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Capturing Urban Stormwater Runoff: A Decentralized Market-Based Alternative

Executive Summary

Urban stormwater runoff is both a source of pollution and a potentially valuable resource. Large centralized facilities traditionally have been used to manage runoff. The deployment of small-scale decentralized capture devices (known as stormwater Best Management Practices, or BMPs) can decrease the need to purchase expensive urban land or use scarce publicly-owned land for centralized facilities.

In this report we investigate the cost-effectiveness of implementing parcel-level BMPs in a Los Angeles area watershed using competitive bidding. We then compare the costs of bidding and centralized alternatives and find that the bidding alternative is significantly less expensive than a centralized alternative for a range of stormwater capture goals. Finally, we examine the water supply value of the stormwater infiltrated by BMPs and find that it can amount to 38% of the total BMP cost.

Our research shows that, in most scenarios involving urban stormwater runoff, decentralized, incentive-based strategies using small-scale capture devices is more cost-effective than centralized strategies. We offer several recommendations on approaches to implement decentralized strategies, including payment mechanisms that discourage early exit, and Internet-based incentive calculation and program monitoring.

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Introduction

Government agencies in many parts of the country have used a variety of voluntary "green payment" schemes to increase the adoption of environmentally friendly practices and technologies by businesses and consumers. Examples include tax breaks for hybrid gasoline-electric vehicles owners, rebates for energy efficient appliance purchases and payments for long-term fallowing of agricultural land. In Southern California, local governments have employed similar financial incentives to persuade homeowners to install low-flow toilets, weather sensitive irrigation systems, and solar panels. This article proposes and investigates a financial incentive program to mitigate the urban stormwater runoff that is the prime cause of pollution in Santa Monica Bay and other Southern California water bodies (Ackerman et al. 2003).

Urban stormwater runoff is both a significant pollution problem as well as a potential resource. The pollution problem results from the "urban sludge" (heavy metals, petroleum residue, salts, solid waste, etc.) that is carried off impermeable surfaces by rainstorm events, and washed into receiving water bodies where it damages ecological and recreational resources (Arnold and Gibbons 1996). By capturing runoff, removing pollutants, and infiltrating the resulting clean water to aquifers, storm water infiltration devices can turn a pollutant into a valuable resource. Given the relatively large quantities of urban runoff typically found in low-density urban areas such as Los Angeles (Ackerman et al. 2003), and in light of recent predictions of the increased likelihood of long-term drought in the American southwest (IPCC 2007, Seager et al. 2007), it is imperative to evaluate the economic viability of augmenting local water resources with runoff capture.

Historically, the key urban runoff concern has been to decrease the damage from floods. Flooding is typically a concern only with large storms that occur on average every ten years or more (Ferguson 1998). In order to control these large storm events flood control agencies have built large centralized facilities (e.g., culverts, detention basins) and sometimes re-engineered natural hydrologic features (e.g., paving the Los Angeles River channel) to quickly convey runoff to receiving waterbodies. These large-scale facilities are needed to handle the massive amounts of runoff generated by the largest storm events that would be impractical to handle on a decentralized parcel-by-parcel basis with small-scale infiltration devices. However, the legacy flood control infrastructure does not treat water quality problems; it avoids flooding by quickly routing polluted runoff to water bodies

More recently, and with the development of federal water quality regulations on diffuse non-point pollution sources, the water quality aspects of urban runoff have become an important issue for local governments. For water quality purposes, smaller rain events (an inch per 24 hours or less in the Los Angeles area) are important because they can lead to frequent violations of water quality standards (RWQCB-LA 2005). However, stormwater agencies have continued to favor centralized approaches for managing water quality challenges. These approaches assume the same strategy as flood control: convey runoff quickly to a large central location. But instead of releasing the polluted runoff directly to a waterbody, it is either infiltrated to groundwater or treated on-site and then released to a waterbody. This centralized approach benefits from economies of scale in construction and maintenance costs compared to a decentralized parcel-level approach. However, in dense urban areas it is often difficult to assemble enough land to either treat/infiltrate without impinging on private land, purchasing contiguous land parcels, or significantly altering redevelopment plans to accommodate centralized facilities. This reasoning implies that land costs can be large for centralized approaches. These costs may come from the direct expense of acquiring land, or the "opportunity cost" of using publicly owned land for stormwater treatment rather than selling the land for market value or putting land in another use such as parks, habitat, etc.

The incentive system we propose would reimburse individual landowners directly for providing ecosystem services (i.e., groundwater recharge and pollution removal) on their properties.[1] This entails a decentralized approach where runoff is captured on each individual property by small-scale stormwater capture devices—commonly called Best Management Practices, or BMPs[2]—such as porous pavement and infiltration trenches. (See Figure 1 for examples of the BMP types used in this paper.) Although decentralized devices cannot provide the same scale economies as centralized facilities, they do not require large contiguous land areas. Furthermore, they can be placed on parcels with relatively low marginal land use value thus effectively reducing the total installation cost. This is particularly beneficial in dense urban areas where land values can be in the millions of dollars per acre. It is therefore an empirical question whether centralized or decentralized runoff control is more cost-effective.

Figure 1: Examples of Stormwater Best Management Practices (BMPs)

Infiltration Pit

Porous Pavement

Our research considers a situation where regulators have no power to compel landowners to install BMPs. This differs from earlier research (Thurston et al. 2003; Thurston 2006) that assumes regulators can impose stormwater fees, or mandatory caps on runoff as part of a cap and trade scheme. Our proposed incentive structures are applicable in situations where regulatory alternatives are limited and economic incentives must provide the entire motivation for landowner participation in the regulatory program. We believe this is more relevant for existing developments than new developments where BMP requirements can be more easily built into the permitting process. However, with minor modifications, our methodology could be used to design an in-lieu fee system where developers would be allowed to pay into a fund to meet water-quality goals through other measures instead of implementing BMPs on their own property.

We use this framework to estimate the cost for implementing decentralized BMPs through a competitive bidding process designed to reduce total agency costs (i.e., budgetary costs for the regulatory agency). We also estimate the cost for an equivalent volume of centralized treatment. Our results show for a range of stormwater capture goals that competitive bidding is more cost-effective than centralized treatment. A sensitivity analysis further demonstrates this result is robust to various combinations of plausible parameter values. Finally we estimate the value of infiltrated water and find that it covers a significant fraction of total BMP costs.

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Modeling Stormwater Capture

We take an economic approach to modeling both the objective of a government regulatory agency and the decisions of landowners to voluntarily adopt BMPs when provided with financial incentives to do so. Coupling our economic model with a hydrologic model of stormwater runoff and BMP capture allows us to estimate the cost for a government agency to achieve a desired level of runoff capture with decentralized BMPs. Our economic approach assumes the regulator wants to minimize the total payments it makes for land, construction, and maintenance costs incurred by landowners while still achieving the desired amount of capture. Furthermore we assume landowners want to maximize the profit they earn from participating in the incentive program. This may not accurately characterize all landowners, some of whom may participate to a limited extent because it is good for the environment or because it creates good publicity. However there is a substantial body of evidence on the private provision of public goods that supports the notion that landowners are primarily self-interested and would demand appropriate compensation in exchange for incurring substantial costs (typically in the thousands of dollars) to help reduce runoff. This reasoning is particularly applicable to the parcels included in this study which are likely to be part of a business. Therefore we also assume landowners who cannot at least break-even by participating in the program will choose not to participate.

We focus our attention on two types of BMPs: infiltration pits and porous pavement. Infiltration BMPs like these (as opposed to BMPs that only filter contaminants such as sand filters or storm drain inserts) are advantageous when faced with an array of water quality, water supply, and water-related ecological goals (Ferguson 1994). We also collected local cost data (described in section 2.1) for these BMPs for our economic modeling. Furthermore it is worth noting that including more BMP options would effectively relax some of the constraints in our model and thus could not increase the cost of a decentralized approach relative to the estimates we present here.

Our study site consists of 918 commercial, industrial, retail, and multi-family land parcels in the Sun Valley watershed near Los Angeles, California. With its heterogeneous land use this watershed is representative of problematic runoff-generating urban landscapes. We do not consider single-family parcels because we judge them to be relatively poor candidates for financial incentives in mixed-use areas: economies of scale would be relatively limited on these parcels, implying smaller BMPs and thus necessitating a large number of participants which would be costly to monitor to ensure compliance with BMP maintenance requirements. Our modeling approach proceeds in several steps: first we simulate runoff and capture for a variety of parcel characteristics and BMP types and sizes using the historical precipitation record for Sun Valley. Using these results, we estimate relationships between parcel characteristics, BMP capacity, and runoff capture for different soil infiltration rates specific to this watershed. Finally we use these estimated relationships to simulate the outcome of using a competitive bidding mechanism to achieve various runoff capture goals.

Our proposed incentive structures are applicable in situations where regulatory alternatives are limited and economic incentives must provide the entire motivation for landowner participation in the regulatory program.

Estimating Costs

The building blocks for our cost estimates are a hydrologic model and three cost models for land, construction, and maintenance expenses (see Figure 2 for a summary of the cost estimation steps.) The hydrologic simulations determine the relationship between the type and size of the BMPs and the amount of runoff reduction.

Figure 2: Steps For Calculating Total Cost of Stormwater BMP Devices

Step 1	Land cost = Square feet of land use displaced by device x cost per sq. ft.
Step 2	Capital cost = Cost of equipment, materials, and installation
Step 3	Maintenance cost = Present value of regular expenditures for operations and maintenance
Step 4	Rehabilitation cost = Present value of periodic major rehabilitation
Step 5	Total Cost = Sum of all costs above

For these simulations we use a version of the STORM (Storage, Treatment, Overflow, Runoff Model) that has been used to find the best mix of stormwater storage and release control strategies over an extended period (Hydrologic Engineering Center 1977).[3] For decentralized BMPs we combine Los Angeles County property records with data on parking and permeable (such as landscaped) area from real estate databases using regression analysis to generate the parcel level estimates of permeable, parking, and roof area required by STORM. For centralized treatment we also use STORM to find the capacities necessary to capture a given proportion of runoff from the 231 hectare watershed.

Land Costs

When landowners dedicate a portion of their parcel to a BMP, they likely forgo other potentially more valuable uses of that land. Losing the opportunity to otherwise employ that land area has a cost, but it is likely less than the cost of buying land because the owner does not lose all uses of the land. This loss of value is the land cost for decentralized BMPs. We assume that it would be prohibitively expensive to tear down buildings to replace them with BMPs. Infiltration pits can be placed within landscaping, so we assume there is no land-related opportunity cost when infiltration pits are placed in current permeable area. However, there is the potential for land opportunity costs when parking area is removed to place infiltration pits. We use a hedonic regression analysis (DeWoody 2007) to estimate the loss of property value when paved area is replaced by infiltration pits (result summary is shown in Table 1).

Table 1: Estimated Parking Land Use Costs for Sun Valley Parcels (in $ per square foot)

Land Use	Mean	Median
Duplex	$0.06	$0.00
Triplex	$0.73	$0.00
Quadplex	$2.98	$2.95
5plex	$30.71	$29.32
Commercial1	$23.34	$11.77
Commercial2	$27.54	$12.13
Industrial	$25.27	$22.74
Total	$23.31	$18.88

Centralized BMPs also occupy land which, whether it is land that is explicitly purchased for the BMP or existing public land, will likely have an opportunity cost similar to the market value of land. Table 2 shows the median price per square foot for vacant land zoned for retail, commercial, or residential uses and for different areas of Los Angeles County. For the comparisons in this paper we use the $65/ft^2 value that is the mean for the San Fernando Valley area where Sun Valley is located. Comparison of Table 1 and Table 2 shows the estimated average parking use values for the parcels in Sun Valley are significantly less expensive than vacant land in the same geographic area.

Table 2: Costs for Vacant Land in Los Angeles (in $ per square feet)

	Commercial	Industrial	Residential	Total
Southwest Los Angeles County				
Cost	$125	$46	$167	$129
Observations (#)	288	96	234	618
San Fernando West of Pasadena				
Cost	$67	$32	$69	$65
Observations (#)	67	21	118	206
San Gabriel Area				
Cost	$59	$26	$61	$54
Observations (#)	141	48	80	269
TOTAL				
Cost	$98	$38	$121	$98
Observations (#)	496	165	432	1,093

Source: Vacant land sales listed in the Costar sales database from 2003-2005, adjusted to 2005 dollars.

Construction and Maintenance Costs

In addition to land costs, for each of the decentralized BMPs and centralized alternatives we also estimate capital, maintenance, and rehabilitation costs. For each type of cost, we develop baseline, high, and low estimates in order to conduct a sensitivity analysis of our results (details are provided in Cutter et al. 2008). Our infiltration pit costs come from an analysis of installed BMPs in the City of Santa Monica. This analysis shows significant economies of scale as BMP capacity increases. For any capacity, we use the average cost prediction from our model as our baseline estimate, and the 25th and 75th percentiles as the low and high estimates. In the absence of maintenance cost data for the Los Angeles region, we use maintenance cost data from the Southeastern Wisconsin Regional Planning Commission (SWRPC 1991) updated to 2005 dollars using the Engineering News Record Los Angeles construction cost index.[4] We also add 1.13% of capital costs per year to reflect periodic rehabilitation costs (EPA 1999).

We calculate porous pavement construction costs based on Los Angeles area costs for porous concrete (Andy Youngs, California Cement Council, verbal communication, 2006). We derive porous pavement maintenance cost estimates by updating SWRPC (1991) estimates to 2005 dollars using the Engineering News Record Los Angeles construction cost index.

For centralized treatment we restrict our attention to two designs proposed by local regulators (RWQCB-LA 2005): infiltration trenches and infiltrations basins. For our baseline construction, maintenance, and rehabilitation cost data we use national-level information contained in RWQCB-LA (2005), Caltrans (2001), USEPA (1999), and Federal Highway Administration (2003). The national level data appears to understate the capital costs of these devices in the Los Angeles area. A comparison with cost data from planned or built infiltration trenches and basins in the Los Angeles area shows that capital costs are on average more than five times higher than the data from FHA(2003) and USEPA(1999) would suggest. Nevertheless, in order to remain conservative we use the national level cost estimates in our baseline estimates. For a sensitivity analyses we generate high and low cost estimates from the range of local cost data.

Optimal Placement and Sizing of Decentralized BMPs

For any combination of BMP types, sizes, and locations, we define the "BMP placement cost" as the present value of all land, construction, and maintenance costs associated with that BMP allocation. We define the "optimal" allocation as the unique combination of decentralized BMPs that achieves the desired level of runoff capture and minimizes the BMP placement cost. This optimal allocation may not be attainable in practice; or it may be attainable only if the regulator pays each landowner a premium for participating in the program and thus incurs costs in excess of the theoretically minimum cost; regardless the optimal allocation and its BMP placement cost are useful metrics against which other outcomes may be compared.

Cutter et al. (2008) show how a fixed subsidy paid per unit of runoff capture can be used to determine the optimal BMP allocation for any desired amount of stormwater capture. However a problem with offering a fixed per-unit subsidy is that it encourages profit-seeking landowners to install BMPs for which the total subsidy revenue (the agency cost) exceeds the BMP placement cost, possibly by a significant amount. One way to reduce the agency cost is to utilize a competitive bidding process in which only the "best" bids (from the agency's perspective) will be accepted. Competitive bidding creates an incentive for bidders to lower their offer prices, thereby giving up some of the excess profit they would earn with a fixed subsidy. The incentive is inherent in the competition among landowners: not knowing how other landowners will bid, a higher price reduces the chance that a bid will be accepted, in which case the landowner earns no excess profit; a lower price increases the chance that it will be accepted, in which case the landowner earns a positive profit. Thus each landowner tends to offer a lower price in hopes of earning at least some excess profit. If landowners can be induced to offer BMP capacities that are similar to those they would install in the subsidy case, a well-designed bidding process should reduce the total agency cost below that for the subsidy case.

In light of this we investigate the cost-effectiveness of a simple bidding instrument for achieving various runoff capture targets in our study watershed. The target is specified as an estimated long-run average reduction in runoff. Basin-wide reduction is the sum of parcel-level reductions. The estimated long-run average reduction at any parcel is determined by simulating the effect of the installed BMP capacity using STORM. The installed BMP capacity at any parcel is given by the solution to a parcel-level optimization problem in which the landowner bids the BMPs that would be installed as well as the annual payment that would be required as compensation for land, construction, and maintenance costs. For example, a landowner might bid to install 1500 square-feet of porous pavement for a $1000 annual payment over 30 years. Thus the landowner's decision to participate in the program is similar to the decision to invest in a financial instrument that pays a fixed annual dividend over some known time horizon; however there are two important and related differences. First, because the landowner gets to specify the dividend (i.e., the bid price), the agency must specify how it will rank bids so that landowners know how to compete for bid acceptance; in the absence of any such ranking method, the agency could expect to receive rather high bid prices from opportunistic landowners.

If all bidders were submitting bids for the same BMP (i.e., the same technology and capacity), then a good metric would be the bid price: the lower, the better. However, in this case landowners will submit bids for different BMPs based on the characteristics of their land. Therefore we need to specify a metric for ranking bids that involves different BMP types and capacities as well as bid prices. To do this, we define an "index function" that converts a bid of the form [infiltration pit capacity, porous pavement capacity, annual payment] into a numerical value with higher values corresponding to "better" bids. We then assume that each landowner submits the bid that maximizes this index function for his/her parcel subject to a "zero excess profit condition," (more on this below) and that the regulator ranks all bids by the index values and accepts bids in rank order until the capture target is satisfied.[5]

For any desired level of runoff capture, the ideal index function would induce landowners to submit bids with the same BMP capacities as would be induced by a subsidy that achieves the same level of capture and to give up all excess profits that would be earned from the subsidy mechanism (i.e., bid their true BMP placement cost). This would allow placement of optimal BMP capacities at each parcel at the lowest possible cost. However, designing and implementing such an ideal index function generally is not possible when the agency has incomplete information. Intuitively, for our case, this is because landowners must be compensated for revealing their private information about land costs. Therefore we implement a simpler index function (details provided in Cutter et al. 2008) that encourages landowners to bid relatively large capacities and relatively low prices (i.e., low cost per unit of capture). However because this index function is not ideal, it does not exactly replicate the optimal BMP locations and capacities produced by a subsidy mechanism; but it does provide an incentive for landowners to reduce their bid prices. Therefore the agency faces a trade-off: departing from the optimal placement and sizing of BMPs tends to increase BMP placement costs and thus increases total agency costs, but competition among bidders tends to reduce excess profits and thus reduces total agency costs. Cutter et al. (2008) find that this tradeoff nearly always favors bidding for the empirical setting considered here.

For example, a landowner might bid to install 1500 square-feet of porous pavement for a $1000 annual payment over 30 years. Thus the landowner's decision to participate in the program is similar to the decision to invest in a financial instrument that pays a fixed annual dividend over some known time horizon.

The second important difference between the bidding and investing is related to the "zero profit condition" mentioned above. Bidding potentially involves strategic behavior by landowners who are competing to have their bids accepted into the program, but who also want to earn excess profit. Despite the incentive to submit lower bids, some landowners may strategically bid above their true BMP placement costs in hopes of earning excess profit. Because the extent of such "bid shading" would be driven by the subjective beliefs and risk preferences of landowners, it is not obvious how landowners will respond to a bidding program and thus how cost-effective a bidding program will be without some additional assumptions about bidding behavior.

In our baseline scenario we examine the best possible case where landowners do not attempt to "shade" their bids (however later we relax this assumption and incorporate bid shading in a sensitivity analysis of the rate of return). In other words, we assume competitive bidding drives down the rate of return from the BMP program to that of the best alternative investment, thus generating no excess profit for bidders. This allows us to specify that any bid must satisfy a zero excess profit condition when the net present value is calculated at a specified rate of return over a specified time horizon. In our baseline scenario we select an 8% rate of return and a time horizon of 30 years. We use this rate of return to reflect the opportunity cost of "investing" in the BMP rather than in other available low-risk investments such as government bonds. This rate is high for safe investments, so it could also be regarded as combining a lower rate of return requirement with some bid shading. Later we conduct a sensitivity analysis of the rate of return. We specify a time horizon of 30 years because it is a common time horizon for long-term investments such as treasury bills and fixed mortgages.

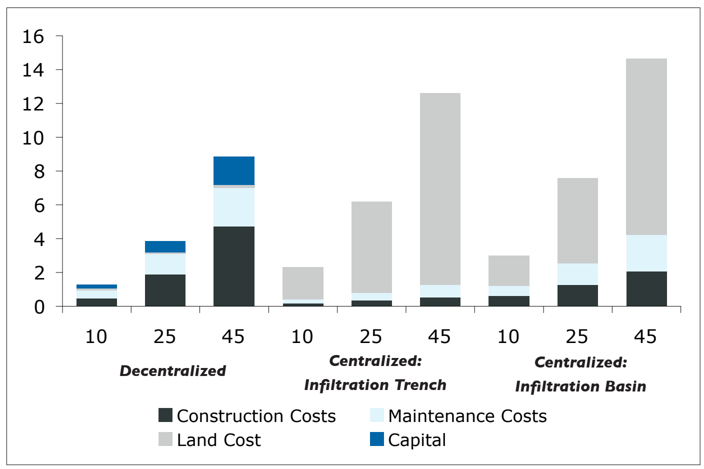
Results

We compare the cost of implementing decentralized BMPs with a bidding mechanism against the cost of a centralized alternative and find that bidding is almost always cheaper.[6] We also examine the value of runoff infiltration and find that it is a significant proportion of decentralized BMP costs.

Baseline Estimates

The key issue in deciding when centralized or decentralized alternatives perform better is whether the land cost savings of a decentralized approach outweigh the capacity cost savings due to the economies of scale of centralized facilities. Figure 3 shows that the land cost savings of an incentive-based system outweigh the economies of scale advantages of a centralized system. Bidding is significantly less expensive than either a centralized infiltration trench or infiltration basin for stormwater capture levels between 10 and 45 percent of total runoff for the baseline parameter values. The cost advantage is greatest at lower capture levels where a bid approach is less than half the cost of an infiltration trench (the most cost-effective centralized approach). At higher capture levels the cost difference narrows, but even at 45% capture the bid cost is only 61% of the costs of the infiltration trench.

Figure 3: Cost Comparison of Bidding and Centralized Treatment Approaches, by Capture % ($ millions)

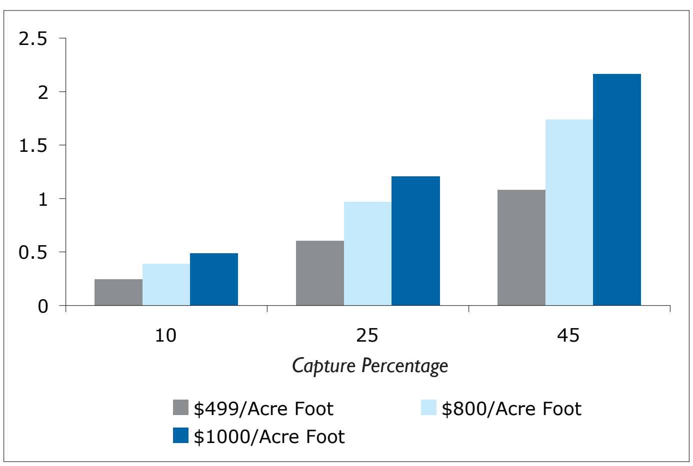


The land costs savings are the major factor in making an incentive based approach more cost-effective. Figure 3 shows that construction and maintenance costs are much higher for the bid approach than the infiltration trench, as we expect given the greater economies of scale for the centralized alternatives. However, the land cost savings more than make up the difference. This implies that some sort of incentive-based mechanism is crucial for deploying parcel-level, decentralized BMPs. A traditional command-and-control regulatory approach might force landowners to displace high-value land uses, which would eliminate the cost advantage of decentralized BMPs.

Figure 3 shows that the land cost savings of an incentive-based system outweigh the economies of scale advantages of a centralized system.

Net costs of runoff capture are further reduced if one considers the value of the infiltrated water. Our analysis considers a range of water values: 1) a low value of $499/Acre foot from The Los Angeles Department of Water and Power; 2) a mid-range value of $800/Acre foot reflecting historical water supply risks from Cutter (2007); and 3) a high value of $1000/Acre foot reflecting future drought risks due to climate change (Seager et al. 2007). For the bidding approach, we then calculate the present value of infiltrated water for a range of capture proportions using the average yearly infiltration modeled over the 2001-2006 precipitation record. Figure 4 together with Figure 3 shows that the present value of the additional water supplies is significant – up to 38% of the total public agency costs.

Figure 4: Value of Infiltrating Runoff ($ millions)



Sensitivity Analysis

We construct plausible ranges for important parameters to test the robustness of our finding that bidding is more cost-effective than a subsidy. We specifically consider low and high values for (1) decentralized BMP costs, given by the 25th and 75th percentiles of our previous cost regressions; (2) required landowner rate of return, specified as 5% and 11%, with the higher value incorporating our best estimate of the amount of bid shading we could expect from landowners who would normally demand an 8% return; (3) BMP infiltration rates, assumed to be 1 inch/hr and 8.5 inches/hr.; and (4) centralized treatment costs, with the low value derived from the national level cost estimates and the high value from our local cost data (see Cutter et al., 2008 for additional explanation.)

We compare all combinations of cost estimates across centralized and decentralized alternatives. Only in 2 out of 144 combinations does the bidding cost exceed the cost of centralized treatment.[7] In these combinations centralized costs are set at their lowest values and decentralized BMP costs at their highest value. In all other cases, bidding has lower costs, often by substantial amounts. The sensitivity analysis suggests that an incentive-based approach will be significantly cheaper than centralized facilities in nearly all situations.

Policy Implementation

Simulating the effects of financial incentives with computer software can oversimplify and abstract from the actual outcomes that may be generated when those same incentives are implemented in practice. Therefore, it likely will be necessary to modify and enhance the simulated mechanism in response to "real world" concerns before attempting to launch a new regulatory program.

Ensuring Long-Term Participation

The bidding mechanism creates an incentive for landowners to remain in the program for the entire duration because early exit (i.e., removing the BMP or failing to perform required maintenance) from the payment schedule reduces the effective rate of return. However, since the bidding mechanism relies on purely voluntary participation by landowners, a well-designed policy should carefully consider the possibility of early exit by landowners from the program. Generally a landowner will withdraw from the program before the planned end-date if a more lucrative opportunity presents itself for the remaining direct costs (maintenance) or land area used. This might include: the opportunity to switch land uses from a BMP to another use such as additional parking or building space with a higher rate of return; similarly, the opportunity to invest resources needed to maintain the BMP elsewhere at a higher rate of return; or the opportunity to sell the entire parcel to another owner who plans a use that is less compatible with BMPs.

> *... [Since] the bidding mechanism relies on purely voluntary participation by landowners, a well-designed policy should carefully consider the possibility of early exit by landowners from the program.*

Our preferred method for promoting long-term participation and one that maintains more of the voluntary nature of the program now and in the future, is to carefully design the program incentives to be competitive with other potential investment opportunities. The mechanisms we simulate here accomplish this because the required 8% rate of return is not achieved until the very last payment is made, at which time the landowner has exactly earned back his initial investment plus an annualized 8% return. If the landowner exits the program early and forfeits future payments, the effective rate of return will be less than 8% and might be negative if the landowner exits very early.

In addition, with the fully annuitized contract design presented in this report, the agency loses little if the owner exits early. For example, suppose the bid is $30,000 and $20,000 of that cost is up-front construction. In the current contract design the city pays an annuity over 30 years to the landowner. That annuity is $2,810/year. If the landowner removes the BMP after five years, then the city has paid out only $12,167 (present value of 5 years of the annuity at the construction year at 5% discount) and has received five years worth of stormwater management. On the other hand, the owner would lose a large amount by removing the BMP after five years; the present value at his 8% discount rate is only $11,220. He would not even make his construction cost back, much less the maintenance expenditures over that period.

Alternative contracts with less "backloading" of payments (i.e., those that reimburse the landowner more quickly with larger initial payments and smaller payments in the future) tend to reduce total program costs for the regulator but increase the likelihood of early exit. Total program costs are reduced because the agency has a lower discount rate than does the landowner, and because the landowner demands a smaller nominal compensation if payments are received sooner. Thus the landowner is not indifferent between slow and fast repayment schedules that have the same present value for the agency, but rather strictly prefers the faster repayment schedule. The likelihood of early exit increases because the landowner has less capital at stake in the program and thus has a lower "hurdle rate" for switching into an alternative investment. Long-term participation can be made more attractive by raising the payments levels, but this obviously increases program costs.[8] However, there may be some types of incentives (e.g., positive press for participating landowners) that encourage participation with relatively minor cost increases. Similarly it may be possibly to rely on tenants' willingness to contribute to environmental clean-up efforts to further subsidize landowner costs and increase the net return from program participation. This could involve, for example, soliciting voluntary donations from residents or employees to defray BMP costs and ultimately achieve a cleaner watershed.

One case where it would be less difficult to assure long-term compliance is where the property owner wants to remove a BMP in order to redevelop a property. The agency could incorporate a BMP review step in its development plan review, so that any permitted change to the property would have to include the construction of an equivalent BMP or repayment of subsidies to the agency. Incorporation of decentralized BMPs into the permitting process would likely cover a significant proportion of those landowners that would wish to remove BMPs.

Another possible approach to manage exit from the program is to write a relatively flexible BMP contract that guarantees a minimum payment level but allows landowners to submit documented cost adjustments to the regulator, and requires the regulator to reject an adjustment before a landowner can exit the program. This "right of first refusal" is analogous to the implicit understanding many employers have with their employees: that the employer should be given the opportunity to counter any employment offers received by the employee before the employee leaves to work elsewhere. The onus is thus placed on the landowner to justify a payment increase in exchange for a more flexible contract; and yet the contract (one that is arguably more enforceable due to its flexibility) still provides the regulator with greater assurance of long-term participation without having to design an incentive mechanism that addresses all possible contingencies.

The final way to encourage landowners to remain in the program is to enter into a stricter contract with penalties for noncompliance. Such a contract will likely raise bid prices and regulator costs and they would not be effective unless enforcement was strong. The key to all these program compliance enforcement proposals is that the regulator be able to monitor when BMPs are not being maintained or are removed. We discuss suggestions for BMP monitoring below.

Web-Based Incentive Contracting

Aside from these mechanism design issues, certain aspects of the proposed BMP incentive program roll-out and implementation merit mentioning. We recommend a web-based approach for soliciting participation in the program. Most landowners will be unfamiliar with infiltration BMPs, so a web-based approach would be beneficial for conveying relevant information in an interactive environment. The interactive ability of a website allows specific information from landowners to be utilized. For example, each landowner could create a web account that includes the parcel number, building area, parking area, etc. The website would then verify the characteristics of the parcel and perform calculations based on our analysis to determine minimum and maximum BMP sizes, runoff capture as a function of BMP capacity, and estimated BMP construction and maintenance costs.

For the subsidy mechanism, each landowner could enter hypothetical BMP capacities and the website would calculate the corresponding annual payments that would be made. After weighing other considerations that are largely unknown to the regulator, such as exact land costs and other unobserved opportunity costs of participation, the landowner could then determine whether to submit an application and, if so, for which BMP capacities. For the bidding mechanism, each landowner could submit hypothetical bids consisting of [BMP capacities, annual payment], and the website would calculate the index function values and advise the landowner how to improve his index score before submitting an actual bid. Effectively the website operationalizes much of the quantitative analysis we have already done, while also taking advantage of landowners' greater familiarity with their own characteristics and opportunity costs.

Monitoring Construction and Maintenance

There are several ways to facilitate the monitoring of BMP construction and maintenance. One possibility is to limit BMP construction to a list of approved BMP types and contractors. Another possibility is to rely on private firms or NGOs for periodic maintenance inspections. A final possibility is to set up a web based BMP location system (e.g., using Google Earth) that allows ordinary citizens to examine locations with BMPs and report if they do not seem to be maintained or operating properly.

The most important step is to limit the incentive program to reliable contractors and BMPs with low maintenance requirements. The contractor list should be flexible enough to allow contractors who come up with improved, more cost-effective designs, to join the list. It should also have provisions to remove contractors who have demonstrated poor performance. The list of allowed BMPs should be limited to devices with proven effectiveness and relatively low maintenance.

Regarding responsibilities for construction and maintenance of installed BMPs, there are important trade-offs to consider. When more of these responsibilities are borne by the regulator, the greater is the burden (cost) of program administration but the smaller is the opportunity for landowners to "shirk" their duties to properly install and maintain BMPs. While there may be an innate tendency to exert relatively more control by retaining more of the responsibility, we urge careful consideration of other options before a final decision is made. If landowners are given specific binding instructions regarding approved BMP contractors and maintenance requirements, and if they are required to submit specific documentation before reimbursement payments are made, we believe administrative costs can be reduced while still ensuring stormwater capture targets are met.

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Another way of decreasing these costs is to have compliance monitoring performed by private firms or environmental NGOs under contract. In this way the city would avoid hiring its own inspectors. The contracted firm would report any violations to the city. This model has been used for other small facilities in pollution prevention programs. A notable example is underground storage tanks, where several states, such as Florida, contract out inspection and monitoring activities.

Conclusions

This research shows that a decentralized incentive-based strategy that effectively targets BMPs at areas with low land use value is likely to be a cost-effective approach for reducing urban runoff. Whether an incentive-based strategy is more cost-effective than a centralized approach ultimately depends on whether the land cost advantage of incentive-based BMPs outweighs the economies of scale advantage of a centralized facility. We find that this trade-off favors decentralized incentive-based BMPs in all but a very few cases, and only when decentralized costs are at the high end of the range we consider. Construction and maintenance costs are lower for the centralized alternative due to economies of scale, but land costs are much greater so the incentive-based approach is overall more cost-effective for our study area. Notably, realizing the land cost advantage of decentralized BMPs requires a mechanism for placing BMPs on areas with low land-use value, something which a command-and-control regulatory approach is unlikely to do.

Endnotes

[1] This research was funded by EPA grant number CP-96950701-0. This article is based on a technical journal article in press at the time of this publication: W.B. Cutter, K. A. Baerenklau, A. DeWoody, R. Sharma, and J. G. Lee, Costs and Benefits of Capturing Urban Runoff With Competitive Bidding For Decentralized BMPs, Water Resour. Res., doi: 10.1029/2007WR 006343. Accepted for publication 2 June 2008. The authors are grateful to the editors of that journal for permission to reproduce portions of that article here. Readers desiring a more detailed presentation of the modeling and additional sensitivity analyses of the results should consult that article.

[2] This is common terminology used by stormwater professionals. In other contexts, "BMP" may imply a broader suite

of management practices, some of which might not necessarily involve physical separation methods. We adopt the application-specific definition here and throughout the article use it to imply small-scale stormwater capture devices.

[3] We customize STORM to the Sun Valley area by incorporating a five year hourly rain file from the nearby La Tuna Canyon rain station.

[4] The SWRPC (1991) data appears to be the only estimate of maintenance costs that is publicly available. It would be preferable to have cost estimates from a semi-arid region similar to Los Angeles. The maintenance costs are likely an upper bound because Wisconsin maintenance costs, with greater rainfall and cold-weather problems, are likely to be higher than Los Angeles area maintenance costs after adjusting for general construction cost differences.

[5] There is a very large literature on mechanism design and auction theory. Latacz-Lohmann and Schilizzi (2005) provide an excellent survey focused on conservation auctions like ours, emphasizing that standard auction theory offers relatively little guidance for conservation auction design. They also state that empirical studies have produced mixed results, thus highlighting the importance of practical implementation issues in auction design. Space limitations prevent a more complete discussion of the rationale for our chosen bidding mechanism, but its characteristics largely reflect the authors' conclusions.

[6] In Cutter, et al. 2008 we examine several different bidding approaches. This paper uses the approach that we find to be superior in that paper.

[7] For the sensitivity analysis we use a high and low value for the landowner's discount rate, infiltration pit cost, and porous pavement cost, generating eight possibilities for decentralized costs. We evaluate these alternatives at each of three stormwater capture levels and two infiltration rates. This results in a total of 48 alternative costs. Then we compare these costs to the low, mid-range, and high costs for the centralized alternatives with the same capture percentage and infiltration rate. The result is 144 comparison cells.

[8] Withholding repayment of all capital plus interest until the program's "maturity date" also discourages early exit, but landowners may be averse to such a payment schedule perhaps due to cash flow constraints.

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Congratulations to Anil Deolalikar and the Public Policy Initiative for the recently-approved School of Public Policy at UC Riverside

From the press release announcing the Board of Regents approval on September 17, 2008:

UC Riverside's location in the fast-growing Inland Empire of Southern California uniquely positions the campus to educate future policy-makers and conduct research in issues related to immigration, population growth and environmental policy, the Board of Regents said today as it unanimously approved the establishment of a School of Public Policy.

The graduate school will admit its first class of students in fall 2010.

Chancellor Timothy P. White said the School of Public Policy will produce graduates trained in policy analysis whose work will benefit residents of the Inland area, California and other fast-growing regions around the world.

"The Inland Empire is one of the fastest-growing regions in the nation and faces a severe shortage of skilled individuals who have the analytical and management skills necessary to plan and deliver public services at the city, county and regional levels," White said. "Because the public-policy problems facing our region are so similar to those faced by many rapidly growing areas around the world, we anticipate there also will be strong national and international demand for the graduate programs to be offered by the School of Public Policy."

The new school will focus on a range of social-policy issues, particularly those related to population growth, as they intersect with environmental policy and will emphasize a regional approach to solving common problems.

"We have fairly ambitious plans," said Anil Deolalikar, associate dean of the College of Humanities, Arts and Social Sciences (CHASS) and director of the CHASS Public Policy Initiative that launched preparations for the School of Public Policy. "We think the school will serve this region well. In many ways the Inland Empire is a living laboratory for policy analysts; the region is experiencing rapid population growth and the problems that typically come with growth – congestion, suburban sprawl, air pollution, water scarcity, stress on social services and increasing inequality of income and opportunity. From a policy point of view, this region is understudied and underserved."

The proposal approved by the regents allocates 12 full-time faculty equivalent positions. One of those slots will be filled by the dean, and five or six more will be filled by faculty assigned exclusively to the school. The remaining positions may be filled by faculty holding joint appointments in relevant departments or schools. The joint appointments will be made with appropriate units in areas that will contribute strength to the School of Public Policy while also furthering existing or developing departmental academic plans.

Classes will meet initially in existing campus facilities. Ultimately, the school will be located in the planned West Campus Professional and Graduate Center, northeast of Martin Luther King Boulevard and Iowa Avenue. The center – with 51,000 square feet of assignable space – will house the School of Public Policy and the Graduate School of Education. Construction costs are estimated at $37.5 million, with occupancy expected in 2013-14.

The School of Public Policy will offer a Ph.D. and a Master of Public Policy degree. The MPP degree may be completed in two years by full-time students, or in up to four years by mid-career public-policy professionals. Also planned are a 15-month Executive MPP program, a fast-track for experienced professionals working in government, nonprofit and community agencies. Non-degree certificate programs will be offered in selected areas.

The school will offer four areas of specialization: environmental and sustainable development policy, population and health policy, higher education policy, and immigration policy.

UCR will begin recruiting a founding dean and core faculty during the 2008-09 year. The school will accommodate a graduate student population of 30 doctoral and 120 master's degree candidates at maturity. Eventually, the School of Public Policy will also include undergraduates from the public policy major and minor programs that were introduced in the College of Humanities, Arts and Social Sciences in fall 2006.

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