MRP - DANQING LI

by Danqing Li

Submission date: 31-Aug-2019 03:26PM (UTC+0100)
Submission ID: 110392730
File name: 64265_Danqing_Li_MRP_-_DANQING_LI_1212390_282816426.pdf (20.44M)
Word count: 13305
Character count: 78231

UNIVERSITY COLLEGE LONDON

FACULTY OF THE BUIT ENVIRONMENT

BARTLETT SCHOOL OF PLANNING

MAJOR RESEARCH PROJECT:

Integrate Lively and Perceptible Flood Adaptation Measures into Public Open Space

Take Hackbridge and Beddington Corner Neighbourhood as an Example

DANQING LI

WORD COUNT:

MAIN TEXT: 8471; DIAGRAM: 1804 ; APPENDIX:274

SUPERVISOR: MING CHENG

Being a Major Project in **Urban Design and City Planning** submitted to the faculty of The Built Environment as part of the requirements for the award of the MSc Urban Design and City Planning at University College London, I declare that this project is entirely my own work and that ideas, data and images, as well as direct quotations, drawn from elsewhere are identified and referenced.

(signature)

(date)

CONTENTS

Figure list

Abbreviation

Abbreviation	Explanation
BMPs	Best management practices
LID	Low impact development
POS	Public open space
SuDS	Sustainable drainage systems
WSUD	Water sensitive urban design

ACKNOWLEDGEMENT

I want to thank those who has given me the opportunity to complete my major research projects, especially to my supervisor Ming Cheng, who guided me through the third term, especially when I was struggling about my research topics. I also want to express my gratitude to Dr. Filipa Wunderlich for her guidance in developing my research questions and organizing workshops. Finally, I would like to thank my parents and my boyfriend, who gave me selfless support and encouragement to complete this project.

ABSTRACT

Due to climate change, many urban areas are under high flood risks, among which urban public open space is one of the most vulnerable places (Matos Silva and Costa, 2017). To make matters worse, public open space with flood adaptation measures are facing problems like spatial compression, poor integration, and low-quality landscape (Leinster et al., 2009). Moreover, current measures are invisible, underground, and engineering-oriented, which is hard to be perceived by people, let alone provide opportunities for people to understand, accept and contribute to it (Wong, 2006). Though with these problems, public open space, which are multifunctional, Interdisciplinary, and civic significant, have entailed characteristics and opportunities for adaptation efforts (Matos Silva and Costa, 2017).

So, the research question is how to integrate lively and perceptible flood adaptation measures into public open space. Through the literature review, the research tries to look into three related fields(1) flood adaptation measures applicable in public open space; (2) how can these measures to be lively elements in public open space; (3) design methods to enhance people's perception of urban flood risks and functions of these flood adaptation measures. Substantial case studies will be followed to fill the research gaps in design methods. Based on the summary of the literature review and case studies, a design toolkit will be formulated to guide the urban design practices in the Hackbridge and Beddington Corner Neighborhood. In conclusion, discussions and limitations will be put forward for future research.

01

INTRODUCTION

Problem

Figure 1. London flood issues in pubic open space (Telegraph.co.uk,n.d.)

01 Damages to physical environment

The consequences of floods are relevant, ranging from impacts on human health to transportation infrastructure, and other damaging effects such as damages to property and psychological stress (Haddad and Teixeira, 2015), among which the damages to physical proximity are the causes of others (Few, 2007). Meanwhile, POS is among the most vulnerable areas where impacts of climate change are more acutely experienced (Matos Silva and Costa, 2017). So, the first problem I would like to address is the urban flood risks.

02 Low-quality landscape and Loss of liveliness due to poor integration

There are multiple and often conflicting uses, needs, and statutory requirements for public open spaces (Leinster et al., 2010). As most of the flood adaptation measures have massive land take, the phenomena that flood adaptation measures are spatially compressed are common(ibid). Most of these measures function a purely engineering and water quality level, but at a social, aesthetic, economic, and cultural level, they might fail (Odea and Nakkan, 2012). The difficulty here is how these measures can be multifunctional, lively, and useful recreation spaces that encourage residents to get outside(ibid). So, the second problem I want to resolve is the unattractive landscape and loss of liveliness resulted from poor integration of flood adaptation measures with POS.

Figure 2(a)

Figure 2(b)

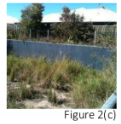


Figure 2(c)

Figure 2 (a)(b)(c). Low-quality landscape resulted from flood adaptation measures (Source: Google)

Figure 3. Community participation in maintaining flood adaptation measures (WLA, 2015)

03 People know little about flooding

Flood control infrastructures are default in most areas to prevent a flood from entering cities, which deprive people's opportunities to learn from smaller floods (Liao, 2013). So, the false sense of security makes the city vulnerable and irresilient in extreme conditions. Meanwhile, most of current flood adaptation measures are invisible, underground, and strongly engineering-oriented, which provide few chances for people to see, to understand, and to participate in (Wong, 2006). Based on the two phenomena, we can speculate that though people's attitudes towards flood adaptation measures are positive (Leonard et al., 2019), they know little about floods and measures around. Also, they have no idea what they can do when the flood comes, let alone contributing to flooding adaptation.

Research question

HOW TO INTEGRATE FLOOD ADAPTATION MEASURES IN PUBLIC OPEN SPACE?

The research question responds to the three problems addressed in the previous chapter and can be divided into three sub-questions.

What flood adaptation measures are applicable in public open space?

Firstly, in order to mitigate the threat of floods to the urban built environment, combining public open space with flood adaptation measures are possible solutions, as it is politically easy to adapt public open space to floods(Liao, 2013). So, the research will try to explore what measures are applicable in public open space, how they function and their possible limitations.

How can these measures contribute to liveliness of public open space?

Secondly, to solve the problem of poor integration of flood adaptation measures and public open space, the research will start from researching on what elements can make up lively public open space, and then explore how these flood adaptation measures can combine with these identified elements.

How to enhance people's perception to both flood risks and understanding of flood adaptation measures?

Thirdly, to address the lack of knowledge in both flood risks and benefits of flood adaptation measures, the concept of perception was put forward. The research will try to find methods to create POS where communities are more likely to perceive and understand the risks of floods, moreover, to participate in the whole life process of these POSs, from the stage of design, usage, maintenance and management.

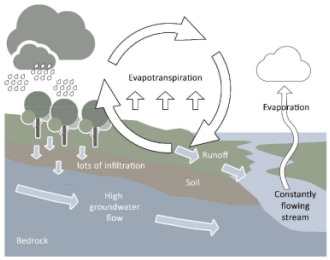


Figure 4(a). The natural water cycle

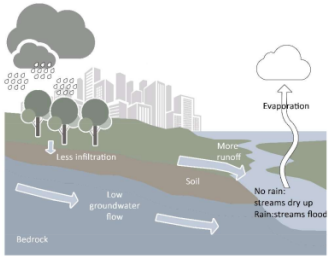


Figure 4(b). The urban water cycle

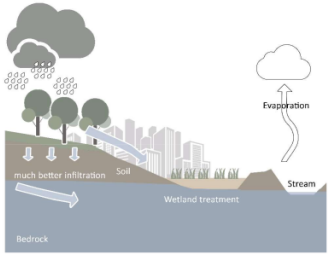


Figure 4(c). Towards a more sustainable urban water cycle

Figure 4(a)(b)(c). Water cycle evolution and future development direction (modified from Auckland Council)

Objectives & contributions

PROJECT OBJECTIVES

REDUCE FLOOD RISKS

The first objective is to reduce flood risks and enhance long-term resilience of urban built environment through flood adaptation measures in POS.

BECOME LIVELY ELEMENTS IN POS

The second objective is to transform these engineering-oriented measures into lively elements in POS through urban design, not only functioning when the flood comes but also serve as contributors to urban liveliness.

ENHANCE PERCEPTION TO FLOOD RISKS

As the research is based on the prerequisite that POS is the capable carrier for flood adaptation measures, the third objective will include two sub-objectives. The first one is to enhance people's experience and perception towards POS itself, to enhance people's sense of responsibility for community spatial assets and place attachment, which is critical for the implementation of flood adaptation measures. The second goal is to raise community awareness of flood risks, including how it works and early assessment of flood risks.

CONTRIBUTIONS TO PRACTICE

The originality lies in two perspectives: (1) Not taking flood adaptation measures as isolated and engineering functions but trying to find its connections with physical features of POS; (2) Seeking methods to make water management facilities a lively part of urban public space, from isolated and engineering-oriented to lively and perceptible.

As for the contributions to practices, a comprehensive toolkit will be formulated which include flood adaptation measures in building scale, street scale, and neighborhood scale. Also, a series of design considerations and spatial requirements will be supplemented to help urban designers to integrate lively and perceptible flood adaptation measures in POS.

Methodology

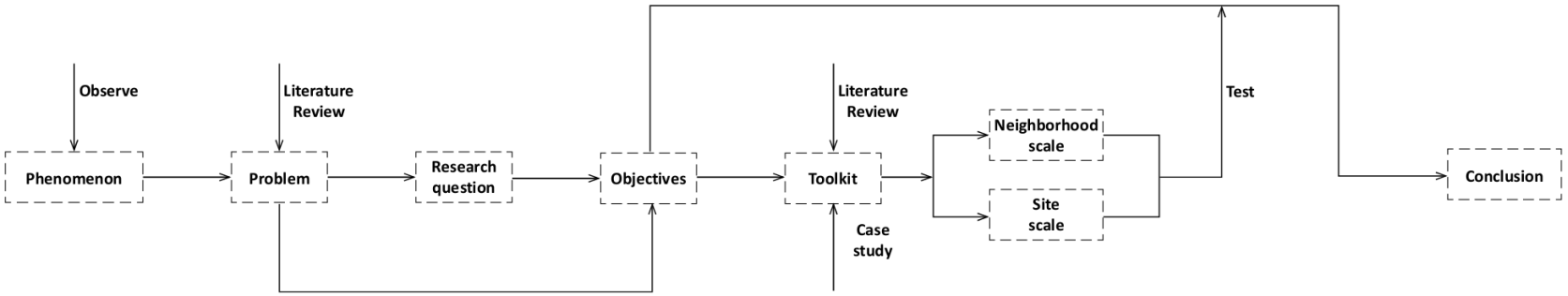


Figure 5. Research methodology

02

LITERATURE REVIEW

Flood adaptation

What is flood adaptation?

Floods are causing increasing damage in the rapidly urbanizing world, which harm a wide range of socio-economic environments, far beyond the direct damage to physical environments (Jongman, 2018).

Climate change adaptation is defined as managing rather than avoiding the consequences (Prior et al., 2018), which shows the difference between flood adaptation and flood resistance(control).

From its working process (Fig.6), we can learn that flood adaptation does not mean preventing flooding from entering cities but also learn from and adjust to its existence. FCI with a specific capacity are default solutions in most cities (Liao, 2013). However, though the system may have a lower risk overall, the impacts of a dike-breaching event can be catastrophic (Jongman, 2018). By preventing learning from smaller floods, FCI may compromise resilience by a false sense of security to increase long-term flood risk (Liao, 2013). As flood adaptation would correct several problems induced by flood control(ibid) and complement it (Wardekker, 2010), exploration of flood adaptation measures is worthwhile.

Besides the non-structural measures, such as land-use planning or evacuation planning, most of the identified frameworks about flood adaptation encompassed structural strategies, which not only cover urban drainage systems, such as SUDS, LID, BMPs and WSUD, but also those related to building design, flood defenses and embankment systems(Matos Silva and Costa, 2017).

The following section will introduce the urban drainage systems and other aspects to do with flood adaptation.

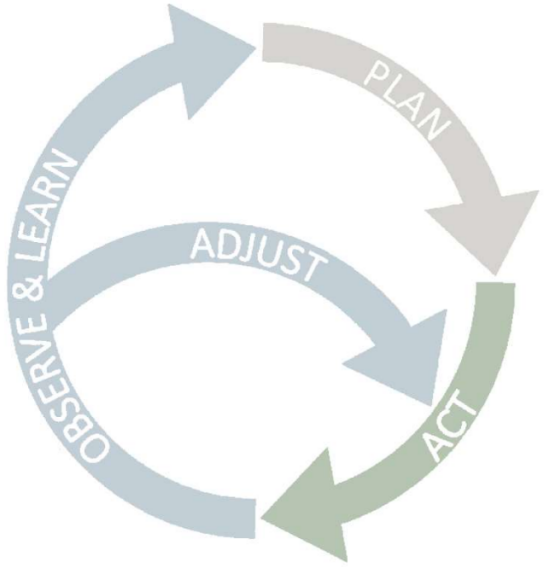


Figure 6. Climate change adaptation circle (Modified from the Blackfeet Climate Change Adaptation Plan, 2018)

Flood adaptation

Components

Urban drainage system

There has been sophisticated theoretical system for urban drainage system, and they are evolving towards a more holistic approach (Fletcher, 2014). These theories provide productive measures to manage urban water (Fig.7). However, the design toolkit is incomplete without applications in other aspects of flood adaptation.

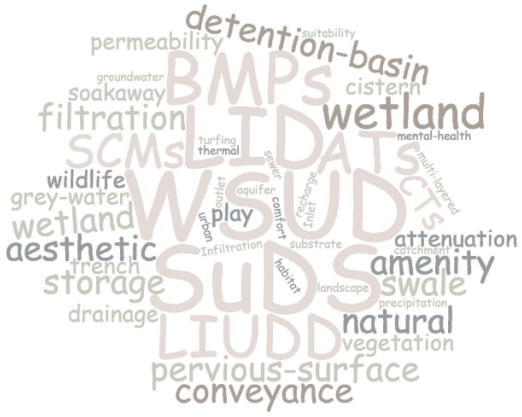


Figure 7. Word cloud of design techniques to do with urban drainage system

Other aspects

Though other aspects of flood adaptation are extensive, Wardekker et al. (2010) systematically summarize measures under six principles from urban resilience theory (Fig.8).

For architectural design, construction materials, flexible structures, mobile facilities, modular and multifunctional buildings, and buildings with non-essential functions on the ground level can be effective solutions (Wardekker et al., 2010). For the evacuation planning, multiple access levels, multiple routes, raising main roads, and early warning/sensory systems are suggested(ibid). In terms of land use planning, the high flux of land use and multifunctional low-lying place design are recommended(ibid). All these mentioned above can be supplements to the urban drainage system management to reach more comprehensive flood adaptation.

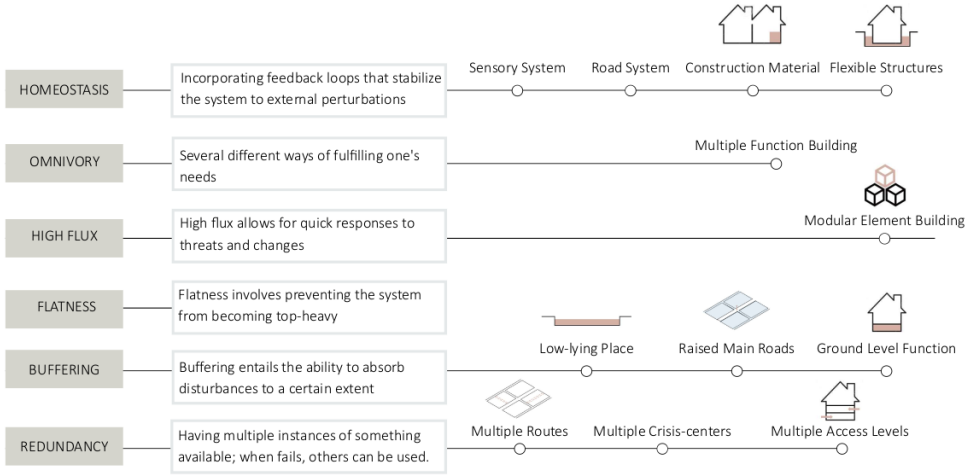


Figure 8. Flood adaptation measures from urban resilience theory (Adjusted from Wardekker et al. 2010)

Flood adaptation & Public open space

Vulnerable but valuable

The POS is an essential component of urban space besides buildings, has been evolving in response to a series of pressures (Carmona, 2010). Moreover, POS is among the most vulnerable areas in the urban built environment as they are where impacts are more acutely experienced (Matos Silva and Costa, 2017).

Nevertheless, it is politically challenging to adapt buildings and infrastructure to floods; it should be relatively easy to do so with POS (Liao, 2013). Matos Silva and Costa (2017) argued that POS entails specific characteristics that are particularly relevant for adaptation efforts: multifunctional, interdisciplinary, and carriers for shared concerns. Therefore, it is both necessary and effective to integrate flood adaptation measures into public open space.

Design to foster benefits and to circumvent drawbacks

Leinster et al. (2010) further confirmed this speculation by finding similarity in objectives associated with flood adaptation and POS, such as environmental protection, amenity, connection, and safety. The similarity indicates the possibility of combining. Leinster et al. (2010) also identified the phenomenon that POS spatially compresses flood adaptation measures. Even worse, the phenomena will create a negative cycle: poor design leads to poor outcomes, and the policymakers will choose to exclude these measures from POS. Appendix-A shows the benefits and drawbacks of combination.

Unlike the architectural design with complete design codes for flooding, flood adaptive urban design is engineering-oriented, which lacks in specific design methods to foster benefits and to circumvent drawbacks.

Flood adaptation measures applicable in public open space

Matos Silva and Costa (2016) systematically sorted out flood adaptation measures applicable to POS (See Appendix. B). Also, Matos Silva and Costa (2016) suggested six infrastructural strategies (harvest; store; infiltrate; convey; tolerate; avoid) to evaluate these measures and the necessity to combine several strategies to achieve a higher level of stormwater treatment.

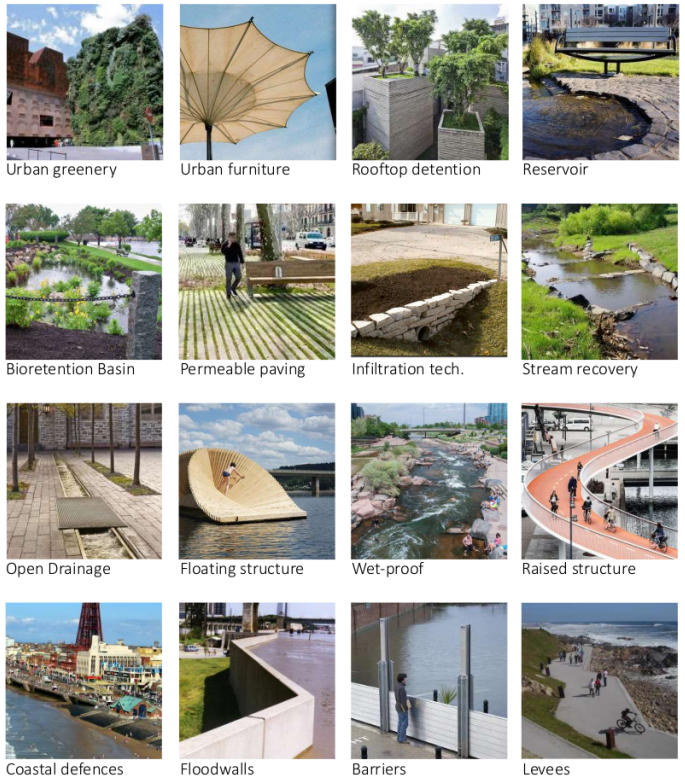


Figure 9. Categories of flood adaptation measures (Adjusted from Leinster et al.,2010)

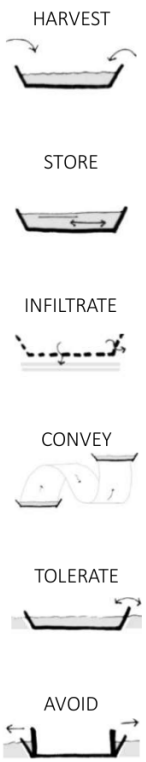


Figure 10. Flood adaptation Infrastructural strategies (Leinster et al.,2010)

Refining the toolkit

INCLUDE MORE DESIGN CONSIDERATIONS

The previous page presents the flood adaptation measures applicable in public open space summarized by Matos Silva and Costa (2016), which is the starting point of my own design toolkit. But obviously, it needs modification.

- Firstly, the toolkit ignores differences in the scales where measures are implemented. Wong (2006) classified flood adaptation measures according to different application scales, which indicates that spatial features of POS will influence the selection of flood adaptation measures. The measures to do with stream recovery will be removed from the toolkit for neighborhood-scale as they should consider conditions of upstream and downstream at district scales.
- Secondly, different measures have different spatial requirements. Kuller et al. (2017) pointed out that the footprint(sizes), retrofit difficulties (low, moderate, high) should also be considered.
- Thirdly, most measures in the initial toolkit are independent, ignoring the possibility of combining them for greater benefits. Moreover, They are just adjuncts to public open space, competing with other uses.
- Lastly, coastal defense, floodwall, barrier, and levee in the toolkit, are more about flood control than flood adaptation. Though they are effective in reducing flood risks overall but are not adaptive, so, they should be removed from the specific design toolkit for flood adaptation.

Table 1. Flood adaptation measures reclassified (adjusted from Matos Silva and Costa,2016)

Building Scale	
Urban Greenery	Green walls
Rooftop Detention	Green roof
	Blue roof
Bioretention	Rain garden
Floating Structure	Floating aisland
Raised structures	Flood resistant ground floor (waddle, 2010)

Street Scale	
Urban Furniture	Inverted umbrella
	Art installation
Reservoirs	Cistern
Bioretention	Bioswale
	Bioretention planters
Pervious paving	Permeable paving
	Porous paving
Infiltration techniques	Infiltration trench
Open Drainage System	Street channel
	Extended channel Enlarged canal
	Check dam

Neighbourhood Scale	
Reservoirs	Artificial detention basin
	Water plaza
	Underground reservoir
Bioretention	Wet bioretention basin
	Dry bioretention basin
Floating Structure	Floating pathway
	Floating platform
Wet Proof	Submergible park
	Submergible pathway
Raised Structure	Cantilevered pathway
	Elevated promenade

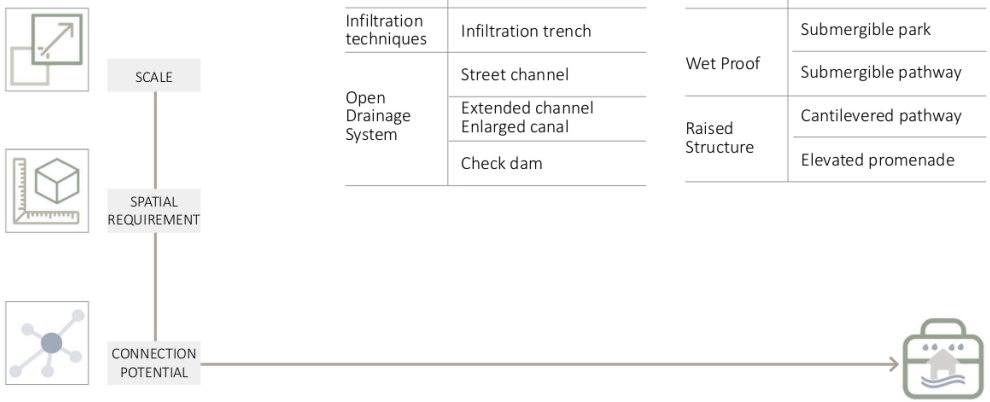


Figure 11. Design considerations added to the initial toolkit(1)

Refining the toolkit

METHODS TO ACTIVATE LIVELINESS

The current measures mainly aim at mitigating flood risks; few have stressed their influences on quality of POS and community acceptance. So, the current toolkit is insufficient to achieve the second and third objectives.

- Place-making is understood as a process to make places lively and meaningful (Flemming, 2007; PPS, 2008; cited in Cilliers and Timmermans, 2014) as well as an end to produce high-quality POS (A. Wyckoff, 2014). Vernon and Tawari (2009) researched on place-making through WSUD, who set community needs as the criteria of high-quality POS. However, the criteria are abstract, more applicable to evaluate a completed project than be a part of the design toolkit.

- Through term usage frequency in papers, Cilliers and Timmermans (2016) identified ten contributors to high-quality POS(Fig.14), which are more practical. However, these standards need further modifications to supplement the design toolkit: (1) Activities are outcomes of the pleasant environment (Gehl, 2001), which cannot be designed. So, it will be combined with "inviting" and "multifunctional" to be "activity facilities" in the toolkit; (2) The " landscape" will be deleted, as it is included in the description of "aesthetics." (3) " Social functions" and "urban experience" will be combined with "accessibility," as all of them aim at promoting community use and social cohesion; (4)"Orientation" falls within fields of perception, which will be discussed later.

- Little research has systematically summarized design methods to make flood adaptation measures lively elements in POS. So, this section only provides a starting point for case studies. Subsequent case studies will summarize design methods to supplement the design toolkit based on the four perspectives.

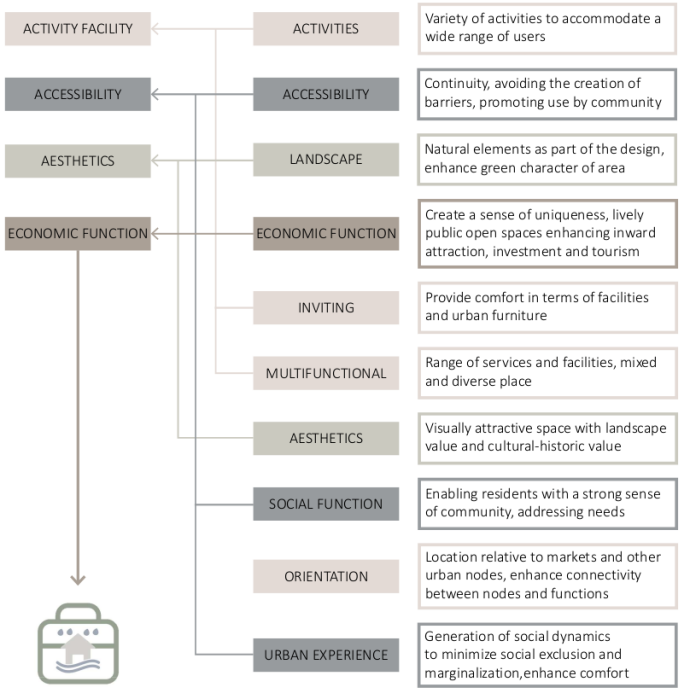


Figure 12. Theoretical characteristics of lively public open spaces (Adjusted from Cilliers and Timmermans, 2016) and design considerations added to the initial toolkit (2)

Refining the toolkit

METHODS TO ENHANCE PERCEPTION

The third objective includes two sub objectives: (1) Raise people's perception of flood risks to correct false sense of security resulted from FCI; (2) Perceive the existence and functions of these measures to enhance community acceptance to improve effects of implementation. So, for this part, we will explore ways to increase perception to flood risks and flood adaptation measures.

senses | participatory activities

Figure 13. Design considerations added to the initial toolkit(3)

DESIGN TO IMPROVE PERCEPTION

The sensation is input about the physical world by our sensory receptors, and the process to interpret these sensations are perception, so senses are the physiological basis of perception (Courses.lumenlearning.com, 2019). For urban designers, senses-related design is the bridge between the physical environment and users. Designers have realized the lack of visual perception of flood adaptation measures will reduce the community acceptance and implementation effects. So, some literature has suggested design methods to enhance the visual perception of flood adaptation measures. Dobbie, M.F. (2016) suggested that exotic plants, particularly those with showy flowers or seasonal displays, can be considered, besides 50% of the planting which functions technically. Warm colors and free lines on green walls are better than rigid lines and cold colors (Engin Eroglu and Sinem Ozdede, 2014, cited in Shawket, 2015). Besides color and shape of vegetation, signage is a useful 'cue to care' and increases knowledge and understanding of rain garden function (Dobbie, M.F., 2016).

However, though the visual sense provides the most information that fuels the human perception, the other sensations also matter (Steward et al., 2015.). Besides vegetation, water is another outstanding landscape element in flood adaptation measures. Though not directly in connection with flood adaptation measures, water is closely related to soundscape design (Song, Hui, and Yin, 2012). Elizondo Garza et al. (2016) suggested the use of fountains as a useful element in the soundscape design as well as its main design factors. For measures with harvest and store functions, water-related soundscape design has the potential to improve people's perception of flood risks and understanding of flood adaptation measures.

The current methods are limited. Also, besides visual and aural perspective, very few talks about design methods to do with other senses. More senses-related design methods directly related to flood adaptation measures should be supplemented through case studies.

PARTICIPATION TO IMPROVE PERCEPTION

Besides sensations, Gao et al. (2018) argued that public involvement in watershed activities could enhance people's perception and deepen their understanding of how these measures function.

Similarly, Leonard et al. (2019) attached importance to communications among communities and proposed methods to enhance participation to do with flood adaptation, including orientation program for new residents; Internal communication; planning of community centers; enable outsiders to visit sustainable developments (such as fishing; fruit picking; green tourism.).

Also, Leonard et al. (2019) stressed roles of activities held by community groups, including planting vegetation; water testing in local waterways; naming of local landmarks during the design process as well as using, monitoring and caring.

General lessons learned

RESEARCH GAPS

The initial toolkit (Matos Silva and Costa, 2017) lacks focus on the physical features of POS, and some of its measures are not flood adaptive. However, the defect has been improved by removing measures which reduced urban resilience and incorporating other physical factors (such as implementation scale and sizes) into the design toolkit.

However, the toolkit is still too engineering. Although we have identified contributors to lively POS from the literature, few of them propose ways to integrate flood adaptation measures into these elements through design.

There are some methods to enhance the perception of flood adaptation measures in POS, especially from the visual and aural perspective. But other senses are missing. The case studies will use six sensations (visual, kinetic, aural, chemical, thermal and tactile) in the notation system formed by Lucas (2009) to evaluate the design outcomes and summarized specific design methods to supplement the design toolkit.

CASE STUDY METHODOLOGY

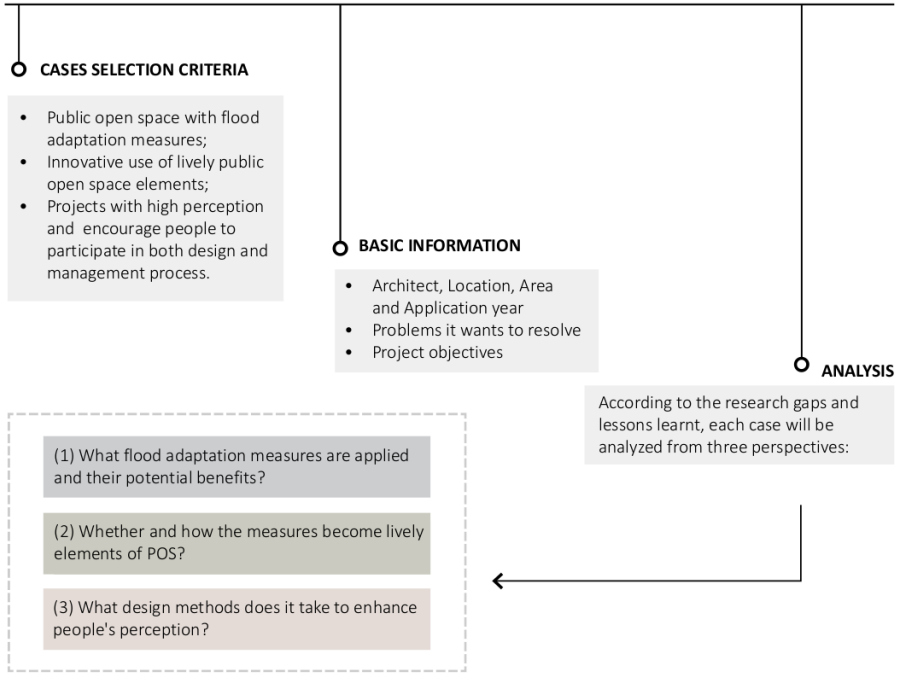


Figure 14. Case study methodology

03

CASE STUDY

Kokkedal Climate Adaptation | Kokkedal

Figure 15. Recreational ground which made rainwater management visible (Sörensen, Ingemann and Tuxen, 2018)

INFORMATION

Architects: Schønherr
Area: 61 ha
Year: 2017

PROBLEM TO BE SOLVED

Water has been a threatening flooding force to Kokkedal, and the area suffers from social division, insecurity, low investment and flooding.

PROJECT OBJECTIVE

(1) Enhancing climate adaptation; (2) Improving urban living and social cohesion; (3) Connecting fragmented urban areas; (4) Creating new attractive meeting points; (5) Bringing nature closer to the residents.

Figure 16. Climbing Facilities (ibid)

Figure 17. Educational park (ibid)

Figure 18. Exercise paths (Ramboll, n.d.)

Figure 19. Skating bowl (Gottlieb Paludan,2012)

Figure 20. Constructed wetland (Ramboll, n.d.)

Figure 21. Urban furniture (ibid)

LESSONS LEARNED

- Multiple basins can be composed through soakaways and trenches;
- The reservoir, raised structure and bioretention can provide various activity facilities
- Colour, shape and lighting can contribute to people's perception
- Nature theme park with food production functions can provide participatory opportunities for the neighbourhood

LIMITATIONS

- The land take of meausres taken is large. Though organic in form, they have a weak relationship with surrounding buildings. So, it is not intructive to be applied in high density areas.

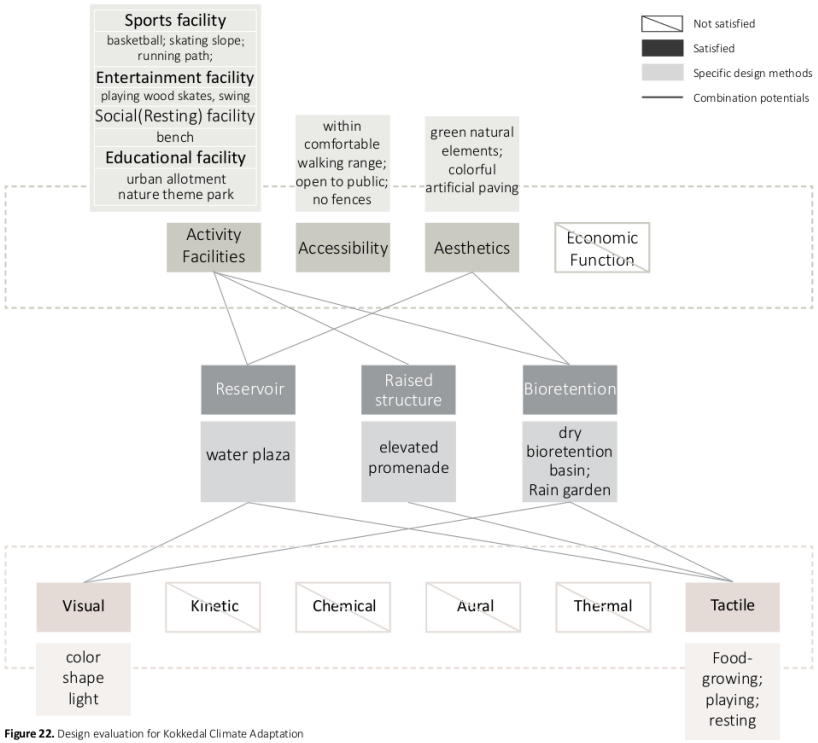


Figure 22. Design evaluation for Kokkedal Climate Adaptation

Diagonal mar park | Barcelona

Figure 23. Bird view of Diagonal mar park (Fluidra, 2017)

INFORMATION

Architects: Enric Miralles and Benedetta Tagliabue
Area: 14 hectares
Year: 2002

PROBLEMS TO BE SOLVED

- Underused space of a previous industrial zone
- Weak connection between the city and the seaside

DESIGN OBJECTIVES

- Recovering abandoned industrial lots;
- Creating a new neighborhood where various activities are available;
- Applying criteria of sustainable development to enhance the use of groundwater, the use of native plants, and the use of sand from the excavations during the construction.

Figure 24. Mist generator (ibid)

Figure 25.Shore with aquatic plants (ibid)

Figure 26. Slides with tree pitch (ibid)

LESSONS LEARNED

- The urban furniture can be combined with other "harvest" measures to generate cloud mist to improve aesthetics and thermal comfort.
- Seesaw can serve as conveyance channel at the natural slope;
- The adoption of native plants in retention basins can lower maintenance cost.

LIMITATIONS

- The park is inaccessible, aiming at upper-class foreign tourists and high-income groups, rather than the permanent aging population.

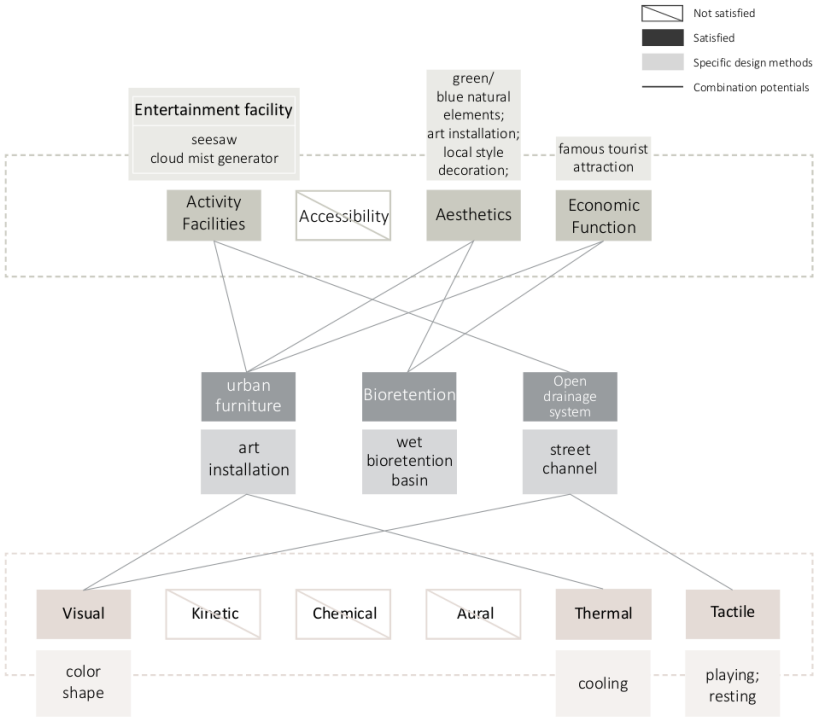


Figure 27. Design evaluation for Diagonal mar park

Water Square I Rotterdam

Figure 28. Bird view of water square (De Urbanisten, n.d.)

INFORMATION

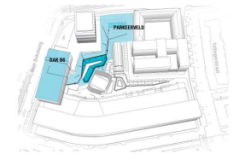
Architects: DE URBANISTEN
Area: X hectares
Year: 2013

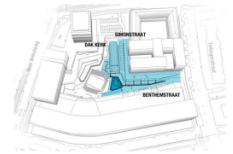
PROBLEMS TO BE SOLVED

- A deficiency of urban growth in the last decades.
- Interstices between buildings were excessive and the free space was tedious and inactive.

DESIGN OBJECTIVES

- From invisible underground water storage to surface water storage system;
- Improving the environmental quality;
- Strengthening the identity and enjoyment of neighborhoods;





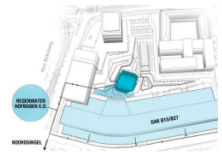


Figure 29. Skating bowl (ibid)

Figure 30. Dancing stage (ibid)

Figure 31. Football and basketball field with grandstand (ibid)

LESSONS LEARNED

- Multiple basins can be composed through street channels
- The reservoirs have high potentials to combine with activity facilities;
- Different workshops can be held among potential users to promote public participation in design schemes;
- Eye-catching colours can be used on the pavings to indicate amphibious uses of POS and enhance perception of flooding

LIMITATIONS

- Only benefit small area
- The stored and infiltrated greywater have not been reused for other uses.

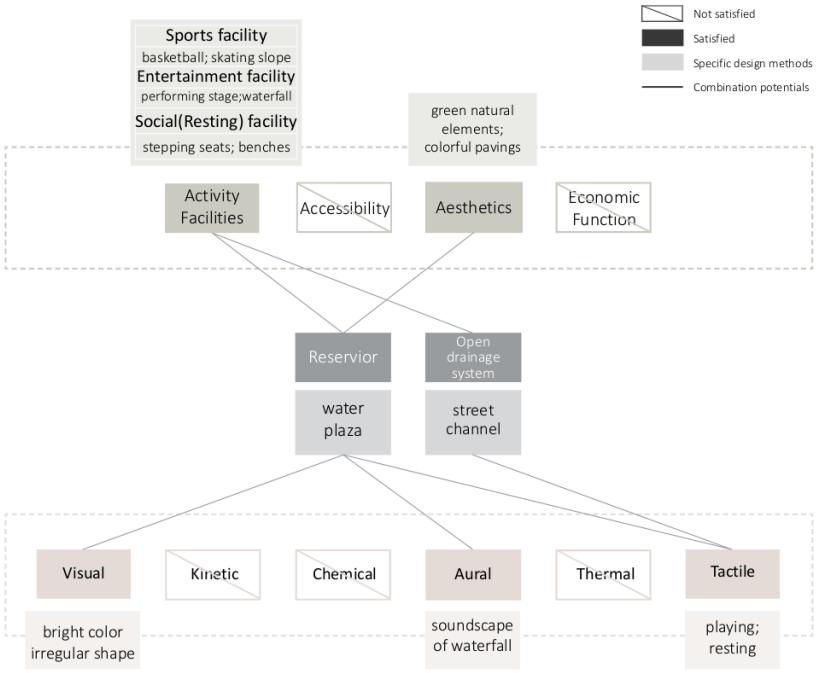


Figure 32. Design evaluation for water square

Floating structures

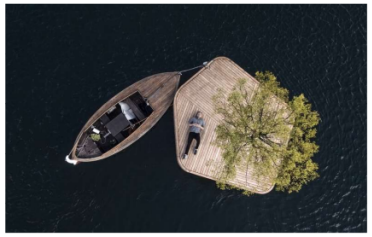


Figure 47. CPH-Ø1(Airflix.com & Memesis-foto.nu,n.d.)

Figure 48. Viewing point (kingscross.co.uk,n.d.)

Figure 49. Swale (Michelle Young, n.d.)

Figure 50. Recycled park (Lonely planet, 2018)

Figure 51. Odyssee Pavilion (Design Gallerist, n.d.)

Figure 52. Floating Pocket Park (Osullivanproperty, n.d.)

LESSONS LEARNED

- Flexible in sizes and suitable for different scales of physical environments
- Provide users with various activity facilities; high potential of aesthetics to do with art and nature
- Serve as perceptible and participatory educational bases for flood adaptation knowledge dissemination

LIMITATIONS

- Safety risks, especially when the parks are moving, making it difficult for lifeguards to detect danger and reach people in the water
- Higher requirements on the width and water quality of the water course

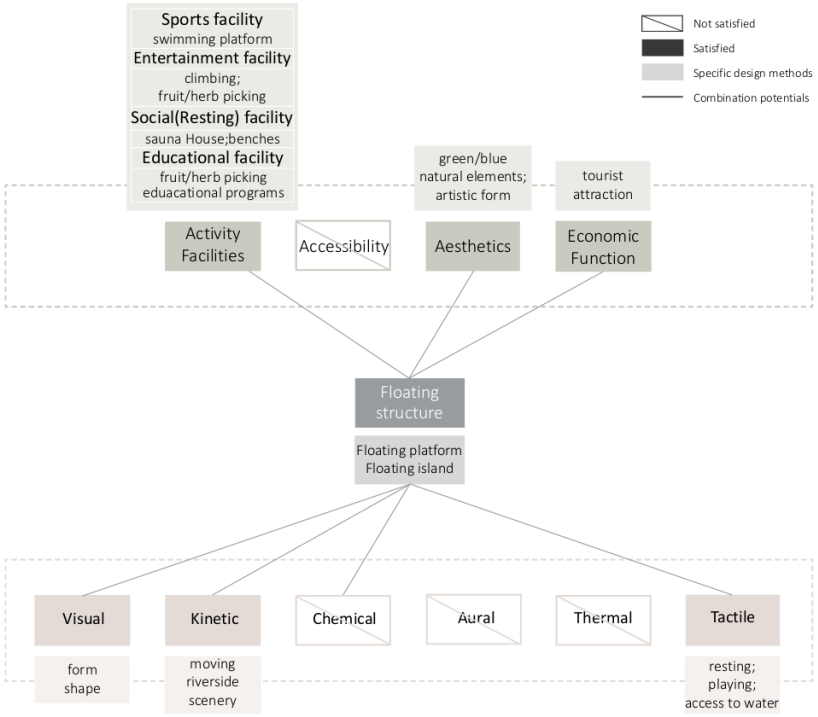


Figure 53. Design evaluation for floating structures

Urban furniture

OasiSaw (play-powered pump)

Figure 54. Conceptualization of play-powered pumps (Troy Turner, 2015)

PROBLEMS & OBJECTIVES

- The play-powered seesaw aims to address water shortage problem.
- This brilliant idea is to combine a pump for deep subterranean wells with a playground equipment. The technology puts pressure on pipes that extend beneath the earth's surface, pumping stored water away and creating fountains for children who sway back and forth.

Rain catcher bench and umbrella

PROBLEMS & OBJECTIVES

- Both urban furniture addresses water shortage and harvest rainwater to reduce stormwater volume.
- Its objective is to provide people with resting facilities in sunny days and serve as rain catcher and irrigation water source when extreme climate hazards happen.

Figure 55. Conceptualization of rain catcher bench (designboom, 2009)

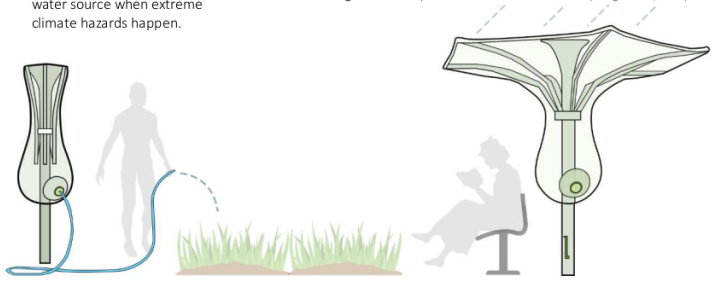


Figure 56. Conceptualization of rain catcher umbrella (Adjusted from Thomas Valcke, 2009)

LESSONS LEARNED

- Small in sizes, easy to fit into all physical environments; combined with other flood "harvest" measures to recycle grey water
- Provide users with activity facilities through design; an average potential of aesthetics to do with art and nature
- Contribute to the perception of flood adaptation and encourage people to participate but need to combine with other more eye-catching measures and activities.

LIMITATIONS

- Because of the smaller sizes, their positive impacts on flood adaptation are limited
- The cost of installation is high

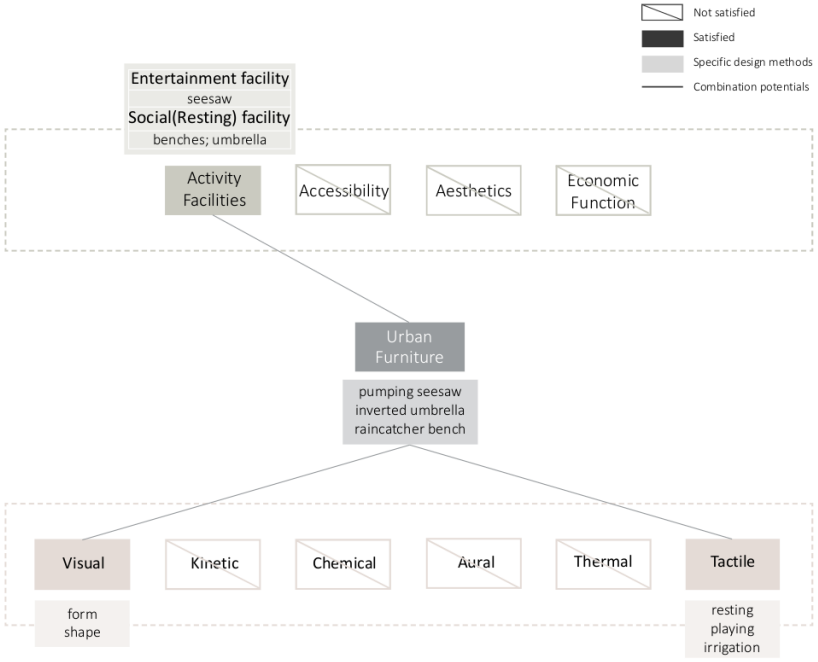


Figure 57. Design evaluation for water-related urban furniture

General lessons learned

Figure 58. Kokkedal Climate Adaptation (Sörensen, Ingemann and Tuxen, 2018)

Figure 59. Diagonal mar park (Fluidra, 2017)

Figure 60. Water square (De Urbanisten, n.d.)

Figure 61. Zollhalen Plaza (UrbanNext,2018)

Figure 62. Klyde warren park (Archdaily, 2012)

Figure 63. Recycled park (Lonely planet, 2018)

Figure 64. Inverted Umbrella (Outdoor design source,n.d.)

Urban Furniture

- **Flood risk reduction:** Depends on the forms and functions, some (rain catcher umbrella and bench) can temporarily store, filtrate and reuse the rainwater;
- **Liveliness activation:** Rain catchers can be combined with irrigation facilities; Others(scloud mist generator and pumping seesaw) are not directly used for flood adaptation but can be the output of the collected rainwater;
- **Perception:** Colour, shape and lighting can contribute to people's perception; Integrated with urban allotments to encourage participatory activities.
- **Connection:** combined with "harvest" and "store" measures
- **Spatial requirement:** enough space

Reservoir

- **Flood risk reduction:** harvest and store flooding water to reduce storm run-off;
- **Liveliness activation:** combined with various activity facilities; high potential to contribute to aesthetics;
- **Perception:** Colour, shape and lighting can contribute to people's perception.
- **Connection:** from smaller ones to larger ones via underground pipes or open drainage system;
- **Spatial requirement:** flexible in sizes and are easy to fit into all kinds of POS.

Bioretention

- **Flood risk reduction:** Temporarily store, infiltrate(filtrate) flooding water to reduce storm run-off and improve water quality;
- **Liveliness activation:** It can be integrated with resting facilities and contribute to aesthetics through vegetation;
- **Perception:** N/A
- **Connection:** same as the reservoir
- **Spatial requirement:** vegetation; filtration layer

Pervious Paving

- **Flood risk reduction:** infiltrate stormwater to reduce storm run-off, improve water quality and benefit tree growing;
- **Liveliness activation:** N/A
- **Perception:** N/A
- **Connection:** N/A
- **Spatial requirement:** porous (allow for fluids to flow through it) or permeable paving (gaps in between); Low weight and traffic volumes.

Open Drainage System

- **Flood risk reduction:** convey stormwater;
- **Liveliness activation:** integrated with resting and entertainment(playful fountains) facilities;
- **Perception:** N/A
- **Connection**: other measures with harvest and store functions;
- **Spatial requirement**: street width

Floating Structure

- **Flood risk reduction:** tolerate riverside flooding;
- **Liveliness activation:** integrated with sports, entertainment, social(resting) facilities; accessibility to water; proper design of shapes adds to its aesthetics;
- **Perception:** the eve-changing position can make people perceive the water level change during flooding; those with allotment for food growing or fruit/herb picking activities encourage people to participate in the management and serve as educational bases.
- **Connection:** N/A
- **Spatial requirement:** Water course width; good water quality;

Raised Structure

- **Flood risk reduction:** Tolerate floods during extreme weather; serve as crisis center
- **Liveliness activation:** Raised pathways serve as running, walking or cycling pathways; Raised buildings with groundfloor open provide additional POS;
- **Perception:** N/A
- **Connection:** N/A
- **Spatial requirement:** Construction codes

LESSONS LEARNED

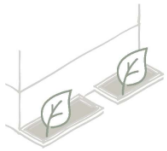
- All the cases are analyzed based on the three design objectives and relevant criteria from the literature review. In the case study review part, all the cases are concluded by (1) how do these measures contribute to flood risk reduction? What benefits can it achieve? (2) how can these measures contribute to POS liveliness? (3) design methods to enhance perception and encourage participation; (4) its potentials to connect with other measures; (5) the spatial requirement.
- The main lessons learned are: (1) Measures can reduce flood risks through different infrastructural strategies; (2) Connections between different measures are mentioned in limited cases, but multiple benefits can be achieved; (3) Senses-related design can enhance people's perception of flood adaptation; (4) Students and community groups are main participants in flood adaptation design and maintenance; (5) Educational activities to do with food/plant growth, and fruit/herb picking are more likely to encourage public participation.

04

DESIGN TOOLKIT

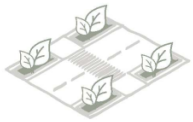
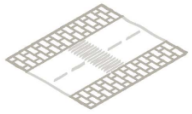
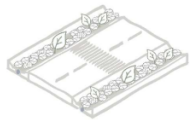
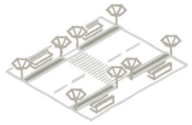
Building scale

● Can be achieved by design ○ Cannot be achieved by design

	BASIC FORM	HOW TO CONTRIBUTE TO FLOOD ADAPTATION/VITALITY/PERCEPTION?															SPATIAL REQUIREMENT
		FLOOD RISK REDUCTION					LIVELINESS				PERCEPTION						
		STORE	HARVEST	INFILRTATE	CONVEY	TOLERATE	activity facility	accessibility	aesthetic	economic function							
URBAN GREENERY Green walls		●	●	●	○	○	○	○	●	○	●	○	○	○	○	○	• load bearing capacity of wall • selection of plants • wetproof design • pest management
		• Reduce stormwater runoff • Convert CO2 emissions and produce oxygen • Reduce the urban heat island effects • Less land take					• Add to urban aesthetics through visually attractive landscape design				• Enhance visual perception through color and shape of vegetation as well as signage						
ROOFTOP DETENTION Green roofs		●	●	●	○	○	●	○	●	○	●	○	○	○	○	●	• an impermeable layer • a susbstrate or growing medium • a drainage layer • shape and size of the roof
		• Reduce stormwater runoff • Convert CO2 emissions and produce oxygen • Reduce the urban heat island effects • Provide wildlife habitat • Capture and harvest rainwater • Less land take					• Provide space for various activity facilities • Add to urban aesthetics through visually attractive landscape design				• Enhance visual perception through color and shape of vegetation as well as signage • Tactile: food growing/resting/playing...						
BIORETENTION Rain gardens		●	○	●	○	○	○	○	●	○	●	○	○	○	○	○	• Not suitable for areas with steep slopes; • downpipes connecting rooftop detentions
		• Reduce stormwater runoff • Convert CO2 emissions and produce oxygen • Reduce the urban heat island effects • Create habitat for wildlife • Capture and harvest rainwater					• Add to urban aesthetics through visually attractive landscape design				• Enhance visual perception through color and shape of vegetation as well as signage						
FLOATING STRUCTURE Floating platfrom Floating island		○	○	○	○	●	●	○	●	●	●	●	○	○	○	●	• High water quality • Safety requirement satisfied • Wet proof materials • Connections to the waterfront or stops for the moving ones
		• float with water levels change, free from being submerged • Create habitat for wildlife • improve water quality • create extra available land					• Serve as various activity facilities, including sports, entertainment, social, rest, etc. • Add to aesthetics through artistic forms; • Attract investment and tourism by its innovative forms				• Enhance visual perception through color and shape ofvegetation as well as signage • Enhance kenetic perception through waves; dynamic scenery of urban waterfront (if the structure can move) • Enhance tactile perception through food growing/resting/playing facilities • Participatory opportunities: Serve as educational bases about climate change for schools and communities						
RAISED STRUCTURE Ground floor use		○	○	○	○	●	●	●	●	○	○	○	○	○	○	○	• Comply with architectural design code; • Sufficient height to avoid compressing feelings • Wet proof materials
		• tolerate flood water excesses • protect mainly-used floor from floods • serve as temporary shelter and crisis center					• Provide extra space for activity facilities • improve continuity of public open space in urban built environment • Add to urban aesthetics through introduction of green natural elements										

Street scale

● Can be achieved by design ○ Cannot be achieved by design

	BASIC FORM	HOW TO CONTRIBUTE TO FLOOD ADAPTATION/VITALITY/PERCEPTION?															SPATIAL REQUIREENT
		FLOOD ADAPTATION					LIVELY				PERCEPTIBLE						
		STORE	HARVEST	INFILRTATE	CONVEY	TOLERATE	activity facility	accessibility	aesthetic	economic function							
BIORETENTION Bioswales / Planters		●	○	●	●	○	○	○	●	○	●	○	○	○	○	●	• Sufficient street width • Not suitable for steep areas
		• Reduce stormwater runoff • Remove pollutants • Convey the runoff to the next stage of the treatment train					• Add to urban aesthetics through visually attractive landscape design				• Enhance visual perception through color and shape of vegetation as well as signage • Participatory opportunities: provide places for participatory planting and maintenance activities						
PERVIOUS PAVING Permeable paving Porous paving		○	○	●	○	○	○	○	○	○	●	○	○	○	○	●	• Roads with low traffic volumes; • Soil type
		• Reduce stormwater runoff • Remove pollutants									• Enhance visual perception through color and shape of vegetation as well as signage • Enhance tactile perception through soft stepping						
INFILTRATION TECH Infiltration Trench		○	○	●	●	○	○	○	○	○	○	○	○	○	○	○	• Sufficient street width • shallow excavations with rubble or stone
		• Reduce stormwater runoff • Remove pollutants															
URBAN FURNITURE Raincatcher bench inverted umbrella		●	●	○	○	○	●	○	●	○	●	○	○	○	○	●	• Sufficient street width
		• Slightly reduce stormwater runoff • Harvest and filtrate to recycle rainwater					• Combine with resting facilities for passers-by and with irrigation facilities for roadside pocket gardens • Add to urban aesthetics through visually attractive forms and combination with green elements				• Enhance visual perception through eye-catching form, the change in storing water volume (early flood warning system) as well as signage • Enhance tactile perception through resting and irrigation facilities						
OPEN DRAINAGE SYSTEM Street channels Check dams		○	○	○	●	○	○	○	●	○	●	○	○	○	○	○	• Sufficient street width • both vegetated and non-vegatated are ok
		• Convey the stormwater runoff between different storage measures • Remove pollutants • Enhance bio-diversity					• Add to urban aesthetics through visually attractive forms and combination with blue and green natural elements				• Enhance visual perception through color and shape of vegetation as well as signage; the change in runoff rates (early flood warning system)						

Desired outcomes

- Compared among three scales, their contributions to overall flood risk reduction are different. Neighborhood-scale measures contributes more to stormwater volume and rate reduction, while street-scale one contributes more to convey stormwater. Building-scale measures contribute less to overall flood risk reduction. However, street-scale measures cannot take "tolerate" strategies to prevent them from damages;
- However, in terms of contributions to liveliness, measures at the neighborhood scale can contribute more, while street-scale ones are less helpful due to the width limits and linear physical form.
- In terms of perception, neighborhood-scale measures can also contribute most.

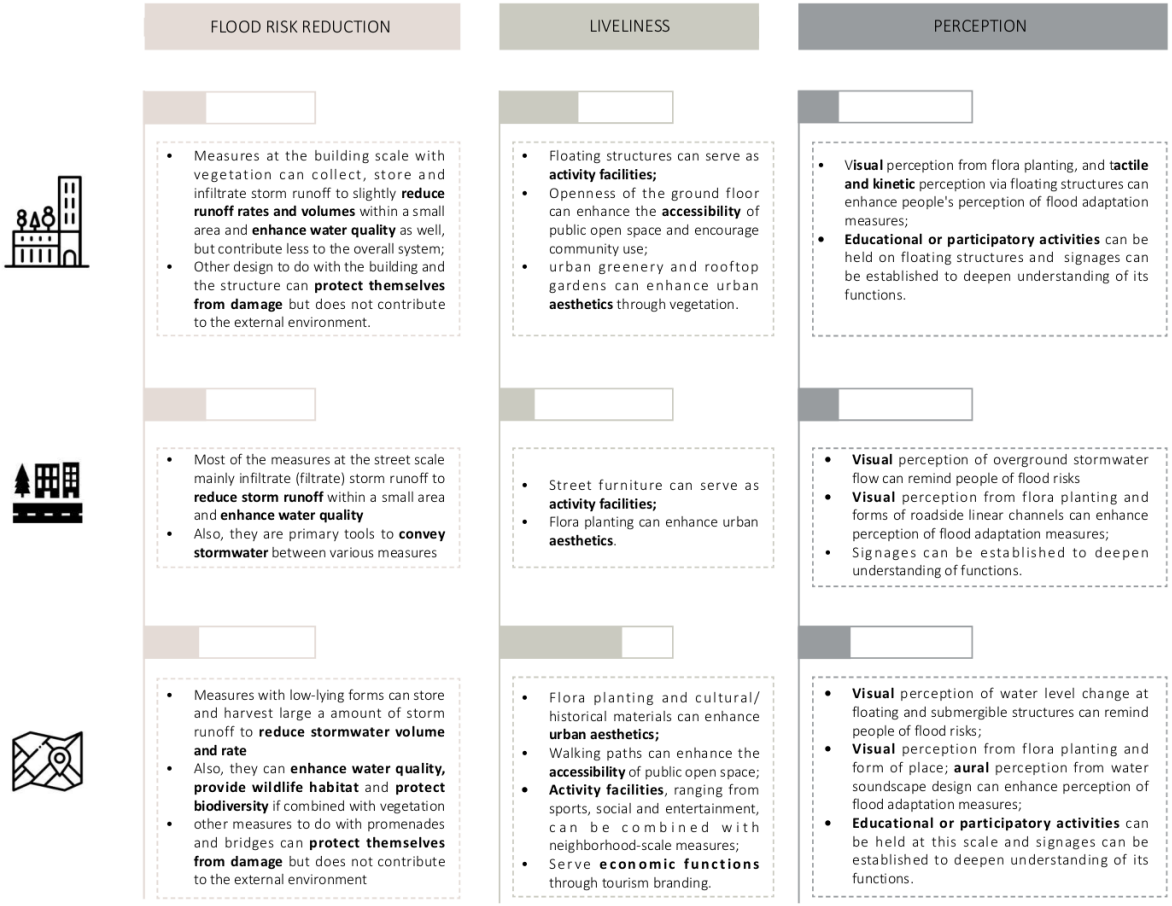


Figure 65. Desired outcomes at different scales

05

APPLICATION

Justification

SITE CONTEXT

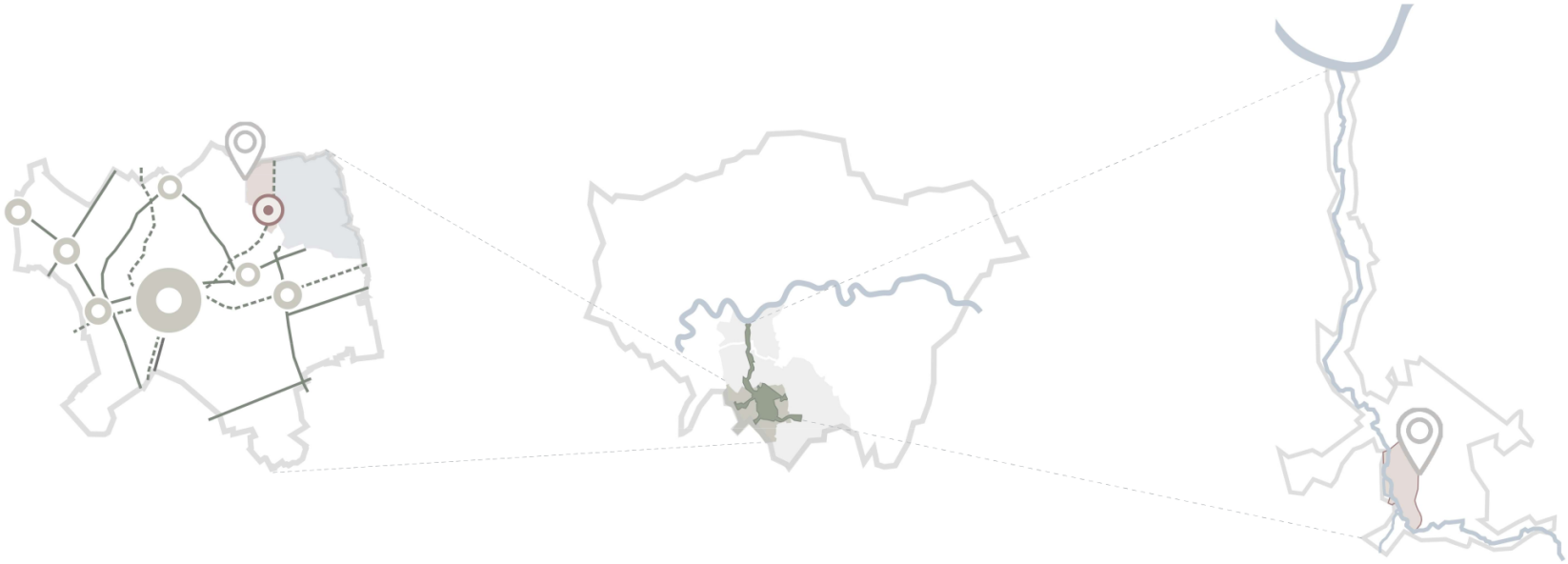


Figure 66. Site location in Sutton Borough

The neighborhood is within intensification and renewal area, providing opportunities for flood adaptive urban design.

Figure 67. Site location in London

The Hackbridge and Beddington Corner Neighborhood is 25 minutes train from the central London, in the northeast of Sutton Borough with River Wandle going through it.

Figure 68. Site location in WVRP

The neighborhood is within the Wandle Valley Regional Park. The river provides abundant open public space as well as high flood risks.

Justification

FLOOD RISK

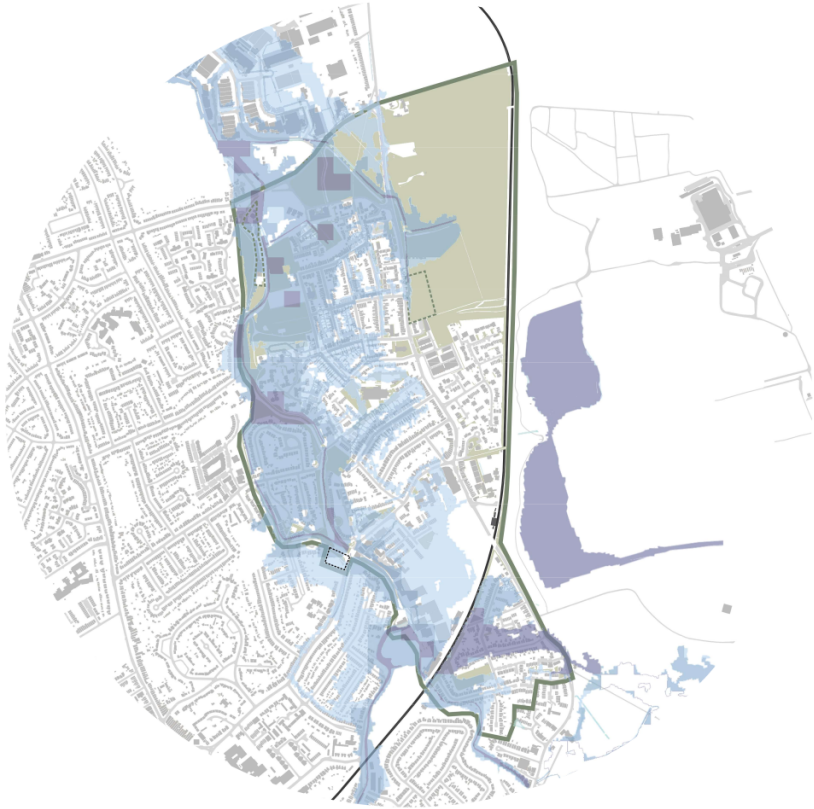
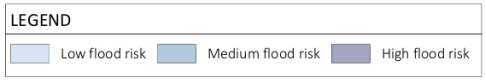


Figure 69. Flood risk from rivers (Adjusted from gov.uk, n.d.)

Figure 70. Flood risk from surface water (Adjusted from gov.uk, n.d.)



Site analysis

Land use & movement

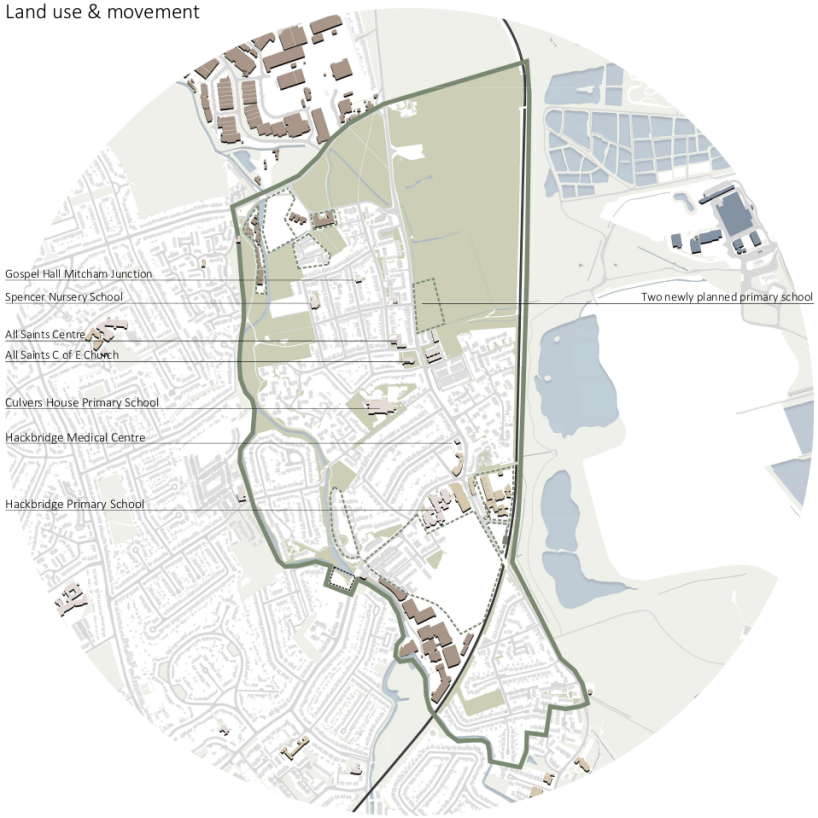


Figure 71. Land use analysis map

Figure 72. Traffic and movement analysis map

- The neighborhood has development sites to introduce flood adaptation measures;
- The neighborhood has more community services than surrounding area, so there are inherent advantages to knowledge dissemination, perception improvement and public participation.

LEGEND

- School/church/ community center
- Commercial
- Industrial
- Discentralized energy center
- Green space
- Water
- Development site

- In the future, this site will not only serve its residents but also serve cyclists and hikers as well as people from central London on weekends due to its abundant public open space and location in Wandle Valley Regional Park.

LEGEND

- Train station
- Rail line
- Bus stop
- Wandle trail
- Primary road

Site analysis

Existing flood adaptation measures

LIMITATIONS

- The existing measures are limited, with which some areas are still under high flood risk;
- Existing flood adaptation measures are unevenly distributed, so that the southern waterfront areas are under relatively high risks.
- These measures make the landscape poor and inaccessible to residents, which pollutes the environment and breeds crimes;
- The parks with the recreational facilities are not fully utilized as flood adaptation measures.

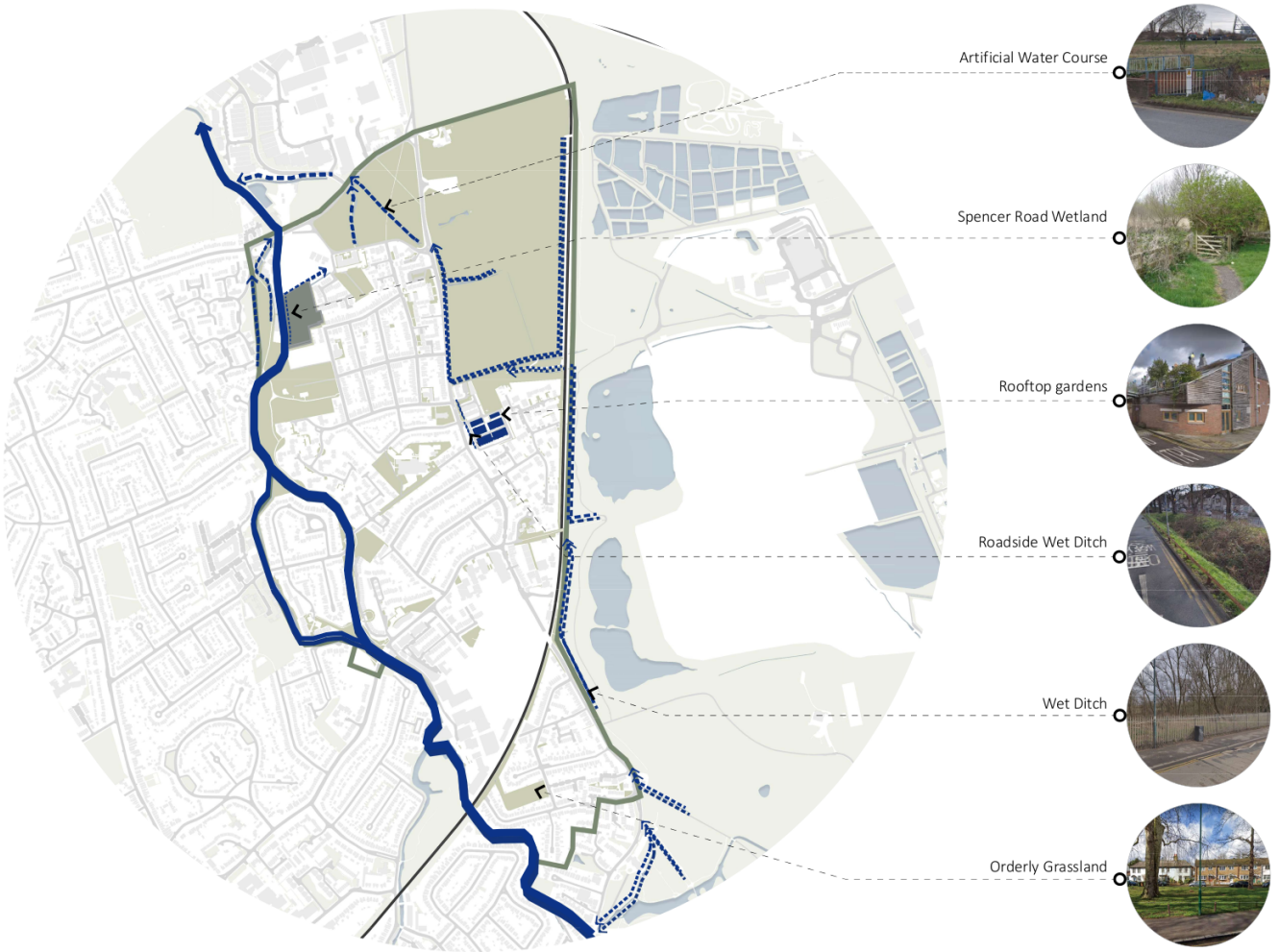


Figure 73. Existing flood adaptation measures analysis map

Site analysis

PUBLIC OPEN SPACE

MILL GREEN PARK (4.95 ha)

- Invisible wet pitch and rough grassland
- Poor landscape; no activity facilities; inaccessible;

COMMUNITY ORCHARD (23 ha)

- Invisible wet pitch and rough grassland
- Community free fruit picking activities(planning);

SPENCER ROAD WETLAND(1.05 ha)

- Boardwalk and dipping platform;
- Volunteer activities held

COMMUNITY GARDEN (0.45 ha)

- Grassland
- Child recreation facilities and parking area; accessible grassland;

ALLOTMENT (1.01 ha)

- Not flood adaptive
- Farm products/rough grassland; Farmhouse and benches;

ORCHARD RECREATION GROUND (23 ha)

- Grassland
- Child recreation facilities; accessible grassland;

WATERCRESS PARK (1.65 ha)

- Grassland
- Accessible grassland; basketball playground and child recreation ground

POCKERT PARK (0.14 ha)

- Grassland
- Well organized grassland and trees; No activity facilities

N

0 100 200 500

LEGEND

- FLOOD RISKS
- FLOOD ADAPTATION MEASURES
- LIVELY ELEMENTS
- PERCEPTIBLE ELEMENTS

WATERFRONT SPACE

- Not flood adaptive
- Poor landscape; inaccessible

ALLOTMENT (0.55 ha)

- Not flood adaptive
- rough grass land and farm products; Farm house and benches; inaccessible;

Figure 74. Public open space analysis map

Site analysis

CONSTRAINTS AND OPPORTUNITIES

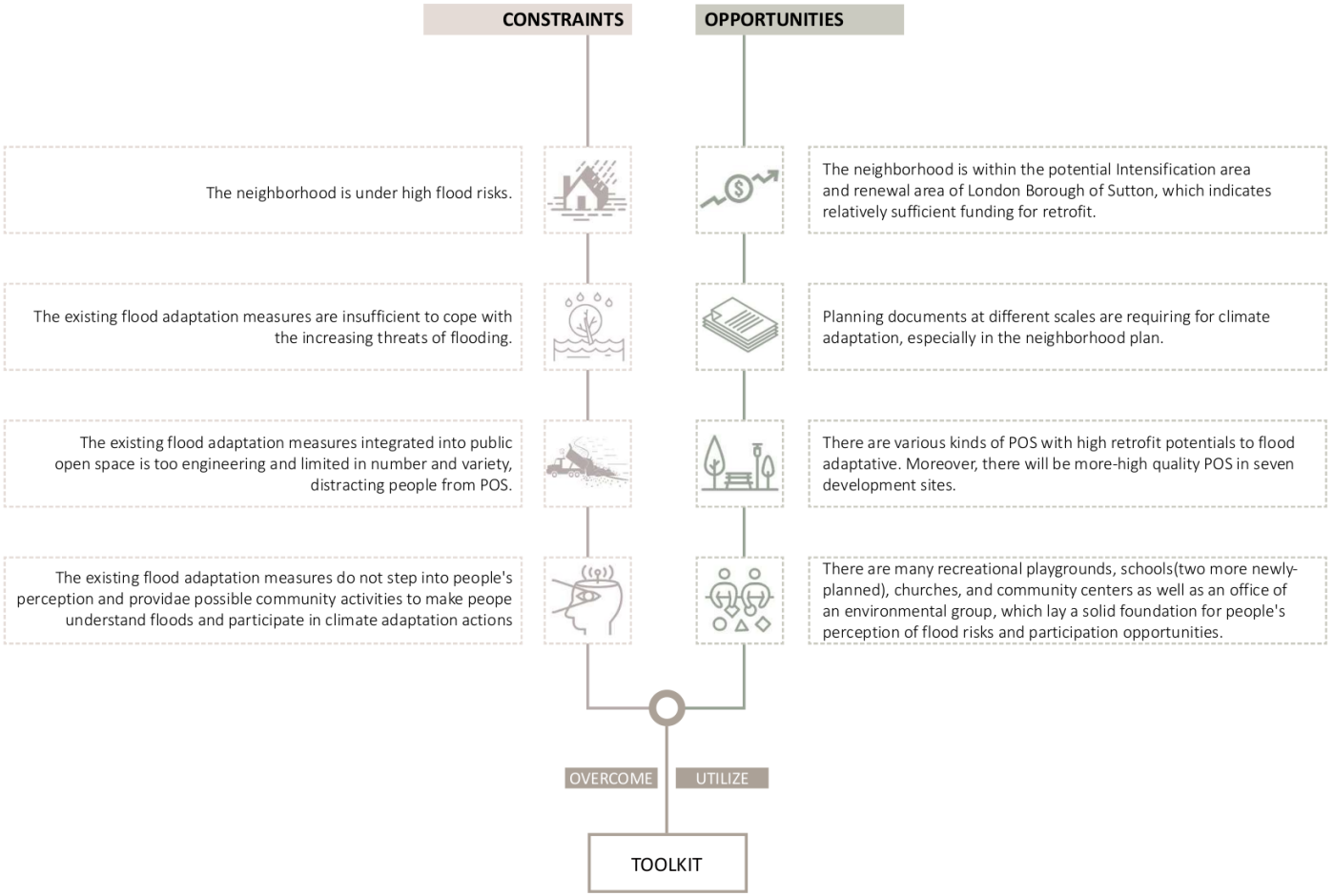


Figure 75.Constraints and opportunities

Design proposition

NEIGHBORHOOD SCALE | MEASURES FROM THE TOOLKIT

- BEFORE
- After


Figure 82(a)


Figure 83(a)


Figure 82(a)


Figure 83(a)


Figure 82(b)


Figure 83(b)


Figure 82(c)


Figure 83(c)


Figure 82(d)


Figure 83(d)


Figure 82(e)


Figure 83(e)


Figure 82(f)


Figure 83(f)

Figure 83. Scene photo (Google maps)
Figure 84. Vision (Pinterest)

1 - COMMUNITY ORCHARD

- Rough grassland >> bioretention basin;
- Accessible paths; more aesthetic natural elements; sustainable trips with free fruit-picking activities;
- Explanatory signages

2 - MILL GREEN PARK

- Rough grassland >> bioretention basin;
- Make existing watercourse accessible; more aesthetic natural elements;
- Explanatory signages and regular participatory activities in maintenance

3 - WATERCRESS PARK

- Playground and underused space >> artificial reservoir;
- Add sports, entertainment and social facilities
- Explanatory signages and perceptible site color and shape

4 - ORCHARD RECREATION GROUND

- Rough grassland >> dry bioretention basin and water-guiding swales
- More activity facilities;
- Explanatory signages and educational activities for nearby school

5 - ROADSIDE POCKET PARK

- Rough grassland >> dry bioretention basin;
- New accessible paths; more water-related activity facilities; mroe aesthetic natural elements;
- Explanatory signages

6 - PARKING LOT

- Cement road >> permeable paving
- Enhance aesthetics by vegetation;

7 - LEFTOVER GREEN SPACE

- Rough grassland >> rain garden;
- Enhance aesthetics by types of flora
- Explanatory signages and participatory maintenance activities with nearby community Centre

Figure 82. Overall flood adaptation infrastructural strategy map (Site No.1-7)

Design proposition

NEIGHBORHOOD SCALE | MEASURES FROM THE TOOLKIT

- BEFORE
- After

Figure 82(a)

Figure 83(a)

8 - MIX USE DEVELOPMENT SITES

- New buildings with rooftop detentions and ground floor open
- Activity facilities on the roof gardens; aesthetic natural elements;
- Explanatory signages

Figure 82(a)

Figure 83(a)

9 - WATERFRONT PROMENADES

- Street channel connecting nearby storage basin; floating islands and submergible paths
- Activity facilities to encourage interaction with water; accessible descending steps and floating islands; aesthetic shape of bank and floating structures.
- Explanatory signages and color to indicate water level change

Figure 82(b)

Figure 83(b)

10 - ALLOTMENTS

- Urban furniture for rain harvest and irrigation; street channel connecting other storage basins
- Aesthetic shape and lighting from furniture
- Explanatory signages; participatory activities with nearby school

Figure 82(c)

Figure 83(c)

11 - TWO NEWLY-PLANNED PRIMARY SCHOOLS

- New school buildings with rooftop detention;
- Aesthetic shape and color of vegetation;
- Explanatory signages; participatory and educational activities to disseminate flood-related knowledge.

Figure 82(d)

Figure 83(d)

12 - ORCHARD AVENUE

- Street channel connecting other storage basin;
- Explanatory signages; creative shape and color on channels

Figure 86. Scene photo (Google maps)

Figure 87. Vision (Pinterest)

Figure 85. Overall flood adaptation infrastructural strategy map (Site No.8-12)

Design proposition

SITE SCALE | SITE ANALYSIS AND CONCEPTUAL DIAGRAM

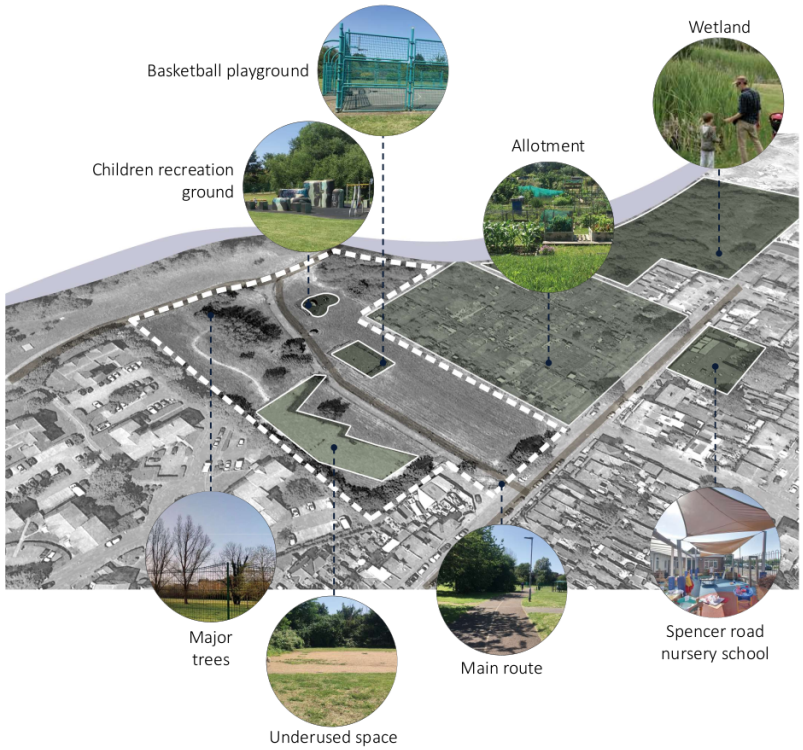


Figure 88. Site scale analysis map

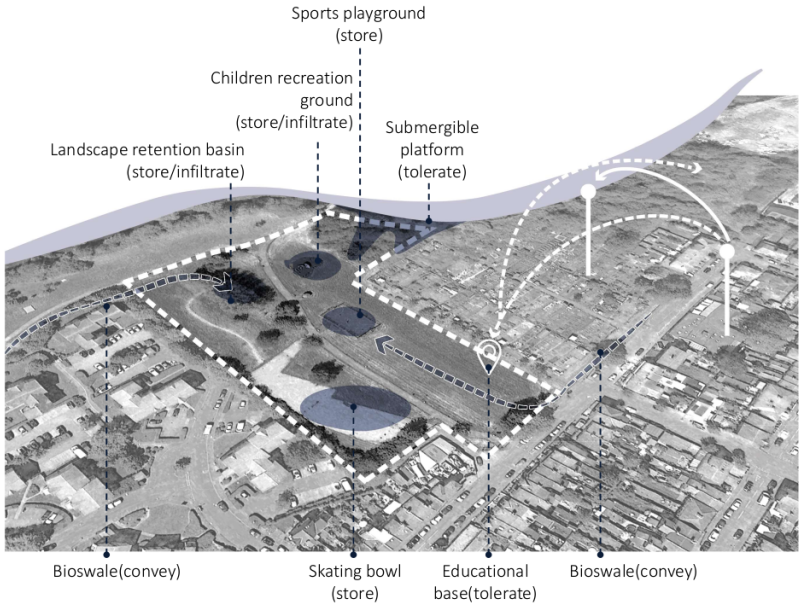


Figure 89. Conceptual diagram for design strategies

The park and its surrounding area are under high flood risk. As shown in Fig.107, It has various land use nearby, which attracts various groups of passers-by and participatory activities in the wetland and allotment. The existing facilities and activities lay a good foundation for introducing lively and perceptible flood adaptation measures. And the underused space also has great potential to be integrated with flood adaptation measures.

- Converting underutilized space and basketball playground into artificial reservoirs with sports facilities, and the latter one to receive stormwater from allotments via bioswales;
- Transforming the major tree area and existing child recreation ground to bio-retention basin, and the former one to receive stormwater from south residential areas.
- Transforming the inaccessible waterfront into the submergible platform to provide people with water-friendly activity space;
- Establishing an education base for the activities of students, volunteers and community workshops.

Design proposition

SITE SCALE | MEASURES FROM DESIGN TOOLKIT

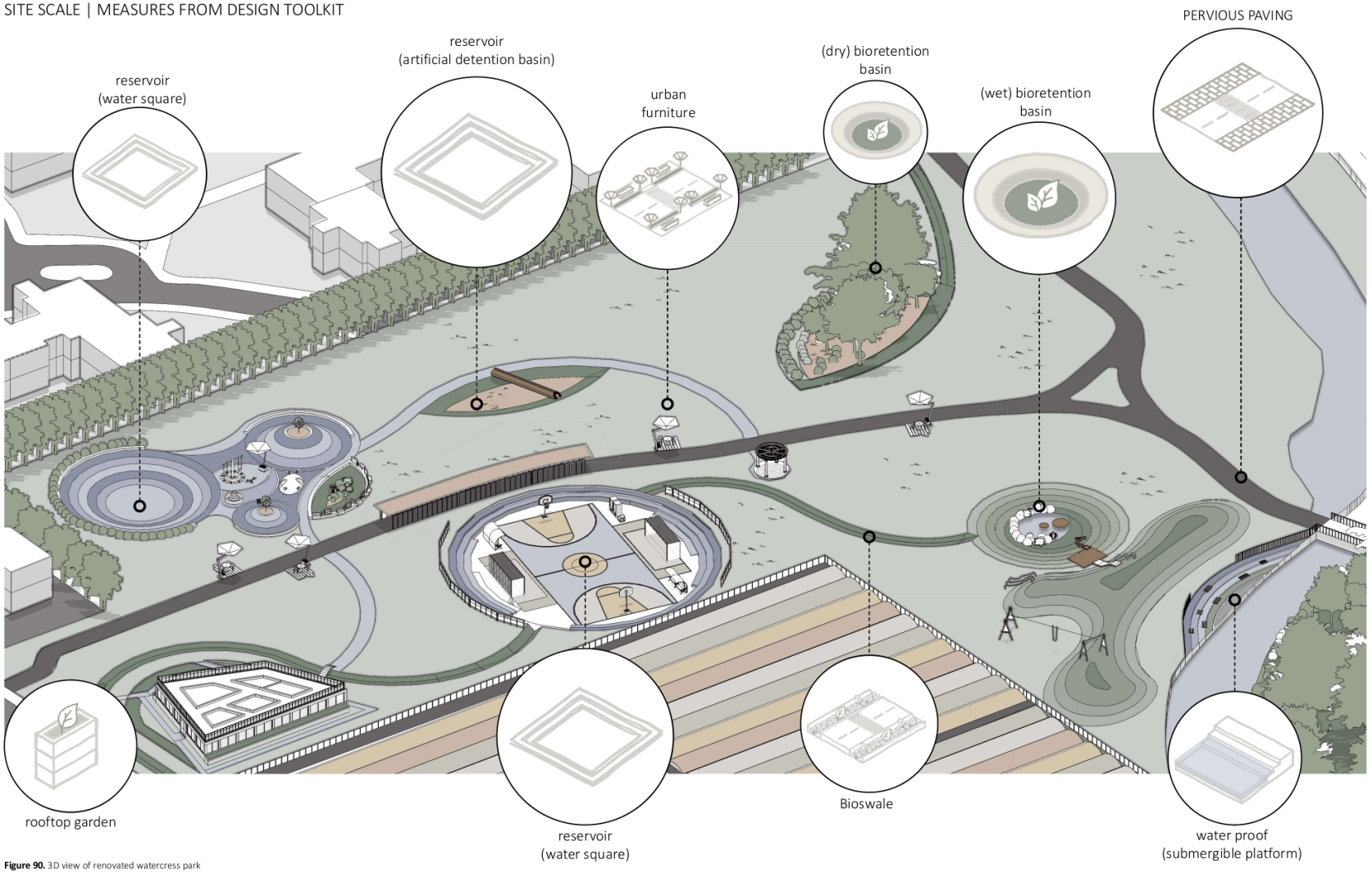


Figure 90. 3D view of renovated watercress park

Design proposition

SITE SCALE | SKATING BOWL

Figure 91. 3D view of skating bowl water square

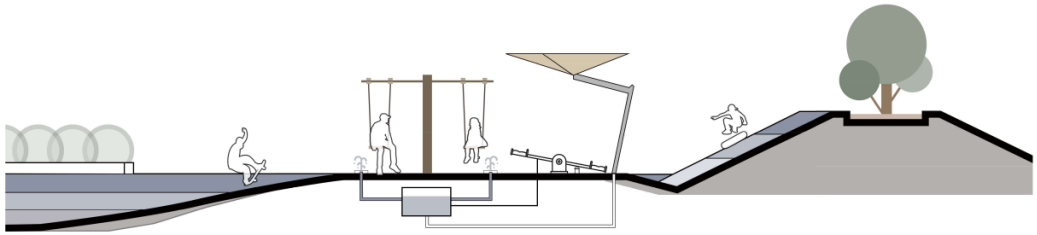


Figure 92. Sections of skating bowl water square

Flooding days	Sunny days
	
Figure 93. "Rain catcher" bench and bioretention basin can harvest and store stormwater on flooding days	**Figure 94.** "Rain catcher" bench can irrigate the plants and the billboard can serve as signages to disseminate knowledge of these flood adaptation measures on sunny days

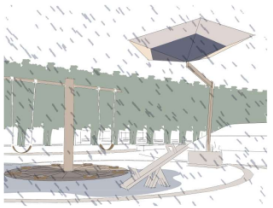
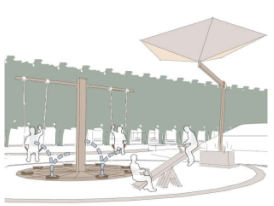

	

Figure 95. The inverted umbrella in the playing area can harvest, store and filtrate rainwater on flooding days	**Figure 96.** When children are playing the seesaw, the collected water from the umbrella will be pumped out of the fountains from underground.

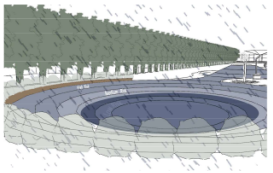
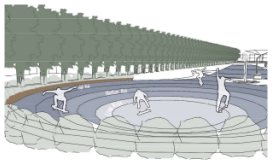

	

Figure 97. Skating bowl can temporarily store rainwater on flooding days and the colors ranging from light to dark indicate the level of flood risks to enhance people's perception towards floods.	**Figure 98.** On sunny days, people can skate in the bowl.

Design proposition

SITE SCALE | RECREATION GROUND & SUBMERGIBLE PLATFORM

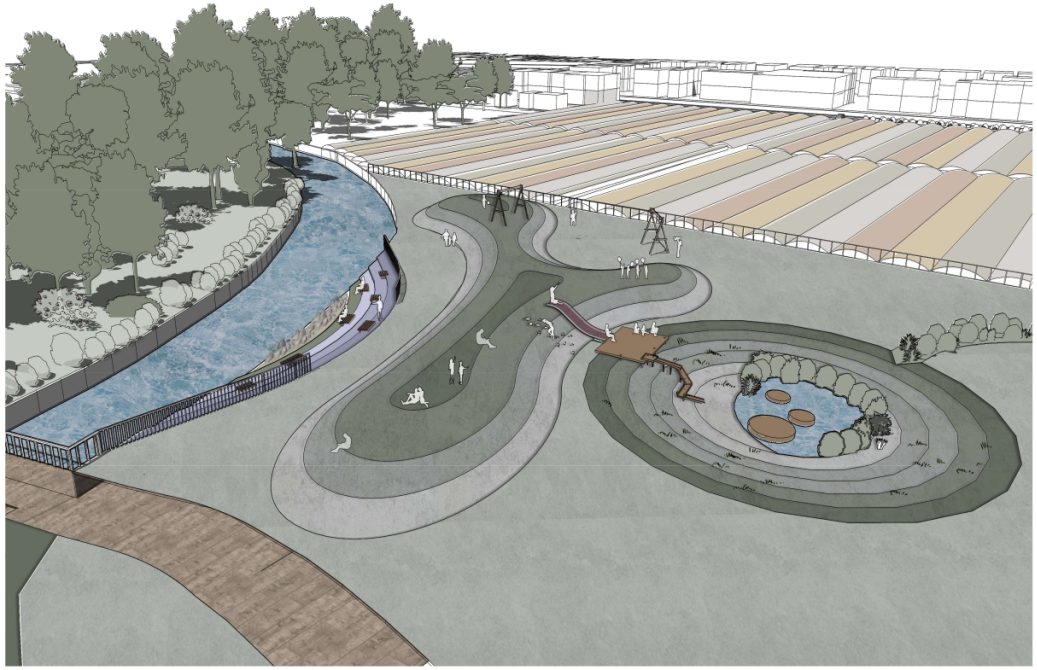


Figure 99. 3D view of waterfront submergible platform and wet retention basin

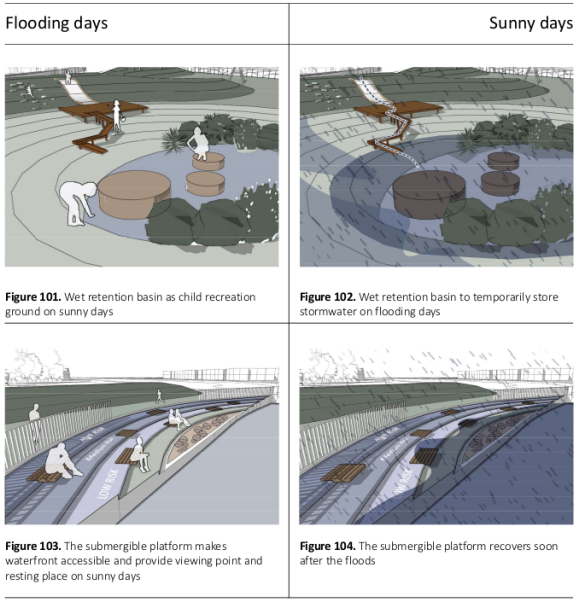


Figure 101. Wet retention basin as child recreation ground on sunny days

Figure 102. Wet retention basin to temporarily store stormwater on flooding days

Figure 103. The submergible platform makes waterfront accessible and provide viewing point and resting place on sunny days

Figure 104. The submergible platform recovers soon after the floods

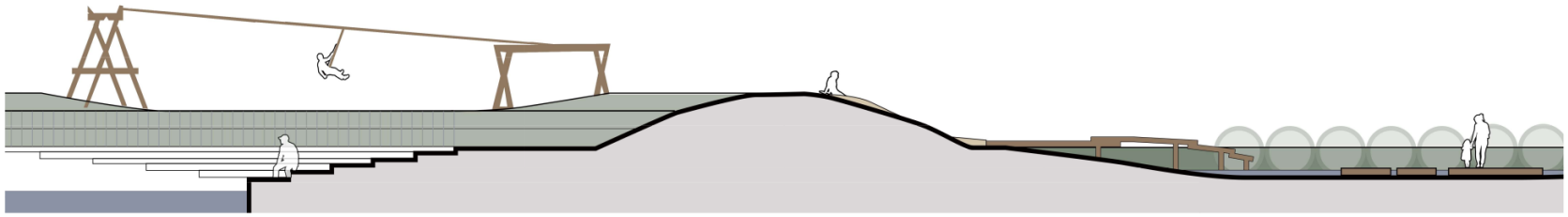


Figure 100. Sections of waterfront submergible platform and wet retention basin

Design proposition

SITE SCALE | WATER SQUARE & EDUCATIONAL BASE

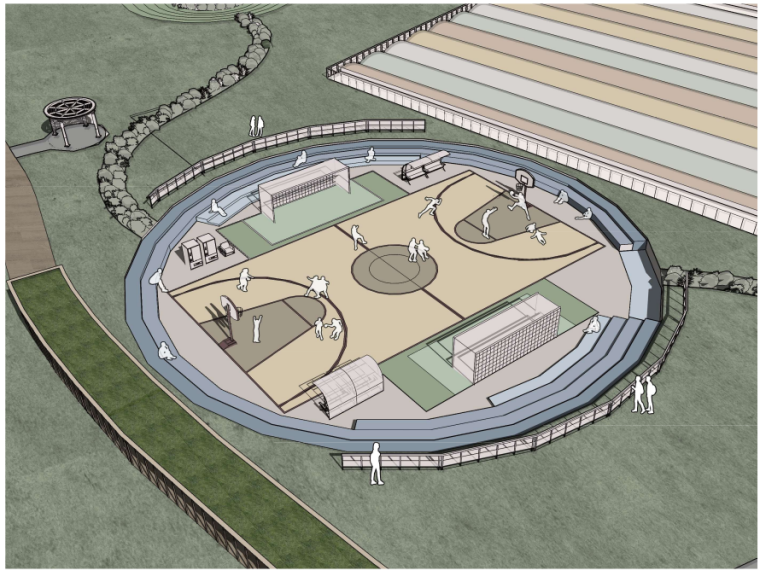


Figure 105. 3D view of water square (sports playground)

Flooding days

Figure 106. The water square can serve as sports playground and resting seats on sunny days

Sunny days

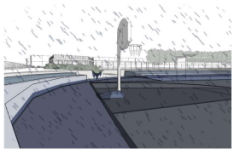


Figure 107. The water square can store stormwater on flooding days; The color of the steps from light to dark blue indicates its functions to do with floods and enhance people's perception.

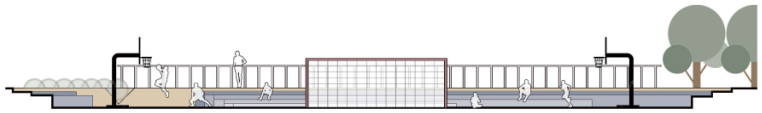


Figure 108. Section of water square (sports playground)

The planned educational base is a public building which is elevated 1 meter from the ground and has a rooftop garden, so it is flood adaptive. It can hold following activities: (1) Provide flood-related classes for two existing schools and two newly planned ones within walk distance; (2)organize maintenance activities of flood measures in the park, so that people can deepen understanding in practice; (2) hold workshops regularly to disseminate knowledge on flood and existing flood adaptive design; (3) Volunteer training for Spencer Road wetland. The building is small but has unlimited potential as a catalyst to stimulate flood perception and community participation.

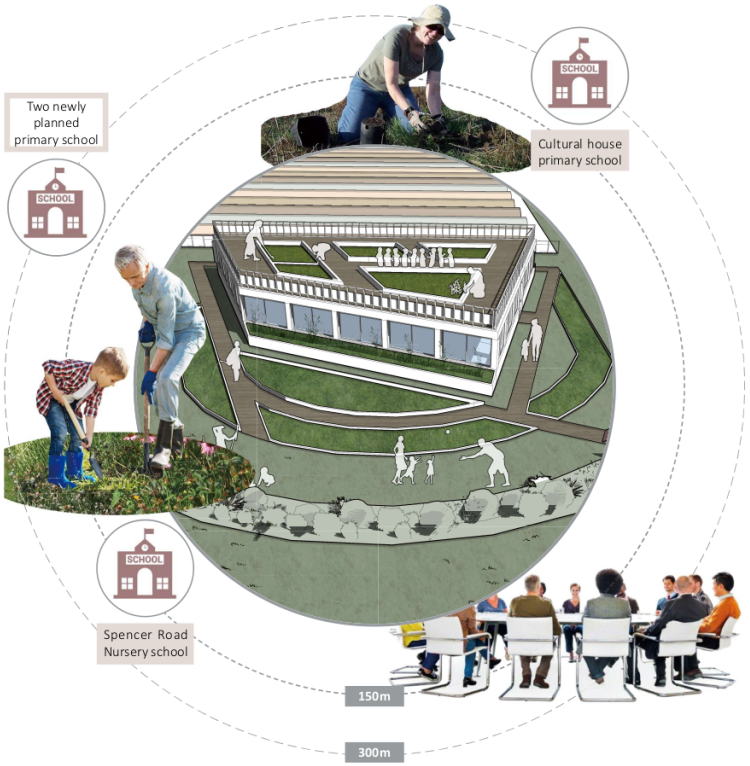


Figure 109. 3D view of educational base and potential activities

06

CONCLUSION

Summary at two scales

01 Neighborhood scale

- For the first objective to reduce flood risks, it is ideal to apply flood adaptation measures at the neighborhood scale to enhance overall flood adaptability. Since the neighborhood is at upstream of the River Wandle, not only the neighborhood but also areas in downstream areas can benefit from the measures. The reason lies in that the neighborhood has various kinds of public open space, those free of flood risks such as parks, squares, and recreational playgrounds, can be complementary to those under high flood risks with less available land. Meanwhile, the measures serving different flood adaptation infrastructural strategies can find a suitable place in public open space according to physical features and form an interconnected network to achieve higher benefits.

- However, its limitations in practice are apparent, as well. Firstly, residential areas within the strict road network are at high flood risks, whose main POS are streets. However, as most of these streets are only enough for traffic movement and roadside courtyard are private-owned, there are little space to put flood adaptation measures. Mostly, the pervious paving can serve to infiltrate stormwater, while its contributions to flood risk reduction are relatively small, especially when the underground drainage system is over-capacity. It is ideal to guide surface water to somewhere elsewhere free of flood risks, but conveyance channel is difficult to find its place given the street width, influence on walkability, typography, and adjacent effect. What is more, it brings about a new difficulty in the combination of new measures with the existing ones, which prevents it from making more significant benefits. So, the objectives could be achievable in development sites but less viable in areas with less available land.

- In terms of activating the liveliness of POS, the proposal of neighborhood-scale can put forward useful design guidance, but it is not detailed enough to respond to criteria of lively POS in the toolkit. Meanwhile, in terms of flood risk reduction and adaptation measures perception, the proposal at the neighborhood scale is mainly implemented at land use planning and the selection of intervention sites able to be perceived by most people.

- To conclude, the neighborhood-scale proposals are effective in reducing flood risks but are less helpful for the activation of liveliness and improvement of perception.

02 Site scale

- When considering within the selected site, all three design goals could be achievable at the site scale. Since the proposal at site scale is part of the system identified by the neighborhood-scale proposal, it is less helpful than a proposal at the neighborhood scale in reducing overall flood risks.

- However, its contributions to activating liveliness of public open space are viable and huge. Instead of having more land take and depriving green space of the original public open space, the site-scale proposal improves the liveliness of existing playgrounds and the underutilized leftover space through activity facilities, aesthetic values, and accessibility to people.

- As for the perception of flood risk and related adaptation measures, the newly-planned educational base surrounding by various flood adaptation measures, the knowledge-disseminating signages and billboards, and design responding to users' sensation, can all provide people with opportunities to know, to learn and to participate in the flood adaptation actions.

- Nevertheless, the implementation also has difficulties to overcome. Firstly, there are many measures related to harvest in this proposal, ranging from urban furniture to wet retention basin. As the collected water is easy to breed diseases and pests if stored for a long time, it will lead to low-quality landscape and drive people away. Also, the cost of regular maintenance will be high. Secondly, most of these measures are about earthwork and digging down, which requires a more detailed study of the geology and topography. Moreover, there is no grading or data calculation of river floods and rainfall in the analysis part. As several measures are connected, the sites initially used as reservoir likely deliver water to the outside instead.

- To conclude, the proposal at the site scale is crucial for liveliness and perception improvement.

General lessons learned and future research directions

- This major research project tried to cope with flood risks and the problems to integrate flood adaptation measures in POS. This project intended to take Hackbridge and Beddington Borner Neighborhood as an example to seek a design solution, which can apply to other areas under high flood risks. The project proposal aimed to integrate lively and perceptible flood adaptation measures in public open space to (1) reduce flood risks; (2)activate liveliness of POS; (3) enhance people's perception of both flood risks and functions of flood adaptation measures.

- Through substantial literature review, case study, and the formulated design toolkit, the implementation was at two scales, including neighborhood scale and site scale. Both of them tried to respond to the three objectives, but their performances are different. The proposal at neighborhood scale is effective in reducing overall flood risks while the one at site scale can provide thorough guidance on implementation and are more helpful in activating liveliness of public open space and enhancing people's perception of both flood risks and functions of adaptation measures.

- Given that their performances for each objective are different but complementary, a recommendation for areas under flood risks are to address the problem in both neighborhood and site scale, in which overall flood adaptability can be improved, and problems in integration can be solved.

- The following research should focus on the design difficulties and limitations mentioned in the summaries. At neighborhood scale, innovative design methods are required in conveyance channels and the combination of new and old measures. At the site scale, the design methods should be more scientific in calculations of stormwater volume and rate, analysis of site geology and typography to prevent the cost of excessive design or the negative impact of poor design.

Appendix Contents

Appendix-A

BENEFITS		DRAWBACKS	
Using land efficiently by allowing multiple uses of space within a constrained land supply			WSUD detracts from open space values
Creating functional landscape features and contributing to public open space amenity			Perceived increased public risk around detained or ponded water, or for water in flowing channels
Activating public open space with multiple uses and activities on more than one level			Concerns that stormwater within treatment systems is dirty
Creating opportunities for passive irrigation and water harvesting to improve water-use efficiency			Concerns that WSUD requires intensive and expensive maintenance
Reducing maintenance costs for local authorities by having less land to maintain.			Risks of poorly conceived, poorly designed and/or poorly delivered infrastructure that may fail or require costly rectification.
Providing opportunities for public education and awareness raising about the water cycle and contributing to sense of place.			

(Adjusted from Leinster et al.2010)

Appendix-B

Urban Greenery	Green walls
Urban Furniture	Inverted umbrella
	Art installation
Rooftop Detention	Green roof
	Blue roof
Reservoirs	Artificial detention basin
	Water plaza
	Underground reservoir
	Cistern
Bioretention	Wet bioretention basin
	Dry bioretention basin
	Bioswale
	Bioretention planters
	Rain garden
Pervious paving	Permeable paving
	Porous paving
Infiltration techniques	Infiltration trench
Stream recovery	Stream rehabilitation
	Stream restoration
	Daylighting stream

Open Drainage System	Street channel
	Extended channel Enlarged canal
	Check dam
Floating Structure	Floating pathway
	Floating platform
	Floating island
Wet Proof	Submergible park
	Submergible pathway
Raised structures	Cantilevered pathway
	Elevated promenade
Coastal defense	Multifunctional defense
	Breakwater
	Embankment
Flood wall	Sculptured wall
	Glass wall
Barrier	Demountable barrier
Levee	Gentle slope levee

(Matos Silva and Costa, 2016)

DANQING LI
URBAN DESIGN AND CITY PLANNING
THE BARTLETT SCHOOL OF PLANNING
UNIVERSITY COLLEGE LONDON