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Introduction

Recent severe flooding events in the United Kingdom and Ireland have once again highlighted the vulnerability of urban settlements to the ever more prevalent effects of climate change. The daily news coverage throughout January and February (2014) provided dramatic images of urban places and communities struggling to cope with a natural disaster. While the initial debate in the aftermath of such flooding events often centres on the immediate recovery efforts, increasingly flood risk (and the potential for increased risk from climate change impacts) raises more fundamental questions concerning how urban places should prepare or transform to cope with increased exposure to flooding events. In this *Practice Paper*, we seek to position urban design as central to flood risk management strategies, advancing an evolutionary resilience framework and design principles, operationalised through green infrastructure at the urban scale.

International literature on flooding has, until recent years, tended to focus upon flood defence measures to reduce the probability of flooding. Of particular note within the recent crisis is how a legacy of past 'hard' engineering interventions that sought to constrain rivers and channel runoff failed in the face of exceptional rainfall. Moreover, as Harries and Penning-Rowell (Harries and Penning-Rowell, 2011) identify, institutional cultures and public perceptions formed when structural, engineered approaches were the norm tend to hamper the ability of government policies to implement a broader range of adaptation measures. However, the potential costs of flooding have driven a renewed interest in flood risk management around the globe. For example, a recent study published in *Nature Climate Change* (Jongman et al., 2014), suggests that the costs of flooding throughout Europe (to homes, businesses, infrastructure etc), are likely to rise from an annual cost of €4.5bn at present to €23bn per year by 2050 under anticipated climate change impacts and current trends in socio-economic development. Both the scale of vulnerability and the complexity of flooding causes, undermines the efficacy of traditional 'keep flood water out' approaches – for example, Figure 1 illustrates the UK's Environment Agency's flood warning map on 8th February 2014, suggesting that physical defences are unlikely to succeed and would be prohibitively costly given the scale of vulnerability. As a result, in many countries, flood risk management is currently undergoing a paradigm shift as it moves beyond a one-dimensional 'keep flood water out' approach, towards a more strategic, holistic and long-

term approach characterised by both *mitigating* flood risk and *adaptation*, or increasing resilience to flooding events. The benefits (damages avoided) of this approach may be very large. Again, taking account of anticipated climate change impacts and current trends in socio-economic development, Feyen and Watkiss (2011) suggest the annual benefits of adaptation to river flooding across Europe will increase from about €1.3bn today to €8.3bn in 2020s, and may be up to €50bn by 2080s. Consequently policy emphasis on adaptation and achieving greater resilience to flooding is reflected in the enactment of EU legislation in the form of the Water Framework Directive 2000/60/EC (CEC, 2000) and the Floods Directive 2007/60/EC (CEC, 2007). Within this context, urban design has the potential to move centre stage as part of a 'whole catchment' framework to risk management, particularly relating to encouraging more ecologically sensitive development.

The causes of flooding are complex, requiring multidimensional management approaches: for example, White (2013) outlines the nature of flood risk to include not only fluvial, tidal and coastal flooding, but also exposure to flood risk from surface water including urban run-off and local drainage failure. Climate change adds a further layer of complexity, with the impact of climate change processes likely to increase flooding vulnerability, both inland and coastal – for example caused by sea level rise and storm surges in coastal locations, and increased frequency of extreme precipitation events is expected to increase risks associated with surface, fluvial and groundwater flooding, with consequences for property, livelihoods, infrastructure, agricultural production and ecosystems (EEA, 2008). In this context, White argues that the lessons of flood risk management in England over the last decade highlights the dangers of 'false precision' when calculating flood risk and translating these risks into spatial plans. Instead, White calls for a more critical stance towards flood risk data and for empowering urban policy-makers to intervene on a more precautionary basis.

The costly and at times irreparable damage left in the wake of traditional flood defences being overwhelmed or failing highlights the lack of critical attention to 'resilience' in approaches to urban flood risk management. Here, resilience denotes a heuristic for conceptualising change management. The term has an inherent normative dimension that seeks to shift thinking towards design approaches that are more responsive to disturbance (Barr and Devine-Wright, 2012; Plieninger and Bieling, 2012). Much contemporary debate

concerning the use of the concept centres on the distinction between ‘equilibrium’ and ‘evolutionary’ interpretations of resilience (Scott, 2013). The former understanding has its roots in disaster management and concerns a ‘survival discourse’ that focuses on the ability of a system to ‘bounce back’ towards ‘business as usual’ following a catastrophe (Shaw and Maythorne, 2013). In contrast, ‘evolutionary’ resilience challenges the desire for a single-state equilibrium or a ‘return to normal’. Instead, it emphasises an ongoing evolutionary change process (Scott, 2013). This interpretation focuses on resilience as enabling transformation such that disturbance delivers the spur for re-invention and thereby ensures strength through continuing reflection (Erixon et al., 2013). Therefore, ‘evolutionary’ resilience entails a more radical and optimistic perspective that embraces the opportunity to ‘bounce forward’ (Shaw and Maythorne, 2013). It seeks to supplant a desire for stability with the acceptance of inevitable change such that it inverts conventional modes of thought by ‘assuming change and explaining stability, instead of assuming stability and explaining change’ (Folke et al, 2003, 352).

Figure 1
Flood risk warning map for England on 8th February 2014
(source: Environment Agency)

This *Practice Paper* seeks to outline the benefit of advancing evolutionary resilience in urban design for flood risk management. It identifies and critically examines three alternative approaches and associated design philosophies in response to the problem urban flooding. The paper first traces the reasons why these three approaches have emerged and discusses the attributes of each. The paper then examines the potential of the green infrastructure approach as a means to realise evolutionary resilience in designing urban environments for enhanced drainage management. The closing section contrasts the three alternative approaches to flood risk management and identifies some implications of advancing the green infrastructure concept in urban design activities.

Designing for Flood Risk Management

Designing for flood risk management is a complex endeavour often involving many variables, uncertainty, large temporal and spatial scales, and a multitude of agents. Nevertheless, it is possible to identify three broad approaches and the design philosophies associated with each. These approaches are characterised by different functional objectives, namely: persistence, adaptation and transformation.

Persistence

The fabric of urban areas was largely produced without much consideration for flood risk (White, 2008). Where regard was had to flooding, this most frequently involved the construction of expensive 'hard' solutions such as levees, flood barriers and the underground piping of historic drainage channels. Consequently, the accumulated legacy of design interventions has often interrupted natural flooding processes by removing vegetation, paving extensive areas with artificial impermeable surfaces, eliminating natural water storage capacity and disrupting flow paths (O'Neill, 2013). The consequence has been a divorcing of urban areas and its population from environmental constraints (White, 2008), and, compounded by the trust people place in technical experts and structural solutions (Terpstra, 2011), an embedding of urban areas with vulnerability to flood risk. Such traditional approaches to flood risk management persist. In essence, these approaches are characterised by a design philosophy focused on resisting the perceived capriciousness of nature and are typified by modes of intervention wherein the functional objective is exclusively directed at flood 'defence'. Exemplifying this established pattern of operation is the situation that persists in many municipal authorities where engineering staff work in a disciplinary 'silo' (Kambites and Owen, 2006), directing policy concerning flood risk management and perpetuating design approaches that demonstrate persistence with 'hard' solutions to urban flood problems. While this technocratic tradition has for a long time enjoyed the legitimacy afforded by specialist engineering knowledges, the enduring failure of such a 'hard' approach to effectively address urban flooding issues has undermined its authority and prompted alternative perspectives on managing flood risk. One such perspective concerns a greater focus on adapting urban environments to the inevitability of flooding.

Adaptation

The turn to adapting urban environments for flood risk management reflects broader societal concerns with the inevitability of some degree of climate change. It is a design response to a projected increase in the frequency and severity of flooding events (Bulkeley, 2013). This perspective seeks to complement rather than challenge traditional 'hard' approaches focused on flood defence through recalibrating design to facilitate a more flood adapted urban environment. In this sense, urban design initiatives focused on adaptation signal a desire to promote a 'bounce-back' form of resilience. Such an approach is characterised by a design philosophy concerned with accommodating the unavailability of flooding events through modifications to architectural detailing and design of the public realm. For example, this approach is evident in raised plinths to 'flood proof' new developments, the allocation of attenuation areas in car parks and sequential methods of land use allocation that aim to steer developments away from identified flood plains (Roaf et al., 2009; Smith, 2009). As a departure from traditional governance approaches, a focus on adaptation encompasses a broader skills set and therefore involves the cooperation of a variety of construction related disciplines. In the case of municipal authorities, this is reflected in efforts to promote greater cooperation between engineers, architects, urban designers, emergence planners and landscape architects.

However, there is an increasing focus on moving beyond urban design adaptation. Such interest echoes wider concern with the appropriateness of current approaches to flood risk management and calls for a more profound re-evaluation of how flooding issues are considered in urban environments. For example, the European Union's Floods Directive advocates 'soft' solutions that 'make space for' water (Merz et al., 2010). Accordingly, authors such as White (2008), Yu et al. (2008), and Berke et al. (2009) have sought to encourage the integration of urban design and flood risk management. In a sense, what these authors are calling for is a transformation in how flood risk is addressed in the urban environments.

Transformation

As with approaches focused on adaptation, those advocating transformative approaches to flood risk management view a measure of climate change as inevitable. However, calls for a

transformation in urban design involves moving beyond a focus on construction-based interventions or simple sequential land use modes of governance aimed at flood risk 'defence' and/or 'accommodation'. Instead, it entails a holistic reassessment of the relationship between the built and non-built components of urban environments (O'Neill and Scott, 2011). In this way, a transformation demands seeing the urban environment as a hydrological unit embedded within a larger, or series of larger hydrological unitsⁱ, rather than as a collection of various built elements adversely affected by flooding. This approach advances a design philosophy focused on bio-mimicry and working with water rather than concentrating solely on controlling or avoiding it (Grant, 2012; Novotny et al., 2010), reducing the hydrological impact of the built environment, thereby transforming the urban footprint of the city (O'Neill, 2013). In this sense, a transformative perspective seeks to orientate urban design towards an 'evolutionary' form of resilience thinking. In desiring greater holism in the consideration of flooding, such an approach necessitates broadening the skills base of those involved in flood risk management beyond disciplines primarily concerned with construction. Hence, it involves new working arrangements with an array of professionals not normally associated with flooding related design issues, such as ecologists, recreation and transport planners, as well as more conventional participants such as engineers, architects, urban designers, emergency planners and landscape architects. Furthermore, a transformative and holistic approach to flooding would require full collaboration in interdisciplinary partnerships as opposed to cooperation between different disciplines that remain largely isolated beyond the requirements of occasional association during flood risk design exercises (Lennon, 2014). This begs the question as to what form such a transformation in urban design could take? A reply to this may be found in the increasing popularity of the green infrastructure approach to planning, design and management.

The Green Infrastructure Approach

The theory and application of green infrastructure (GI) has grown in depth and breadth over the past decade (Barnhill and Smardon, 2012; Comhar, 2010; Davies et al., 2006; Dunn, 2010; Kilbane, 2013; Mayer et al., 2012; Mell, 2013; Thomas and Littlewood, 2010; Wright, 2011). Although there remain an array of interpretations as to what exactly it entails (Cameron et al., 2012; EC, 2012; Ellis, 2012), most understandings resonate with the

explanation offered by Benedict and McMahon (2006, 1) as: ‘an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions...and provides a wide array of benefits for people and wildlife’. Prominent among these ‘benefits’ is the retention of water so that drainage into watercourses is more protracted and the peaks in flow associated with flood events are avoided. A GI approach seeks to realise such benefits by giving greater consideration to multifunctionality in the design process. In this context, GI potentially provides a holistic approach towards addressing source-pathway-receptor models applied in contemporary flood risk assessment (DEHLG/OPW, 2009; Shaw et al., 2007) particularly in providing a design response focused on the receptors of flooding (people and assets) and the pathways by which flood water reaches these receptors (e.g. river channels, drainage systems etc.), by enabling water retention in the built environment through ecologically sensitive development patterns.

Attention to enhancing the multifunctional potential of sites is a key attribute differentiating the GI design philosophy from more conventional approaches focused solely on flood ‘defence’ or ‘accommodation’. Referencing the multiple environmental, economic and community benefits that accrue from such a transformative perspective, Rouse and Bunster-Ossa (2013, 19) assert that ‘these benefits derive from the multiple and overlapping functions provided across different systems – hydrology, transportation, energy, economy, and so on – that can intersect in green infrastructure’. Indeed, advocates of a GI design approach contend that the multifunctional potential of the wider urban environment can be maximised by combining the need for temporary flood storage with other ongoing functional, recreational and ecological uses (White, 2008).

The city of Portland, Oregon in the north western United States of America presents an example of how a GI design approach to flood risk management can provide an array of benefits for the local community at the site and neighbourhood scales. Prompted by an excessive burden on the city’s drainage system, resulting in an average of 50 combined sewer overflows (c. 6bn gallons) to the Willamette River in 1990, Hoyer et al, (2011) note how Portland’s municipal authority has employed a suite of GI design initiative to alleviate the pressure on the sewer system and reduce adverse impacts to urban watercourses. Such measures have included financial incentives for downpipe disconnection (with stormwater

redirected to lawns, gardens, and infiltration into the ground), the construction of green roofs that enhance local biodiversity, and the provision of a green space recreational network that simultaneously serves to slow rainwater runoff into the Willamette River. These ongoing GI initiatives comprised part of a 20-year plan known as the Combined Sewer Overflow (CSO) Abatement Programme that provided for low-cost and small-scale GI 'Cornerstone Projects', in combination with high-cost grey infrastructure 'Big Pipe' projects (CoP, 2011). The cumulative effect of numerous local small-scale GI measures (e.g. 56,000 downpipe disconnections, 2,800 infiltration sumps and sedimentation manholes, and green streets programme) has helped to reactivate the local hydrological cycle, thereby easing pressure on the city's combined sewer system by over 2.1bn gallons annually and consequently reducing flood events generated by under-capacity in the urban drainage system. Furthermore, these GI initiative helped reduce CSO discharges to the Willamette River by about 35% down to an average of four overflows each winter and one every third summerⁱⁱ (CoP, 2011, 2012). Importantly, this has been achieved without compromising on aesthetic appeal (Hoyer et al., 2011, 43). This contrasts with the objectionable appearance of many flood defence interventions associated with traditional 'hard' engineering approaches to flood risk management, such as flood barriers (Entrix, 2010). Indeed, 'soft' design initiatives undertaken by the municipal authority to reduce the quantum of impervious surfaces in the urban area have improved the appearance and experience of the urban landscape. Such initiatives include roadside tree planting, increasing the number of publically accessible green spaces and the construction of attractive swales and rain gardens in residential streets which are specifically designed to supplement a decentralised approach to drainage management, enhance streetscape appearance and boost local biodiversity (Hoyer et al., 2011). Erickson (2006) examines similar multifunctional and local level drainage initiatives in Vancouver, Canada. Here, the municipal authority has promoted a Green Streets programme that offers local residents the opportunity to engage in urban gardening by sponsoring a roadside enhancement project. This project augments the degree of permeable surface within the city while concurrently supporting community development by encouraging a sense of ownership and pride in a neighbourhood's public realm through helping to dissolve firm delineations between public and private spaces.

Figure 2

Social housing scheme in Sydney with multifunctional greenspace
(which serves as storm water sink)

Guildford in England offers an example of how a GI approach can be applied at the masterplanning scale. In this case, about 67 hectares of the settlement is situated within the 1 in 100 year floodplain of the River Wey, and contains approximately 620 vulnerable properties within it (GBC and EA, 2009). Moreover, almost 47 hectares of this area would normally be defined as a floodplain with a probability of flooding at 1 in 20 years or greater. In the absence of a feasible 'hard' engineering option, the challenge for Guildford has been to identify a solution to the problem of flood risk by 'using redevelopment opportunities to provide increased safety, additional floodwater storage, and improved floodwater flows, whilst making space for water and the enjoyment of the River Wey' (GBC & EA, 2009, 2). To achieve this, the municipal authority stipulates a policy whereby as local redevelopment opportunities arise, effort is directed at reducing the probability of flooding by ensuring that new building footprints are set back from the River Wey to allow greater space for floodwater. Furthermore, the municipal authority seeks to restore flood plains and flood flow paths where feasible so that natural water storage capacity is increased in the urban landscape (O'Neill, 2013).

At the city-wide scale, guidance on how a GI design approach may be advanced is provided by points based planning regulations in Berlin (Kazmierczak and Carter, 2010), Malmö (Kruuse, 2011) and Seattle (Beatley, 2010). The objective of such schemes is to increase the quantum and quality of permeable surface area in a move towards achieving water infiltration rates experienced in natural ground cover. This is promoted through increased planting to deliver a combination of reduced water runoff rates, enhanced biodiversity and an improved aesthetic experience of urban spaces. These schemes enable designers to flexibly integrate landscaping elements into developments by allowing them to propose designs that respond to the particular opportunities and constraints of a specific site. The 'Biotope Area Factor' (Berlin) and 'Green Factor' (Malmö and Seattle) operate by allocating

different scores to different design elements. The developer must ensure that the proposed design exceeds a certain minimum threshold to proceed with construction on site. For example, in commercial (C) and neighbourhood commercial (NC) zones NC1, NC2, NC3, C1 and C2 in Seattle, developments must achieve a minimum Green Factor score of 0.30 under the provisions of Seattle Municipal Code 23.47A.016 (see Figure 3). The scoring mechanisms include a variety of functions and are weighted according to relative functional desirability. Prominent in these scoring mechanisms are issues concerning drainage management, ecological enhancement, recreational space provision and aesthetic benefit. In Berlin, focus is placed on the use of planting schemes in private properties to increase on-site water retention. In Malmö, greater emphasis has been placed on improving user experience of semi-private residential courtyards through constructing new water retention areas that provide ecologically rich habitats and offer recreational opportunities for local residents. These private and semi-private space issues are also addressed in the Seattle Green Factor scheme, although here, considerable stress has also been given to public spaces. In this scheme, applicants to the municipal authority are permitted to include landscape-enhancing elements in public areas adjacent to the development site. This has increased the permeable surface cover in public areas by incentivising developers to improve the quality of the public realm through investing in the streetscape. As noted by Rouse and Bunster-Ossa (2013, 78), 'Where bare, five-by-five-foot tree pits used to be the norm, planting strips now tend to be larger and include understory planting'.

Successfully implementing these initiatives involves the acquisition of new design skills and knowledge concerning less interventionist, yet innovative approaches to maintenance. For example, Portland has attempted to reconcile aesthetic appeal with a low-cost approach by 'refining the planting plans for green streets to ensure they are both attractive and low-maintenance' (Hoyer et al, 2011, 44). This approach has been synergised with community development initiatives by supporting local residents in helping maintain the appearance and functionality of green street initiatives. Such new design and maintenance approaches echo the achievements of Vancouver's 'Green Streets' initiative discussed above. They likewise confirm the benefits of innovative design and maintenance approaches identified by Erickson (2006, 199) regarding the 'Country Lanes' initiative in Vancouver where alleys have been retrofitted by removing impermeable surfaces and installing low-maintenance

planted pervious material that can support vehicles. In this sense, city-wide GI initiatives can have a direct positive impact on urban design at a range of scales and cater for a variety of functions. These different approaches also reflect different design traditions, property rights and regulatory approaches, and environmental contexts. However, the key principle is transferable across these contexts – the enhancement, creation and the integration of multifunctional green networks and spaces into ecologically sensitive urban development. Uniting these approaches is a holistic and optimistic perspective to forging positive synergies between the complex abiotic, biotic and cultural dimensions of the urban environment (Ahern, 2013). Each of the examples outlined above thereby advances evolutionary resilience by promoting a future-orientated stance that elevates innovation through continuing reflection in a desire to ‘bounce-forward’ in response to an assumption of ongoing change.

Figure 3

Seattle Green Factor Score Sheet

(Source: <http://www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor>)

Figure 4

Green roofs in new residential areas in Ostfildern

(located in the urban periphery of Stuttgart)

Conclusions

The persistence of traditional approaches to flood risk management is evident in much urban design activity. This design philosophy is manifested in projects that seek to resist, disrupt and dominate the natural hydrological cycle. These ‘defence’ focused design perspectives involve intensive and expensive interventions with limited function beyond the reduction of flood risk. Furthermore, such ‘hard’ solutions are generally inflexible and once

their capacity to prevent flooding is exceeded, they can require considerable effort and cost to rebuild. Problems associated with this approach to resisting nature has prompted the emergence of design approaches focused on adapting to flood risk by advancing a form of 'bounce-back' resilience. While an improvement on traditional approaches, this paper calls for a more profound change in how the issue of flood risk management is incorporated into the design of urban areas. As argued by Carmona (2014), the emergence of more ecologically focused 'urbanisms' (e.g. sustainable urbanism, landscape urbanism, ecological urbanism) 'seek to neatly package favoured physical forms with prescribed social and/or ecological content and philosophical meaning, but often end up in circular debates about aesthetics' (2014, 4-5). However, in this paper we argue for a transformative understanding of the role in urban design in place-resilience. This involves attention to the multifunctional potential of sites and seeks to engender an 'evolutionary' resilience that facilitates on-going reflection on how to deliver more sustainable urban forms. The attributes characterising this progression from resistance to bounce-back and evolutionary resilience are illustrated in Table 1.

<Table 1 in here>

This paper advances the GI approach as a means for realising evolutionary resilience in urban flood risk management. The paper does not oppose the application of traditional or adaptation focused approaches to flooding, as these are likely to be the most appropriate modes of action in certain circumstances. However, the paper does challenge the dominance of traditional 'hard' solutions to issues of flood risk management, while concurrently suggesting that an adaptation focused approach is often limited in scope and ambition. Thus, in seeking to complement these two approaches, this paper advances an alternative design perspective that advocates 'working with' as opposed to 'dominating' or 'adapting to' nature. Such an approach necessitates a broader skills set than that which is currently deployed in addressing urban flooding issues. For example, a challenge arising is to advance urban design that 'works with' nature by creating a more 'permeable landscape' which provides for: water absorption and storage; habitat connectivity; recreational access;

and the requirements of emergency response (legible evacuation route to safety). Consequently, it requires greater collaboration between an array of different specialisms. However, it is contended that the hard work of producing these new interdisciplinary working arrangements will ultimately result in an aesthetically and functionally enhanced urban public realm.

In this paper, we focus on the role of green infrastructure in adapting and transforming urban places in the context of increased flood risk. In a northern European context, anticipated climate change will increase flooding risk with increased frequency of precipitation events. Within this context, a tension potentially arises between GI measures to adapt to climate change and policies designed to mitigate climate change. For example, over the last two decades, urban planning orthodoxy has promoted compact urban form and higher densities to reduce energy consumption and the ecological footprint of cities (Howley et al., 2009). However, as McEvoy et al. (2006) outline, densification efforts often pose problems for urban drainage systems, while brownfield sites targeted for development may actually serve more important functions in terms of water retention, recreational uses and urban cooling. At the same time, a GI approach may undermine compact city policies through a greater emphasis on multifunctional greenspace provision and less intensive urban development patterns. Within the context of mitigation/adaptation tensions, the role of urban design is to reconcile these competing demands within the design process. For example, a GI approach may suggest promoting higher density development within key nodes or public transport corridors (reducing the need for car travel) intermeshed with multifunctional green corridors, or promoting green roofs and green walls to promote water retention within densely developed areas.

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ⁱ Such larger hydrological units are most commonly referred to as ‘river basins’ in the British Isles or ‘watersheds’ in North America.

ⁱⁱ Following its 20-year implementation, Portland’s Combined Sewer Overflow CSO Abatement programme (green and grey infrastructure) has resulted in a 94% reduction in combined sewer overflows to the Willamette River down from about 50 overflows per year to an average of four overflows each winter and one every third summer. Implementation has enabled the City of Portland to meet regulatory standards and legal obligations (CoP, 2011, 2012).