivision, we identify the set of all houses that are within 250 ft (within our rings) and those outside of that boundary. We then calculate the average year built for houses in these groups, the average structural quality grade, the average house and parcel size, and the number of full bathrooms. Structural quality grade is a variable generated by the Computer Assisted Mass Appraisal (CAMA) data, one of our data sources, which measures the quality of the materials used to build the house on an eight-point scale where 1 is low-cost and 8 is luxury-plus.

Across all variables, there are no significant differences in means between the houses closest to the basin and those located further away. In the case of year built, houses closest to the basin are built, on average, two months later. The resulting Welch's t-statistic – based on the null of mean difference of zero and unequal variances – is not significant. For structural grade, both groups receive average structural grades of 4.22 and 4.23, respectively, which both fall within the grade of "good" with the t-statistic not significant. We find similar results for house square footage, parcel size, and number of full bathrooms, each with no indication of statistically significant differences in underlying means in the groups.

Table 1
Summary statistics for houses sold in Baltimore County.

Housing characteristics (n = 90,948)				
Variable	Mean	Std. deviation	Min	Max
Sale price	218,185	162,142	10,000	2,805,000
Ln sale price	12.09	0.618	9.21	14.85
House ft^2 (100 s)	16.27	7.582	5.18	69.77
Full bath	1.729	0.721	1	6
Parcel size (acre)	0.26	0.534	0.0151	6.986
Year built	1969	23.06	1898	2008
Stories	1.707	0.473	1	3
Basement	0.814	0.389	0	1
Air conditioning	0.793	0.405	0	1
Garage	0.349	0.477	0	1
Pool	0.0311	0.173	0	1
Percentage of housing transactions by year				
House sold in 1996				4.6%
House sold in 1997				4.7%
House sold in 1998				5.7%
House sold in 1999				6.7%
House sold in 2000				6.4%
House sold in 2001				7.4%
House sold in 2002				8.3%
House sold in 2003				9.1%
House sold in 2004				10.9%
House sold in 2005				12.6%
House sold in 2006				12.5%
House sold in 2007				11.2%

5. Main Model Results

To estimate the capitalization of stormwater basins in nearby house prices and to explore if basins deliver any co-benefits, we estimate two different specifications of Eq. (2) and report the results in Table 4. In the first model, we include only the adjacent ring and find all structural characteristics are significant at the 1% level or higher. House square footage, housing parcel size, number of full bathrooms, and the presence of a basement, garage, and pool all contribute positively to house price valuation, which mirror previous studies. Age of house is negative and significant. We also include squared terms for house square footage, parcel size, and age of the house to capture any non-linearity in these characteristics that may influence housing prices. We find evidence of non-linearity in both house size and parcel size, as evidenced by significance of the included squared terms.

Table 2
Summary statistics for basins in Baltimore County.

Variable	Mean	Std. deviation	Min	Max
Stormwater basin statistics, full set				
Feet to nearest basin (100 s)	12.871	10.524	0	86.478
Basin area (acre)	0.384	0.469	0.00189	31.181
Basin built date	1991	10.054	1970	2007
Number of basins	1763			
Stormwater basin statistics, pre-2001 policy shift				
Feet to nearest basin (100 s)	12.963	10.644	0	86.478
Basin area (acre)	0.385	0.475	0.00189	31.181
Number of basins	1313			
Stormwater basin statistics, post-2001 policy shift				
Feet to nearest basin (100 s)	12.507	10.023	0	56.273
Basin area (acre)	0.38	0.443	0.00587	4.169
Number of basins	450			
Average percentage of houses sold after nearest basin				
Across Subdivisions	0.89	0.196		
Across Census Block Groups	0.881	0.17		
Across Census Tracts	0.872	0.148		
Average percentage of houses built after nearest basin				
Across Subdivisions	0.712	0.392		
Across Census Block Groups	0.79	0.238		
Across Census Tracts	0.774	0.213		
Other basin statistics (% of housing transactions)				
Adjacency to basin	0.03%			
Houses within 100 ft	3.8%			
Houses within 250 ft	7.4%			
Houses near new basin (0 years old)	5.6%			
Houses near basin 1–3 years old	10.3%			
Houses near basin 4–6 years old	8.3%			
Houses near basin 7+ years old	64%			
Mean age of houses near basins	7			

Table 3
Subdivision analysis of differences in means of housing characteristics.

	Mean	Std. deviation	Welch's t-statistic
Year built			
Houses w/i 250 ft of basin	1990.99	11.41	0.413
Houses > 250 ft of basin in same subdivision	1990.78	11.40	
Structural grade			
Houses w/i 250 ft of basin	4.22	0.93	−0.318
Houses > 250 ft of basin in same subdivision	4.23	0.94	
House ft^2			
Houses w/i 250 ft of basin	22.17	10.20	0.498
Houses > 250 ft of basin in same subdivision	21.94	9.82	
Parcel size			
Houses w/i 250 ft of basin	0.52	0.79	1.352
Houses > 250 ft of basin in same subdivision	0.48	0.69	
Full bathrooms			
Houses w/i 250 ft of basin	2.20	0.66	0.0802
Houses > 250 ft of basin in same subdivision	2.20	0.60	

We find that our main variable of interest, the stormwater treatment group, generates a negative price capitalization of 14%.[8] This means that houses adjacent to a basin and sold subsequent to its construction see a large negative price effect. This provides evidence that proximity to a stormwater basin capitalizes in the form of lower house prices and not positively as expected if these basins conferred positive co-benefits to nearby homeowners. The lack of significance associated with both the *distance to basin* and *distance to basin ∗ post construction* terms indicate that a linear distance variable is not capturing evidence of any capitalization effects at increasing distances and any house price capitalization is largely confined to adjacent homes.

In our second specification, we add the 100-foot and 250-foot rings and remove the linear distance terms. We find the coefficients on housing characteristics are significant and of the same magnitude as in our first estimation. Looking to treatment group results, we find similar results for the adjacent houses as with the first model with houses in the treatment group seeing a negative price capitalization effect of approximately 13%, which is smaller than in the previous estimation but still a significant result. In the additional ring groups, we find neither an open space capitalization effects nor any negative effects from being located near a stormwater basin.[9] This suggests that the basins are providing a highly localized capitalization effect, likely excluding their use as recreational destinations.[10]

[8] We utilize the Halvorsen and Palmquist (1980) correction for interpreting binary variables in a semi-log model.

[9] As a robustness check for our subdivision fixed effects specification and to account for the possibility of any between-subdivision basin effects, we change the spatial scale for the fixed effects and estimate specifications of our first model with both block group and tract fixed effects and report these in Appendix A. Our findings of a significant negative price capitalization effect remain unchanged.

[10] There remains a possibility of some overlap between proximity to local parks and stormwater basins that could affect our results if the overlap is significantly large. Using information on park location within Baltimore County from Livy and Klaiber (2016) and our basins location data, we find that the overlap is minimal. After removing the set of basins located within a park's boundaries, <5% of remaining basins are located within 300 ft of a park. To the extent that any overlapping parks offset some of the negative capitalization, our results would be a lower bound of the negative capitalization effect of basins.

Table 4
Estimation results for stormwater basin proximity.

	LogPrice	LogPrice
Adjacent to basin	0.122***	0.111***
	(0.0170)	(0.0205)
Adjacent * post construction	−0.151***	−0.139***
	(0.0295)	(0.0321)
Distance to basin	0.000484	–
	(0.000856)	
Distance to basin * post construction	0.000411	–
	(0.000583)	
Non-adjacent–100 ft of basin	–	−0.00194
		(0.0227)
100 ft * post construction	–	0.00497
		(0.0231)
101–250 ft of basin	–	0.0136
		(0.0151)
250 ft * post construction	–	−0.0165
		(0.0156)
Basin area	−0.00395	−0.00419
	(0.00547)	(0.00554)
Post construction	−0.00546	0.000712
	(0.0102)	(0.00713)
House ft^2	0.0295***	0.0295***
	(0.00129)	(0.00129)
Number of full baths	0.0667***	0.0666***
	(0.00341)	(0.00340)
Age of house	−0.00233***	−0.00231***
	(0.000764)	(0.000761)
Parcel size	0.236***	0.235***
	(0.0186)	(0.0186)
House sold: 1997	−0.00474	−0.00481
	(0.00780)	(0.00783)
House sold: 1998	0.0215***	0.0215***
	(0.00815)	(0.00817)
House sold: 1999	0.0584***	0.0584***
	(0.00781)	(0.00783)
House sold: 2000	0.0992***	0.0991***
	(0.00837)	(0.00837)
House sold: 2001	0.145***	0.145***
	(0.00792)	(0.00791)
House sold: 2002	0.223***	0.223***
	(0.00792)	(0.00793)
House sold: 2003	0.352***	0.352***
	(0.00832)	(0.00832)
House sold: 2004	0.518***	0.518***
	(0.00856)	(0.00857)
House sold: 2005	0.718***	0.718***
	(0.00855)	(0.00855)
House sold: 2006	0.846***	0.846***
	(0.00812)	(0.00812)
House sold: 2007	0.855***	0.855***
	(0.00833)	(0.00833)
Stories	0.00551	0.00554
	(0.00813)	(0.00811)
Air conditioning	0.0706***	0.0707***
	(0.00524)	(0.00525)
Pool	0.0674***	0.0674***
	(0.00913)	(0.00913)
Garage	0.0705***	0.0707***
	(0.00475)	(0.00475)
Basement	0.0321***	0.0321***
	(0.00656)	(0.00656)
House size squared	−0.000244***	−0.000244***
	(0.00000)	(0.00000)
Age of house squared	0.00000	0.00000
	(0.00000)	(0.00000)
Parcel size squared	−0.0315***	−0.0313***
	(0.00330)	(0.00331)
Constant	11.07	11.07
R-squared	0.643	0.644
Number of observations	90,948	90,948
Fixed effects level	Subdivision	Subdivision
Number of groups	5944	5944

Note: clustered standard errors presented in parentheses. *, **, *** indicates significance at 0.1, 0.05, and 0.01 levels respectively.

5.1. Basin Aging Effects

We next explore changes in basin capitalization by examining how the naturalization process of basins over time affects home price capitalization. As basins age, they gradually merge into the surrounding landscape due to an increase in vegetative growth. This could be pleasing to potential homebuyers as it can provide an area for wildlife observation, which would lead to a positive price effect. However, as a basin ages, it can also accumulate debris, become overgrown, and accumulate excessive sedimentation, all of which would lead to a negative valuation. The latter point is especially noteworthy, as previous research has shown the value placed on flood reduction by stormwater basins (Cadavid and Ando, 2013) and excessive sediment in a basin would impair its functionality.

The natural aging process of the basin corresponds to the aging of a subdivision itself, which could bias our results upward if not addressed. Fortunately, our use of subdivision level fixed effects addresses both the subdivision construction period and controls for ongoing, routine stormwater maintenance within each subdivision, allowing for consistent estimates of any basin aging effect on house price capitalization. The latter point is especially important, as we can now estimate the effect of the basin aging irrespective of the amount of routine maintenance required for each basin.

We modify our hedonic price approach from Eq. (2), define a naturalization dummy variable for basins of a different age groups – new basins, basins between one and three years old, basins between four and six years old, and basins seven years or older. We then create an interaction term for the naturalization variable with the post construction variable and report the results in Table 5.

While the baseline effect of basin treatment remains negative, we find a small and significant positive capitalization in price for houses sold near new basins. Thus, while the overall effect of adjacency is still negative, the effect of being adjacent to a new basin is not as severe. In contrast, we find that houses sold near basins of older vintages have a negative coefficient and that this negative effect increases in intensity as the basin ages. For houses adjacent to basins of the oldest vintage, the combined treatment effect of basins results in an over 17% decrease in house price.

We also examine the effect of the 2001 policy shift in stormwater management that occurred in Maryland during the period of our study, which modified the requirements on stormwater basin construction. This shift required that all basins built after 2001 were required to deliver an explicit water quality improvement on all water collected and discharged by a basin, a change from the former requirement that a stormwater basin hold the initial flush from a storm. This did not necessarily affect the external appearance of the basins but did change their internal structure to provide for water filtering. We refer the reader to Appendix B for our model explanation and our results but to summarize, we find no statistically significant treatment effect that these modified basins capitalize positively in house prices the but see a continued negative effect from basin adjacency.

5.2. Placebo Test

As a robustness check, we adopt a placebo test by shifting forward the basin creation date by five years, creating a false treatment group. This new variable will capture any unobserved time-varying trends the primary model fails to account for that could drive our resulting estimates. However, if it is insignificant, it indicates that unobserved time varying trends are unlikely to be driving our results. We report our falsification estimates in Table 6. The falsified treatment effect is insignificant which provides additional verification that our treatment group is correctly specified and not spurious. All remaining housing and neighborhood characteristics remain of the same significance and magnitude as in the previous estimations.

Table 5
Estimation results for naturalization.

	LogPrice
Adjacent to basin	0.122***
	(0.0169)
Adjacent ∗ post construction	−0.148***
	(0.0296)
Distance to basin	0.000623
	(0.000858)
Distance to basin ∗ post construction	0.000231
	(0.000602)
Basin area	−0.00353
	(0.00551)
Basin 0 years old	−0.0277*
	(0.0147)
Basin 0 years old ∗ post construction	0.0444***
	(0.0147)
Basin 1–3 years old	0.00892
	(0.0124)
Basin 1–3 years old ∗ post construction	−0.0194
	(0.0148)
Basin 4–6 years old	0.0204
	(0.0156)
Basin 4–6 years old ∗ post construction	−0.0433**
	(0.0174)
Basin 7+ years old	0.0140
	(0.0149)
Basin 7+ years old ∗ post construction	−0.0420***
	(0.0156)
House ft^2	0.0295***
	(0.00129)
Number of full baths	0.0666***
	(0.00339)
Age of house	−0.00253***
	(0.000797)
Parcel size	0.236***
	(0.0185)
House sold: 1997	−0.00445
	(0.00781)
House sold: 1998	0.0222***
	(0.00820)
House sold: 1999	0.0591***
	(0.00793)
House sold: 2000	0.100***
	(0.00844)
House sold: 2001	0.147***
	(0.00800)
House sold: 2002	0.225***
	(0.00806)
House sold: 2003	0.354***
	(0.00853)
House sold: 2004	0.520***
	(0.00886)
House sold: 2005	0.720***
	(0.00871)
House sold: 2006	0.848***
	(0.00838)
House sold: 2007	0.857***
	(0.00866)
Stories	0.00518
	(0.00812)
Air conditioning	0.0706***
	(0.00523)
Pool	0.0674***
	(0.00912)
Garage	0.0706***
	(0.00474)
Basement	0.0321***
	(0.00655)
House size squared	−0.000244***
	(0.00000)
Age of house squared	0.00000
	(0.00000)
Parcel size squared	−0.0315***
	(0.00330)
Constant	11.07***
R-squared	0.643
Number of observations	90,948
Fixed effects level	Subdivision
Number of groups	5944

Note: clustered standard errors presented in parentheses. *, **, *** indicates significance at 0.1, 0.05, and 0.01 levels respectively.

6. Conclusions

This paper provides the first robust empirical evidence of the price capitalization effects of stormwater basins for nearby households and whether this type of green infrastructure generates co-benefits, e.g., due to natural amenities. Using a revealed preference approach and a robust estimation strategy, we find that rather than providing hypothesized co-benefits, the presence of a stormwater basin is capitalized as lower house prices for the set of houses that are directly adjacent with no effect on nearby, non-adjacent houses. This effect is robust to a number of different specifications with a decrease in mean house price between 13 and 14%.

For the average house in our sample, this corresponds to a house price that is at least $28,000 lower, a factor solely attributed to stormwater basin proximity. Additionally, basins continue to influence house prices negatively as they age. For a house adjacent to a basin that is at least seven years old, we estimate that the total negative price capitalization associated with stormwater basins to be over 17%. Within the entire Baltimore County, the most conservative back of the envelope estimate of the total cost[11] of stormwater basin proximity would be over $77 million dollars in decreased housing value over our study period.

While this work does not consider the full costs and benefits of stormwater basins, the results do imply that any ecological benefits further downstream must be sufficiently large to offset the losses in capitalized housing value due to basins. In addition, they indicate an uneven distribution of the costs and benefits across residents at local and regional scales. Presumably, the water quality benefits of stormwater basins accrue to all residents living in the region, provided this additional green infrastructure contribute to reduced runoff and improved water quality in regional waterbodies, most notably the Chesapeake Bay. Any benefits from stormwater basins must at least meet the above-calculated total cost imposed by their presence. However, the costs of this development regulation are borne disproportionate by those living closest to the stormwater basins. By absorbing the negative effects from basins, these adjacent households incur an additional cost that not imposed on others.

This work also leaves open the question of the potential for co-benefits from other types of green infrastructure projects, which we do not study. Smaller projects, such as rain gardens or green streets—could improve the curb appeal of nearby houses and contribute to higher house prices. However, these projects are significantly smaller than basins and highly spatially dispersed. Results from this study suggest that a more purposeful approach to green infrastructure design is needed if the goal is to generate both improved water quality and natural amenity co-benefits. Future work is especially vital in this area as shifts toward the encouragement of these smaller scale projects to address stormwater infrastructure needs, as Maryland did in 2008. If there were a way to optimally design basins that lessen the negative cost associated with basin proximity and/or utilize smaller projects instead of a basin-centric approach, such empirical evidence would prove tremendously valuable for policy makers.

This work is subject to several important limitations. As noted, we cannot adequately address the welfare question of whether the value of the ecological services provided by basins exceeds the costs, including the costs imposed by a basin's presence within a subdivision. Such work would require a large scale monitoring effort over time within a targeted

[11] This is calculated using the number of basins in our sample, lowest bound on the range of price effects, and ignoring any naturalization effects.

Table 6
Placebo robustness estimation.

	LogPrice
Adjacent to basin	0.0158
	(0.0252)
Adjacent ∗ post construction	−0.0211
	(0.0466)
R-squared	0.589
Number of observations	90,948
Fixed effects level	Subdivision
Number of groups	5944

Note: clustered standard errors presented in parentheses. *, **, *** indicates significance at 0.1, 0.05, and 0.01 levels respectively.

watershed that could clearly delineate any water quality improvements attributable to basins. Additionally, this model would have to account for the potential effects of aging basins on house prices, which we find to be negative and increasing with age. Previous work (Istenič et al., 2012; Al-Rubaei et al., 2017) has shown the relationship between basin age, maintenance, and performance, thus empirically estimating a model that accounts for these factors would be crucial for measuring the total amount of ecosystem services generated by basins in a region.

Finally, we are unable to account for potential sources of heterogeneity in the types of basins that could influence household valuation. Future work with a richer set of basin-level data could address whether specific features or designs of basins provide additional co-benefits or if the level of management, including inspection and maintenance frequency, drive valuation by households. If these aspects matter, then the design and level of management not only influences the basins' ecological functioning, but also their capitalized value over time. Knowing more about households' valuation of specific basin attributes, including management characteristics, is necessary for improved urban stormwater design and management that can deliver both improved water quality and amenity co-benefits.

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Appendix A. Additional Spatial Fixed Effect Results for Main Models

We re-estimate our main model specification (2) with a more spatially aggregated fixed effects at the block group and tract level as a robustness check against our subdivision fixed effects specification and to account for the possibility of any between-subdivision basin effects. We report our results in Table A.1 and in short, we find a continued negative price capitalization effect in our treatment group with each of these additional estimations. However, the use of such a spatially aggregated fixed effect allows previously controlled unobserved spatial correlation to bias the basin treatment effect and we prefer our initial model specification in the text.

Table A.1
Additional results for main model.

	LogPrice	LogPrice
Adjacent to basin	0.145***	0.194***
	(0.0311)	(0.0296)
Adjacent ∗ post construction	−0.188***	−0.245***
	(0.0435)	(0.0444)
Distance to basin	0.000356	0.000778
	(0.000811)	(0.000867)
Distance to basin ∗ post construction	−0.000110	−0.000500
	(0.000689)	(0.000775)
Basin area	−0.00170	−0.00865
	(0.00717)	(0.00773)
Post construction	0.00862	0.0181
	(0.0124)	(0.0144)
House ft^2	0.0377***	0.0401***
	(0.00161)	(0.00181)
Number of full baths	0.0732***	0.0781***
	(0.00412)	(0.00464)
Age of house	−0.00537***	−0.00582***
	(0.000735)	(0.000815)
Parcel size	0.193***	0.193***
	(0.0215)	(0.0272)
House sold: 1997	−0.00472	−0.00539
	(0.00805)	(0.00817)
House sold: 1998	0.0190**	0.0175**
	(0.00870)	(0.00856)
House sold: 1999	0.0625***	0.0627***
	(0.00812)	(0.00818)
House sold: 2000	0.102***	0.0997***
	(0.00968)	(0.0108)
House sold: 2001	0.151***	0.147***
	(0.00870)	(0.00901)
House sold: 2002	0.227***	0.226***
	(0.00883)	(0.00914)
House sold: 2003	0.361***	0.359***
	(0.00978)	(0.0105)
House sold: 2004	0.520***	0.517***
	(0.0100)	(0.0109)
House sold: 2005	0.716***	0.714***
	(0.00962)	(0.0102)
House sold: 2006	0.846***	0.845***
	(0.00854)	(0.00940)
House sold: 2007	0.852***	0.849***
	(0.00821)	(0.00834)
Stories	−0.0798***	−0.0912***
	(0.00964)	(0.0111)
Air conditioning	0.0696***	0.0705***
	(0.00598)	(0.00753)
Pool	0.0727***	0.0773***
	(0.00985)	(0.0118)
Garage	0.116***	0.123***
	(0.00585)	(0.00627)
Basement	−0.00316	−0.00984
	(0.00786)	(0.0101)
House size squared	−0.000290***	−0.000326***
	(0.00000)	(0.00000)
Age of house squared	0.00000	0.00000***
	(0.00000)	(0.00000)
Parcel size squared	−0.0280***	−0.0282***
	(0.00369)	(0.00453)
Constant	11.15	11.13
R-squared	0.677	0.632
Number of observations	90,948	90,948
Fixed effects level	Block Group	Census Tract
Number of groups	481	200

Note: clustered standard errors presented in parentheses. *, **, *** indicates significance at 0.1, 0.05, and 0.01 levels respectively.

Appendix B. Stormwater Policy Shift Results

In the text, Table 1 describes the basic comparison statistics between the basins built in each regulatory period. Basins built post-2001 are, on average, slightly smaller than the basins built before the policy change but the means between each group do not differ by a statistically significant amount. The houses located next to the newer basins tend to be located almost 50 ft closer to their nearest basin and sell for nearly $70,000 more than houses nearest to a pre-policy change basin. The latter result can be explained by our use of nominal house prices and reflect the general increases in houses prices due to the housing boom of the early and mid-2000s.

We estimate a variation on our main model specification and include additional variables to identify separately basins built post-2001. We also include an interaction term with distance specifications for our three distance ring groups of adjacent, 100, and 250 ft, respectively. Existing literature establishes that water quality can influence house prices in certain circumstances (Leggett and Bockstael, 2000), thus if households would value the water quality component of these basins, we would expect some indication of that valuation through a positive price capitalization associated with newer basins. We expect houses located closer to these types of basins to see an additional positive price capitalization if households value such water quality improvements. The results, located in Table B.1, show no statistically significant treatment effects associated with basins that are more recent while the indicator variable for basins built after 2001 is positive and significant at the 10% level.

Table B.1
Policy shift estimation results.

	LogPrice
Adjacent to basin	0.122***
	(0.0151)
Adjacent ∗ post construction	−0.156***
	(0.0356)
Distance to basin	0.000330
	(0.000781)
Distance to basin ∗ post construction	0.000586
	(0.000413)
Basin area	−0.00341
	(0.00546)
Closest basin built after 2001	0.0214*
	(0.0122)
Basin built after 2001 ∗ post construction ∗ adjacent	0.0243
	(0.0472)
Basin built after 2001 ∗ post construction ∗ within 100 ft	0.000248
	(0.0132)
Basin built after 2001 ∗ post construction ∗ within 250 ft	−0.0115
	(0.0117)
House ft^2	0.0295***
	(0.00129)
Number of full baths	0.0667***
	(0.00340)
Age of house	−0.00231***
	(0.000766)
Parcel size	0.236***
	(0.0186)
House sold: 1997	−0.00488
	(0.00782)
House sold: 1998	0.0213***
	(0.00815)
House sold: 1999	0.0580***
	(0.00780)
House sold: 2000	0.0987***
	(0.00838)
House sold: 2001	0.144***
	(0.00794)
House sold: 2002	0.222***
	(0.00791)
House sold: 2003	0.351***
	(0.00827)
House sold: 2004	0.516***
	(0.00843)
House sold: 2005	0.716***
	(0.00854)
House sold: 2006	0.844***
	(0.00816)
House sold: 2007	0.853***
	(0.00835)
Stories	0.00564
	(0.00813)
Air conditioning	0.0706***
	(0.00523)
Pool	0.0673***
	(0.00913)
Garage	0.0706***
	(0.00474)
Basement	0.0321***

Table B.1 (*continued*)

	LogPrice
	(0.00656)
House size squared	−0.000243***
	(0.00000)
Age of house squared	0.00000
	(0.00000)
Parcel size squared	−0.0315***
	(0.00330)
Constant	11.06***
R-squared	0.643
Number of observations	90,948
Fixed effects level	Subdivision
Number of groups	5944

Note: clustered standard errors presented in parentheses. *, **, *** indicates significance at 0.1, 0.05, and 0.01 levels respectively.

References

Abbott, Joshua K., Klaiber, H. Allen, 2010. Is all space created equal? Uncovering the relationship between competing land uses in subdivisions. Ecol. Econ. 70 (2), 296–307.
Abbott, Joshua K., Klaiber, H. Allen, 2011. An embarrassment of riches: confronting omitted variable bias and multi-scale capitalization in hedonic price models. Rev. Econ. Stat. 93 (4), 1331–1342.
Abbott, Joshua K., Klaiber, H. Allen, 2013. The value of water as an urban club good: a matching approach to community-provided lakes. J. Environ. Econ. Manag. 62 (2), 208–224.
Al-Rubaei, Ahmed Mohammed, Merriman, Laura S., Hunt III, William F., Viklander, Maria, Marsalek, Jiri, Blecken, Godecke-Tobias, 2017. Survey of the operational status of 25 Swedish municipal Stormwater management ponds. J. Environ. Eng. 35 (3).
Anderson, Soren T., West, Sarah E., 2006. Open space, residential property values, and spatial context. Reg. Sci. Urban Econ. 36 (6), 773–789.
Baltimore County Code, 2010. Art. 33. § 4: Stormwater Management.
Bond, Michael T., Seiler, Vicky L., Seiler, Michael J., 2002. Residential real estate prices: a room with a view. J. Real Estate Res. 23 (1), 129–138.
Braden, John B., Ando, Amy W., 2012. Economic costs, benefits, and achievability of low-impact development-based stormwater regulations. In: Thurston, H.W. (Ed.), Economic Incentives for Stormwater Control. CRC Press, Boca Raton, FL, pp. 45–70.
Cadavid, Catalina L., Ando, Amy W., 2013. Valuing preferences over stormwater-management outcomes including improved hydrologic function. Water Resour. Res. 49 (7), 4114–4125.
Cho, Seong-Hoon, Clark, Christopher D., Park, William M., Kim, Seung G., 2009. Spatial and temporal variation in the housing market of lot size and open space. Land Econ. 85 (1), 51–73.
Cropper, Maureen L., Deck, Leland B., McConnell, Kenneth, 1988. On the choice of functional form for hedonic price functions. Rev. Econ. Stat. 70 (4), 668–675.
Downing, Bob, 2015. Akron unveils initial three green projects to help correct city's overflowing sewers. Akron Beacon J. 24 (June, Available online: http://www.ohio.com).
EPA National Enforcements Initiative, 2015. Status of civil judicial consent decrees addressing combined sewer systems (CSOs). (January 15, 2016). http://tiny.cc/bmqfky.
EPA Office of Enforcement and Compliance, 2008. Four of the Nation's Largest Home Builders Settle Storm Water Violations. (March 15, 2016, available online:). https://yosemite.epa.gov.
Geoghegan, Jacqueline, 2002. The value of open spaces in residential land use. Land Use Policy 19 (1), 91–98.
Gray, Wayne B., Shimshack, Jay P., 2011. The effectiveness of environmental monitoring and enforcement: a review of the empirical evidence. Rev. Environ. Econ. Policy 5 (1), 3–24.
Halvorsen, Robert, Palmquist, Raymond, 1980. The interpretation of dummy variables in semilogarithmic equations. Am. Econ. Rev. 70 (3), 474–475.
Irwin, Elena G., 2002. The effects of open space on residential property values. Land Econ. 78 (4), 465–480.
Irwin, Elena G., Bockstael, Nancy E., 2001. The problem of identifying land use spillovers: measuring the effects of open space on residential property values. Am. J. Agric. Econ. 83 (3), 698–704.
Isteničč, Darja, Arias, Carlos A., Vollertsen, Jes, Nielsen, Asbjørn H., Wium-Andersen, Tove, Hvitved-Jacobsen, Thorkild, Brix, Hans, 2012. Improved urban stormwater treatment and pollutant removal pathways in amended wet detention ponds. J. Environ. Sci. Health A 47 (10), 1466–1477.
Kuminoff, Nicolai V., Parmeter, Christopher F., Pope, Jaren C., 2010. Which hedonic models can we trust to recover the marginal willingness to pay for environmental amenities. J. Environ. Econ. Manag. 60 (3), 145–160.
Lee, Jae Su, Li, Ming-Han, 2009. The impact of detention basin design on residential property value: case studies using GIS in the hedonic price modeling. Landsc. Urban Plan. 89 (1–2), 7–16.
Leggett, Christopher G., Bockstael, Nancy E., 2000. Evidence of the effects of water quality on residential land prices. J. Environ. Econ. Manag. 39 (2), 121–144.
Livy, Mitchell R., Klaiber, H. Allen, 2016. Maintaining public goods: the capitalized value of local park renovations. Land Econ. 92 (1), 96–116.
Los Angeles County Department of Public Works, 2016. Oxford basin multiuse enhancement project. (March 21, 2013). http://tiny.cc/dkqfky.

Mahan, Brent L., Polasky, Stephan, Adams, Richard M., 2000. Valuing urban wetlands: a property price approach. Land Econ. 76 (1), 100–113.
McConnell, Virginia, Walls, Margaret, 2005. The Value of Open Space: Evidence From Studies of Nonmarket Benefits. Resources for the Future, Washington, DC.
National Research Council, 2009. Urban Stormwater Management in the United States. National Academies Press, Washington, DC.
Poor, P. Joan, Boyle, Kevin J., Taylor, Laura O., Bouchard, Roy, 2001. Objective versus subjective measures of water clarity in hedonic property value models. Land Econ. 77 (4), 482–493.
Rosen, Sherwin, 1974. Hedonic prices and implicit markets: product differentiation in pure competition. J. Polit. Econ. 82 (1), 34–55.
Thurston, Hale W., 2012. Background and introduction. In: Thurston, H.W. (Ed.), Economic Incentives for Stormwater Control. CRC Press, Boca Raton, FL, pp. 1–8.
Walsh, Randy, 2007. Endogenous open space amenities in a locational equilibrium. J. Urban Econ. 61 (2), 319–344.
Walsh, Patrick, Walter Milon, J., Scrogin, David, 2011. The spatial extent of water quality benefits in urban housing markets. Land Econ. 87 (4), 628–644.
Wooldridge, Jeffry M., 2003. Cluster-sample methods in applied econometrics. Am. Econ. Rev. 93 (2), 133–138.