CLOUDBURST RESILIENCY PLANNING STUDY

EXECUTIVE SUMMARY

Environmental Protection

RAMBØLL

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Prepared by Ramboll A/S

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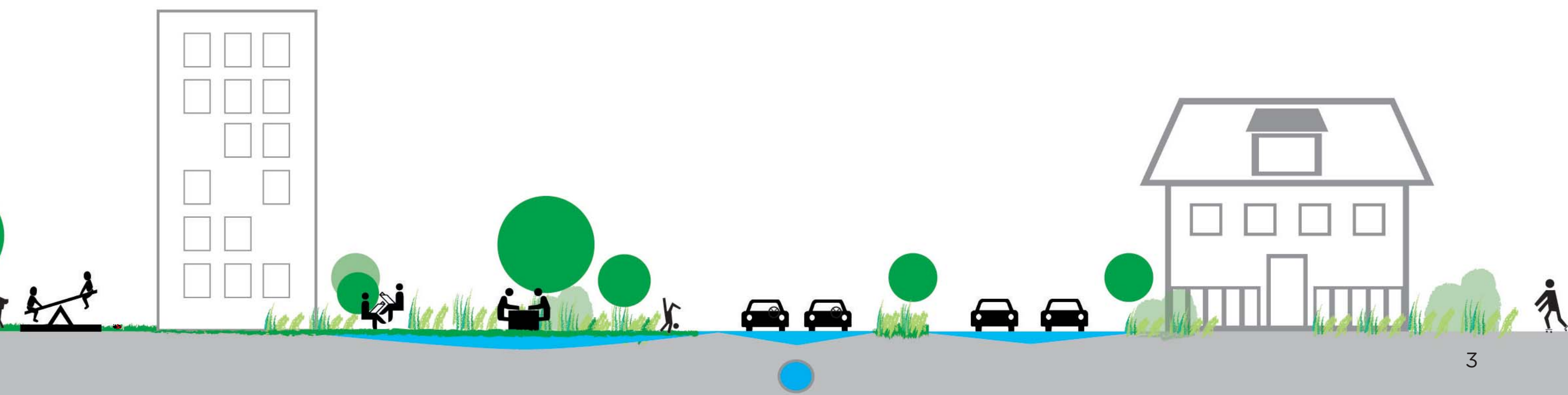


INTRODUCTION

FOREWORD

New York City faces increasing risks from the impacts of global climate change. Recent storms, including heavy rain events and coastal flooding, demonstrate that the city's water and wastewater system has risks from extreme weather that must be addressed through implementation of further climate adaptation interventions. Heavy rainfall events ("cloudbursts") can inundate urban areas and potentially cause severe damage.

The NYC Department of Environmental Protection (DEP) has started to develop innovative solutions to heavy rainfall and associated physical and societal impacts by conducting the Cloudburst Resiliency Planning Study, focusing on a pilot area in Southeast Queens.

The purpose of this project is to provide insight on ways to advance climate resiliency projects and traditional stormwater solutions to mitigate inland flooding and accommodate future increase in rainfall intensity through integration with ongoing urban planning and development. This executive summary describes the process and findings from the Cloudburst Resiliency Planning Study carried out by Ramboll in 2016. The methodology builds upon Ramboll's experience and city-to-city collaboration regarding cloudburst solutions development for the City of Copenhagen.

The study is developed in close cooperation between DEP, Ramboll Water and Ramboll Management, and Arcadis. Several NYC agencies have provided crucial input in the process along with the City of Copenhagen. We would like to extend our gratitude towards all the contributors.

All monetary values are shown in US dollars.

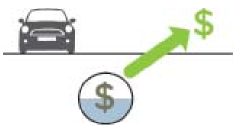
Children interact with the water features at Queens Botanical Garden

BACKGROUND & REASONING

DEP is seeking to address intense rainfall through integration of traditional underground drainage infrastructure with above-ground solutions into ongoing urban infrastructure planning. The focus is to enhance stormwater management through storage and surface flow conveyance, whilst creating inspiring urban areas with co-benefits for the citizens, local businesses, and the city.

The Cloudburst Resiliency Planning Study analyzes best-available data related to NYC rainfall, recommends methodologies for incorporating findings into ongoing resiliency planning initiatives, and identifies best practices for considering climate change in future neighborhood-specific planning studies. As an outcome of the study, opportunities for intervention are identified within the designated study area to provide retention and conveyance for extreme conditions, while also offering community and environmental benefits in normal conditions.

The study is designed around two main pillars: **Integrated Planning (IP)** and **Blue-Green Infrastructure (BGI)**. In trying to understand the potential of integrated planning of BGI in NYC, the following questions were used to guide the study:

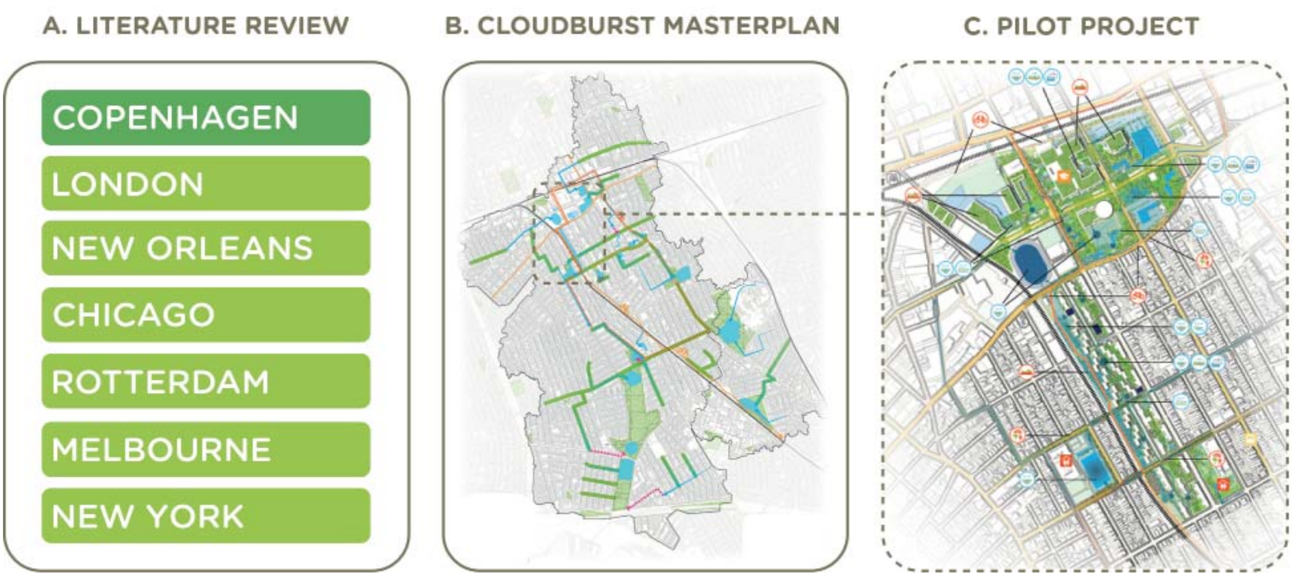


1. Is it possible to achieve greater urban value and co-benefits for capital investments by using BGI for stormwater management?

2. Is it possible to add a buffer from extreme rain events using BGI for a similar budget as traditional stormwater infrastructure?

3. Is it possible to increase cooperation across city agencies and stakeholders and maximize output of invested money through IP?

The study findings are communicated through three overall deliverables: (A) a literature review summarizing challenges and approaches from six cities that are leading the world on climate change, (B) a cloudburst masterplan for a selected study area, and (C) conceptual designs for pilot project areas.



KEY CONCEPTS

Integrated Planning (IP) comprises a system of interlinked actions which seeks to bring about a lasting improvement in the economic, physical, social, and environmental conditions of a city or an area. In IP, all policies and projects are considered in relation to one another.

Based on principles of sustainability, **LIVEABILITY** describes the living conditions of communities including their physical and mental well-being. Liveability depends on an integrated and balanced approach to the different elements of a city.

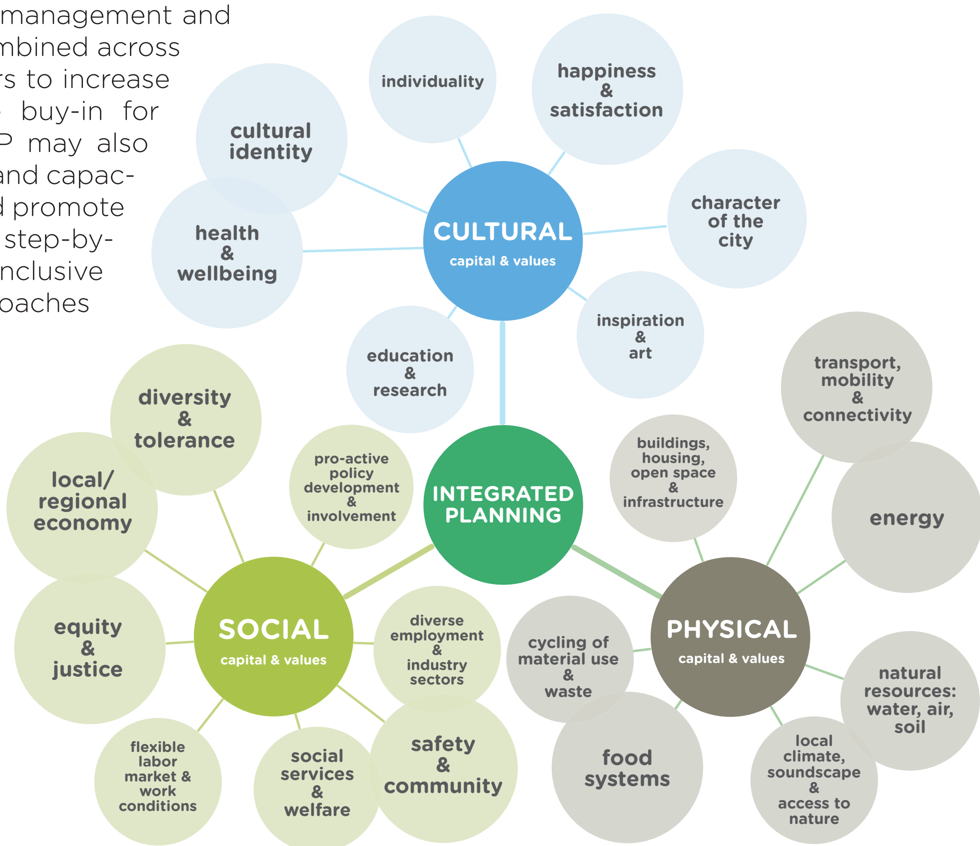
Creating liveable urban environments encompasses a wide range of interrelated aspects of city life from governance, economy and planning to physical infrastructure, sustainable buildings, climate adaptation and environment. An integrated and balanced approach to these elements enables cities to develop and prosper sustainably, and thus, IP is becoming an inherent part of urban planning. The Environmental Protection Agency (EPA) for instance has promoted the benefits of incorporated IP in local efforts to comply with the Clean Water Act.

By applying IP to cloudburst management and planning, budgets may be combined across city agencies and stakeholders to increase available funds and provide buy-in for agencies and stakeholders. IP may also foster increased cooperation and capacity building across the city and promote movement from traditional step-by-step, silo planning to more inclusive and interdisciplinary approaches across all agencies involved.

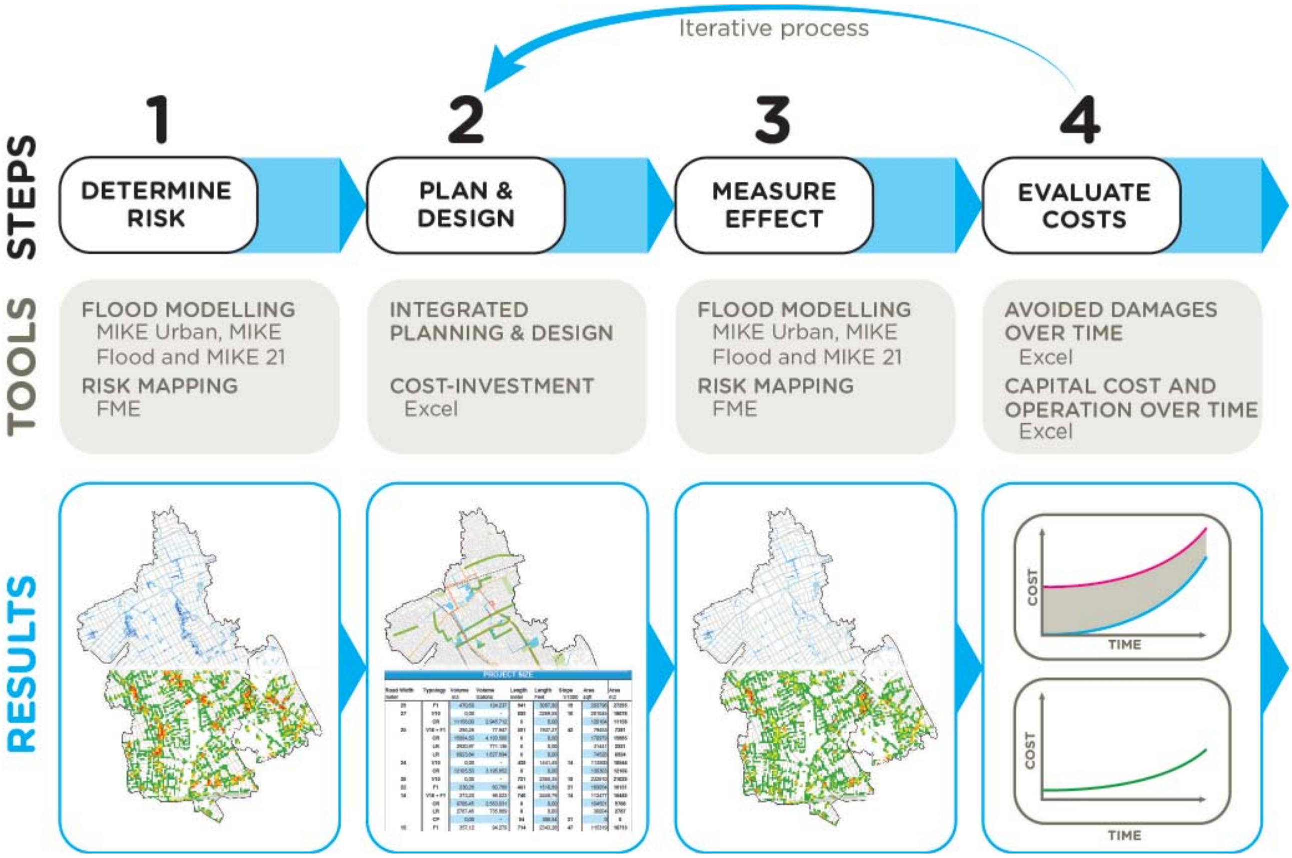
Blue-Green Infrastructure (BGI) connects urban hydrological functions (blue) with vegetation systems (green) and offers valuable solutions for urban areas facing the challenges of climate change. BGI generates social and environmental value for the local area, and may often reduce the need for traditional grey infrastructure.

BGI is often used in isolation or implemented in a spatially dispersed manner. **A cloudburst masterplan refers to a network of BGI projects** that provides an additional buffer on top of the storm sewer network.

Copenhagen, a leading city in storm-water management, uses the term "**CLOUDBURST**" for an extreme amount of rain in a short period of time. As this study builds on experiences from Copenhagen, the term is also used throughout this project.



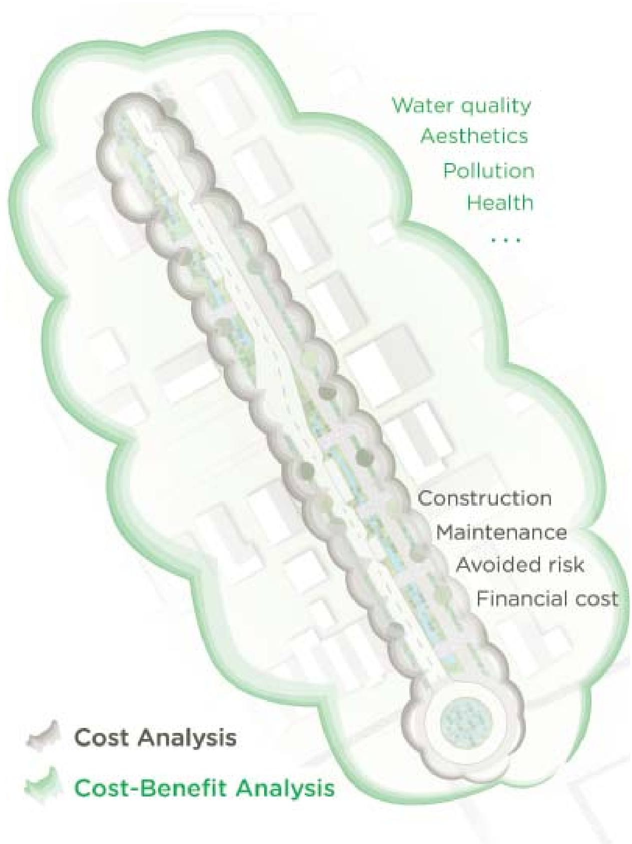
THE CLOUDBURST RESILIENCY APPROACH



A **4-step approach to cloudburst resiliency planning** was applied based on experiences from Copenhagen and abroad. GIS data act as the foundation of the study and are crucial in providing a solid basis for informed decision-making. Spatial overlay of datasets and analyses at multiple levels help to identify potential synergies and cumulative effects.

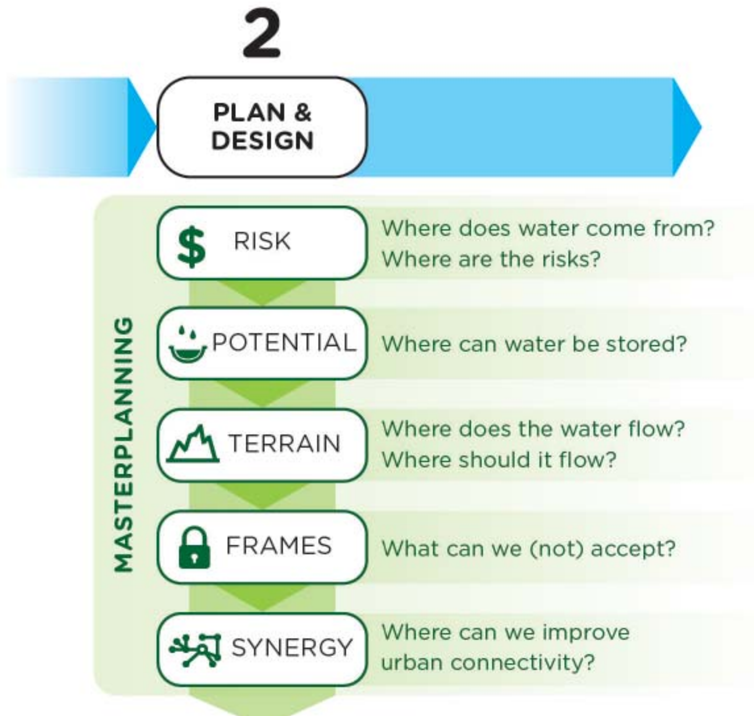
The figure above illustrates the **iterative process** of moving from initial determination of risks, to the development of a resiliency plan, and documenting the adaptation effect. The outcomes are incorporated into a Direct Cost Analysis comparing investment and avoided damage costs over time. If the effect or cost of the developed plan does not meet predetermined standards or thresholds, Step 2 is repeated in order to adjust designs and plans.

It is often valuable to take the analysis a step further and evaluate co-benefits as a result of the masterplan in a **Cost-Benefit Analysis (CBA)**. A CBA includes the direct costs in the project area and extends to the broader social impacts of a masterplan (see right).



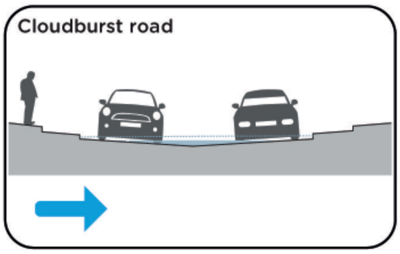
CLOUDBURST MASTERPLANNING

A crucial part of the 4-step process is the creative Plan & Design phase (Step 2). Step 2 has dual purpose: Developing a masterplan, and estimating associated capital investment and operational costs. The figure to the right summarizes the overall considerations shaping the actual design of a masterplan. Relevant stakeholders go through the process of understanding where flood waters flow, where water can be stored or conveyed, which limiting or supporting frameworks or decisions apply, and finally where connections to other plans for the urban environment can be established, such as parks or bike lanes. Stakeholders might go through the process several times as the design must be updated when new knowledge is obtained.

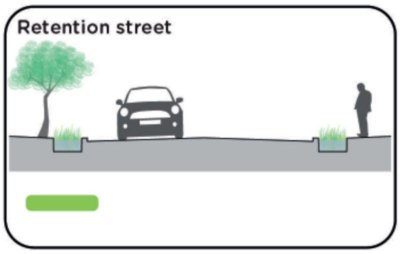


CLOUDBURST MASTERPLAN ELEMENTS

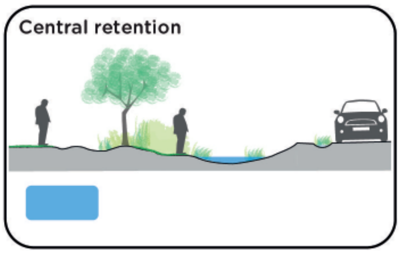
Stakeholders map their cloudburst management approach using predefined BGI elements to store or convey water. The BGI elements include cloudburst roads, retention streets, and central and local retention. The network of BGI solutions may be supplemented with grey infrastructure such as cloudburst pipes.



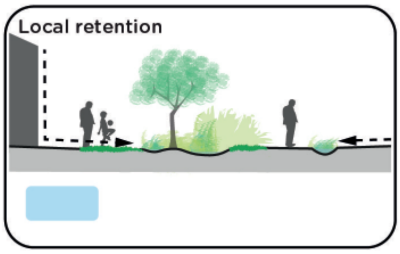
Used to convey water where terrain is favorable



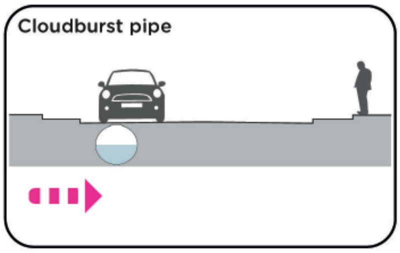
Used to retain water where terrain is favorable



Used to retain water in a larger area connected to other BGI projects



Used to retain water in larger areas from roofs and local surroundings



Used to convey water where terrain does not permit BGI projects

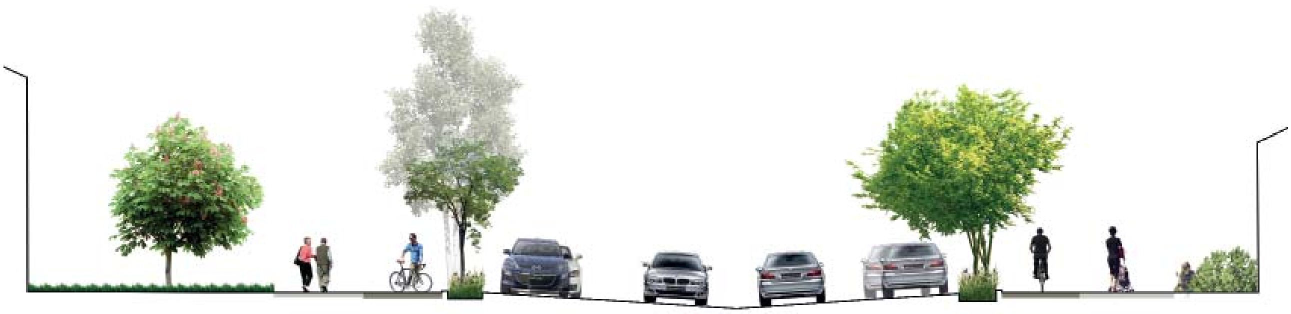
DESIGN EXAMPLES

Tanner Springs Park in Portland, Oregon, is situated in an area that was once a wetland. Due to urbanization the wetlands were slowly filled and Tanner Creek was rerouted. Today, the park serves as a **central retention** and recreational area with art performances on the floating deck, and grass areas and paddle pools for everyday recreation.

In this **retention street** in suburban Copenhagen rainbeds separate the sidewalk and bike path from the main road and increase road traffic safety, while filtering and retaining rainwater.

Rainbeds serve as **local retention** in Freiburg Zollhallenplatz in Germany, where rainwater is cleansed and filtered before it reaches the groundwater. No stormwater is discharged to the sewer system, even during heavy rainfall.

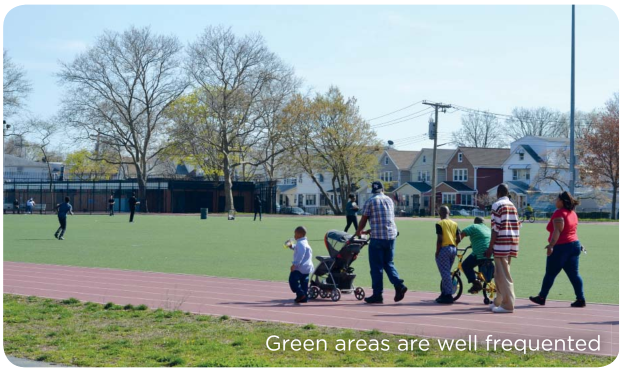
Sankt Annæ Plads in Copenhagen has been turned into a **cloudburst street**, where rainwater runs from the roads on each side to a wide lowered grass area in the middle.

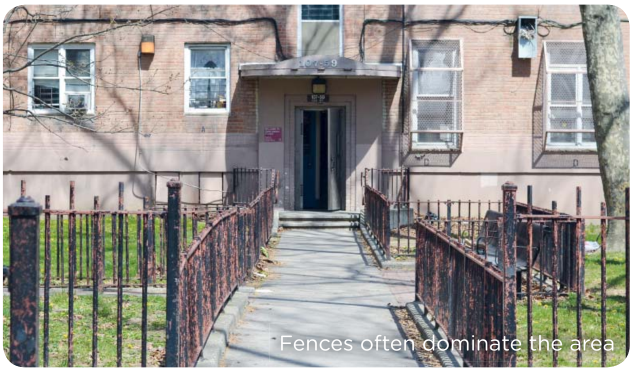


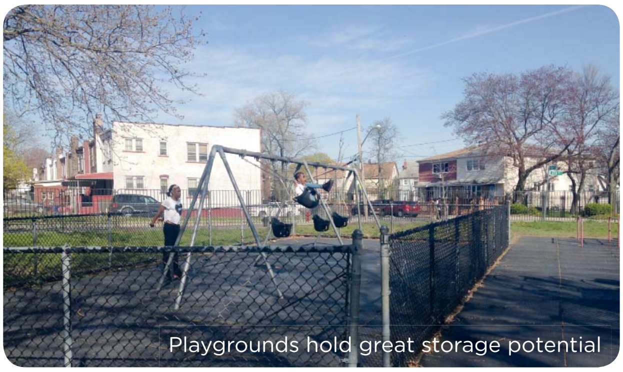
Illustrative example of a cloudburst road

CLOUDBURST RESILIENCY PLANNING

STUDY AREA


Green areas are well frequented


Fences often dominate the area


Playgrounds hold great storage potential

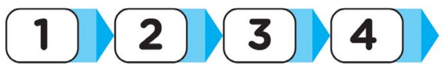

Fences often dominate the area

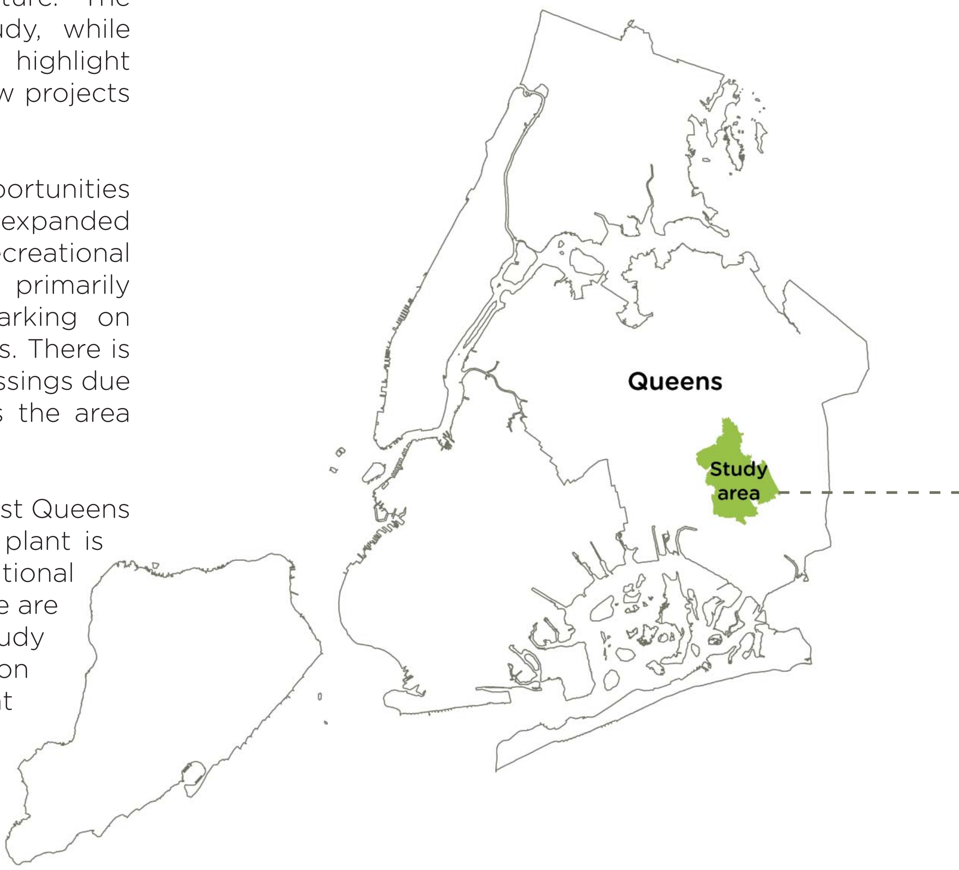
The area spans over 3,200 acres and is home to approximately 110,000 people. The long-term strategy for this area is to reduce chronic flooding through sewer built-out, complemented with innovative, site-specific solutions, such as Bluebelts and green infrastructure. The Cloudburst Resiliency Planning Study, while conceptual, is also intended to highlight potential opportunities to include new projects in the ongoing work in this area.

The study area may also present opportunities to align cloudburst projects with expanded biking paths and improvement of recreational spaces. The roads in the area are primarily residential two-way streets with parking on both sides, street trees, and sidewalks. There is an east/west division with limited crossings due to the railroad tracks cutting across the area from north to south.

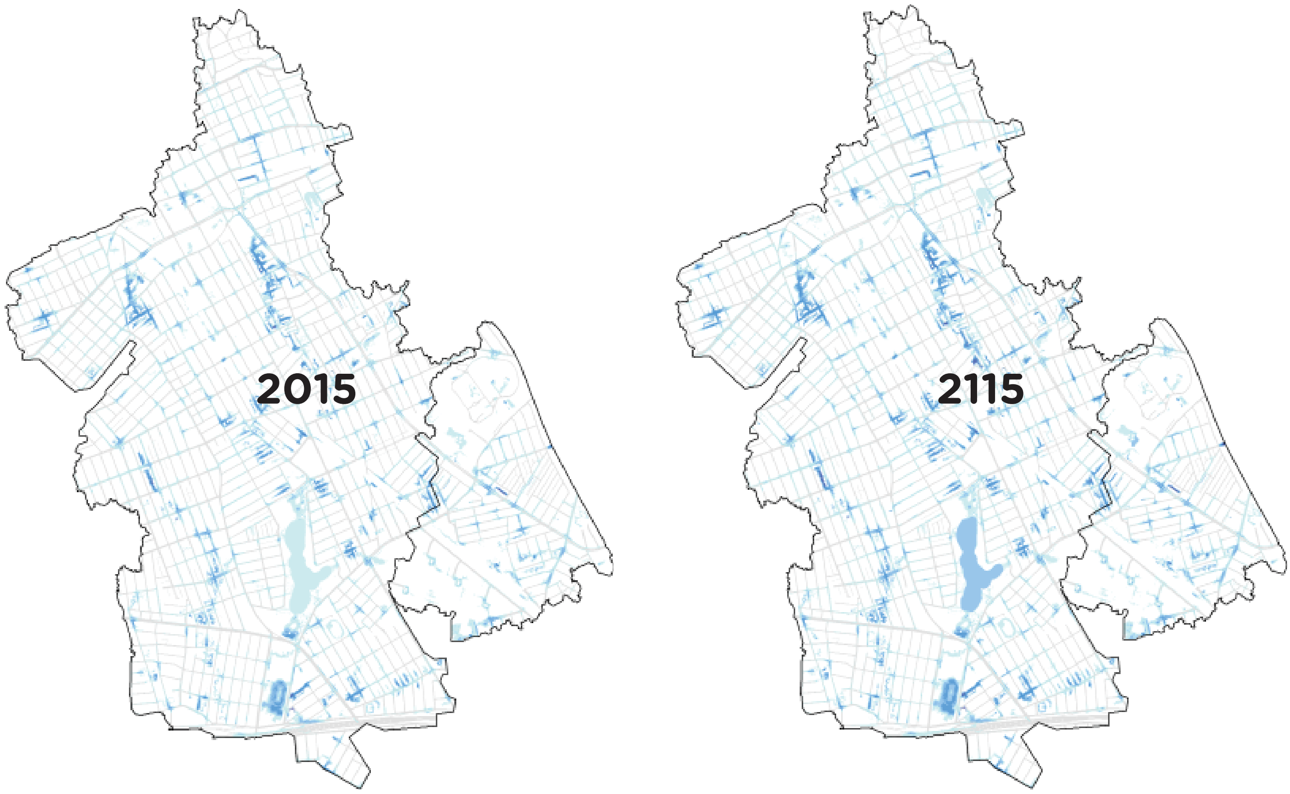
Stormwater from this area of Southeast Queens drains to Jamaica Bay. A treatment plant is located near John F. Kennedy International Airport, south of the study area. There are no stormwater pumps within the study area but St. Albans pumping station is located just outside the catchment and pumps into the sewer network in the study area.

On the following pages the 4-step approach presented on page 7 is applied to the study area in Southeast Queens .

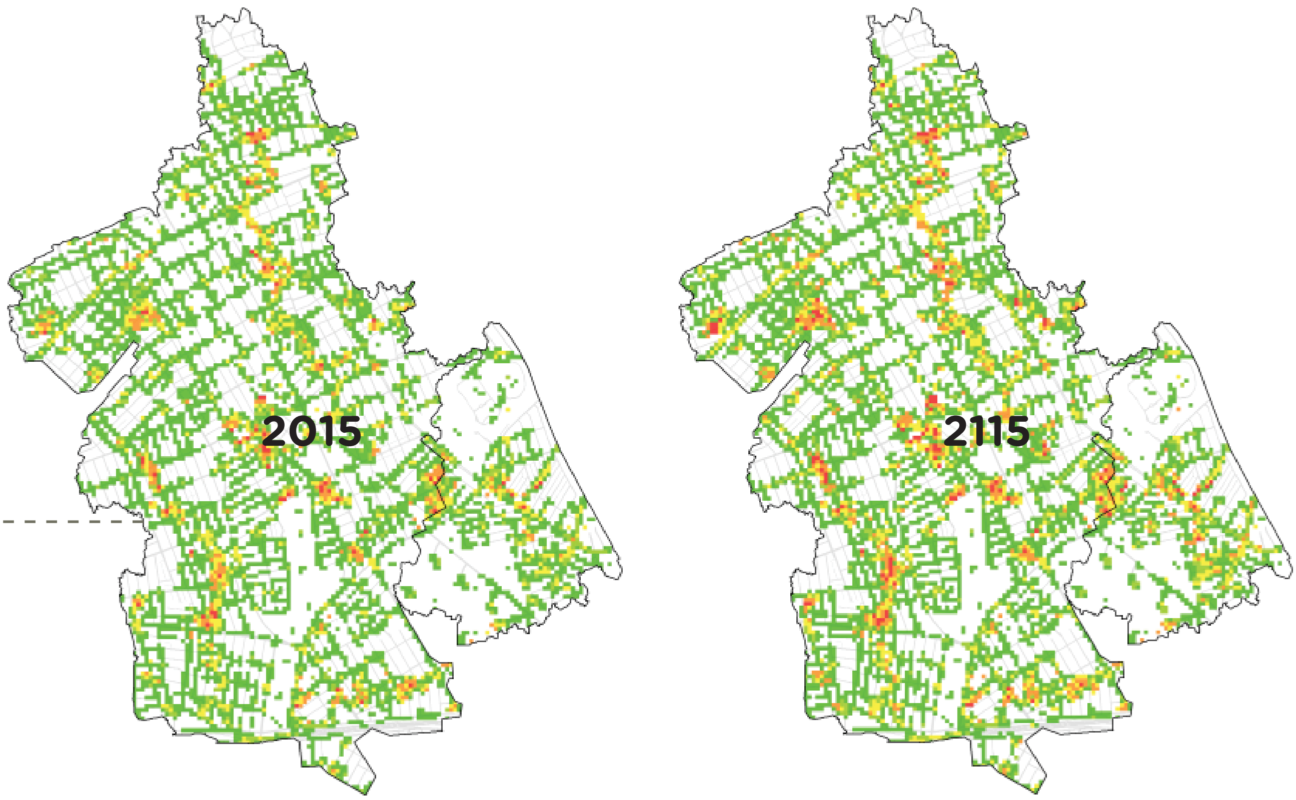




1 DETERMINING RISK



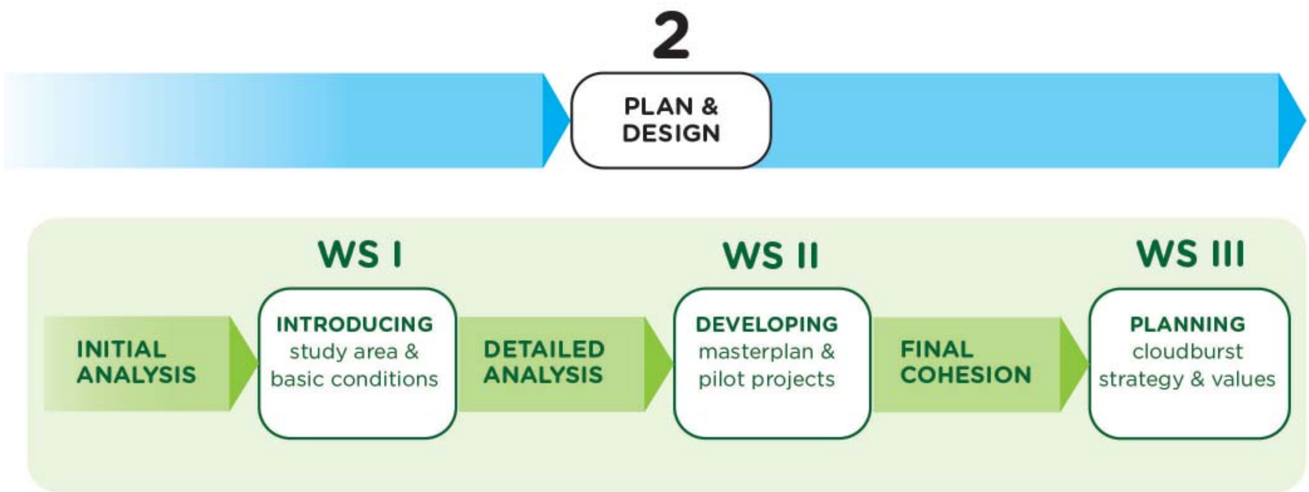
The hydraulic models simulate a cloudburst flood, defined as a 100-year storm in the years 2015 and 2115. While the model setup is advanced, the simulation results are rough estimates based on coarse GIS data of the sewer system combined with a digital terrain model.



The risk mapping is based on hydraulic results for a 10, 50, and 100-year storm in 2015 and 2115, and coarse land-use data combined with rough estimates of potential damage costs. The color scale indicates risk in terms of damage costs from green (low) to red (high).

2 PLANNING & DESIGN

In the 4-step approach to cloudburst resiliency planning, Steps 1, 3, and 4 are of technical character and, as such, relatively similar from project to project. Step 2, on the other hand, is a creative phase that needs to be adapted to reflect the context and nature of the local environment to which it is applied. For the Cloudburst Resiliency Planning Study, the process is designed around three stages of analysis connected via three workshops with stakeholders.



Workshop I was held to review basic data and literature and to gather input on additional information to advance the project. The purpose of the first workshop was to supplement computational data with local knowledge and identify opportunity areas and challenges.

Outputs from Workshop I were combined to produce the first draft of the Cloudburst Masterplan and pilot designs. These results were presented at Workshop II, where stakeholders were invited to further develop the plans and designs, and consider other aspects of cloudburst resiliency planning, e.g. key values and thresholds. At this workshop, it was agreed to use a 100-year storm as the safety level for the Cloudburst Masterplan.

SAFETY LEVEL refers to the return period, including potential climate factors, used as design criteria for a resiliency plan. In general, the higher the safety level, the higher the capital investment costs.

Ultimately, the input from Workshop II was used to finalize the plans and merge the designs to be presented at Workshop III, which focused on strategic planning and next steps. On the following pages, the three stages are presented with findings and associated figures.

LITERATURE REVIEW

City	Adaptation strategy year	Extreme rain terminology	Return periods: Drainage	Return periods: Safety level
COPENHAGEN	2009	Cloudburst	5	100
LONDON	2011	Heavy rain // extreme rain	30	30-100
NEW ORLEANS	2009	Heavy rainfall // rainfall storm		10
CHICAGO	2003	Heavy rain // extreme rain event	5	100
ROTTERDAM	2008	Extreme rainfall // heavy downpour	2	100
MELBOURNE	2009	Overland flow // flash flood // storm	5	100
NYC	2007	Heavy downpour // cloudburst	5	100*

**As designated for the purpose of this study*

To understand how other cities have confronted similar challenges, the study team researched 30 publications describing climate impacts and solutions for six leading cities in the field of climate adaptation: Copenhagen, London, New Orleans, Chicago, Rotterdam, and Melbourne. The six cities have all weathered extreme rain events in the past, and some of the cities are also dealing with sea level rise and extreme heat events. The findings were presented at Workshop II to discuss and establish terminology, values, and thresholds relevant to this study (above).

As this study builds on experiences from Copenhagen and findings in the literature review, stakeholders agreed to use the term "cloudburst" to refer to extreme rain and to use the design criteria of a 100-year storm, which is the safety level most often used by the case study cities.

The literature review also compared relevant water parameters for NYC and Copenhagen in order to understand the scale of impacts and solutions in the two cities (below).

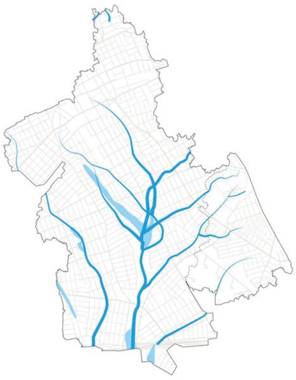
Parameter	CPH	NYC
Population size (million people)	1.2	8.6
Area size (square miles)	40	300
Price of 100 cubic foot of water (USD)	16	10
Length of sewer network (thousand miles)	2	7
Number of wastewater treatment plants	3	14
Wastewater design capacity (million gallons/day)	270	1800
Combined sewer overflows (million gallons/year)	0.3	20
Stormwater design standard (years)	5	5
100-year storm event in 2015 (inches/hour)	2.0	3.0
100-year storm event in 2115 (inches/hour)	2.4	3.5

INITIAL ANALYSIS & WORKSHOP I

In the Initial Analysis phase, background data such as land-use, terrain, infrastructure, and reports of flooding were mapped. By overlaying GIS data, problem and opportunity areas were communicated visually.

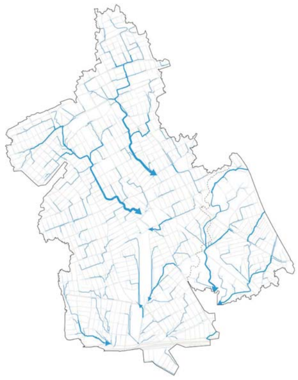
Maps were presented at Workshop I to illustrate the current level of knowledge of the study area and to supplement with new knowledge from stakeholders. Participants then mapped and sketched their input to the masterplan design as well as individual BGI projects.

Historic waterways

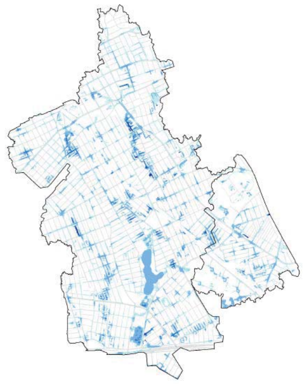


Elevation map

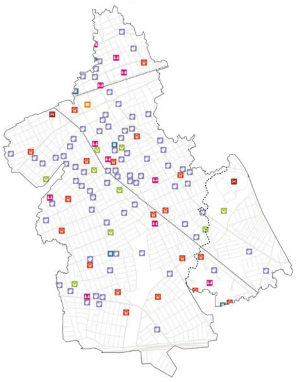
Terrainbased flowlines



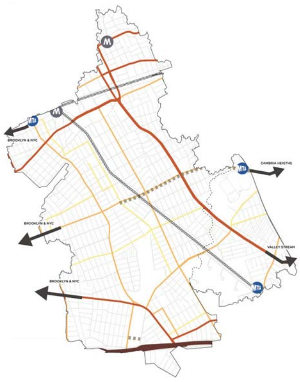
Cloudburst flooding in 2115



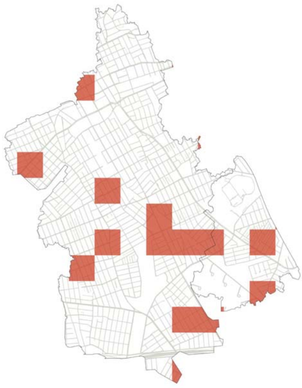
Social infrastructure



Transport infrastructure

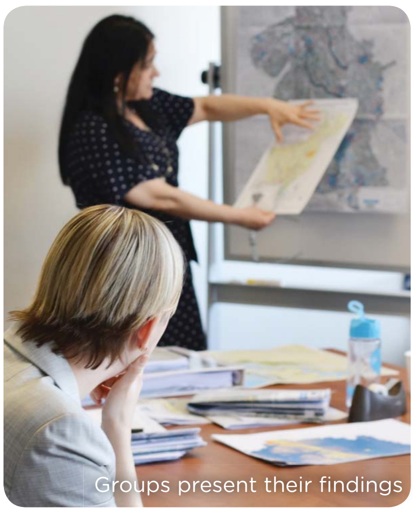


Areas with reports of flooding



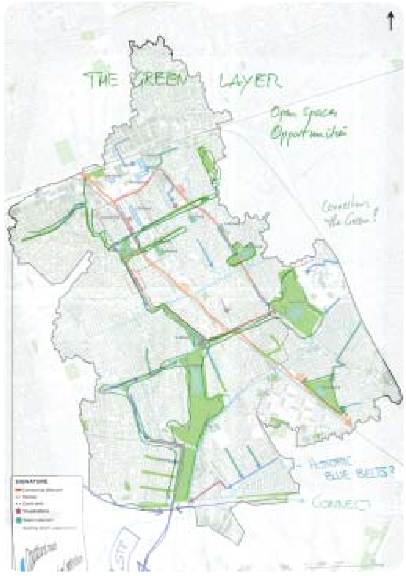
Green connections

Hand sketches illustrate potential BGI in roads



Groups present their findings

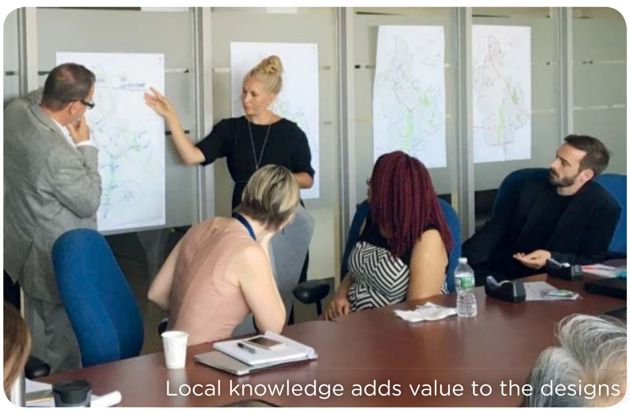
DETAILED ANALYSES & WORKSHOP II

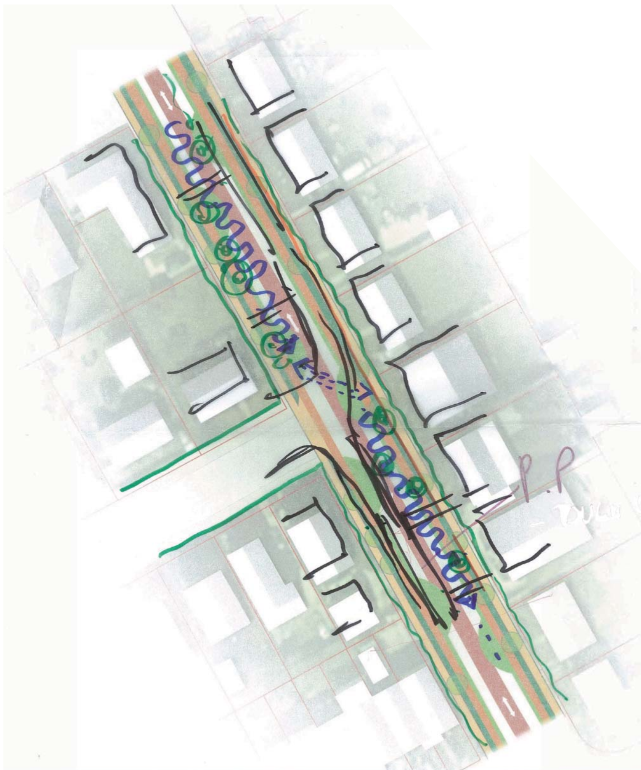


In the Detailed Analysis phase, outputs from Workshop I were supplemented with flood modelling results, illustrating spatial flood dynamics over time. Complex GIS models were then used for **risk mapping**. By looking at the probability and consequence of flooding on a cell-by-cell basis, the yearly damage costs associated with flooding over time could then be estimated.

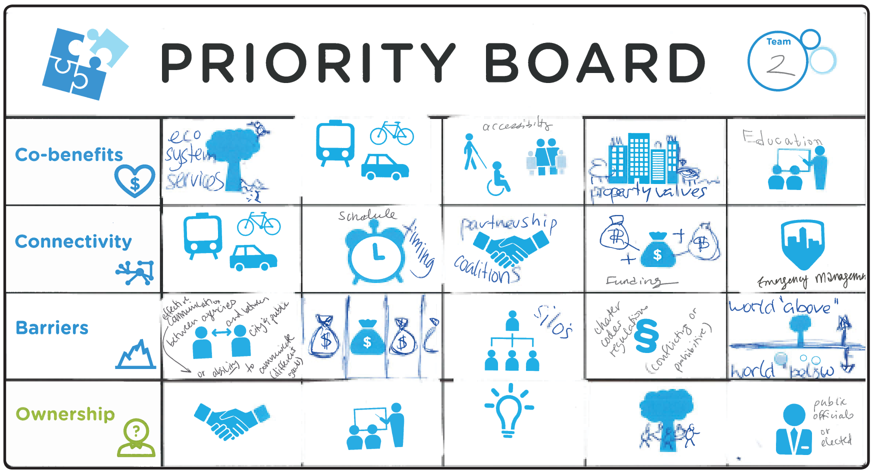
At Workshop II the initial masterplan and pilot project designs were presented. Participants supplemented the designs with additional thoughts on functions, opportunities, and synergies.


Design experts present their proposal


Local knowledge adds value to the designs


Hand sketches illustrate potential in design roads

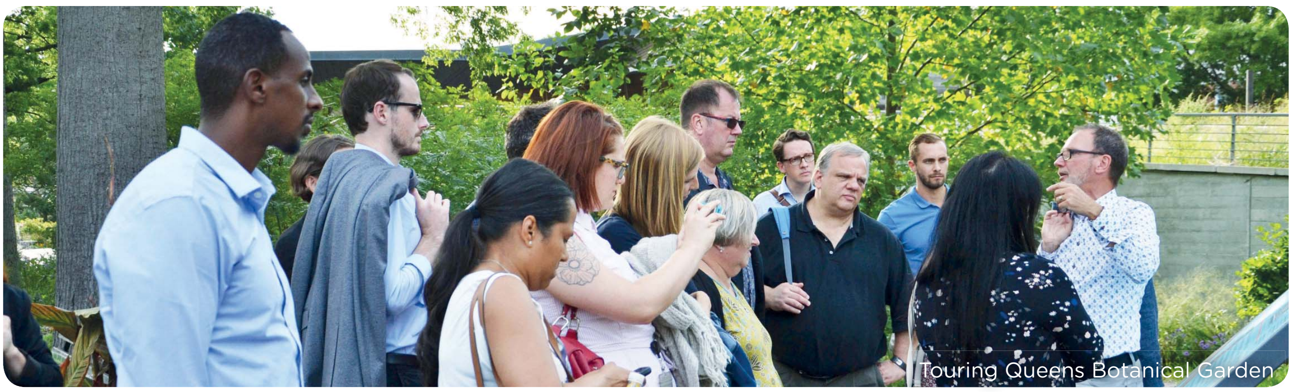
FINAL COHESION & WORKSHOP III



In the Final Cohesion phase, revised designs and additional inputs from Workshop II were used to develop the final masterplan and pilot project designs presented at Workshop III.

A clear strategy for systematic planning and implementation is an important aspect in order for cloudburst resiliency planning to be effective. At Workshop III the participants built a citywide Cloudburst Strategy using a Priority Board for brainstorming and a Strategy Folder for key messages and implementation steps.

In general the participants welcomed a new planning approach, but were concerned about budget and responsibility sharing. There is a joint perception that increased collaboration will provide multiple benefits for the citizens and for the city as a whole.

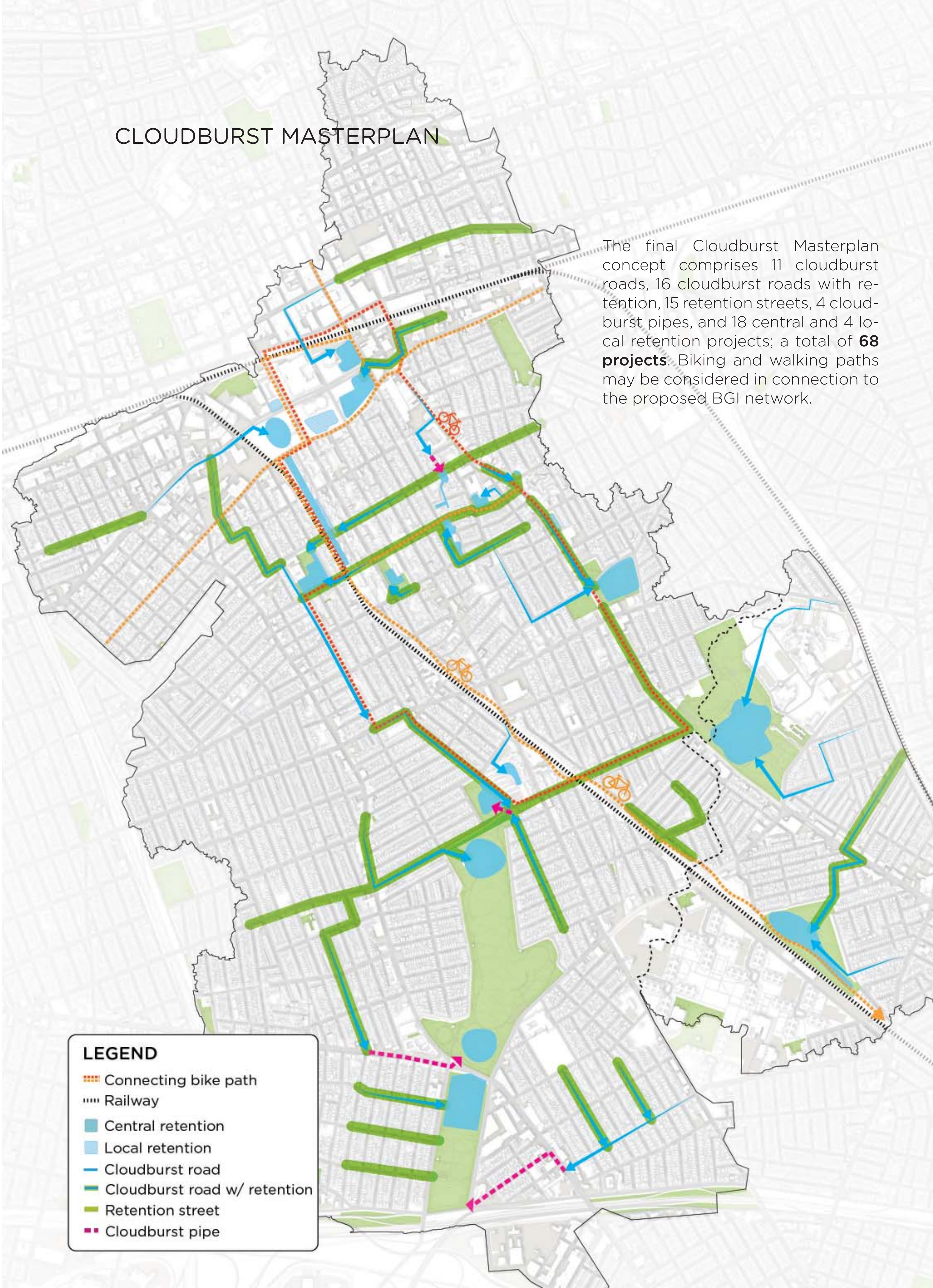

Touring Queens Botanical Garden


Stakeholders prioritize elements of cloudburst planning


Stakeholders envision implementation strategy

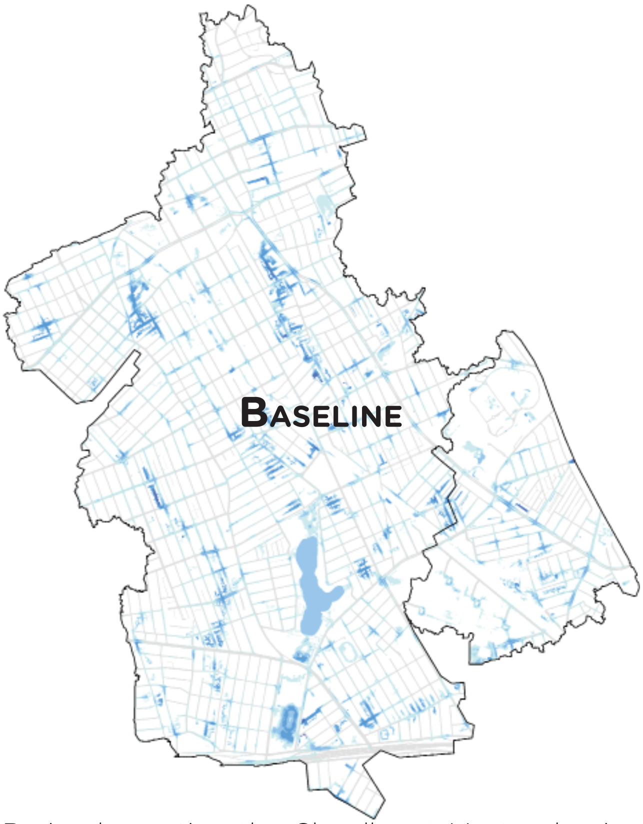
CLOUDBURST MASTERPLAN

The final Cloudburst Masterplan concept comprises 11 cloudburst roads, 16 cloudburst roads with retention, 15 retention streets, 4 cloudburst pipes, and 18 central and 4 local retention projects; a total of **68 projects**. Biking and walking paths may be considered in connection to the proposed BGI network.



3 MEASURING EFFECT

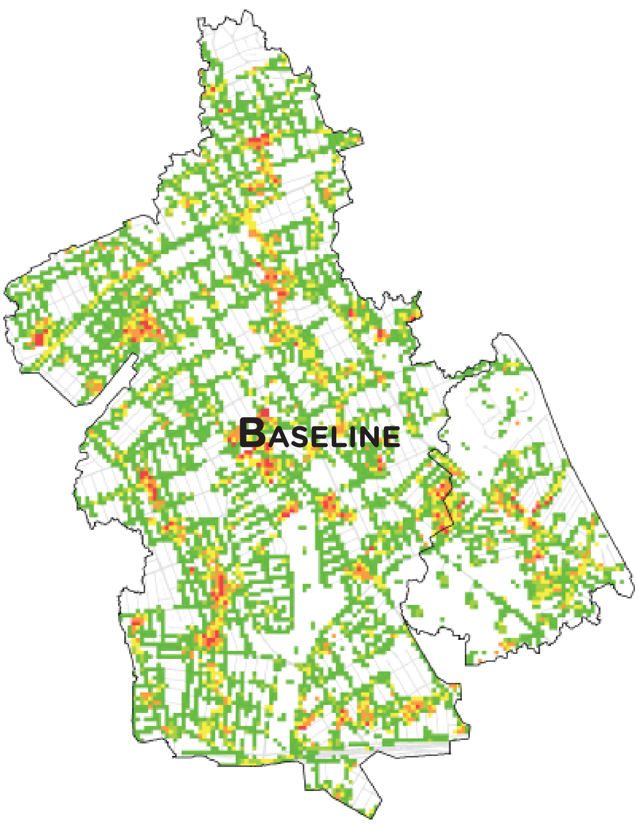
CLOUDBURST FLOODING 2115

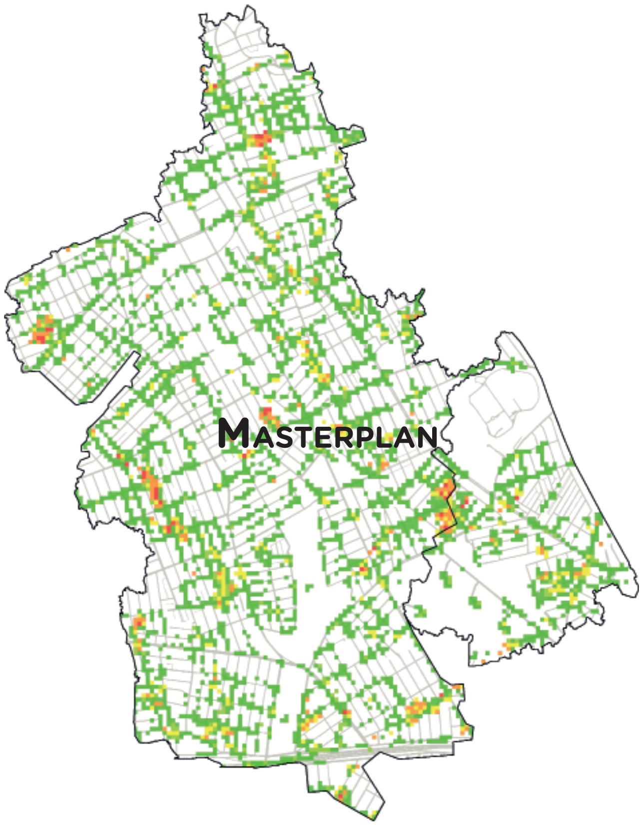


By implementing the Cloudburst Masterplan in the hydraulic model, the effect of the plan can be simulated. The maps show the impacts of a 100-year storm in 2115 in baseline conditions, and after implementation of the masterplan.

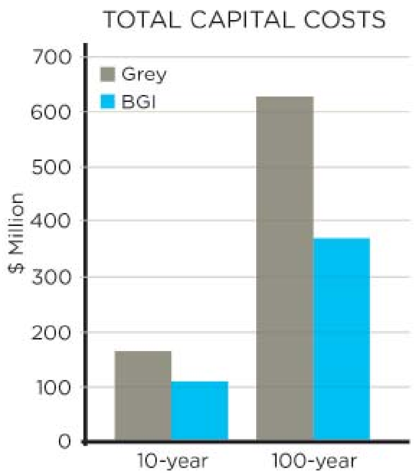
The associated risks are determined based on the cloudburst flood results, and illustrated in the maps below. The color scale indicates risk in terms of damage costs from green (low) to red (high).

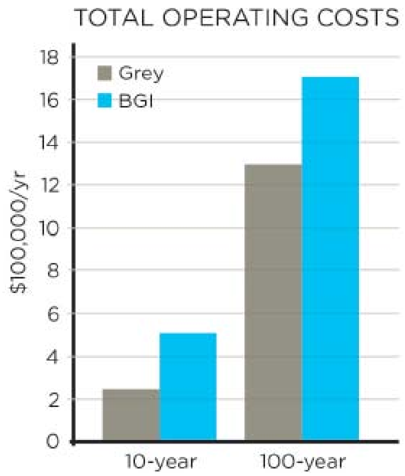
RISK ASSESSMENT 2115

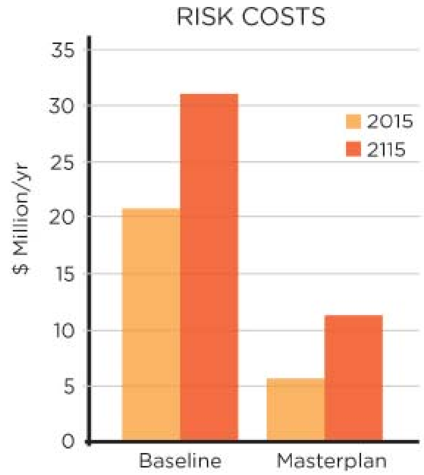




4 EVALUATING COSTS







The last step of the 4-step approach is a to evaluate costs. Capital, operational, and financing costs are compared to the avoided risk costs over time in a Direct Cost Analysis. Capital costs cover implementation, whilst financing costs cover potential loans and interests.

Based on the study assumptions, the Cloudburst Masterplan designed to a 100-year storm costs approximately $370 million in capital investment costs (left plot) and $1.7 million/yr in operational costs (middle plot). Over the 100 year period with a discount rate of 7% and including financing costs, the **total present value of the costs of the Masterplan is approximately $330 million**.

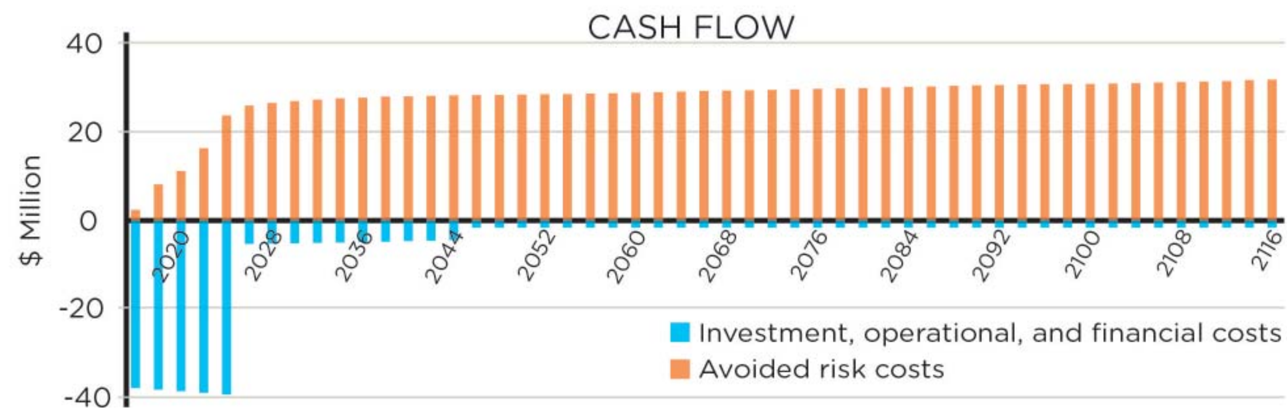
It is approximately double the cost to build the Masterplan using grey infrastructure rather than BGI (left plot). On the other hand, yearly operational costs are roughly 30% higher for BGI than grey infrastructure (middle plot).

If the masterplan was designed to a 10-year storm ($110 million) instead, it would reduce absolute capital costs to about a third (left plot).

As point of reference, the NYC's 10-year Capital Strategy designed to safeguard roughly the same area to a 5-year storm using grey infrastructure is about twice the price of the Cloudburst Masterplan. The masterplan go above and beyond the Capital Strategy and might be considered as alternative solutions for funded projects not yet scoped.

The avoided risk is calculated as the present value of the damage costs over the project time (right plot), subtracted from damage costs over time without implementation (Baseline) of the Cloudburst Masterplan. Baseline damage costs increase roughly by 50% from 2015 to 2115. The damage costs are reduced by 75% after implementing the Masterplan in 2015 and by 70% in 2115. The **risk over the entire period of 100 years total approximately $310 million** in net present value.

The result of the Direct Cost Analysis shows that the present values of the direct costs over the entire period is a **net loss of $20 million** (see cash flow below).



COST-BENEFIT ANALYSIS

COSTS & BENEFITS

In order to evaluate the full impact of the Cloudburst Masterplan a Cost-Benefit Analysis (CBA) is performed. A CBA differs from a Direct Cost Analysis by considering also the **social and environmental costs and benefits associated with a project.** It is a strong tool to communicate the wider social impacts and co-benefits of a masterplan to relevant stakeholders and decision-makers. It provides an overview of the complete business case of the masterplan for society. In this CBA the masterplan is compared to a baseline scenario which describes the situation without the masterplan. In this case the baseline scenario is a "do-nothing" scenario.

	Avoided costs			Created values	
	ECONOMIC RISKS	SOCIAL	ENVIRONMENTAL	SOCIAL	ENVIRONMENTAL
Benefits	Physical damages Output loss	Injuries Mental stress and anxiety	Improved water quality control	Health benefits Recreational value Aesthetic value	Pollutant removal Carbon sequestration

In a CBA all negative impacts are considered a cost, whilst all positive impacts are considered a benefit, including avoided direct costs. Hence, only investment, operational, and financing costs make up the **COSTS** in a CBA, and the present value of the costs of the Cloudburst Masterplan is $330 million over the entire period.

It is worth noting that the investment costs are relatively high as it is very costly to adapt to a 100-year safety level.

BENEFITS include the avoided risks and also cover the positive impacts of the created social and environmental co-benefits. Added benefits arise from the positive effect Blue-Green Infrastructure has on the local community and society as a whole. These include improved health, recreational, and aesthetic values, as well as pollutant removals and carbon sequestration (see above).

Based on the study assumptions the avoided risk costs total $310 million, the avoided social and environmental costs total $290 million and the created social and environmental values total $3 million. **In total the benefits provide a positive impact of $603 million.**

COSTS	$M
Investment costs	-280
Operational costs	-20
Financial costs	-30

Note that the avoided risk costs are relatively low compared to other cloudburst adaptation studies. This is partly due to the fact that the study area is not a densely built out area.

Also, there are other co-benefits that have not been monetised in this CBA, e.g. the impact on real estate prices, and impacts of increased biking. These effects could further increase the total benefits related to the Cloudburst Masterplan.

The costs and benefits are listed below.

BENEFITS	$M
Avoided risk costs	310
Physical damages	185
Output loss	125
Avoided social costs	290
Injuries	90
Mental stress and anxiety	200
Avoided environmental costs	0.02
Improved water quality	0.02
Created social values	2.5
Health benefits	0.0
Recreational value	1.9
Aesthetic Value	0.6
Created environmental values	0.3
Pollutant removal	0.1
Carbon sequestration	0.2

ANALYSIS OUTCOME

The CBA shows that when socio-economic parameters are included, the project provides a return. **The Net Present Value is $273 million, with a benefit-cost ratio of 1.8**. The key figures from the CBA are illustrated in the table (right).

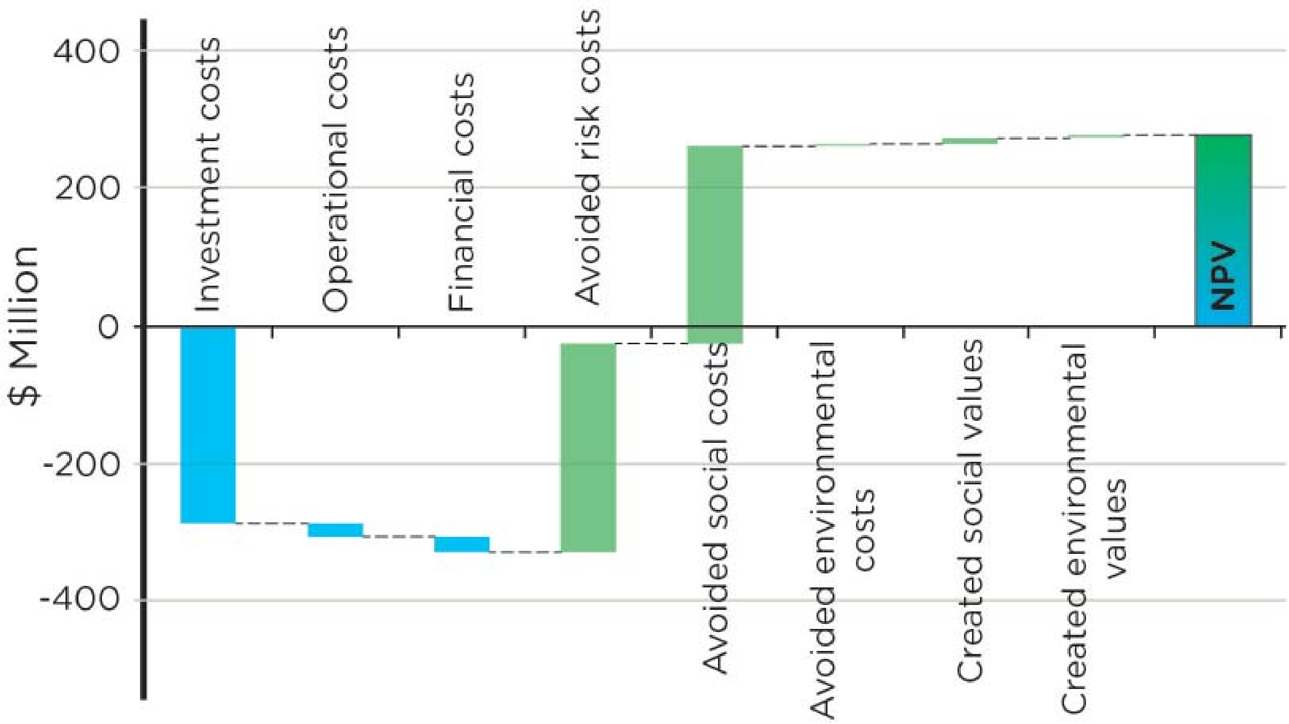
The masterplan thus proves to be a socio-economic benefit despite the relatively low avoided risk costs, when the full impact of the plan is taken into account.

In short, the CBA shows that **the Cloudburst Masterplan provides social and environmental benefits that outweigh the costs**.

KEY FIGURES	
Total Costs	$-330M
Total Benefits	$603M
Net Present Value	$273M
Benefit-cost ratio	1.8
Internal rate of return	14%

The **BENEFIT-COST RATIO** indicates that for every $1 the City invests in BGI, the City makes $1.8 in return in the local area.

Costs and benefits



PILOT PROJECTS

SOUTH JAMAICA HOUSES

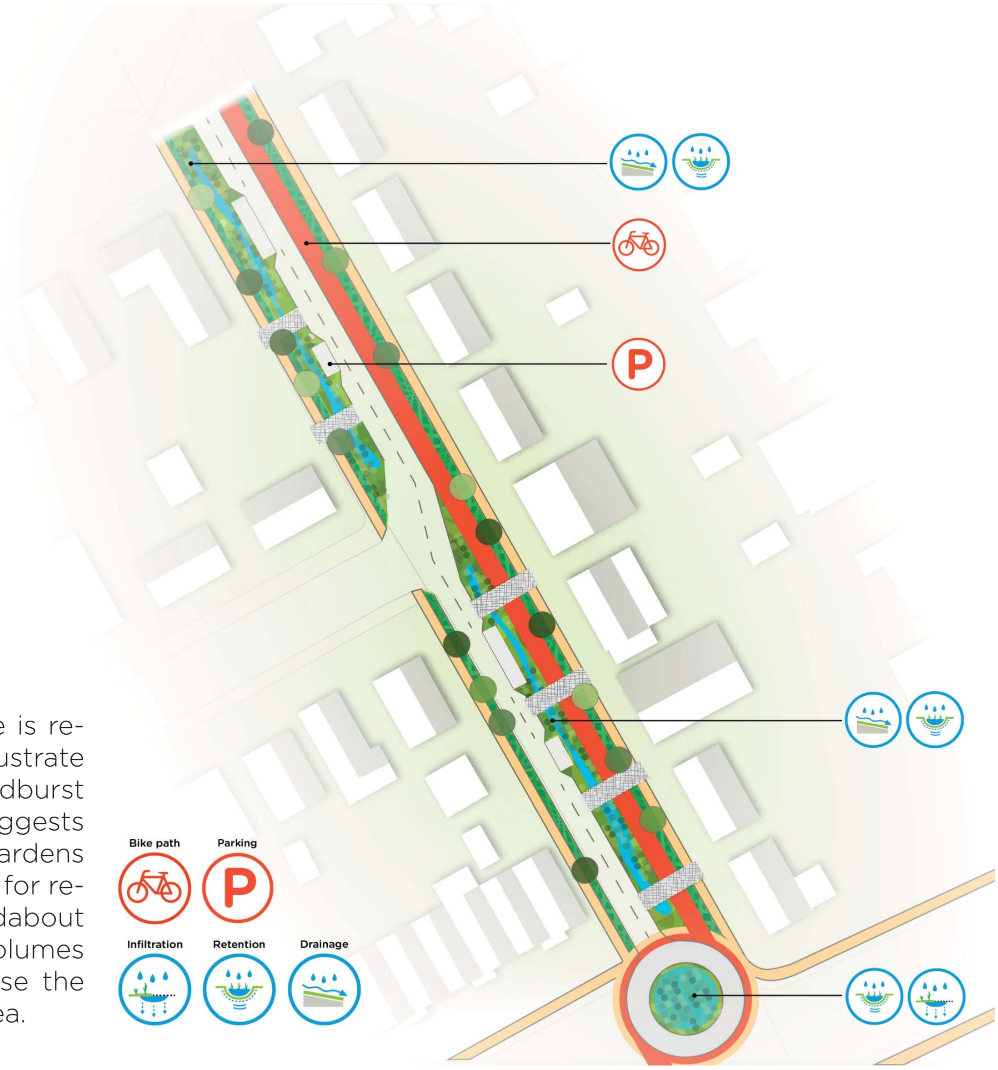
The area of South Jamaica Houses south of York College is chosen as a pilot area, as the New York City Housing Authority has shown interest in improving the liveability of the area. York College is included in the conceptual plan as a way to further integrate the college into the community. The plan may be integrated with other community enhancements, such as bike paths.

South Jamaica Houses in its current state

Future concept for South Jamaica Houses (dry day)

Future concept for South Jamaica Houses (very wet day)

CONCEPTUAL CLOUDBURST ROAD



A generic road profile is re-designed in order to illustrate the potential of cloudburst roads. The design suggests a bike lane and rain gardens in the side of the road for retention. A green roundabout can also retain large volumes of water and help ease the transit through the area.

A conceptual cloudburst road with rain gardens for retention

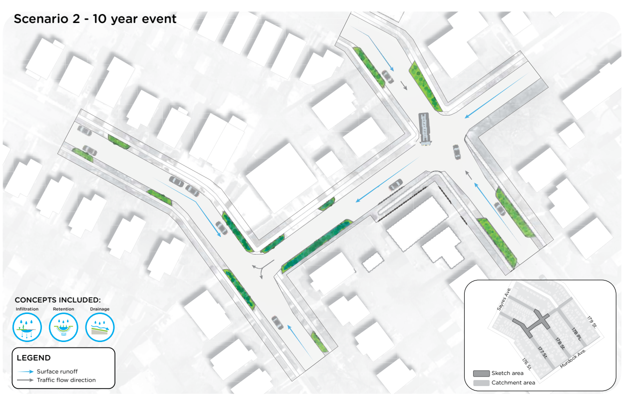
ST. ALBANS PUMPING STATION

At the request of various stakeholders present at Workshop II, an additional pilot project was developed for St. Albans pumping station to manage local flooding in the area.

St. Albans pumping station lies just outside the study area, but it pumps limited volumes of stormwater into the area on a daily basis. Three proposals were developed to reduce the stormwater volumes in the pumping station service area.

First, a design to handle a 100-year storm through mainly BGI is presented, thereby replacing the need for the pump (Scenario 1). For a lower design criteria of a 10-year storm, a smaller BGI solution is developed (Scenario 2). Lastly, a design to upgrade the pump to a 10-year storm connected to limited BGI is proposed. Water would then be pumped to the nearby St. Albans Memorial Park (Scenario 3).

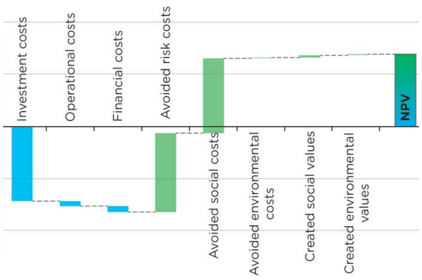
The different designs to meet the same challenge illustrate the potential and dynamics of using connected BGI for cloudburst management.



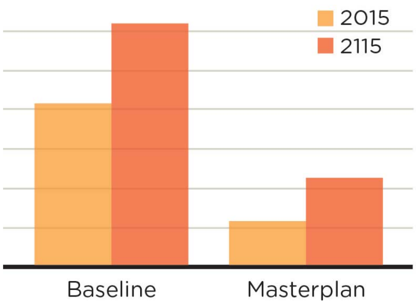
CONCLUSIONS

KEY FINDINGS

In order to gain insight on ways to advance climate resiliency projects and address intense rainfall through integration of grey and blue-green strategies, this study concludes on the three foundational questions posed in "Background & Reasoning":



1. Findings in the CBA show, that it is possible to achieve greater urban value and co-benefits for capital investments by using BGI for stormwater management. When socio-economic parameters are included in terms of avoided cost or created value, the benefits of the masterplan outweigh the costs, even for a masterplan designed to a 100-year storm.



2. The estimated capital investment costs show that it is possible to add a buffer from extreme rain events using BGI for a similar budget as traditional stormwater infrastructure. However, in order to not over- (or under-) estimate dimensions for the masterplan, research should go into finding the optimum safety level for cloudburst management through BGI. Oversizing can be unnecessarily expensive in terms of capital investment costs, while undersizing might prove relatively expensive, yet less effective in reducing risk costs.

3. The dynamics and outputs from the workshops show, that it is possible to increase cooperation across city agencies and stakeholders and maximize output of invested money through IP. Involved stakeholders show high interest in participating in cloudburst management, and a general desire for increased cooperation across agencies. While many barriers remain as to applying new methodologies at a higher level, stakeholders express optimism and willingness to overcome these challenges, leaving much potential and momentum for decision-makers to act.

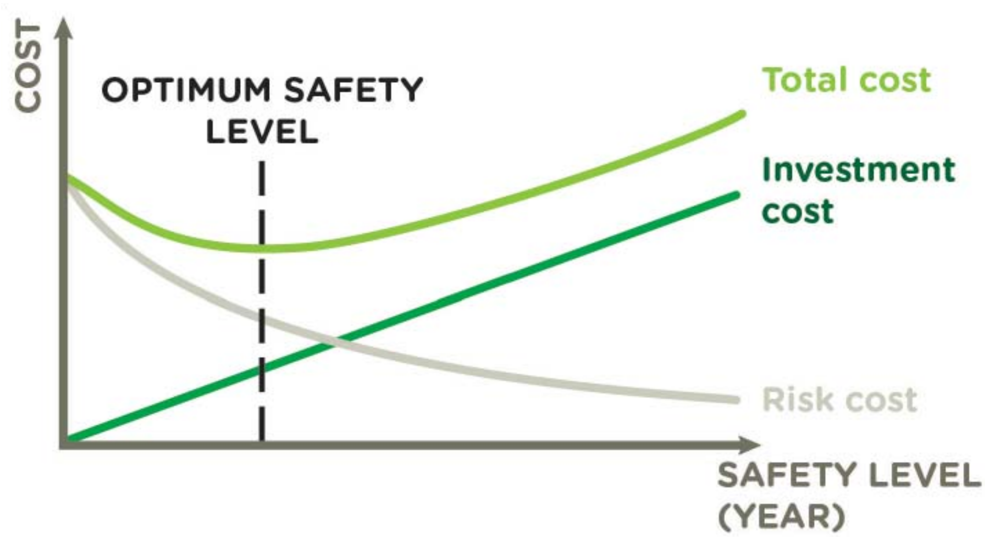
NEXT STEPS

The Cloudburst Resiliency Planning Study is intended as a pilot for new approaches to cloudburst management, however, many of the inherent and intermediate outcomes are valuable for the continued resiliency planning in NYC.

In order to lift cloudburst management in NYC to an even higher level, the city should focus on four overall aspects. First, **detailed hydraulic modelling should map flood dynamics** over time and in general provide the basis for informed decision-making and cloudburst resiliency planning.

Second, the city should **explore the optimum safety level for cloudburst management**. As illustrated by the findings in the CBA, safeguarding cost-effectively to extreme events (often a 100-year storm) is challenging. The relationship between risk and adaptation needs to be balanced in a way, that decision-makers can ensure a sufficient level of protection for reasonable investment costs.

The optimum safety level is determined by evaluating flood damage costs against investment and maintenance costs of adapting to a specific safety level. Costs are distributed over time and the optimum safety level is found where the sum of all costs are at a minimum (see graph).



Third, once the optimum safety level is determined, catchment-wide plans for extreme cloudburst management should be developed based on updated **cloudburst elements that reflect the local context.**

Finally, **integrated planning should increasingly be applied across agencies**, encouraged from above and utilized from initial analyses for conceptual designs through to detailed designs and implementation. In order to secure that ambitious BGI plans, such as the South Jamaica Houses, bring about a holistic solution and added value, an integrated approach is crucial rather than the traditional, step-by-step planning. It is important to include stakeholders early and maintain interdisciplinarity throughout the process .

The overarching first step to set the transition in motion is a **citywide strategy for climate resiliency planning**. This strategy can naturally be nested in the **OneNYC** plan. Building on and learning from city partnerships can be an easy way to integrate planning approaches for NYC.

NYC Environmental Protection

RAMBOLL