6.0 Comparison and Applicability

The integrated approach to storm water management requires consideration of many new concepts and practices. However, a direct comparison of the costs and performance of these new practices to conventional engineered storm drainage systems, or for that matter to each other, should be handled with caution for a number of reasons:

1. The practices apply to different areas and situations. Some, such as rain barrels, apply only to residential areas, whereas others, such as rooftop storage, would be implemented only in large commercial/industrial/ institutional buildings, and others, such as inlet restrictors, would be installed in paved areas. The level of performance (amount of water controlled) also varies widely.

2. Onsite storm water reduction practices offer a widely-varying range of benefits beyond storm water reduction, such as water quality benefits, groundwater recharge, habitat improvement, and educational values.

3. The integrated approach involves small scale, distributed practices that will have accumulated results - maybe not always more efficiently than engineered solutions, but often more effective, with improved benefits and increased participation and long term implementation.

4. The concepts of green infrastructure, sustainable development, and improved site design will require a mix of structural, nonstructural, institutional, and educational elements. Implementation of these elements will necessitate increased partnerships. The onsite practices attractive to private residents offer partnership opportunities with community and neighborhood groups, special interest groups (such as garden clubs), and municipalities. The practices that are more appropriate for institutional or commercial property owners offer the City the opportunity to partner with existing organizations that have many properties, such as school districts, banks, or developers.

5. The onsite practices offer a wonderful opportunity to educate the public about storm water and watershed health and protection. Residential programs lend themselves to enhancing homeowner understanding of storm water issues.
Practices such as rain gardens or downspout disconnects are very tangible, easily understood concepts. Practices that involve established institutions allow the City to raise awareness among large groups of people, such as service organizations or tenants of properties. Practices such as green roofs, when partnered with a school district, offer the City the chance to build an education program for school children and their parents. Establishing some sort of recognition program to residents/institutions who participate in storm water reduction practices provide the City with additional education/awareness opportunities through publicity and media coverage.

It is helpful to evaluate the attributes and limitations of the storm water reduction practices and to understand the conditions under which these practices perform best. For each practice, Table

6.1.1 summarizes the flow benefits, environmental features, implementability, function, operation and maintenance needs, and potential to promote environmental awareness.

1.1. Evaluation of Green Design Techniques

1. All practices provide some reduction in storm water flow (otherwise, of course, they would not be included in the table). However, the level of hydrologic/hydraulic performance varies widely.

2. Three-fourths of the practices have the potential - depending on the design - to provide at least marginal benefits during “major” (> 1”) storms.

3. All but two of the practices may be expected to provide pollutant removal and water quality benefits.

4. While many practices are believed to be acceptable to the public, a fairly intensive public education program will be needed for successful implementation.

5. Over three fourths of the practices offer opportunities for partnerships.

6. About 65% of the practices utilize vegetation; 82% increase infiltration; and 53% involve storm water storage.

7. Over one-half of the practices have a “good” or “very good” potential to help promote environmental responsibility and awareness.

8. A few practices - French drains, dry wells, and infiltration sumps - may have limitations that merit site specific soils investigations.

Table 6.1.2 presents the cost effectiveness of the practices. Capital costs and costs per impervious acre served are provided. Note that the amount of storm water reduction varies: a rain barrel may store only ¼” of runoff from a roof, while a green roof may accommodate more than 2” of rainfall. The cost effectiveness estimates do not reflect these variations in performance. The cost per impervious acre served ranges from less than $1,000 per acre to $653,400 per acre. The median cost is approximately $16,000 per impervious acre.

Table 6.1.1: Evaluation of Storm Water Reduction BMPs
(Milwaukee Metropolitan Sewerage District (MMSD), 2005)

	Flow					Environmental		Implementability							Function				
Stormwater Reduction Practice	Delays Runoff	Reduces Runoff Volume	Reduces Peak Flow	Increases Infiltration	Effective in Major Storms	Water Quality Protection	Ecology/ Habitat Improvement	Public Acceptance	Public Education Needed	Financial Incentive Needed	Sensitive to Proper Operation	Opportunity for Partnership	Applicability	Limitations	Plant Uptake	Infiltration	Storage	Operations and Maintenance Needs	Environmental Awareness
1. Downspout Disconnection	Yes	Yes	Yes	Yes	Yes	Yes	No	Good	Yes	Yes	No	Yes	CSSA only.	Interior downspouts. House foundations. Basement flooding. Safety / ice concerns.	*	*		Low. Inspections.	Good. Residential / neighborhood.
2. Rain Barrels	Yes	Yes	Yes	Maybe	No	Maybe	No	Good	Yes	Yes	Yes	Yes	Residential.	Mosquitos. Small lots. House foundations. Winter.	*	*	*	Moderate. Must be emptied. Winter storage. Check fittings and connections.	Very good. Residential.
3. Cisterns	Yes	Yes	Yes	Maybe	Yes	Maybe	No	Fair/Poor	Yes	Yes	Yes	Yes	Residential. Commercial. Industrial.	May reuse water (potential: laundry, toilet, outdoor uses). Winter.			*	Moderate. Check fittings and connections. Disconnect / empty in winter.	Average.
4. Rain Gardens	Yes	Yes	Yes	Yes	No	Yes	Yes	Good	Yes	Maybe	Yes	Yes	Residential and light commercial/industrial.	Land availability. Unsuitable soils.	*	*		Moderate. Plant upkeep. Weed control. Occasional watering.	Very good. Residential/community.
5. Green Roofs	Yes	Yes	Yes	No	Maybe	Yes	Yes	Fair	No	Yes	Yes	Yes	Flat roofs (subject to limitations). Industrial. Commercial.	Load-bearing capacity. Moisture and root penetration resistance.	*	*	*	Moderate. Plant upkeep and maintenance of roof structure. More maintenance than a conventional roof.	Good. Institutions/commercial/industrial.
6. Rooftop Storage	Yes	Maybe	Yes	No	Yes	No	No	Good	No	No	No	Yes	Commercial, industrial, and institutional flat roofs.	Load-bearing capacity. Waterproofing. Mosquitos.			*	Low.	Good.
7. Green Parking Lots	Yes	Yes	Yes	Yes	Maybe	Maybe	Yes	Good	Yes	No	No	Yes	Commercial, industrial, institutional.	Open space. Suitable soil	*	*		Moderate. Maintain vegetation.	Good public display.
8. Stormwater Trees	Yes	Yes	Yes	Yes	Maybe	Maybe	Yes	Good	Yes	Yes	No	Yes	Most pervious areas, and in planters.	Pervious open space.	*	*		Moderate. Routine tree maintenance and watering.	Good for community group participation.
9. Porous Pavement	Yes	Yes	Yes	Yes	Yes	Yes	No	Fair	Yes	Maybe	Yes	Yes	Low traffic areas and parking lots. Sidewalks.	Winter freeze/thaw.		*		High. High maintenance and cleaning needed to prevent clogging. Monthly vacuuming and power	Good.
10. Inlet Restrictors/ Pavement Storage	Yes	No	Yes	No	Yes	No	No	Poor	Yes	No	No	No	Streets with flat grades, low traffic, and curbs and berms to impound water. Residential feeder streets.	Safety. Street access.			*	Low. Minimal.	Average. Maybe good for municipal recognition.

Table 6.1.1: Evaluation of Storm Water Reduction BMPs, continued

	Flow					Environmental		Implementability							Function				
Stormwater Reduction Practice	Delays Runoff	Reduces Runoff Volume	Reduces Peak Flow	Increases Infiltration	Effective in Major Storms	Water Quality Protection	Ecology/ Habitat Improvement	Public Acceptance	Public Education Needed	Financial Incentive Needed	Sensitive to Proper Operation	Opportunity for Partnership	Applicability	Limitations	Plant Uptake	Infiltration	Storage	Operations and Maintenance Needs	Environmental Awareness
11. Bioretention	Yes	Yes	Yes	Maybe	Maybe	Maybe	Yes	Good	No	No	No	Yes	Open land areas. Well-drained soils (or w/ under drain).	Land availability. Unsuitable soils.	*	*	*	Low. Vegetation upkeep - mowing, removal of invasive species, replanting, removal of debris, and corrosion control.	Average.
12. On-site Filtering Practices	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Fair	Yes	Yes	Yes	Yes	Small drainage area.	No steep slopes. Risk of clogging. Standing water.	*	*		High. Inspections and cleaning to prevent clogging.	Average.
13. Pocket Wetlands	Yes	Yes	Yes	No	Yes	Yes	Yes	Fair/Poor	No	No	No	Yes	Parking lots. Small sites.	Supplemental irrigation. Site requirements. Mosquitos. Winter & salt.	*	*	*	Low. Sediment removed. Invasive species.	Good.
14. French Drains and Dry Wells	Yes	Yes	Yes	Yes	Maybe	Yes	No	Poor	Yes	No	No	Yes	Small drainage areas. Residential.	Permeable soils. Adequate depth to gw. Clean water.		*	*	Low. Annual training. Replace rock and clean out sediment.	Average.
15. Infiltration Sumps	Yes	Yes	Yes	Yes	Maybe	Yes	No	Fair	No	No	No	No	Residential areas <50% impervious. Placed in rights of way of smaller streets.	Permeable soils. Adequate depth to gw.		*		Low. Clean out sumps every 2-3 years. Every year inspection.	Average.
16. Compost Amendments	Yes	Yes	Yes	Yes	No	Yes	Maybe	Fair	Yes	Yes	No	Yes	Highly compacted soils with low organic matter and nutrients.	Temporarily disturbs vegetative cover.	*	*		Low. None.	Average.
17. Stormwater Rules and Redevelopment Policies	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Fair	No	No	No	No	New development and redevelopment.	Prescriptive. Rigid criteria.	*	*	*	Low. None.	Average.

Table 6.1.2: Cost Effectiveness of Storm Water Reduction BMPs
(Milwaukee Metropolitan Sewerage District (MMSD), 2005)

Stormwater Reduction Practice	Capital Cost	$/Impervious Acre Served (min)	$/Impervious Acre Served (max)	Vol of Runoff/ Imp Ac [gal]	$/gal (min)	$/gal (max)	Assumptions
1. Downspout Disconnection	$50 to $250/downspout.	$4,400	$21,800	12,938	0.34	1.68	Each downspout disconnection drains 500 square feet of roof
2. Rain Barrels	$150/each rain barrel.	$13,100	--	10,345	1,27	NA	Each rainbarrel drains 500 square feet of roof and captures 0.4".
3. Cisterns	$1,000 (500 gallon) to $5,000 (6,500 gallon underground).	$43,600 $10,000		19,400 12,938	2.25 0.77	NA 1.55	500-gallon cistern drains 1,000 square feet of roof for 0.75" rain. Two 6,500 gal can capture 1". Water re-use may reduce water supply costs.
4. Rain Gardens	$5 to $10/square foot.	$21,800	$43,600	25,875	0.84	1.69	100 square foot rain garden drains 1,000 feet of roof.
5. Green Roofs	$15/square foot of roof $8/sq ft (net)	$348,480	$653,400	12,938	26.93	50.5	Complete green roof system includes watertight membrane, protective layer, insulation, drainage system, filter layer, soil, and plants.
6. Rooftop Storage	$100/drain restrictor. $5/square foot waterproofing	$4,356	$222,200	25,875	0.17	8.59	One restrictor per 1,000 square feet of roof. Waterproof entire roof.
7. Green Parking Lots	$200/tree pit. $13,000-$30,000/acre bioretention. $2/square foot turf pavers.	$10,000	$11,700	25,875	0.39	0.45	10% of parking lot area is bioretention, and 10% is turf paved.
8. Stormwater Trees	$200 - $340/tree	$27,800	$47,260	22,869	1.22	2.07	Each acre of trees receives drainage from one impervious acre. $670 per residential acre; $3,300 per commercial/industrial acre. Street trees assume 20' diam. canopy/tree (314 sq ft).
9. Porous Pavement	$2-$4/square foot	$81,700	$174,000	25,875	3.16	6.72	Lower cost is turf or gravel paver; higher cost is porous asphalt or concrete.
10. Inlet Restrictors / Pavement Storage	$400-$1,200 per restrictor	$450	$1,350	54,450	0.01	0.02	Each inlet restrictor serves 1.5 acres @ 60% impervious.
11. Bioretention	$13,000-$30,000/acre.	$6,500	$15,000	25,875	0.25	0.58	Each bioretention acre drains two impervious acres.
12. On-site Filtering	Swales: $3,500/5-acre residential site. Sand filter: $35,000-$75,000/5-ac commercial site. Filter Strips: $13,000/$30,000/acre.	$1,200 $8,700 $2,600		25,875 25,875 25,875	0.05 0.34 0.10	NA 0.72 NA	Swales: 5-acre 80% impervious residential site. Sand Filters: 5-acre 80% impervious commercial site. Filter Strips: Each acre of filter strip serves 5 impervious acres.
13. Pocket Wetlands	$60,000/acre/foot.	$16,000		25,875	0.62	NA	0.5 acre, 3-foot deep pocket wetland serves 5 acres, 1/2 of which is impervious.
14. French Drains and Dry Wells	French drain: $15-$17 linear foot. Dry Well: $900 to $1,400/each	$26,136 $78,400	$29,621 $122,000	12,938 12,938	2.02 6.06	2.29 9.43	Each dry well drains 500 square feet of roof.
15. Infiltration Sumps	$5,000 to $10,000 per sump.	$5,500	$11,000	25,875	0.21	0.43	Each sump serves 1.5 acres @ 60% impervious.
16. Compost Amendments	$1-$2/square foot.	$21,800	$43,600	12,938	1.68	3.37	Each acre of compost amended soil drains two impervious acres.

Notes:
Volume of runoff per impervious acre based on assumption that practices treat between 0.4 and 1.0 inches, depending on the practice. WQv =(Rv)(A)(P), Rv = 0.95 assuming 1ac of impv.
1" yields (0.95)(43560 sqft)(1"/12)(7.5 gal/cuft)=25,875 gal
0.75" yields (0.95)(43560 sqft)(0.75"/12)(7.5 gal/cuft)=19,400 gal
0.5" yields (0.95)(43560 sqft)(0.5"/12)(7.5 gal/cuft)=12,938 gal
0.4" yields (0.95)(43560 sqft)(0.4"/12)(7.5 gal/cuft)=10,345 gal
Street tree assumptions are based on installed costs of b/w $200-$340 per tree,rainfall interception of 0.525 gal/sqft(22,869 gal per canopy ac),average canopy per tree of 314 sq ft (139 trees per canopy acre).
Inlet restrictor assumes 0.75' depth at gutter, 0% longitudinal street slope, and 7260 cuft of runoff.

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