SUPPLEMENTARY INVESTIGATION OF THE FEASIBILITY AND BENEFITS OF LOW-IMPACT SITE DESIGN PRACTICES ("LID") FOR THE SAN FRANCISCO BAY AREA

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ABSTRACT

The Clean Water Act NPDES permit that regulates municipal separate storm sewer systems (MS4s) in the San Francisco Bay Area, California will be reissued in 2007. The draft permit includes general provisions related to low impact development practices (LID) for certain kinds of development and redevelopment projects. Using eight representative development project case studies, based on California building records, the author investigated the practicability and relative benefits of LID options for the portion of the region having soils potentially limiting to infiltration. The principal LID option applicable in this situation is roof runoff harvesting, supplement by dispersion of the roof water in single-home sites. Other site runoff would be treated by conventional stormwater best management practices (BMPs), as specified in the permit. The results showed that effectively managing roof runoff and treating the remainder with conventional BMPS can: (1) reduce annual runoff volumes by almost half to more than 3/4, depending on land use characteristics, with much of the water saved available for a beneficial use; and (2) decrease mass loadings of pollutants to receiving waters by 63 to over 90 percent, depending on pollutant and land use.

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INTRODUCTION

Background

A report titled Initial Investigation of the Feasibility and Benefits of Low-Impact Development Practices ("LID") for the San Francisco Bay Area used six representative development project case studies, based on California building records, to investigate the practicability and relative benefits of LID options for the majority of the region having soils potentially suitable for infiltration either in their natural state or after amendment using well recognized LID techniques. The results demonstrated that: (1) LID site design and source control techniques are more effective than conventional best management practices (BMPs) in reducing runoff rates; and (2) in each of the case studies, LID methods would reduce site runoff volume and pollutant loading to zero in typical rainfall scenarios.

For a broad regional assessment of relatively large scale use of soil-based, infiltrative LID practices, the initial report covered areas having soils in Natural Resources Conservation Service (NRCS) Hydrologic Soil Groups A, B, or C as classified by the Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Depending on site-specific conditions, A and B soils would generally effectively infiltrate water without modification, whereas C soils could require organic amendments according to now standard LID methods. This supplementary report covers locations with group D soils, which are generally not amenable to infiltration, again depending on the specific conditions on-site. A minority but still substantial fraction of the Bay Area has group D soils (39.3, 68.0, 18.3, and 50.1 percent of the mapped areas of Alameda, Contra Costa, San Mateo, and Santa Clara Counties, respectively). Regarding any mapped soil type, it is important to keep in mind that soils vary considerably within small distances. Characteristics at specific locations can deviate greatly from those of the major mapped unit, making infiltration potential either more or less than may be expected from the mapping. The soil survey data are regarded as appropriate for use in broad-scale assessments such as underlie this and the initial report, but once site-specific implementation begins, it is important to verify site conditions.

General Assessment Methods

The assessment for group D soils reported herein emphasizes the use of LID practices appropriate in areas with relatively restrictive soils to the greatest possible extent, supplemented by conventional stormwater management practices implemented at fully practicable, high levels of effectiveness. The assessment was performed in a manner analogous to the analysis for the other soil groups and as described in the initial report. To recap briefly, with respect to each of several development case studies, three assessments were undertaken: a baseline scenario incorporating no stormwater management controls; a second scenario employing conventional BMPs; and a third development scenario employing LID stormwater management strategies. In each assessment, annual stormwater runoff volumes were estimated, as well as concentrations and mass loadings (the products of concentrations times flow volumes) of four pollutants: (1) total suspended solids (TSS), (2) total recoverable copper (TCu), (3) total recoverable zinc (TZn), and (4) total phosphorus (TP). The results of the second and third assessments were expressed in terms of the extent to which the management practices would reduce pollutant concentrations and loadings and runoff volumes, converting stormwater discharge a potential beneficial use (direct consumption or, in the case of group A, B, C soil areas, groundwater recharge).

Six case studies were selected to represent a range of urban development types considered to be representative of the Bay Area. These case studies involved: a multi-family residential complex (MFR), a relatively small-scale (23 homes) single-family residential development (Sm-SFR), a restaurant (REST), an office building (OFF), a relatively large (1000 homes) single-family residential development (Lg-SFR), and a single home (SINGLE). The land cover types for these various land uses were derived from building permit and other public records from the Bay Area or elsewhere in California.

Adaptation of Methods for Areas with Group D Soils

A key LID technique in a setting with soils relatively restrictive to infiltration is water harvesting, which can be applied at larger scales in commercial and light industrial developments and at smaller residential scales using cisterns or rain barrels. Harvesting has been successful in reducing runoff discharged to the storm drain system and conserving water in applications at all scales. For example, in downtown Seattle the King County Government Center collects enough roof runoff to supply over 60 percent of the toilet flushing and plant irrigation water requirements, saving approximately 1.4 million gallons of potable water per year (http://www.psat.wa.gov/Publications/LID_studies/rooftop_rainwater.htm, http://dnr.metrokc.gov/dnrp/ksc_tour/features/features.htm). A much smaller public building in Seattle, the Carkeek Environmental Learning Center, drains roof runoff into a 3500-gallon cistern to supply toilets (http://www.harvesth2o.com/seattle.shtml). Collecting drainage from individual dwellings for household use is a standard technique around the world, particularly in areas deficient in rainfall and without affordable alternative sources.

An additional general category of LID practices for poorly infiltrating locations, applicable especially at single homes and other relatively small-scale developments, is runoff dispersion for storage in vegetation and soil until evapotranspiration and some infiltration occurs. Section C.3.c of the California Regional Water Quality Control Board San Francisco Bay Region "Administrative Draft" NPDES Municipal Regional Stormwater Permit ("the Permit") requires all single-family home projects that create and/or replace 5,000 square feet or more of impervious surface to implement one or more stormwater lot-scale BMPs from a selection of: (1) diverting roof runoff to vegetated areas; (2) directing paved surface runoff flow to vegetated areas; and/or (3) installing driveways, patios, and walkways with pervious material such as pervious concrete or pavers. Another way of distributing and dissipating roof runoff used successfully in varied soils in the state of Washington is the downspout dispersion system, consisting of a splash block or gravel-filled trench serving to spread roof runoff over a vegetated area (Washington Department of Ecology 2005 [Volume III, Section 3.1.2]).

The basis of the group D soils assessment was harvesting roof runoff to the maximum possible degree, supplemented in smaller-scale developments by runoff dispersion methods. The report asserts that, through these LID BMPs, it is practicable to prevent the entrance of any roof runoff into the municipal storm drain system in any soils setting in the Bay Area. In group D soils, infiltration likely cannot be relied upon to reduce runoff from other portions of developments, such as walkways, driveways, parking lots, access roads, and landscaping. Some water loss would undoubtedly occur, especially through evapotranspiration and at least some infiltration of runoff generated on or directed to landscaping. The analysis presented in this report does not take account of these losses and hence is somewhat conservative in estimating benefits.

As required by the Permit, any runoff not attenuated by harvest, evapotranspiration, or infiltration would be subject to quantity and quality controls. The analysis assumes that extended-detention basins (EDBs) with water residence times up to 72 hours would provide this control. EDBs are one of several general-purpose, conventional stormwater BMPs available for this service, others being wet ponds, constructed wetlands, sand or other media filters, and biofiltration swales and filter strips. The California Department of Transportation (Caltrans, 2004) tested the performance of all of these practices in its BMP Retrofit Pilot Program, conducted in San Diego and Los Angeles Counties. The initial report investigating LID for A, B, and C soils presented estimates of benefits for EDBs, swales, and filter strips, along with continuous deflective separation (CDS) units, a practice that effectively captures only large particulate pollutants. For brevity, this follow-up report focuses on just EDBs as the supplement to LID. In performance, EDBs tend to fall between swales and filter strips for total suspended solids, slightly lower than the other two BMP types for metals, and either between the two or comparable to swales for total phosphorus.

These practices were applied to the same six case studies used in the initial analysis and described in Table 1 of the first report. Two additional case studies were defined for the assessment reported here: a sizeable commercial retail installation (COMM) and an urban redevelopment (REDEV). The hypothetical COMM scenario consists of a building with a 2-acre footprint and 500 parking spaces. Parking spaces were estimated to be 176 sq ft in area, which corresponds to 8 ft width by 22 ft length dimensions. A simple, square parking lot with roadways around the four sides and a square building with walkways also around the four sides were assumed. Roadways and walkways were taken to be 20 ft and 6 ft wide, respectively. The REDEV case was taken from an actual project in Berkeley involving a remodel of an existing structure, built originally as a corner grocery store with apartments above and a large side yard, and the addition of a new building on the same site to create a nine-unit, mixed-use, urban infill project. Table 1 summarizes the characteristics of these two case studies. The table also provides the recorded or estimated areas in each land use and cover type.

Table 1. Characteristics and Land Use and Land Cover Areas of Added Case Studies

	COMM[a]	REDEV[a]
No. buildings	1	1
Total area (ft^2)	226,529	5,451
Roof area (ft^2)	87,120	3,435
No. parking spaces	500	2 uncovered
Parking area (ft^2)	88,000	316 uncovered
Access road area (ft^2)	23,732	-
Walkway area (ft^2)	7,084	350
Driveway area (ft^2)	-	650
Landscape area (ft^2)	20,594	700

[a] COMM—retail commercial; REDEV—commercial/residential infill

The assessment for group D soils employed the same methods as the earlier analysis to estimate annual stormwater runoff volumes and pollutant discharges. Please refer to the initial report for details on those methods. The Natural Resource Conservation Service (NRCS, 1986) methodology cited in that report was applied to estimate that infiltration in group D soils would be roughly 60 percent of the amount through landscaping or the bed of a conventional BMP in C soils, which were the basis for establishing runoff coefficients in the first analysis. While that initial analysis was performed for both 14- and 20-inch average annual runoff zones, typical of different Bay Area locations, this supplementary work covered only the former condition. This simplification was made in the interest of brevity in this report, given that the first analysis showed almost no difference in conclusions between the two situations.

RESULTS OF THE ANALYSIS

Table 2 provides a comprehensive summary of the results. Rows shaded in gray compare runoff and pollutant discharges with and without treatment by CDS units, which can capture relatively large solids but have no mechanisms for dissolved substances and the finer particles. Having no soil contact and very limited residence time for evaporation, this BMP cannot reduce runoff volume at all. It can achieve some substantial reductions in TSS and TP for land uses relatively high in landscaped area but little removal of metals, especially copper.

The blue-shaded rows show the performance of conventional EDBs. In the group D soils considered in this analysis, they were estimated to reduce annual runoff volumes by 13-23 percent, the higher values for land uses with relatively small impervious footprints (OFF and REST). These BMPs can capture the majority of the long-term mass loading of most pollutants from most land uses in these soils, falling below 50 percent in reducing metals in stormwater flowing from residential developments.

Rows shaded in green present the results of applying LID BMPs appropriate for group D soils, roof runoff harvesting supplemented by dispersion in single-home land uses, plus treating the remaining runoff with EDBs. Comparing annual runoff volumes with and without LID, it can be seen that removing roof runoff from the storm drain system affords very significant benefits in reducing surface discharge and putting much of that water to productive use. Compared to directing all site runoff to EDBs, LID is expected to reduce volume by almost 10 times in the REDEV case, by about five times for the various residential land uses, 3.6 times for the large commercial development, and around twice for the OFF and REST cases. This management strategy can recover over 3/4 of the stormwater that would otherwise go down the drain in the intense redevelopment case, approximately 2/3 for the multi- and single-family residential cases, over half in the COMM development, and almost half in the office and restaurant cases with relatively small roof footprints.

Reduction of volume translates to decreases in pollutant loadings also. The combination of LID and EDB treatment is estimated to raise copper and zinc reductions to about 70 to over 90 percent in all except the developments with relatively low roof proportions (60-65 percent in these cases). TSS predictions come in at a quite consistent 75-82 percent across land uses. Total phosphorus estimates are a similarly consistent 63-71 percent, a bit higher in the highly impervious REDEV case.

Effectively managing roof runoff gives a way out of the dilemma posed by group D soils in the Bay Area. The analysis has demonstrated that harvesting this runoff stream, supplemented by ground dispersion techniques with sufficient space, shows strong promise to reduce the majority of flow inputs to municipal storm drain systems while conserving water. Moreover, this strategy can also stem the majority of solids, copper, zinc, and phosphorus transport to receiving waters.

Table 2. Runoff Volume and Pollutant Loading Reductions with Conventional and Low-Impact Development (LID) Best Management Practices (BMPs) for Eight Land Use Case Studies in Hydrologic Group D Soils

	COMM[a]	OFF[a]	REST[a]	REDEV[a]	MFR[a]	Lg-SFR[a]	Sm-SFR[a]	SINGLE
Total annual runoff with no BMPs (ac-ft)	5.29	0.80	0.47	0.12	8.57	75.66	1.74	0.10
Total annual runoff with CDS units[b] (reduction)	5.29 (0.0%)	0.80 (0.0%)	0.47 (0.0%)	0.12 (0.0%)	8.57 (0.0%)	75.66 (0.0%)	1.74 (0.0%)	0.10 (0.0%)
Total annual runoff with EDBs[b] (reduction)	4.43 (16.3%)	0.63 (21.3%)	0.36 (23.2%)	0.11 (8.1%)	7.48 (12.7%)	65.27 (13.7%)	1.50 (13.7%)	0.09 (13.3%)
Total annual runoff with LID[b] (reduction)	2.22 (58.0%)	0.44 (45.0%)	0.28 (40.4%)	0.03 (78.9%)	2.80 (67.3%)	26.72 (64.8%)	0.61 (64.8%)	0.04 (65.7%)
CDS TSS reduction[b, c]	19.4%	44.8%	33.9%	22.1%	27.1%	37.1%	37.1%	37.7%
CDS TCu reduction[b, c]	0.4%	11.0%	4.2%	0.9%	2.7%	7.3%	7.3%	7.6%
CDS TZn reduction[b, c]	25.3%	29.1%	25.5%	25.5%	24.1%	25.6%	25.6%	25.9%
CDS TP reduction[b, c]	25.9%	63.7%	54.3%	35.7%	46.7%	57.6%	57.6%	58.2%
EDB TSS reduction[b, c]	64.7%	78.1%	74.9%	66.5%	62.8%	70.3%	70.3%	70.9%
EDB TCu reduction[b, c]	57.9%	51.6%	56.4%	53.2%	51.4%	43.5%	43.5%	43.6%
EDB TZn reduction[b, c]	57.6%	49.6%	48.9%	58.1%	48.5%	47.7%	47.7%	48.0%
EDB TP reduction[b, c]	44.4%	67.6%	63.3%	52.8%	56.3%	64.4%	64.4%	64.7%
LID + EDB TSS reduction[b, c, d]	74.6%	80.3%	77.0%	81.5%	79.4%	81.3%	81.3%	81.8%
LID + EDB TCu reduction[b, c, d]	71.9%	60.3%	62.2%	82.3%	73.8%	68.9%	68.9%	69.5%
LID + EDB TZn reduction[b, c, d]	79.7%	65.1%	60.9%	92.3%	78.9%	76.4%	76.4%	77.0%
LID + EDB TP reduction[b, c, d]	63.1%	69.8%	66.0%	75.2%	69.4%	70.8%	70.8%	71.1%

[a] COMM—retail commercial; OFF—office building; REST—restaurant; REDEV—commercial/residential redevelopment; MFR—multi-family residential; Lg-SFR—large-scale single-family residential; Sm-SFR—small-scale single-family residential; SINGLE—single family home

[b] CDS— continuous deflective separation; EDBs—extended-detention basins; reduction—comparison with no BMPs

[c] TSS—total suspended solids; TCu—total recoverable copper; TZn—total recoverable zinc; TP—total phosphorus

[d] LID + EDB—roof runoff harvesting for COMM, OFF, REST, REDEV, AND MFR; harvesting supplemented by dispersion of roof runoff for Lg-SFR, Sm-SFR, and SINGLE; treatment of remaining runoff by EDBs

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