Identifying success factors in urban surface water BMP implementation: Mission impossible?

Identification des facteurs de succès pour la mise en œuvre de bonnes pratiques de gestion des eaux pluviales urbaines (BMP) : mission impossible ?

J Bryan Ellis*, Colin Green#, D Michael Revitt*

* Urban Pollution Research Centre, Middlesex University, The Burroughs, Hendon, London. NW4 4BT. UK. (B.Ellis@mdx.ac.uk; M.Revitt@mdx.ac.uk)

\# Flood Hazard Research Centre, Middlesex University, Trent Park, Bramley Road, London. N14 4YZ. UK. (C.Green@mdx.ac.uk)

RÉSUMÉ

La conception et la planification de mesures structurelles et, dans une moindre mesure, de mesures dites non structurelles pour réduire le ruissellement des eaux pluviales et des polluants associés est maintenant bien établie. Mais leur mise en œuvre reste très variable d'un pays à l'autre et selon l'échelle d'application. Les facteurs-clefs de succès dans la mise en œuvre de telles mesures sont ici examinés. De même les problèmes et les avantages d'un passage d'une approche décisionnelle centralisée à une approche coopérative entre différents acteurs sont étudiés. Le système de gouvernance est identifié comme un problème prioritaire, du fait de la complexité des processus de gouvernance et des niveaux hiérarchiques existants entre acteurs. L'importance d'un dialogue réussi entre ces différents niveaux pour définir une stratégie appropriée est discutée dans le cadre de l'application et de l'intégration d'approches dites individuelles, compétitives, coopératives, collaboratives et coordonnées.

ABSTRACT

The design and planning of structural and, to a lesser extent, non-structural controls for attenuating urban surface runoff and associated pollutant loadings is now well established but their implementation varies according to scale of application and from country to country. The prime success factors driving the implementation of successful urban stormwater management controls are examined together with the problems and opportunities arising from the shift from single, centralised organisational implementation to multi-stakeholder engagement process and actions. Governance is identified as a priority issue with varying hierarchical levels for stakeholder and governance processes contributing to the attainment of sustainable urban stormwater management. The relevance of achieving interaction between these levels to obtain the most appropriate drainage options is discussed through the application and integration of 'individual', 'competitive', 'cooperative', 'collaborative' and 'coordination' approaches.

KEYWORDS

Urban stormwater; BMP drainage; success factors; stormwater governance

1 INTRODUCTION

It is clear that countries throughout the world have recognised the need for more effective and sustainable best management of stormwater runoff from impermeable urban surfaces. A variety of Best Management Practice (BMP) stormwater management techniques for more sustainable drainage infrastructure to protect receiving water bodies have been developed in response to the legislative requirements for sustainable integrated urban surface runoff and pollution control. Such BMP systems are no longer based solely on levels of protection measured by maintenance of pre-development peak flow, volumes or flood control to a specified return period. Source control and best management practice (BMP) treatment are now additional sustainable criteria to conventional drainage systems, providing a more complete measure of stormwater drainage system performance. The basic approaches place emphasis on the maintenance of the site pre-development water balance, with control measures targeting attenuation of peak flows and capture of more frequent events for runoff and pollution control respectively. The control measures can be applied at source, site or sub-catchment levels as structural and/or non-structural forms and many jurisdictions at national, state or local level in North America, Europe and Australia now have guidelines (and/or standards) for their planning and design. Initial guidance focussed on end-of-pipe storage BMP facilities such as detention/retention basins and wetlands, but more recently the regulatory focus has shifted to source bio-infiltration systems and distributed non-structural BMPs as part of catchment-based Low Impact Development (LID) and a wider “green infrastructure” management approach (Ellis, 2009; Balascio and Lucas, 2009). However, whilst there is now a considerable technical maturity that can be demonstrated in terms of the knowledge and design of sustainable urban drainage technologies, their implementation varies considerably both between and within countries.

This raises the question as to the fundamental reasons for their advancement under some jurisdictions and not in others. Are there specific national and/or local institutional and legal frameworks, organisational structures and stakeholder arrangements which stimulate the introduction and promotion of source control and BMP technologies? Are there threshold conditions and supporting management frameworks necessary for the successful implementation and adoption of urban drainage BMPs and can these be generalised and be made transferable between differing geographic, climatic, administrative and social circumstances? The major impediments to the widespread implementation of BMP practices have been widely recognised with fragmented responsibilities, resistance to change, insufficient design and performance standards, lack of funding and market incentives being the principal barriers to success that are most frequently cited e.g Roy *et al.*, (2008). This paper examines the generic challenges currently associated with the decision-making processes, organisations and structures driving urban stormwater drainage management and explores the problems and opportunities arising from the global shift in urban drainage management from single, centralised organisational implementation to multi-level stakeholder engagement processes and actions.

2. URBAN STORMWATER BMP MEASURES

Table 1 provides an outline characterisation of the principal structural and non-structural measures available for urban surface water management, together with their scale of application and the major responsible managing agencies and their support capabilities. It is these latter capability and applicability indices which perhaps hold the greatest variability and uncertainty for management strategies, particularly when extrapolating individual BMP site performance to sub-catchment (neighbourhood) and catchment levels. The type of BMP implementation varies according to the scale of application, with treatment measures essentially being restricted to the individual plot or site and runoff volume reduction being more important at the sub-catchment scale. However, a combination of interacting and reinforcing practices from “roof to river” need to be used for full and effective sustainable stormwater management (National Research Council, 2008; Ellis, 2009). As indicated in the final columns of Table 1, the applicability of BMP options to different urban land uses offers considerable flexibility in choice, with the possible exception of retrofitting.

3. PRIORITY SUCCESS FACTORS

3.1 Legislation and regulation

It has been argued that the most significant factor in the successful introduction of sustainable urban

BMP/Source Control Measure	Scale/Level of Application	Principal Responsible Managing Agencies	Design, O&M Guidance	Performance Appraisal	Urban Landuse Applicability			
					Greenfield	Suburban, Retail, Commercial	Dense Urban, Industrial	Retrofit
STRUCTURAL								
Stormwater volume reduction (with limited treatment); *vegetated forms: green roofs, buffer strips, swales, bioretention*	Plot/Site	Municipality (planning), developer, regulatory and highway agencies	D: ✓ O&M: ✓	Rather limited	✓✓✓	✓✓✓	✓✓	✓✓
Stormwater volume reduction (with treatment); *infiltration forms: soakaways, pits/trenches/basins, porous surfacing*	Plot/Site	Municipality (planning), developer, regulatory and highway agencies	D: ✓ O&M: ✓	Available	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Stormwater volume reduction; *rainwater harvesting and re-use*	Plot	Municipality (planning), developer, property owner	D: ✓ O&M: ✓	Rather limited	✓✓✓	✓✓✓	✓✓	✓✓
Stormwater volume storage, attenuation, treatment: *dry/wet ponds, wetlands*	Site/Sub-catchment	Municipality (planning), developer, regulatory and highways agencies, water and wastewater utilities	D: ✓ O&M: ✓	Commonly available	✓✓✓	✓✓✓	✓	✓
Stormwater treatment: *sand filters, rain gardens, street planters, pocket wetlands, swirl devices, gully inserts, oil interceptors*	Site	Municipality (planning), developer, regulatory and highways agencies	D; ✓ O&M: ✓	Rather limited	✓✓✓	✓✓✓	✓✓	✓✓
Urban receiving water rehabilitation, restoration, channel daylighting	Sub-catchment	Municipality (planning), regulatory agencies	D; ✓ O&M: limited	Rather limited	✓✓	✓✓	✓✓	✓✓
NON-STRUCTURAL								
Urban landuse planning (including LID)	Site to regional catchment	National/state authorities, municipality (planning) National/state authorities, municipality (planning)	D: ✓ O&M: ✓	Limited	✓✓✓	✓✓✓	✓✓	✓✓
Minimisation of impervious surfaces (including roof disconnection)	Plot,/Site	National/state authorities, municipality, developer, wastewater utility	D: ✓ O&M: rare	Limited	✓✓	✓✓✓	✓✓	✓✓
Illicit sewer connections	Site/sub-catchment	Municipality/highways authorities	D: ✓ O&M: ✓	Rather limited	✓✓✓	✓✓✓	✓✓✓	✓✓
Street sweeping, road gully cleaning, snowmelt controls	Site/sub-catchment	National/state authorities. regulatory agency, municipality	D: ✓ O&M: ✓	Available	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Industrial/commercial "hotspot" control; pollution prevention codes	Plot/ site	National/state authorities, Regulatory agencies, municipality	D ✓ O&M: rare	Rather limited	✓✓	✓✓	✓✓✓	✓✓✓
Stormwater education and public awareness schemes	Site/sub-catchment	Municipality (planning), developer, riparian owners	D: ✓ O&M: limited	Limited	✓✓✓	✓✓	✓✓	✓
Urban "green" corridors, riparian management	Sub-catchment to Catchment	National/state authorities, regulatory agencies	D: limited O&M: limited	Limited	✓✓	✓✓✓	✓	✓
Product substitution	Catchment	National/state authorities, regulatory agencies		Available	✓✓	✓✓✓	✓✓✓	✓✓✓
Emission controls: vehicles, industrial	Catchment			Available	✓✓	✓✓✓	✓✓✓	✓✓✓

KEY for Urban Landuse Applicability: ✓✓✓ Highly appropriate for specified landuse; ✓✓ Appropriate; ✓ Rarely used

Table 1. Source control and BMP measures for urban stormwater management.

drainage systems is the presence of a comprehensive regulatory system set in a supporting legislative framework (Dodson and Maske, 2001: Campbell *et al*., 2005). However, this contention can be challenged by reference to the experience of US and UK legislation in the field of urban stormwater drainage control. By far the most extensive regulations covering urban stormwater discharges are those included in the US EPA National Pollutant Discharge Elimination System (NPDES) permit programme under Sections 402 and 101 requirements of the Clean Water Act (Ryan, 2003). The 1987 Phase I and follow-on 1999 Phase II conditions of the NPDES permitting procedure now apply to all urban areas having total populations exceeding 10,000 and with densities greater than 1000 persons per square mile (386 persons/km^2). The emphasis of municipal separate sewer system (MS4) permits is on the application of BMP technology to limit receiving water pollutant exposure to the "*maximum extent practicable*" through the development and implementation of stormwater management plans (SWMPs). These plans must identify minimum control measures for: construction site runoff; post-construction stormwater management; illicit discharge detection and elimination; municipal "house-keeping" (or source control) procedures; public participation; education and outreach. The US approach has therefore focussed on minimum technology-based standards, relying on best professional judgement, site-specific factors and associated monitoring, and acknowledges the inherent variability in urban surface runoff.

Various issues have been identified with the NPDES stormwater programme of which the most significant are related to the relatively limited evidence-base and monitoring capabilities regarding the effectiveness and longevity of source control and BMP approaches (GAO, 2007). This is despite the evidence of over 300 BMP studies incorporated into the US national Stormwater BMP Database (www.bmpdatabase.org). MS4 permits are difficult to enforce as permit requirements have not been translated into standardized procedures to establish numerical discharge limits. The permitting process has been beset by litigation principally associated with causal linking of BMP impact studies to identified receiving water impairment problems. The use of general stormwater permits also limits public consultation and involvement in the development and oversight of SWMPs and permit requirements. Other problems relate to compliance inspection and enforcement as well as the quality of SWMPs as required under Section 208 regulations.

Municipalities are free to set their own standards and to self-monitor and this has led to both lack of consistency and rigorous implementation and compliance (GAO, 2007). It is not clear from the legislation whether federal jurisdiction can be asserted over BMP infiltration systems which convey and receive infrequent and low volume waters or for wet (retention/detention) basins not directly connected to recognised receiving waters. The regulation focuses primarily on specific pollutants and largely ignores discharge volumes and also overlooks the impact of cumulative contributions from multiple sources. Perhaps a more significant defect is the frequent de-coupling of stormwater management from land use planning within municipalities (National Research Council, 2008), but this is a common problem in many other countries including the UK. The US EPA are considering the adoption of a catchment-based approach for NPDES permits (EPA, 2007) along the lines already contained within the European Union Water Framework Directive (WFD) with credit trading, more flexible indicator development and monitoring included in the management strategy. This would adopt a "bottom-up" approach with stormwater permitting responsibility vested mainly in municipalities working in partnership. This calls for the forging of new institutional arrangements and interactive administrative networks involving both public and private organizations. The collaborative association of multiple regulatory agencies into such integrated "umbrella" arrangements will not be easy to coordinate or administer and is likely to be a continuing source of tension and contention.

Greater and more effective regulatory implementation is evident in those states such as Maryland and Oregon, where municipalities already possessed stormwater regulations prior to the advent of the national stormwater programme (GAO, 2007). Communities adjacent to important and sensitive waterbodies such as Chesapeake Bay, were also in the regulatory vanguard, as were jurisdictions having very specific permit requirements and progressive SWMPs. The early development of municipal stormwater byelaws defining the administration and enforcement of the six SWMP control measures intended to facilitate Phase 1 and II NPDES compliance appear to be also important in achieving early management success. Such byelaws minimized potential conflicting regulations and created a single set of control standards as well as forming an appropriate basis for stimulating BMP/LID techniques and a more effective management framework than the mere mechanistic adoption of codes and ordinances (National Research Council, 2008). However, given the general lack of national auditing and the widespread confusion and disparity in state practice, it is rather difficult to judge how successful regulatory implementation of itself has been in the US in advancing alternative sustainable drainage practice for stormwater management. However, even given these reservations and alleged deficiencies, this is not to say that the NPDES system is structurally or pathogenically flawed, but rather that the specific legal requirements need a sharper focus and tying up more closely with more effective institutional structures to ensure robust and consistent delivery mechanisms.

On consideration of the comparable situation in the UK, it is clear that the lack of a co-ordinated and comprehensive regulatory system for stormwater management in the UK has been a principal reason for non-adoption. Long standing legislative issues over acceptance of surface water discharges to sewer, the definition of a BMP within sewered regulation, the functional split of flow and quality regulation and questions over BMP/SUDS adoption have all constrained their large scale introduction. Varying storm design standards applying to differing parts of the urban sewer system have also lacked legal clarification and are only now being considered in respect of surface water pluvial flooding (Defra, 2008), with an expectancy that such flooding should not exceed 3% of the mean annual probability. Such legal equivocations are exacerbated by the potential derogation of many UK urban receiving watercourses as “heavily modified water bodies” (HMWBs) under WFD legislation which could further constrain and delay BMP implementation. The requirement for strategic flood risk assessment (SFRAs) and catchment flood management plans (CFMPs) will perhaps assist municipal local authorities and regulatory agencies to better assess the impact of spatial development plans. However, the development and existence of such plans, including SWMPs, do not necessarily mean that they will result in reformed stormwater management practice or in the integration of urban diffuse discharge and pollution control strategies. It is the process of drainage infrastructure planning as well as the quality of the final plan that are critical for effective stormwater management rather than the production of plans themselves; the “how” rather than “what”.

3.2 Institutional arrangements and stakeholder participation

Stakeholder engagement in the decision-making process is considered by many as being an essential ingredient for the transition to sustainable urban drainage management and a number of successful organizational arrangements have been reported from around the world notably in Australia and New Zealand (Mitchell, 2009). However, these collaborative structures have all been supported (and often driven) by an appropriate catchment and risk-based regulatory framework (ANZECC, 2000). Nevertheless, socio-political stakeholder and institutional impediments are considered to be much more important than technical issues, the availability of SWMPs or even regulatory drivers for the achievement of integrated urban water management (IUWM) in Australian practice.

Organizational capacities and cross-sectoral interactions are seen as being the key to underpin effective progress towards IUWM and best drainage practice (Brown, 2005). The Australian government has also now recognized that planning legislation needs to be coupled and coordinated with institutional structures to achieve better organizational delivery (National Water Initiative, 2007). However, there is uncertainty as to whether this should be progressed by organizational re-structuring or through improved organizational and stakeholder interactions stimulated by incentives and subsidies. This again, is a common source of friction and contention as individual groups and institutions seek to establish powers commensurate with their perceived responsibilities. Irrespective of this, the Australian experience would stress that reform approaches for urban drainage management require an explicit recognition of institutional and professional inertia and the need for enhanced organizational capacity-building in addition to a legislative/regulatory baseline.

However, urban planners and institutions face a significant challenge in that they frequently have only limited options and powers to address the most important sources of urban flooding and associated diffuse pollution. They also often lack the technical expertise and/or administrative structures to focus and guide drainage infrastructure planning or facilitate programme evaluation and infrastructure adaptation. Organisational and social indicators to describe and monitor the capacity, skills, knowledge, values and behaviour of individuals, communities and organisations are either lacking or largely subjective in character. The prime locus of planning responsibilities in relation to surface water management is still too often focussed around technical implementation rather than being concerned with community activities and practices intended to achieve behavioural change or engendering community stewardship into the urban planning process. The concepts and working tools to achieve participating processes are not well defined, understood or accepted and their clarification and systematic application represents an outstanding institutional challenge. The most relevant indicators for stormwater management would be those providing information about institutional behaviour and the factors influencing successful BMP adoption by differing organisational and stakeholder groups.

3.3 Costing

Without doubt, one of the biggest challenges to the successful implementation of stormwater management programs is inadequate base costing. It is estimated for example, that for Wisconsin cities in the population range of 5,000 – 50,000, the average cost to meet a 40% reduction in Total Suspended Solids (TSS) alone would be in the range of \$0.5M – \$9.2M, or \$35 per capita per year over the lifetime of the BMP device (Bachhuber, 2008). Thus it might be considered unreasonable to expect compliance for all pollutants (and particularly soluble species) and discharges (to 80% capture and treatment) for urban sites having a high impervious cover, even if there were to be a maximum BMP application. Under such a scenario, there must be a requirement to establish investment priorities and for firm connections to be made between landuse and catchment-based goals. The work of Heaney *et al* (2002) would indicate that there is an incremental cost of about \$2 - \$3/ft^2 (€15.3 - €22.1/m^2) for storage BMPs over and above the costs of conventional sewered systems. This could represent as much as 15% - 19% of the total development cost which might represent a significant deterrent to the developer, although the implementation of on-site infiltration BMPs could reduce the overall cost differential. Whole life costing based on US and UK BMP data, has suggested however, that very little differential exists in comparison to conventional drainage systems (WERF, 2005). Budgets often appear to be primarily aesthetically and ecologically driven rather than aimed at improving BMP functionality with costing comprising only a marginal, albeit important, factor in the final decision on drainage options.

One factor in the penetration of BMP practice in the US in comparison to the UK can be explained by their relative urban densities, with an average of only 1000 – 1500 persons per km^2 in the US in contrast to 4000 – 5000 persons/km^2 in the UK (www.citymayors.com). Thus development land uptake and associated start-up costs are easier in terms of availability to introduce BMPs within the US, even for inner urban areas. Irrespective of this, it has been demonstrated that clustered LID approaches incorporating the full range of BMPs, can be successfully adopted even in high density development situations carrying 40 – 50 dwellings/hectare (Ellis *et al*., 2004). It has been argued that the legal definition of a sewer as a pipe in the UK has been a significant factor in the wastewater utilities refusing to adopt BMPs/SUDS. However, it is much more probable that uncertainty regarding adoption arrangements and capital costs together with long term O&M costs have been a more significant deterrent.

The success of BMP drainage and green roof technologies in the German Emscher region of Rhine-Westphalia is frequently referred to the imposition of a state stormwater tax based on impervious area averaging €0.80/m^2 (\$0.1/ft^2). This is substantially higher than the average for US cities which varies between \$5 - \$20/1000 ft^2 (€0.04 - €0.16/m^2) , or about \$1 - \$7 (€0.71 - €5.3) per off-street parking space (PCW, 2002). The Emscher stormwater tax was reinforced by a convention for stormwater management agreed in 2005 between the regional water authority (Emschergenossenschaft), the Federal State Ministry and 17 municipalities to implement a 15% disconnection rate over the next 15 years (the 15:15 project). On completion of the 15:15 project, for the 266 km^2 Emscher catchment, this would disconnect some 26.4 billion m^3/annum from the surface water drainage system.The agreement has no binding legal contract but provides a mutual understanding between the three organizational tiers to implement source control and BMP treatment together with roof disconnection.

The German stormwater tax levels do provide a considerable incentive for large scale retail/commercial premises where impervious roof and hard standing areas frequently exceed 10,000 – 50,000 m^2. For residential developments, in addition to (modest) disconnection savings, it is argued that an improved aesthetic landscaping provides a further communal motivation to an already high public awareness and acceptance of green technologies and BMP approaches (Sieker *et al*., 2006). Nevertheless, the fee-saving potential for individual householders is relatively small, and well focussed education and awareness-raising campaigns are planned, as well as the promotion of motivated focus groups and demonstration sites (Emschergenossenschaft, 2004). The award of certificates of good practice (wasserzeichen) to individuals and groups is intended to provide a further local stimulus for best practice take-up. Thus whilst cost structures and incentives are undoubtedly influential in promoting BMP drainage, a basic community motivation for improved civic environmentalism has been an inherent social norm underlying the emergence of institutional interactions to develop supportive stormwater management frameworks in the Emscher region. This level of public environmental awareness and stewardship is not duplicated everywhere and will require considerable high level institutional effort and resources to successfully introduce and achieve equivalent societal values and expectations of environmental quality in many other countries and local situations.

However, it is the combination of credit incentives, community environmental vales and the pivotal importance of the joint coordinated policies of the regulatory water authority and municipal landuse planning authorities, that are providing a collective drive to successful BMP implementation. It is not at all clear whether any one of the individual drivers on their own, and particularly that of the cost driver, would be sufficient to achieve threshold conditions. Nevertheless, there is evidence that can be found to suggest that tradable runoff allowances (based on impervious surface area), can have leverage as a low-cost method to stimulate developers in adopting BMP practices (Thurston *et al*., 2003).

4. STORMWATER GOVERNANCE AND BMP IMPLEMENTATION

4.1 The process of governance

The review of priority success factors would argue that it is a basic crisis in governance mechanisms rather than any inherent defects in technical, legislative, climatic conditions or economic instruments which presents the major issue for future integrated urban stormwater management (IUSM). Whilst this is not a surprising or even new conclusion, the central issue is perhaps more concerned with a changing balance in the “power process” for decision-making between stakeholders, following a generalised move away from single functional actions and centralised institutional arrangements over the last decade. Governance is essentially concerned with the exercise of political, economic and administrative authority and comprises sets of hierarchical structures (or institutions) and processes which define organizational behaviour and relationships through rules and regulations which in turn delimit formal powers. In terms of urban stormwater management, governance is concerned with who possesses “power” and for what purposes such powers are used.

The process of governance is also concerned with choice in terms of technology, economic and socio-political options. Green (2009) has identified a number of ways of organizing drainage management resources to address the question of how resources and institutions might be administratively brought together:

- ***coordination***: as illustrated by the traditional hierarchical “top-down” control-command model commonly embodied in national and/or regional policy formulation for urban catchment management

- ***collaboration***: institutional and administrative arrangements, often under formal agreements and rules, to bring together agencies/groups/individuals for medium to long term interaction and integration as required in the production of SWMPs

- ***cooperation***: generally informal administrative arrangements for agencies/groups to undertake actions to achieve targeted short to medium term objectives such as the Emscher 15:15 initiative

- ***competition***: where agencies/groups/individuals commission expertise from the market, as with private consultancy approaches to develop specific management tools and modelling approaches as well as in site design

- ***individual***: the mobilization of single agency/group/individual resources often characterised for example, by public awareness-raising campaigns such as the UK Oil Care Campaign

These organizational definitions can be used as a basis for exploring the relationships between governance mechanisms and stormwater BMP interventions and other key management indicators as illustrated in Table 2.

Governance Form	Landuse Control & Re-location	Runoff Control		Receiving Water Quality	Structural BMPs		Non-structural Source Control	In-stream Improvement and Restoration	Stormwater Collection and Re-use	Flood & Pollution Insurance
		Runoff reduction	Peak flow attenuation		Storage	Infiltration				
Individual		X			X	X			X	X
Competitive									X	
Cooperative			X	X	X	X	X	X	X	
Collaboration	X	X	X	X	X	X	X	X		
Coordination	X	X	X	X	X	X	X	X		X

Table 2. Governance and stormwater interventions

4.2 Institutional structures and BMP interventions

The introduction of BMP controls at catchment scale appears to be most successful under cooperative institutional arrangements and actions involving middle level (federal/state and municipal) organizations as illustrated by the Emscher and Melbourne initiatives in Germany and Australia respectively, although the strategic approach requires coordination with higher level national policy and legislation. Competitive arrangements are often associated with site-based BMP implementation, frequently championed by individual developers or municipalities as illustrated by recent motorway service station and school drainage developments in the UK (www.ciria.org.uk/suds/case_studies.htm), or the residential highway LID street edge alternatives (SEAs) introduced in Seattle, Washington and Portland, Oregon (Vogel, 2006). Many municipal LID designs have been championed by individual developers as illustrated by the 43 acre (17.4 ha) Pembroke sub-division in Frederick County, Maryland, US (Lehner *et al*., 2001) or the 354 ha (875 acre) Dunfermline (DEX) site in Scotland, UK (Greene and Brannan, 2004).

However, which governance approaches and administrative level(s) in urban surface water management are most appropriate to a particular risk management intervention? Clearly the most appropriate forms of stormwater drainage intervention will be dependent upon factors such as resource requirements, performance effectiveness and contributions to wider socio-ecological objectives. Economies of scale will also operate in this decision, particularly in terms of physical interventions for flood risk management which are frequently beyond the means of individual property owners or even individual municipalities. Based on the intervention strategy and the form of governance, which is the best combination required to deliver it effectively and efficiently? Table 2 attempts to answer this question with the shaded areas representing those cases where responsible organizations need to rely upon social power and community acceptance to influence the behaviour of users in order to effect a particular form of BMP intervention.

Table 2 suggests that some forms of BMP intervention cannot be delivered by all forms of governance, with competitive structures being largely inappropriate at the highest tiers of stakeholder organization. Private organizations become important at the lower tiers in terms of consultancy modelling, project management, O&M or individual site design. Stormwater collection, re-use, insurance, disconnection and infiltration approaches frequently require a supportive public-private partnership arrangement and are dependent on individual behaviour and public awareness for their successful implementation. The most critical forms of integrative management intervention clearly lie between land and water management which demand formal coordination and collaborative institutional arrangements organized at the higher and middle levels of administrative governance. However, the critical importance of public involvement in defining and delivering fields of action in BMP management at the lower governance levels is still to be realised (Ryan and Brown, 2000). There needs to be a managed approach which balances community issues of environmental quality with the technical concerns of the professional planning and water agencies. This will require a consensus decision-making structure of governance where all stakeholders can constructively contribute and engage in the planning process.

The traditional technocratic “decide-announce-defend” (DAD) command-control model of coordinated urban stormwater management has been replaced by a more deliberately cooperative and democratic stakeholder approach with governance mechanisms that might be termed as “meet-understand-modify” (MUM) approaches. Given the possibilities of impartiality resulting from active engagement of articulate, vested-interest stakeholders in more cooperative and competitive arrangements, there is a need for much more rigorous evaluation of the decision-making process, especially in terms of equity, representation, transparency and accountability. These principles, in respect of drainage infrastructure provision, are particularly important when considering implementation of retrofit opportunities within built-up inner urban areas. A governance process which places emphasis on the modes and styles of institutional engagement and empowerment will perhaps better express individual stakeholder participation in the decision-making framework, although the opinions and consensus reached by these lower level groups may not necessarily be foremost in the final policy or procedural determinations, which are still likely to remain vested in the middle and higher level organisational tiers. Nevertheless, despite policy guidance under most national/state administrations on development and flood risk becoming more detailed and prescriptive, there is still considerable scope for differences in definition and interpretation over issues such as what constitutes acceptable risk, effective mitigation measures or safety that emerge in local implementation and which commonly benefit from wider stakeholder consultation and approval.

5. CONCLUSIONS

The major impediments and barriers to BMP implementation and IUSM are not technology dependent but rather are related to institutional, social and governance issues none of which have been well addressed to date given the emphasis on technology and planning issues within the water industry which are frequently driven by legal and market-led targets. It is nevertheless the case, that inertia related to a combination of legal, regulatory, administrative, skills and resource constraints remains widespread. However, many studies would suggest that institutional acquisition barriers comprise the most embedded and difficult to reform (Rauch *et al*., 2005; Brown and Farrelly, 2008), and the issue of institutional governance is perhaps the most intractable problem of all. The lack of institutional outreach capability to address the role of community participation and civic environmentalism provides a considerable constraint to successful widespread BMP implementation and sustainable urban drainage infrastructure planning. Without such participatory strategies and accompanying governance structures, a common understanding of shared values, behaviours and stewardship will not be readily nurtured and achieved. There is at the same time, increasing tension and lack of coherence in national and/or federal/state level policy on sustainability, housing development, planning and flood/pollution risks which far too often become apparent in policy and management implementation at the lowest local organisational levels.

In addition, the increased emphasis being given to flood risk reduction through site layout, development form, resilient building design, flood/emergency warnings and evacuation in addition to source BMP controls, comprise relatively new elements for integrated planning and management policy at both middle and higher levels of organisational administration. It is clear that there has to be an integrated approach to future urban drainage management which incorporates the landuse management, development and transport aspects of urban planning as well as an integration of the institutional frameworks involved in the design and implementation of the drainage infrastructure. The effective integration and delivery of all these planning and infrastructure elements with a coherent and consistent governance framework will continue to represent a considerable challenge in the on-going mission to achieve successful and sustainable urban surface water BMP implementation.

Acknowledgement

This study has been carried out within the framework of the European research project SWITCH (Sustainable Urban Water Management Improves |Tomorrow's City's Health). SWITCH is supported by the European Commission under the 6th Framework Programme (Contract number: 018530-2) and contributes to the thematic priority area of "Global Change and Ecosystems".

LIST OF REFERENCES

ANZECC. 2000. *Guidelines for Fresh and Marine Waters*. Australia and New Zealand Environment & Conservation Council. Dept. of Environment, Water, Heritage and the Arts, Environment Australia. Canberra. Australia.

Bachhuber, J. 2008. *Assessment Report of TetraTech's Support of California's Municipal Stormwater Program*. Tetra Tech Inc., Pasadena, California. US.

Balascio, C.C and Lucas, W.C. 2009. A survey of stormwater management water quality regulations in four Mid-Atlantic states. *Journ.Env.Mangt*., 90, 1 – 7..

Brown. R.R. 2005. Impediments to integrated stormwater management: The need for institutional reform. *Envir. Mangt*., 36(3), 455 – 468.

Brown, R.R and Farrelly, M.A. 2008. Sustainable urban stormwater management in Australia: Professional pwerceptions on institutional drivers and barriers. *Proc 11th Int.Conf. on Urban Drainage* (ICUD). August 2008, Edinburgh, Scotland. IWA London UK. ISBN 978 1899796 212.

Campbell, N., D'Arcy, B., Frost, A., Novotny, V and Sansom, A. 2005. *Diffuse Pollution: An Introduction to the Problems and Solutions*. IWA Publishing, London, UK. ISBN 978 1900222 532.

Defra. 2008. *Summary of Responses to the Consultation on Improving Surface Water Drainage*. September 2008. Department of Environment, Food & Rural Affairs. London. UK.

Dodson, R.D and Maske, C.D. 2001. Regulation of stormwater collection systems in the US. Chapter 2 in Mays, L.W (Edit): *Stormwater Collection Systems Design Handbook*. McGraw Hill Professional. New York, US. ISBN 0-07135471 9.

Ellis, J.B. 2009. Third generation urban drainage: From rooftop to the receiving water sub-catchment. *Proc 11th Int.Conf. on Urban Drainage* (ICUD). August 2008, Edinburgh, Scotland. IWA London UK. ISBN 978 1899796 212.

Ellis, J.B., Scholes, L., Revitt, D.M and Oldham, J. 2004. Sustainable approaches for urban development and drainage in the 21st century. *Journ. Inst. Civil Eng., Municipal Engineer*. 157 (ME4), 245 – 250.

Emschergenussenschaft. 2004. *Rain on the Right Track: Sustainable Stormwater Management in the Emscher Catchment*. Eigenverlag, Emschergennussenschaft, Essen. Germany.

EPA. 2007. *Watershed-based NPDES Permitting technical Guidance*. Report 833-B-07-004. Office of Wastewater Management. Environment Protection Agency, Washington DC. US

GAO. 2007. *Further Implementation and Better Cost Data Needed to Determine Impact of EPA's Stormwater Program on Communities*. Report GAO-07-479. General Accounting Office. Washington DC. US.

Green, C. 2009. The practice of power: Governance and flood risk management. *Proc.Int. Conf. Sustainable Flood Risk Management.* November 2009. Seoul, Korea.

Greene, M and Brannan, J. 2004. *Retrofitting SUDS: Dunfermline Case Study*. Report NEO2351/D1. Scottish Executive, Edinburgh, Scotland. UK

Heaney, J.R., Sample, D and Wright, L. 2002. *Costs of Urban Stormwater Control.* Report 600/R-02/021. Office of Research & Development, US Environment Protection Agency. Cincinnati, Ohio. US.

Lehner, P., George, P., Clark, A., Cameron, D.M and Frank, A.G. 2001. *Stormwater Strategies: Community Responses to Runoff Pollution*. Natural Resources Defense Council (NRDC). New York. US.

Mitchell, V.G. 2009. Applying integrated urban water resource management concepts: A review of Australian experience. *Envir. Mangt*., (In Press).

National Research Council. 2008. *Urban Stormwater Management in the United States*. National Academies Press. Washington DC. US. ISBN 978 030912539 0.

National Water Initiative. 2007. *Institutional and Regulatory Models for Integrated Urban Water Cycle Management.* National Water Commission, Commonwealth of Australia. Barton, Canberra. Australia. ISBN 978 192110729 0.

Novotny, V and Brown, P (Edits). 2007. *Cities of the Future : Towards Integrated Sustainable Water and Landscape Management.* IWA Publishing, London. UK. ISBN 9781843391364.

PCW. 2002. *Existing Water District Funding Sources: Legislation and Reguklatory Issues*. Technical Advisory Committee, Project Clean Water (PCW). (www.projectcleanwater.org). San Diego, California. US.

Pitt, M. 2008. *Learning Lessons from the 2007 Floods: The Pitt Review*. The Cabinet Office, London. UK.

Rauch, W., Seggelke, K., Brown, R.R and Krebs, P. 2005. Integrated approaches in urban storm drainage: Where do we stand? *Environment Management*, 35(4), 396 – 409.

Revitt, D.M., Scholes, L and Ellis, J.B. 2008. The best management practice catalogue developed within the DayWater project. Chapter 8, 79 – 86 in Thevenot, D.R (Edit): *DayWater: An Adaptive Decision Support System for Urban Stormwater Management*. IWA Publishing, London. UK. ISBN 978 184339 160 9.

Roy, A.H., Wenger, S.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R., Shuster, W.B., Thurston, H.W and Brown, R.R. 2008. Impediments and solutions to sustainable, watershed-scale urban stormwater management : Lessons from Australia and the US. *Journ. Env., Managt.*, 42 (2), 344 – 359.

Ryan, M.A (Edit). 2003. *The Clean Water Act Handbook*. American Bar Association. Chicago, US. ISBN 159 031217 1.

Ryan, R and Brown, R.R. 2000. The value of participation in urban watershed management. *Proc. Watershed 2000*. 8 – 12 July 2000. Vancouver, British Columbia, Canada.

Sieker, H., Bandermann, S., Becker, M and Raasch, U. 2006. Urban stormwater management demonstration projects in the Emscher region. *Proc. 1st SWITCH Scientific Meeting*. University of Birmingham, UK. 9 -10 January 2006. (www.switchurbanwater.eu).

Thurston,H.W., Goddard, H.C., Szing, D and Lemberg, B. 2003. Controlling stormwater runoff with tradable allowances for impervious surfaces. *Journ. Water Resources Planning & Mangt.*, 129(5), 409 – 418.

Vogel, M. 2006. Moving towards high-performance infrastructure. *Urban Land*, October 2006. 73 – 79.

WERF. 2005. *Performance and Whole Life Costs of BMPs and SUDS*. Report 01CT521TA. Water Environment Research Foundation (WERF). Alexandria, Virginia, US.