ASSESSMENT OF HYDROLOGIC AND WATER QUALITY IMPLICATIONS OF STORMWATER MANAGEMENT UNDER PROVISIONS OF THE SAN FRANCISCO BAY REGION MUNICIPAL REGIONAL STORMWATER NPDES PERMIT

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BACKGROUND

During the development of the San Francisco Bay Region Municipal Regional Stormwater NPDES Permit, the author prepared a report titled Initial Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Francisco Bay Area (Horner 2007a). Using six representative development project case studies, based on California building records, the report investigated 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 (hydrologic group A, B, and C soils). The results demonstrated that: (1) LID site design and source control techniques would be more effective than conventional best management practices (BMPs) in reducing runoff rates; and (2) in each of the case studies, LID methods, including water harvesting for reuse along with infiltrative methods, would reduce site runoff volume and pollutant loading to zero in typical rainfall scenarios. The author prepared a subsequent report covering the remainder of the region, where hydrologic group D soils predominate (Horner 2007b). This report showed that combining LID techniques with conventional BMPs where infiltration opportunities are limited would: (1) reduce annual runoff volumes by almost half to more than 3/4, depending on land use characteristics, with much of the water saved being 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.

A tentative draft of the permit was issued in 2009 with provisions encouraging but not requiring LID practices. In section C.3.c.i.(2) it presents a hierarchy starting with these fully or highly water retentive methods but proceeding on to less retentive vegetation- and soil-based techniques, then to conventional surface BMPs, and finally to vault-type systems. In each case, practice specification proceeds to the next step in the hierarchy after the preceding step has been exercised "... as much ... as practicable", a standard that is not defined.

METHODS OF ANALYSIS

The same analytical techniques described in the initial report were applied to investigate the implications, regarding the discharge of runoff and the pollutants it conveys, of utilizing stormwater management strategies lower on the hierarchy, in comparison to the full LID approach outlined by Horner (2007a). Two scenarios were defined and applied to the original six case studies set in the more infiltrative soils regime and two rainfall zones typifying the San Francisco Bay Region. The first scenario assumes a mixed strategy, with 35 percent of each site's runoff managed by the full-LID approach, consistent with permit provisions C.3.c.i.(2)(d) and (e); 15 percent by the types of practices represented by provision C.3.c.i.(2)(f) (e.g., bioretention with underdrains); 30 percent by conventional surface BMPs, according to provision C.3.c.i.(2)(g); and the remaining 20 percent by wet vaults, as provided by provision C.3.c.i.(2)(h). The second scenario assumes treatment of 51 percent of the site runoff by conventional surface BMPs and 49 percent by wet vaults. This split represents near the maximum vault treatment allowed by the permit without special permission, per paragraph C.3.c.i.(6).

In addition to the methods described by Horner (2007a), the analysis relied on several other procedures. The amount of water retained, and not discharged, by conventional surface BMPs was estimated as the average measured for extended-detention basins and conventional biofiltration swales and filter strips in the California Department of Transportation's (Caltrans, 2004) BMP Retrofit Pilot Program, 40 percent. The fraction of retention by bioretention with underdrains was taken as the average obtained by Davis

(2008) in research on these BMPs, namely 59 percent. With the lack of any opportunity for infiltration and extremely limited evaporation, vault discharge was taken to be equal to the influent volume.

To assess water quality, pollutant mass loading reduction efficiencies afforded by conventional surface BMPs over an extended period of time, representing multiple storms, were based on Caltrans' (2004) results for extended-detention basins (EDBs), which were generally intermediate between two other common BMPs of this type, conventional biofiltration swales and filter strips: 69 percent for total suspended solids (TSS), 62 percent for total recoverable copper (TCu), 60 percent for total recoverable zinc (TZn), and 63 percent for total phosphorus. These efficiencies are functions of the 40 percent volume decrease occurring in EDBs plus extraction of pollutants in the basins, which lowers their concentrations. Davis (2007) provided equivalent efficiencies for bioretention cells with underdrains: 57 percent for TSS, 80 percent for TCu, 62 percent for TZn, and 78 percent for TP. There has been little research on wet vaults. The performance of these devices is limited by the lack of light, soil, and vegetation, which mediate a number of the pollutant removal mechanisms in surface BMPs, as well as by virtually no volume reduction. Shapiro and Associates, Inc. (1999) measured the water quality of discharge from a wet vault serving as pretreatment for a sand filter in Bellevue, WA. This study found reductions of 36 percent for TSS, 13 percent for TCu, 26 percent for TZn, and 7 percent for TP.

RESULTS

Table 1 presents the hydrologic comparisons for the various management scenarios assessed. In the full LID case defined by Horner (2007a) all of the water estimated to recharge groundwater in the pre-development situation can be captured either by infiltration or harvest in all six land use case studies and both rainfall zones. A mixed strategy of LID BMPs with and without underdrains, conventional surface BMPs, and vaults results in some loss of water for beneficial purposes, from 8 to 24 percent depending on land use. Resorting to just conventional BMPs and vaults more than doubles those losses in every case.

Table 1. Water Captured Annually (in acre-ft) from Development Sites for Beneficial Use with a Full LID Approach In Comparison to Capture from Developments Served Entirely or Largely with Conventional BMPs Allowed by the San Francisco Bay Region Municipal Regional Stormwater NPDES Permit

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall:						
Pre-development recharge[b] (acre-ft)	11.9	3.29	0.83	2.30	144	0.19
Full LID case[c]—						
Post-development runoff capture (acre-ft)	11.9	3.29	0.83	2.30	144	0.19
Post-development recharge lost (acre-ft)	0	0	0	0	0	0
Post-development % recharge lost	0%	0%	0%	0%	0%	0%
Mixed LID and conventional BMP case[d]—						
Post-development recharge[b] (acre-ft)	8.95	2.76	0.69	2.12	120	0.17

Table 1 (continued)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Post-development recharge lost (acre-ft)	2.89	0.52	0.15	0.18	22.7	0.03
Post-development % recharge lost	24%	16%	18%	8%	16%	16%
Conventional surface BMP and vault case[e]—						
Post-development recharge[b] (acre-ft)	5.92	2.15	0.52	1.84	93.3	0.13
Post-development recharge lost (acre-ft)	5.93	1.14	0.31	0.46	49.5	0.07
Post-development % recharge lost	50%	35%	37%	20%	34%	37%
20 Inches/Year Rainfall:						
Pre-development recharge[b] (acre-ft)	16.9	4.71	1.19	3.30	205	0.27
Full LID case[c]—						
Post-development runoff capture (acre-ft)	16.9	4.71	1.19	3.30	205	0.27
Post-development recharge lost (acre-ft)	0	0	0	0	0	0
Post-development % recharge lost	0%	0%	0%	0%	0%	0%
Mixed LID and conventional BMP case[d]—						
Post-development recharge[b] (acre-ft)	12.8	3.94	0.98	3.03	171	0.24
Post-development recharge lost (acre-ft)	4.12	0.74	0.21	0.25	32.3	0.04
Post-development % recharge lost	24%	16%	18%	8%	16%	15%
Conventional surface BMP and vault case[e]—						
Post-development recharge[b] (acre-ft)	8.44	3.06	0.75	2.62	133	0.19

Table 1 (continued)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Post-development recharge lost (acre-ft)	8.46	1.62	0.45	0.66	70.6	0.10
Post-development % recharge lost	50%	34%	38%	20%	34%	37%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; SINGLE—Single family home.

[b] Quantity of water infiltrating the soil; the difference between precipitation and runoff.

[c] Assuming all runoff managed by BMPs consistent with permit provisions C.3.c.i.(2)(d) and (e) [BMPs retaining runoff through infiltration, evapotranspiration or harvesting for reuse, assuming full retention as demonstrated by Horner (2007)].

[d] Assuming runoff managed as follows: 35% by BMPs consistent with permit provisions C.3.c.i.(2)(d) and (e); 15% by BMPs consistent with permit provision C.3.c.i.(2)(f) [BMPs treating runoff through vegetation and soil contact but conveying it via underdrains for surface discharge]; 30% by BMPs consistent with permit provision C.3.c.i.(2)(g) [conventional surface BMPs]; and 20% by BMPs consistent with permit provision C.3.c.i.(2)(h) [subsurface vaults].

[e] Assuming runoff managed as follows: 51% by BMPs consistent with permit provision C.3.c.i.(2)(g); and 49% by BMPs consistent with permit provision C.3.c.i.(2)(h).

Table 2 presents the water quality comparisons for the respective development cases and stormwater management scenarios. Because the full LID approach would discharge no surface runoff, all pollutant discharges would be reduced to zero. The mixed case would reduce loadings by approximately two-thirds to three-quarters. Not taking advantage of the full capabilities of LID would still produce, for example, 6670 lbs. of TSS and 1.77 lbs. of copper, a metal of great concern in San Francisco Bay, in discharges from just these six developments in the 20-inch/year rainfall zone each year. Using only conventional surface BMPs and vaults would attenuate just slightly over half of the TSS, 40 percent of the TZn, and one-third of the TCu and TP. In this scenario the total TSS and copper discharges would grow to 10,990 and 3.42 lbs./year, respectively, an approximate doubling of the copper relative to the mixed BMP scenario. Compounded over the whole region, these discharges would substantially add to the pollutant burden in receiving waters, unnecessarily in that practical, economical LID techniques exist to replace less effective traditional practices.

Table 2. Comparison of Pollutant Mass Loading Reduction Estimates in Runoff from Development Sites with a Full LID Approach Versus Development Cases Based on Conventional BMPs Allowed by the San Francisco Bay Region Municipal Regional Stormwater NPDES Permit

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
14 Inches/Year Rainfall[b]:						
No treatment case—						
Lbs. TSS discharged/year	1254	328	119	230	14249	20
Lbs. TCu discharged/year	0.44	0.070	0.030	0.043	3.04	0.0041
Lbs. TZn discharged/year	2.94	0.576	0.165	0.286	25.04	0.034
Lbs. TP discharged/year	6.24	2.27	0.68	1.69	98.55	0.14
Full LID case[c]—						
TSS reduction	100%	100%	100%	100%	100%	100%
TCu reduction	100%	100%	100%	100%	100%	100%
TZn reduction	100%	100%	100%	100%	100%	100%
TP reduction	100%	100%	100%	100%	100%	100%

Table 2 (continued)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	SINGLE[a]
Mixed LID and conventional BMP case[d]—						
TSS reduction	71.2%	72.9%	74.4%	75.1%	72.9%	73.0%
TCu reduction	68.2%	66.3%	69.5%	68.5%	66.3%	66.3%
TZn reduction	67.4%	67.4%	67.6%	68.1%	67.4%	67.4%
TP reduction	66.7%	69.0%	68.8%	70.0%	69.0%	69.1%
Conventional surface BMP and vault case[e]—						
TSS reduction	52.4%	55.3%	57.9%	59.0%	55.3%	55.5%
TCu reduction	37.9%	34.8%	40.1%	38.5%	34.8%	34.8%
TZn reduction	43.2%	43.1%	43.5%	44.3%	43.1%	43.2%
TP reduction	35.0%	39.0%	38.7%	40.6%	39.0%	39.2%
20 Inches/Year Rainfall:						
No treatment case—						
Lbs. TSS discharged/year	1864	501	180	360	21781	30
Lbs. TCu discharged/year	0.63	0.10	0.043	0.063	4.44	0.006
Lbs. TZn discharged/year	4.22	0.83	0.24	0.42	36.2	0.050
Lbs. TP discharged/year	9.60	3.55	1.05	2.71	154.4	0.22
Full LID case[c]—						
TSS reduction	100%	100%	100%	100%	100%	100%
TCu reduction	100%	100%	100%	100%	100%	100%
TZn reduction	100%	100%	100%	100%	100%	100%
TP reduction	100%	100%	100%	100%	100%	100%
Mixed LID and conventional BMP case[d]—						
TSS reduction	71.4%	73.1%	74.6%	75.2%	73.1%	73.3%
TCu reduction	68.1%	66.3%	69.4%	68.4%	66.3%	66.3%
TZn reduction	67.4%	67.3%	67.6%	67.9%	67.3%	67.4%
TP reduction	67.0%	69.2%	69.0%	70.1%	69.2%	69.3%
Conventional surface BMP and vault case[e]—						
TSS reduction	52.7%	55.7%	58.2%	59.3%	55.7%	55.9%
TCu reduction	37.9%	34.7%	40.0%	38.3%	34.7%	34.8%
TZn reduction	43.1%	43.0%	43.4%	44.1%	43.0%	43.1%
TP reduction	35.6%	39.3%	39.0%	40.9%	39.3%	39.5%

[a] See Table 1 footnote a.

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

[c, d, e] See Table 1 footnotes a, b, and c.

CONCLUSIONS AND RECOMMENDATIONS

Conventional surface and subsurface stormwater management practices lose as much as half of the rainfall that could be captured to supplement the San Francisco Bay Region's water supply, simultaneously draining into the region's water bodies the majority of harmful contaminants like heavy metals and nutrients picked up while flowing over urban lands. Substituting low impact development practices for these traditional methods saves water and pollution in relation to how much LID is utilized.

Making maximum use of such practices available today and proven in practicability can save all of the rainfall for some beneficial purpose and, concomitantly, avoid any further degradation of water bodies by urban pollutants.

The permit should be restructured to require the use of these practices at new developments and redevelopments. Clear performance metrics should be included that calibrate the amount of rainfall that must be retained through LID practices to match the technical capability that I have verified in my investigations. Furthermore, the permit should set thorough, objective criteria that a project proponent must use to demonstrate inability to satisfy the full water quality and hydromodification requirements of the permit on-site. For those cases where such a demonstration can be convincingly made, the permit should require and provide for installing compensating, equivalent LID works off-site, so as to assure that the relative water quality and quantity benefits identified herein are realized on a watershed basis when not realized on-site .

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