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Adaptive Decision Support System (ADSS) for the Integration of Stormwater Source Control into Sustainable Urban Water Management Strategies

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## Criteria Relevant to the Assessment of BMP Performance

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## 1 Introduction

Urban drainage systems for impermeable surface stormwater runoff represent a particular issue for developers, regulatory agencies and water service companies given the increasing pressure to achieve sustainable drainage solutions. Best management practices (BMPs) applied to drainage systems can offer secondary benefits of water quality and amenity/ecology improvements in addition to flow control and pollution removal. The application of BMPs involves a variety of stakeholders in both the public and private arenas and therefore their development and design can be subject to differing degrees of uncertainty with regard to the relevance of influencing political, organisational, technical and environmental factors. In addition to being effective in terms of long term efficiency, they also need to be cost-effective when compared with conventional systems. Sustainability criteria therefore are required to be referenced against the critical design parameters which relate primarily to water attenuation, water quality improvements and enhancement of amenity/ecological provision. Thus design and construction, environmental/ecological impact, operation and maintenance, health and safety, social/urban community as well as economic and legal issues become prime potential sustainability criteria to facilitate comparisons and accreditation of drainage options with regard to capital cost, resource use, acceptability, performance etc. Given such dependences and variabilities, it is relevant to consider how multi-criteria analysis can be utilised to assess the relative importance of the factors which specifically influence the use of BMPs within surface drainage systems.

The selected terms for describing the factors which influence BMP selection are defined in Section 2 of this report. Subsequently (in Section 3) the key criteria are identified for assisting stakeholders in the determination of the most appropriate stormwater BMP(s) for a specific catchment area. The seven identified criteria categories are subdivided into primary and secondary indicators and then benchmarked using appropriate threshold values or units. The primary indicators are those which can be considered to be generic to each of the criteria and the secondary indicators provide a more detailed description of the BMP characteristics/properties which are being assessed. The benchmarks take this process a step further by identifying the important factors or conditions appropriate to each secondary indicator and for each benchmark relevant threshold values are assigned. At this stage, actual values have not been allocated but these will be introduced in the form of quantitative or qualitative inputs, according to which is more appropriate. It is anticipated that this deliverable will enable end-users to identify the most appropriate stormwater BMP(s) with regard to a range of often contrasting and conflicting demands such as system performance, adoption, community benefits and life cycle costs. The comprehensive range of criteria, indicators and benchmarks may prove to be too detailed for many end-users and therefore these have been ranked to prioritise those which are considered to be of the most relevance. These are identified in Section 4 and it is envisaged that when incorporated into the ADSS, users would have the opportunity to initially access the highly ranked indicators and benchmarks and move to the second, more extensive tier, when a more sophisticated analysis is required.

## 2 Definition of terms

### 2.1 Criteria

In the context of this report, criteria are defined as the major factors on which a final judgement, evaluation or decision is made.

The following seven criteria relevant to the assessment of BMP performance have been identified:

- Site Characteristics
- Technical and Scientific
- Operation and Maintenance
- Environmental
- Social and Urban Community Benefits
- Economic
- Legal and Urban Planning.

### 2.2 Indicators

Indicators are diagnostic states or conditions which are used to describe the relevant and appropriate properties of the criteria identified in Section 2.1. The Tables listed in Section 3 identify the primary and secondary indicators which have been assigned to each of the seven criteria.

### 2.3 Benchmarks

A benchmark is identified as a threshold value or condition (qualitative or quantitative) which can comprise a point of reference for decision-making. A wide range of benchmarks corresponding to each of the secondary criteria are given in the following Section and are each assigned an appropriate threshold value or unit.

## 3 Details of Selected Criteria

Each of the identified criteria is described in the following sub-sections using individual Tables to identify the indicators, benchmarks and threshold values/units which are considered appropriate in each case. It is intended that the combinations of descriptors provides a comprehensive coverage of all aspects relevant to each of the criteria.

The following key sets out the abbreviations used within the tables:

ha = hectare  
H/M/L = high/medium/low  
av = average  
RI = return interval  
C:B = cost:benefit  
STP = sewage treatment plant  
CSO = combined sewer overflow  
O & M = operation and maintenance  
WQOs = water quality objectives

**Table 3.1 Site Characteristic Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
Site Area	(i) Drainage characteristics  (ii) Physical site restrictions	(i) - Percentage of impermeable contributing area - Minimum land-take required to accommodate a specific BMP or combination of BMPs - Design storm runoff volumes - Time series runoff volume(s) - Receiving water body type  (ii) - Site gradient - Water table level - Potential for excessive site construction sediment concentrations - Fissure/matrix flow	- %  - m <sup>2</sup> - m <sup>3</sup> /ha - m <sup>3</sup> /ha/hr - stream/river/lake/coastal  - %; ratio - m - mg/l - fissure/matrix
Soil/ground Characteristics	(i) Infiltration capability/ groundwater protection  (ii) Soil/ground stability  (iii) Earthquakes	(i) - Soil type  - Infiltration rates - Storage volume of unsaturated zones - Vegetation cover type  (ii) – Liability to subsidence/land slip  (iii) – Seismic risk	- hydraulic conductivity (k value) (m/s) - mm/hr - m <sup>3</sup> /ha - none/grass/trees etc  - yes/no  - Richter scale

**Table 3.2 Technical & Scientific Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
System Performance	(i) Storage and flood control  (ii) Water quality treatment	(i) - Design storm return interval (RI; 1,5,10, 25....yrs) storage volume - Length of antecedent dry periods - Response rate for superimposed critical/historic storm durations - Ratio of storage to contributing drainage area - Number of floods per year within catchment - Overflow frequency and duration - Discharge or throttle rate - Uniform flow distribution  (ii) - Pollutant concentration probability exceedance for given target levels  - First-flush capture potential (10/15mm effective runoff treatment for all storms) - %age pollution capture for given RI storms and retention times	- m <sup>3</sup> /ha - days - m <sup>3</sup> /ha/hr - ratio - 1....n - 1....n - m <sup>3</sup> /s - H/M/L  - % exceedance for given target level  - mm runoff/av storm event - % capture for given RI or retention time
System flexibility, adaptability and potential for reuse	Capability for change over time	- Design freeboard for storage and water quality change - Ease of retrofitting and modification - Costs of retrofitting and add-on structures/features - Potential to recycle system components/waste	- %; m <sup>3</sup> /lifetime - H/M/L - € (av.cost) - H/M/L
Impact on drainage system	Integration with existing system	- Flow reduction to STP and CSOs - Reduction in stormwater flows	- %; m <sup>3</sup> - %; m <sup>3</sup> /ha

**Table 3.3 Operation and Maintenance Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
System Reliability	(i) Performance reliability, health & safety  (ii) Risk management	(i) - Hydraulic retention time - In-basin quality condition and health hazards  - Alarm/intervention procedures - Safety level/provision for accidental pollution etc - Number of in-basin/receiving water pollution complaints  (ii) - Probability of system failure - Consequences of storm event exceeding design storm RI	- Hours - Trophic state; smell; stagnant water; bacteriology etc. - yes/no - H/M/L - number/yr  - % probability - Flooding depth (m)
System Durability	Design life	- Operational lifetime - Sedimentation rates and storage volume - System robustness	- Years - m <sup>3</sup> /yr; % reduction in storage volume/yr - H/M/L
Maintenance and Servicing Provision	O & M requirements	- Need and frequency for O & M servicing to maintain: technical/environmental/amenity/habitat objectives - Risk to maintenance operative's safety - On-site herbicide/pesticide applications - De-icing chemicals - Sediment disposal - Plant replacement in constructed wetlands - Risk of littering - Risk that public lose interest leading to O&M problems	- H/M/L; frequency/yr - H/M/L - Number/yr; litres/yr - Number/yr; tonnes/yr - m <sup>3</sup> /yr - Frequency/yr - H/M/L - H/M/L



**Table 3.4 Environmental Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
Water Volume Impact	Flooding	<ul style="list-style-type: none"> <li>- Draw-down times</li> <li>- Downstream erosion</li> <li>- Groundwater recharge</li> <li>- Downstream flow protection value</li> </ul>	<ul style="list-style-type: none"> <li>- Hours</li> <li>- H/M/L</li> <li>- m<sup>3</sup>/year</li> <li>- H/M/L</li> </ul>
Water Quality Impact	Pollution control	<ul style="list-style-type: none"> <li>- Treatment retention times</li> <li>- Dilution ratios</li> <li>- Litter/gross solids; floating matter; surface oils</li> <li>- Receiving water classification</li> <li>- Groundwater quality</li> <li>- Thermal effects</li> <li>- %age compliance with consent/receiving water WQOs and standards</li> </ul>	<ul style="list-style-type: none"> <li>- Hours/av storm event</li> <li>- Ratio</li> <li>- H/M/L</li> <li>- 1...n</li> <li>- 1...n</li> <li>- H/M/L</li> <li>- %/year</li> </ul>
Ecological Impact	Habitat and ecological diversity	<ul style="list-style-type: none"> <li>- Receiving water hydrobiological scores</li> <li>- Number of key species introduced/attracted</li> <li>- Pests/vermin introduced</li> <li>- Invasive/unwanted species</li> <li>- Conservation status (plant/insect/invertebrate/mammal)</li> </ul>	<ul style="list-style-type: none"> <li>- 1...n</li> <li>- 1...n</li> <li>- yes/no</li> <li>- yes/no</li> <li>- H/M/L</li> </ul>

**Table 3.5 Social and Urban Community Benefits Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / units</b>
Amenity; Aesthetics; Access and Community Benefits	Social inclusion and multi- functional use	<ul style="list-style-type: none"> <li>- Level of amenity provision (fishing, boating, recreation etc)</li> <li>- Increased access provision</li> <li>- Community participation (ranger service, liaison groups, volunteer nature groups etc) and formal community recognition through nature trails, bird-watching; environmental days etc.</li> <li>- Numbers of visitors etc.</li> <li>- Vandalism</li> <li>- Residents' perception of increased environmental benefits</li> </ul>	<ul style="list-style-type: none"> <li>- H/M/L</li> <li>- H/M/L</li> <li>- H/M/L</li> <li>- H/M/L</li> <li>- yes/no</li> <li>- %user survey</li> </ul>
Public Information and Awareness	Public awareness and understanding	<ul style="list-style-type: none"> <li>- Interpretation boards, signage, brochures/literature, visitors centre etc</li> <li>- Awareness in local/regional community</li> <li>- Use as educational and/or technical demonstration site</li> <li>- Public meetings/hearings</li> </ul>	<ul style="list-style-type: none"> <li>- H/M/L</li> <li>- % awareness survey</li> <li>- Number of site visits; yes/no</li> <li>- Number/year; yes/no</li> </ul>
Stakeholder Acceptability	Perceived Acceptability and Impacts	<ul style="list-style-type: none"> <li>- Local community willingness-to-pay</li> <li>- Acceptance of on-site treatment as opposed to conventional drainage systems</li> <li>- Level of inhabitant willingness to participate in on-going site improvement</li> </ul>	<ul style="list-style-type: none"> <li>- H/M/L</li> <li>- H/M/L</li> <li>- H/M/L</li> </ul>
Health and Safety Risks	Risk Audits	<ul style="list-style-type: none"> <li>- Local community concerns (injury, infection, drowning etc)</li> <li>- Formal technical risk exposure audit (flood risk, health risk, safety risk)</li> </ul>	<ul style="list-style-type: none"> <li>- % user survey</li> <li>- H/M/L</li> </ul>
Sustainable development	(i) Sustainable urban living	<ul style="list-style-type: none"> <li>- Contribution to urban sustainable development policies</li> <li>- Role in Agenda 21</li> <li>- Role in Biological Action Plans (BAPs)</li> <li>- Additional benefits offered by different BMPs</li> </ul>	<ul style="list-style-type: none"> <li>- H/M/L</li> <li>- H/M/L</li> <li>- H/M/L</li> <li>- yes/no</li> </ul>
	(ii) Resource use	<ul style="list-style-type: none"> <li>- Material use: aggregate/concrete/top-soil use and costs</li> <li>- Energy use: construction, operation and maintenance energy consumption</li> </ul>	<ul style="list-style-type: none"> <li>- H/M/L; €</li> <li>- kW; kW/m<sup>3</sup> storage</li> </ul>

**Table 3.6 Economic Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / Units</b>
Life Cycle Costs	(i) Investment and operational costs  (ii) Community costs	(i) - Design (including site survey costs) - Capital costs - Operational & maintenance costs - Sediment disposal costs - Site decommissioning costs  (ii) - Stormwater fees - O&M fees	€ € €/yr €/yr (or lifetime) €  Increase/decrease yes/no; €/year
Financial Risks	Risk exposure	- Cost-Benefit analysis - Investment loss risk - Site reclaim value - Existence of system failure insurance	C:B ratio H/M/L; € H/M/L; € yes/no
Affordability	Long term affordability	- Adoption and liability coverage - Economic add-on value (enhanced land/property values) - Amenity income streams - Long term management provision	H/M/L; € €/ha €/year H/M/L
Land cost	Land take	- Land costs/m <sup>2</sup>	€/m <sup>2</sup>

**Table 3.7 Legal and Urban Planning Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / units</b>
Urban Stormwater Management Issues	(i) Stormwater regulations	(i)- Fulfilment of European regulations - Fulfilment of national regulations - Fulfilment of local regulations	yes/no yes/no yes/no
	(ii) Non-stormwater regulations	(ii) Fulfilment of legislation relating to construction, nature conservancy and preservation, groundwater, housing density and type, urban planning, building regulations, health and safety and sanitary codes	yes/no
Planning and Development Issues	Conformity to building standards	- Number of units - Design flexibility - Treatment train benefits	1...n H/M/L H/M/L
Adoption	Legal status	- Legally binding contract - Health and safety - Operation and maintenance - Legislation to enforce use of BMPs on private property	yes/no yes/no yes/no yes/no



## **4 Ranking of Criteria**

In this Section, the range of primary and secondary indicators and hence the associated benchmarks under each of the criteria have been reduced by only including those that are considered to be of prime importance when assessing the applicability of a BMP or combination of BMPs to a specific urban drainage situation. It is possible that some end-users would only need to refer to this 'first rank' of criteria and descriptors whereas for many other end-users the information provided would contribute to a first stage analysis before reaching a decision on whether to apply the full range of criteria identified in Section 3. The choice of the 'first rank' criteria has been discussed with the UK core end-users but the authors would appreciate further feedback from end-users within the project regarding the appropriateness of this priority classification.

**Table 4.1 Site Characteristics**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
Site Area	(i) Drainage characteristics	(i) - Percentage of impermeable contributing area - Design storm runoff volumes - Time series runoff volume(s)	- % - m <sup>3</sup> /ha - m <sup>3</sup> /ha/hr
	(ii) Physical site restrictions	(ii) - Water table level	- m
Soil/Ground Characteristics	(i) Infiltration capability/ groundwater protection	(i) - Soil type  - Infiltration rates - Storage volume of unsaturated zones	- hydraulic conductivity (k value) m/s - mm/hr - m <sup>3</sup> /ha

**Table 4.2 Technical and Scientific Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
System Performance	(i) Storage and flood control	(i) - Design storm return interval (RI; 1,5,10,25 yrs) storage volume - Length of antecedent dry periods - Response rate for superimposed critical/historic storm durations	m <sup>3</sup> /ha - days - m <sup>3</sup> /ha/hr
	(ii) Water quality treatment	(ii) - Pollutant concentration probability exceedance for given target levels	- % exceedance for given target level

**Table 4.3 Operation and Maintenance Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
System Reliability	Risk management	- Probability of system failure e.g. clogging in infiltration systems	- % probability
Maintenance and Servicing Provision	O & M requirements	- Need and frequency for O & M servicing to maintain: technical/environmental/amenity/habitat objectives	- H/M/L; frequency/yr

**Table 4.4 Environmental Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values/ units</b>
Water Quality Impact	Pollution control	- Groundwater quality - %age compliance with consent/receiving water WQOs and standards	- 1...n - %/year

**Table 4.5 Social and Urban Community Benefits**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / units</b>
Amenity; Aesthetics; Access and Community Benefits	Social inclusion and multi-functional use	- Level of amenity provision	- H/M/L
Sustainable development	(i) Sustainable urban living	- Contribution to urban sustainable development policies	- H/M/L



**Table 4.6 Economic Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / Units</b>
Life Cycle Costs	(i) Investment and operational costs	(i) - Capital costs - Operational & maintenance costs	- € - €/yr
	(ii) Community costs	(ii) - Stormwater fees	- Increase/decrease
Affordability	Long term affordability	- Adoption and liability coverage	- H/M/L; €
Land cost	Land take	- Land costs/m <sup>2</sup>	- €/m <sup>2</sup>

**Table 4.7 Legal and Urban Planning Criteria**

<b>Primary Indicators</b>	<b>Secondary Indicators</b>	<b>Benchmarks</b>	<b>Threshold values / units</b>
Urban Stormwater Management Issues	(i) Stormwater regulations	(i) - Fulfilment of national regulations	- yes/no
	(ii) Non-stormwater regulations	(ii) - Fulfilment of legislation relating to construction, nature conservancy and preservation, groundwater, housing density and type, urban planning, building regulations, health and safety and sanitary codes	- yes/no
Planning and Development Issues	Conformity to building standards	- Number of units	- 1...n