STORMWATER CLIMATE RESILIENCE

NEWEA ANNUAL CONFERENCE JANUARY 22, 2018

BOSTON, MASSACHUSETTS

STEVEN P. ROY
TRINE STAUSGAARD MUNK
RAMBOLL LIVEABLE CITIES LAB
CLIMATE ADAPTATION & GREEN INFRASTRUCTURE

COPENHAGEN HARBOUR – BEFORE (CIRCA 1995)

- 2 WWTPs
- CSO's
- Hydraulic modelling and real-time management controls
- Goal of 1 in 100 CSO event

COPENHAGEN HARBOUR - AFTER (2014)
CLEAN WATER AND NEW RECREATIONAL USE

RAMBOLL ENVIRON

COPENHAGEN HAS ALSO BEEN FACING CHALLENGES DUE TO CLIMATE CHANGE......

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EXTREME CLOUDBURSTS IN 2010 AND 2011….

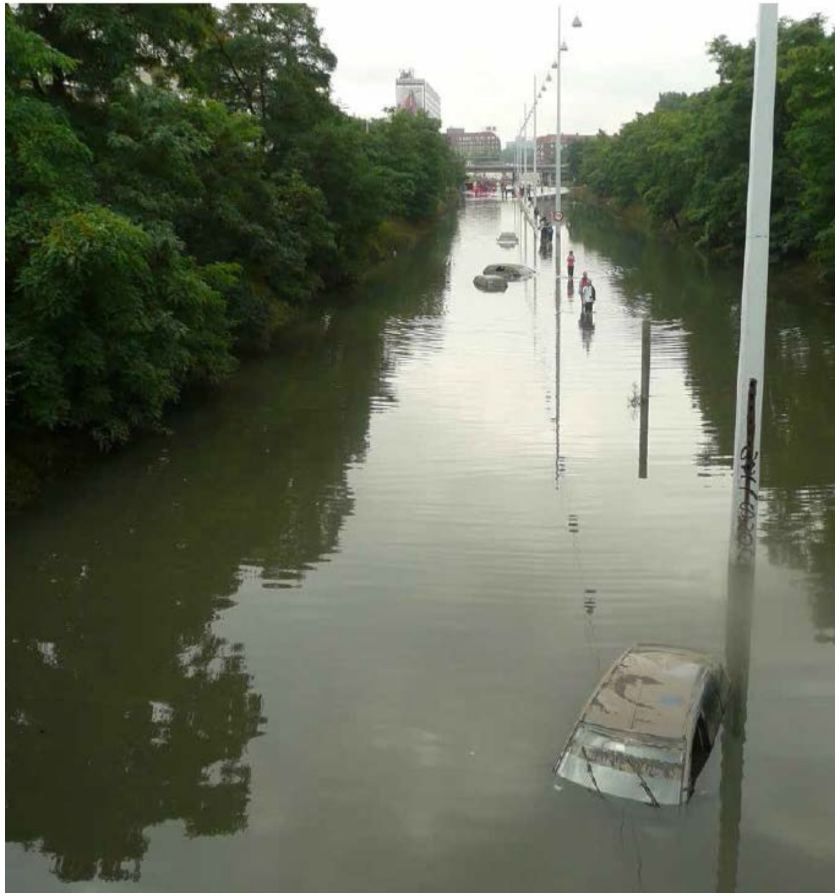
- Copenhagen was hit by the worst and most destructive cloudburst in the city's history
- Damages caused by floods: 6 billion DKK (~1 billion USD)
- 6.9 inches of rain in 2 hours


Major economic losses due to closed transportation, limited mobility, and business closures in addition to direct flood damages

COPENHAGEN CASE
DRIVERS AND PROCESS

- Climate plan KK, 2009
- **Extreme cloudburst 15 August 2010**
- Climate adaptation plan, 2011
- **Extreme cloudbursts 2 July and 15 August 2011**
- Cloudburst Masterplan, 2012
- 300 Specific projects 2014 ->

THE CITY OF COPENHAGEN
CLOUDBURST MANAGEMENT PLAN 2012



Hans Tavsens Park - The night-time summer rain disappears within a few hours and the rolling grass plains again fill up with people.

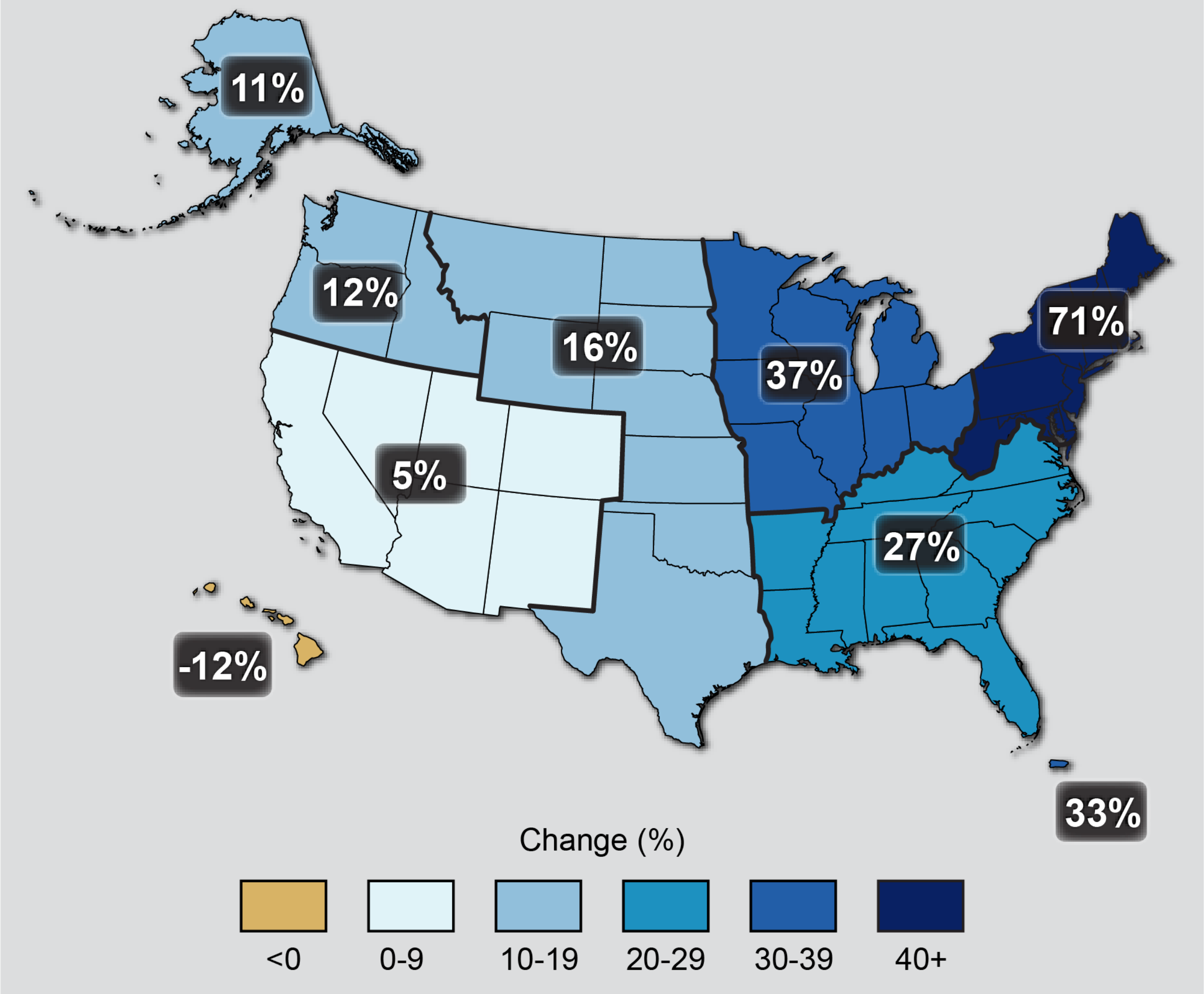
Hans Tavsens Park - Peace of mind after the cloudburst

INCREASE IN EXTREME PRECIPITATION EVENTS

FM Global –
Coping With Extremes, 2016

Increasing frequency of extreme precipitation events is a major risk facing US businesses

Observed Change in Very Heavy Precipitation



Source:

Climate Change Impacts in the US: The Third National Climate Assessment, 2014

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NYC PRECIPITATION PROJECTIONS

Mean annual precipitation is projected to **increase**

- 4 to 11 percent* by the 2050s
- 5 to 13 percent* by the 2080s

Source: NYC Panel on Climate Change, 2015

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NYC CLIMATE PROJECTIONS HEAT

Mean annual temperatures to increase

- 4.1 to 5.7°F* by the 2050s
- 5.3 to 8.8°F* by the 2080s

Heat waves

- Triple by 2080s from 2 to 6 per year

Hot days above 90°

- Triple by 2050s from 18 to 57 days

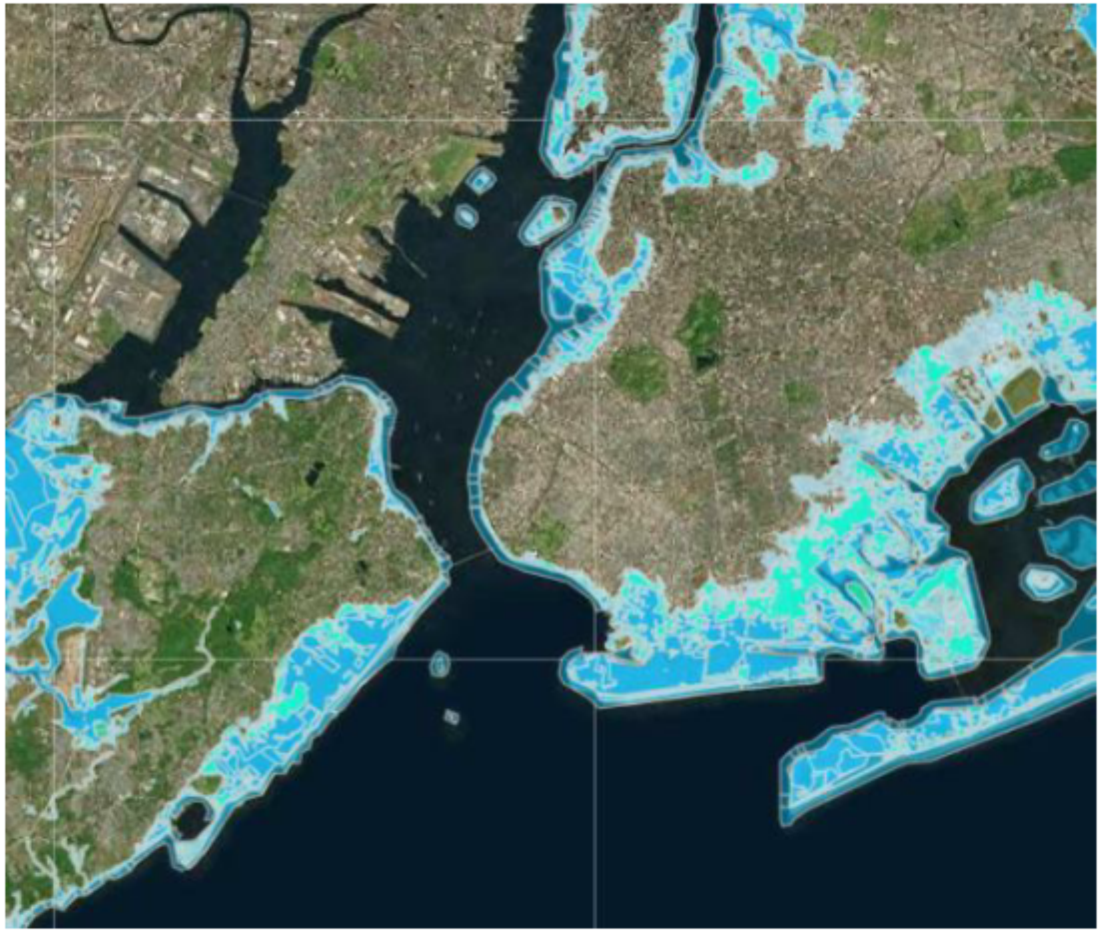
Birmingham, AL currently has 52 days above 90 degrees

Source: NYC Panel on Climate Change, 2015

CLIMATE PROJECTIONS – SEA LEVEL RISE

Sea level is expected to **rise**

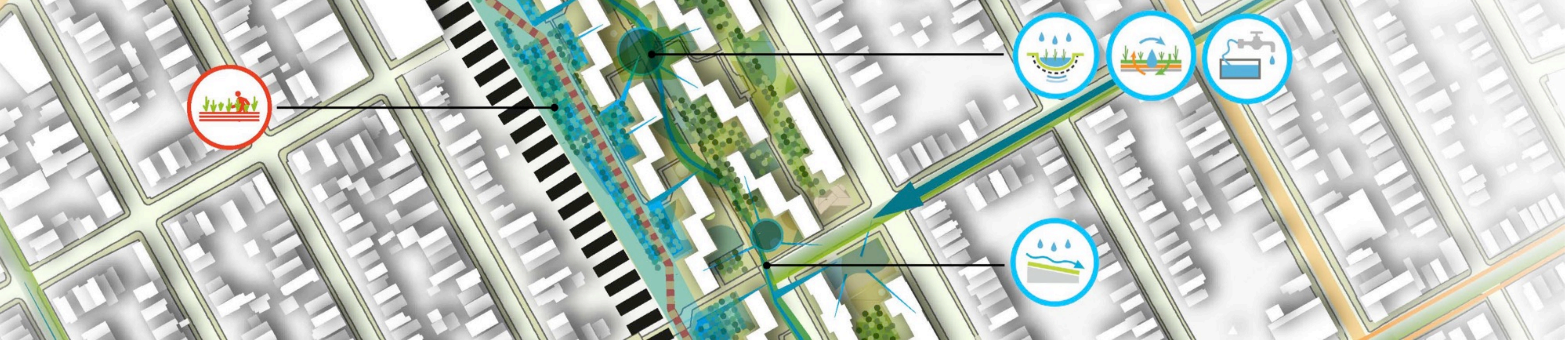
- 11 to 21 inches* by the 2050s
- 18 to 39 inches* by the 2080s,
- 6 feet by 2100 (high estimate)



FEMA PFIRM 2015, Future Floodplain 2050s (1% with 30" of SLR)

Projected sea level changes alone would **increase the frequency and intensity of coastal flooding** (absent any change in storms themselves)

Source: NYC Panel on Climate Change, 2015



NEW YORK CITY SE QUEENS CLOUDBURST/CLIMATE RESILIENCE PILOT

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22/01/2018

NYC – CLIMATE RESILIENCY STUDY

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

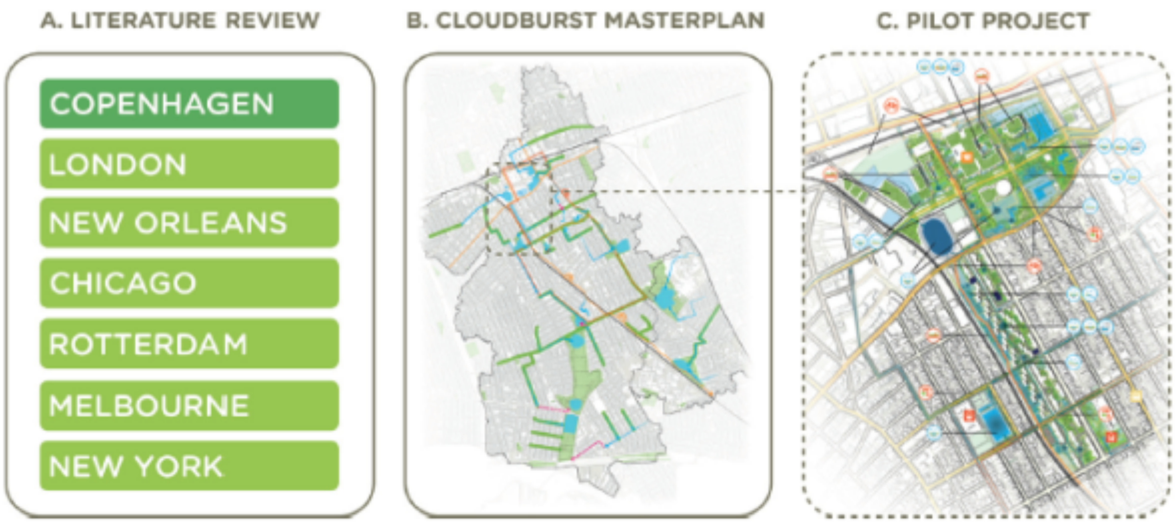
T=5 → T=100

2. Is it possible to **reduce risks using BGI** for a similar budget as traditional stormwater infrastructure?

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

NYC – CLIMATE RESILIENCY STUDY

- Deliverables
- Key concepts
  - Integrated planning
  - Liveability
  - Blue-Green Infrastructure (BGI)



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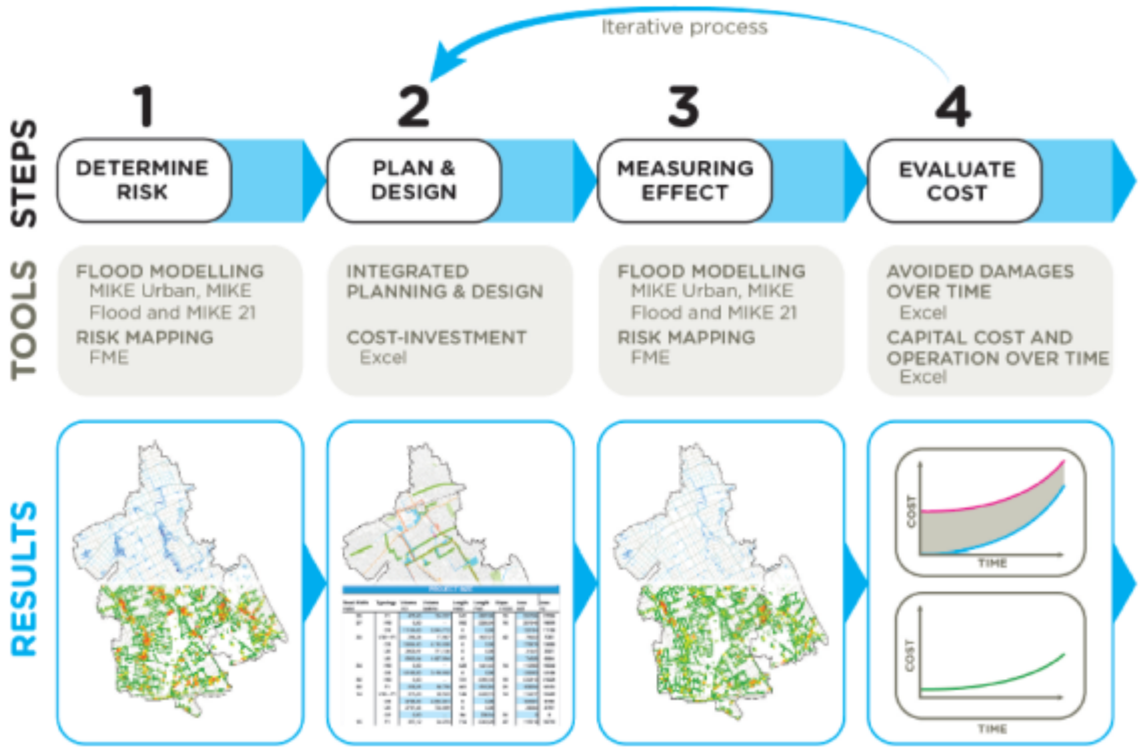
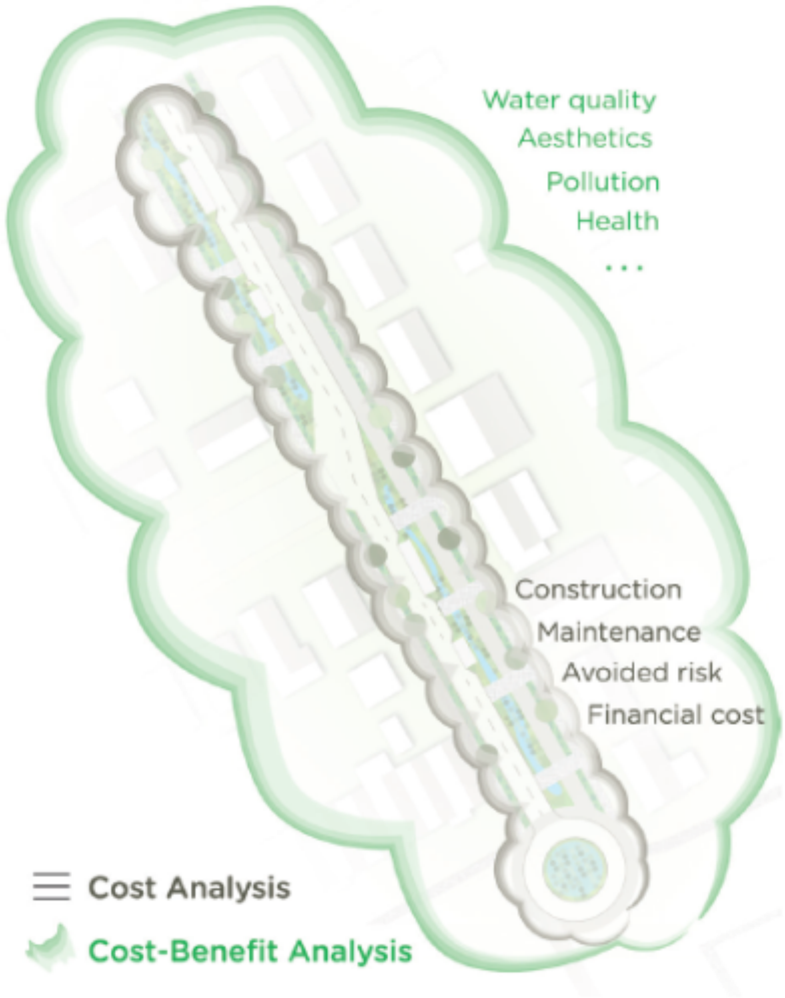
NYC – CLIMATE RESILIENCY STUDY

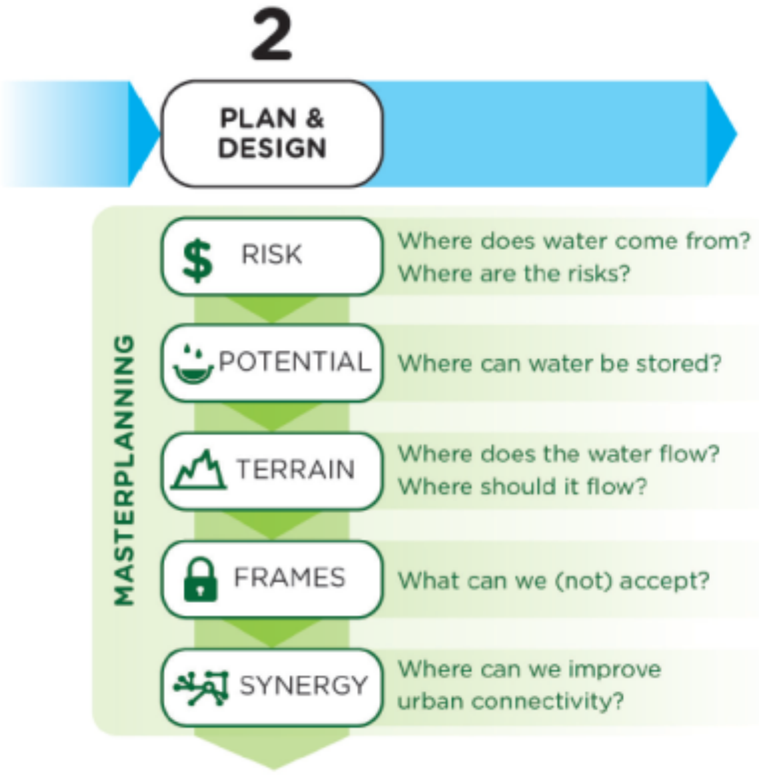
- 4-step approach to cloudburst resiliency planning
  - An iterative process
- Cost analysis vs. Cost-Benefit Analysis

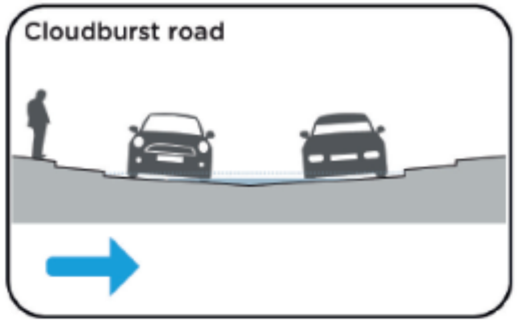




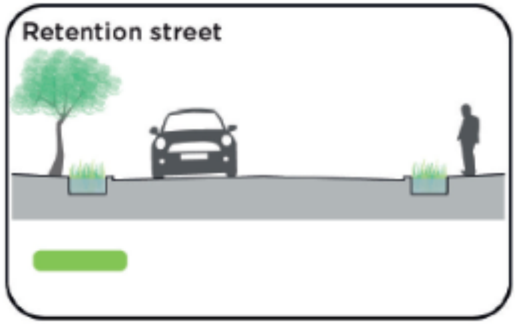
NYC – CLIMATE RESILIENCY STUDY

- Designing a masterplan
- BGI Elements

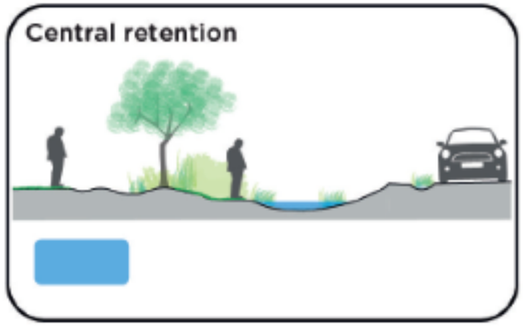




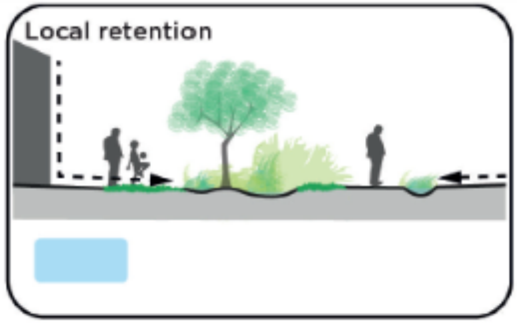
Used to convey water where the terrain is favourable



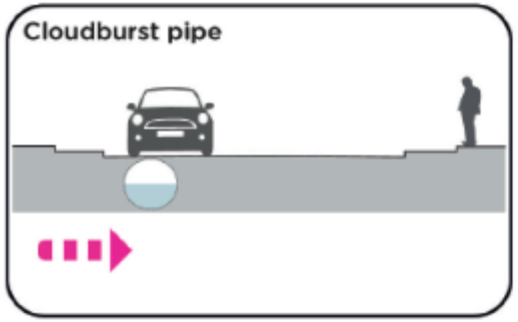
Used to retain water where the terrain is favourable



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 the terrain does not permit BGI projects

NYC – CLIMATE RESILIENCY STUDY

- BGI Examples
  - Cloudburst Road (Skt. Annæ Plads)
  - Retention Street (Kong Hans Allé)
  - Central Retention (Tanner Springs Park)
  - Local Retention (Freiburg Zollhallenplatz)

Illustrative example of a cloudburst road

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NYC – CLIMATE RESILIENCY STUDY – SE QUEENS

- Study area
  - 3,200 Acres 110,000 residents
  - Dominated by fences
  - Low to middle income families

Fences often dominate the area

Fences often dominate the area

Playgrounds hold great storage potential

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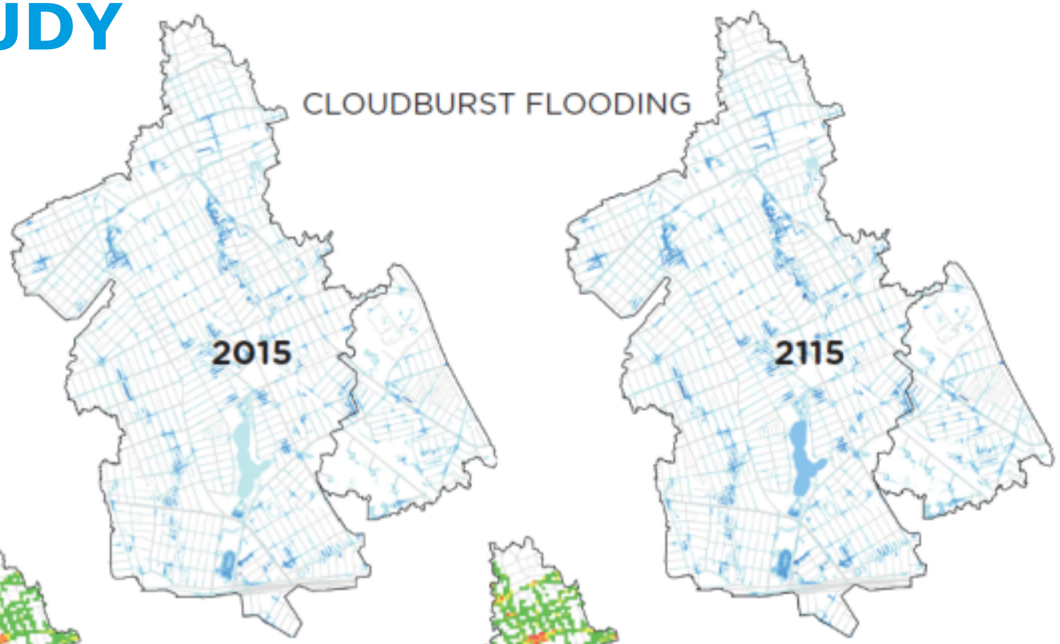
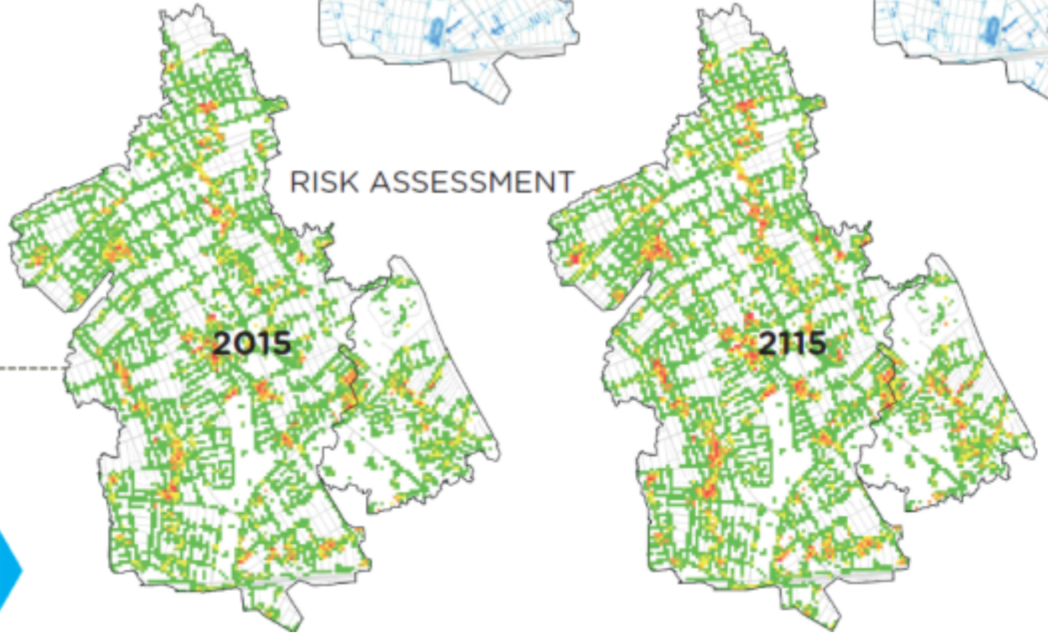
NYC – CLIMATE RESILIENCY STUDY

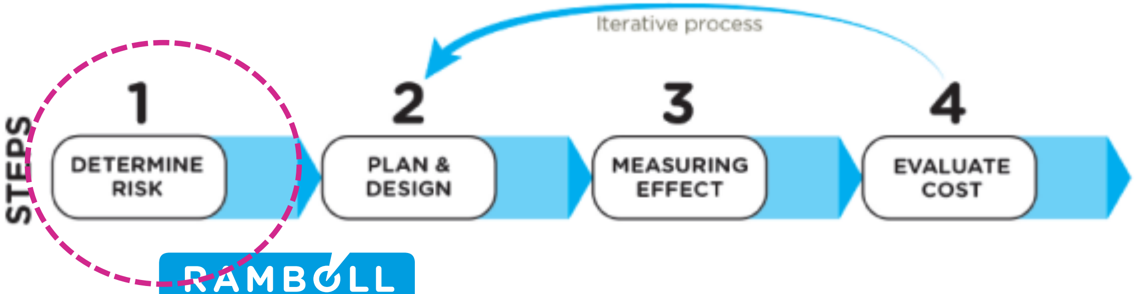


DETERMINING RISK

The hydraulic models simulate a cloudburst flood (top), 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 (below) 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.





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NYC – CLIMATE RESILIENCY STUDY

			Return periods	
CITY	ADAPTATION STRATEGY YEAR	EXTREME RAIN TERMINOLOGY	DRAINAGE	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*

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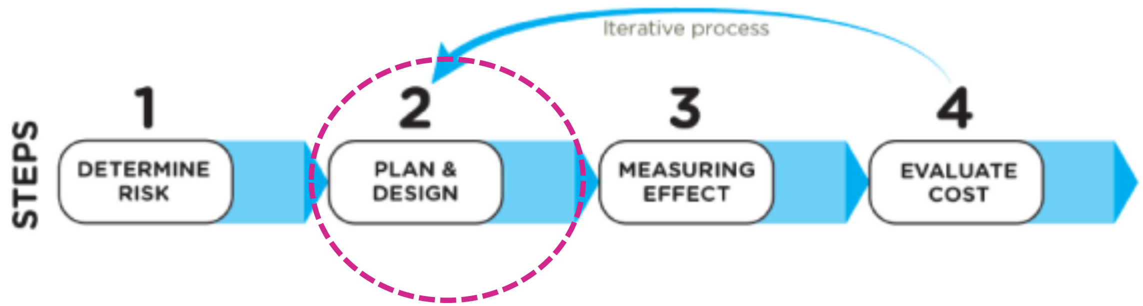
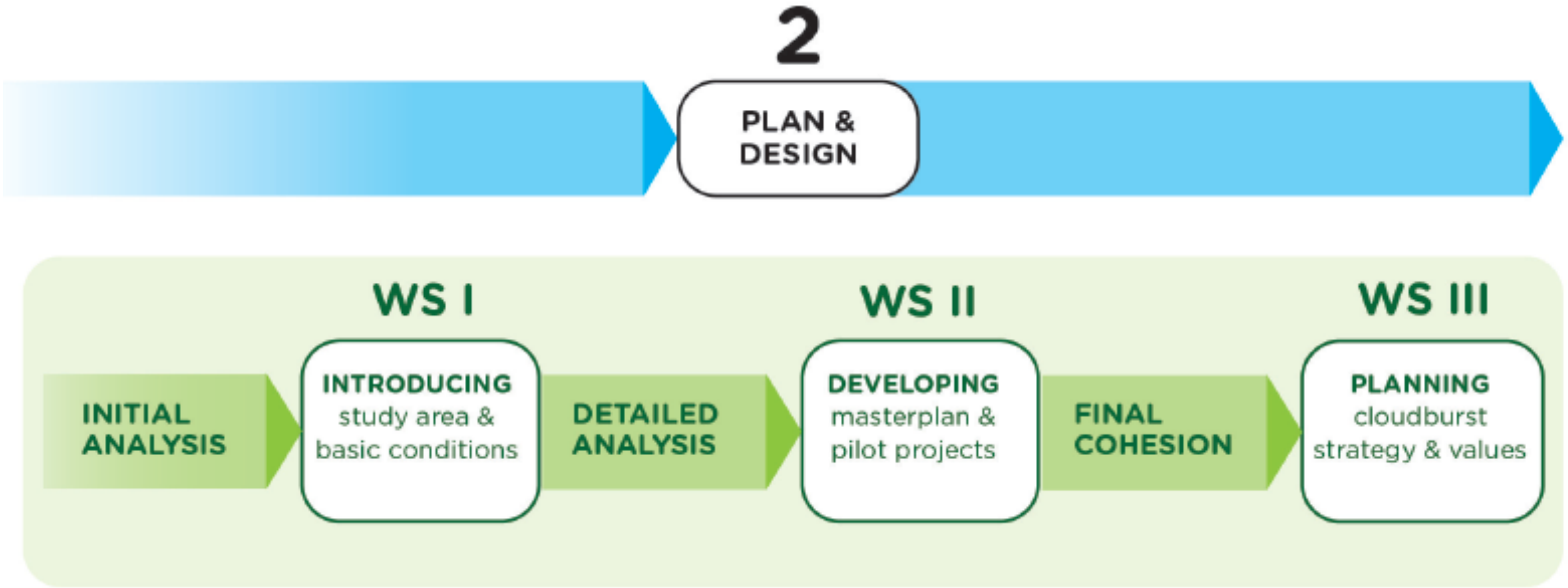
NYC – CLIMATE RESILIENCY STUDY

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

NYC – CLIMATE RESILIENCY STUDY

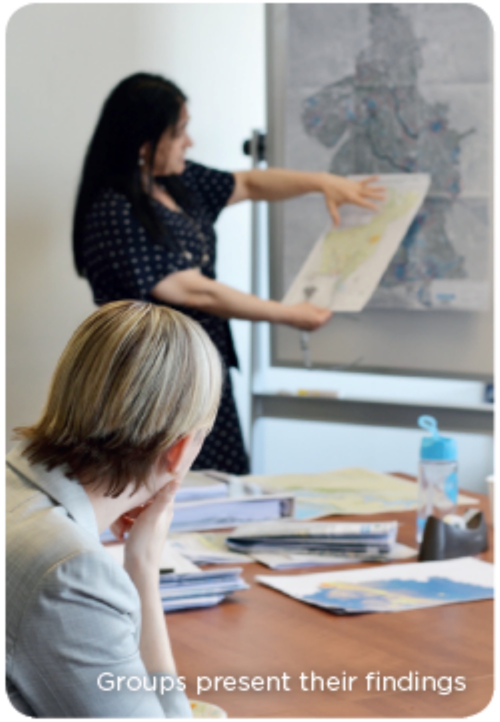
- Workshops
  - Local knowledge
  - Ownership (be part of the “evolution”)



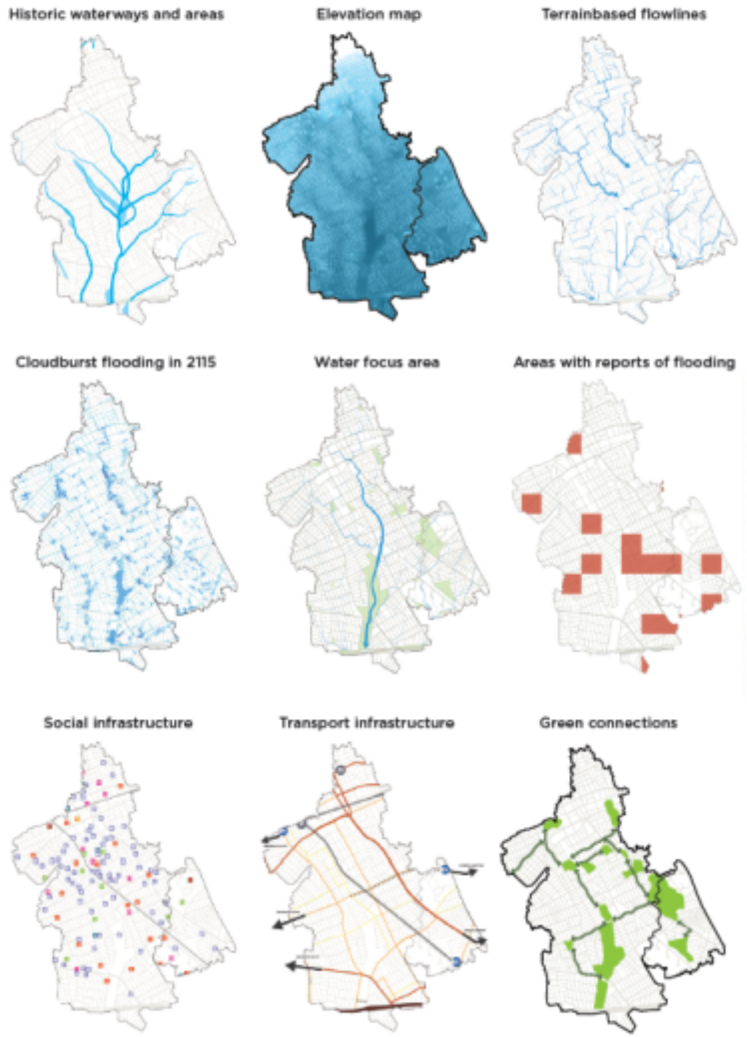


NYC – CLIMATE RESILIENCY STUDY

- Initial analysis
  - Land-use data
  - Terrain
  - Infrastructure (transport and social)
  - Green areas etc.
- Workshop I
  - Supplement with local knowledge
  - Identify challenges and opportunities


Groups present their findings


Hand sketches illustrate potential BGI in roads



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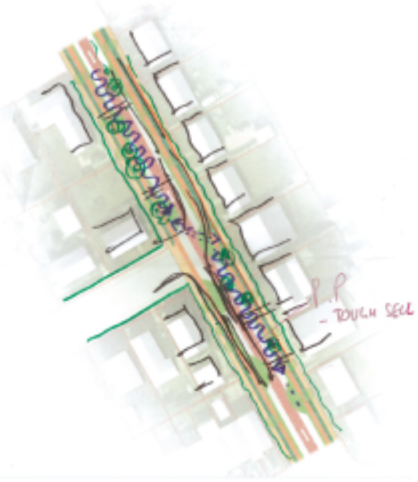
NYC – CLIMATE RESILIENCY STUDY

- Detailed analysis
    - Flood modelling
    - GIS analysis
    - Risk mapping
    - Masterplan drafts
- Workshop II
    - Supplement with local knowledge
    - Identify challenges and opportunities

Design experts present their proposal

Local knowledge adds value to the designs



Hand sketches illustrate potential in design roads

NYC – CLIMATE RESILIENCY STUDY

- Final cohesion
  - Final masterplan
  - Final pilot projects

- Workshop III
  - Strategic planning exercise
  - Next steps
  - Evaluation


Touring Queens Botanical Garden


Stakeholders prioritize elements of cloudburst planning


Stakeholders envision implementation strategy

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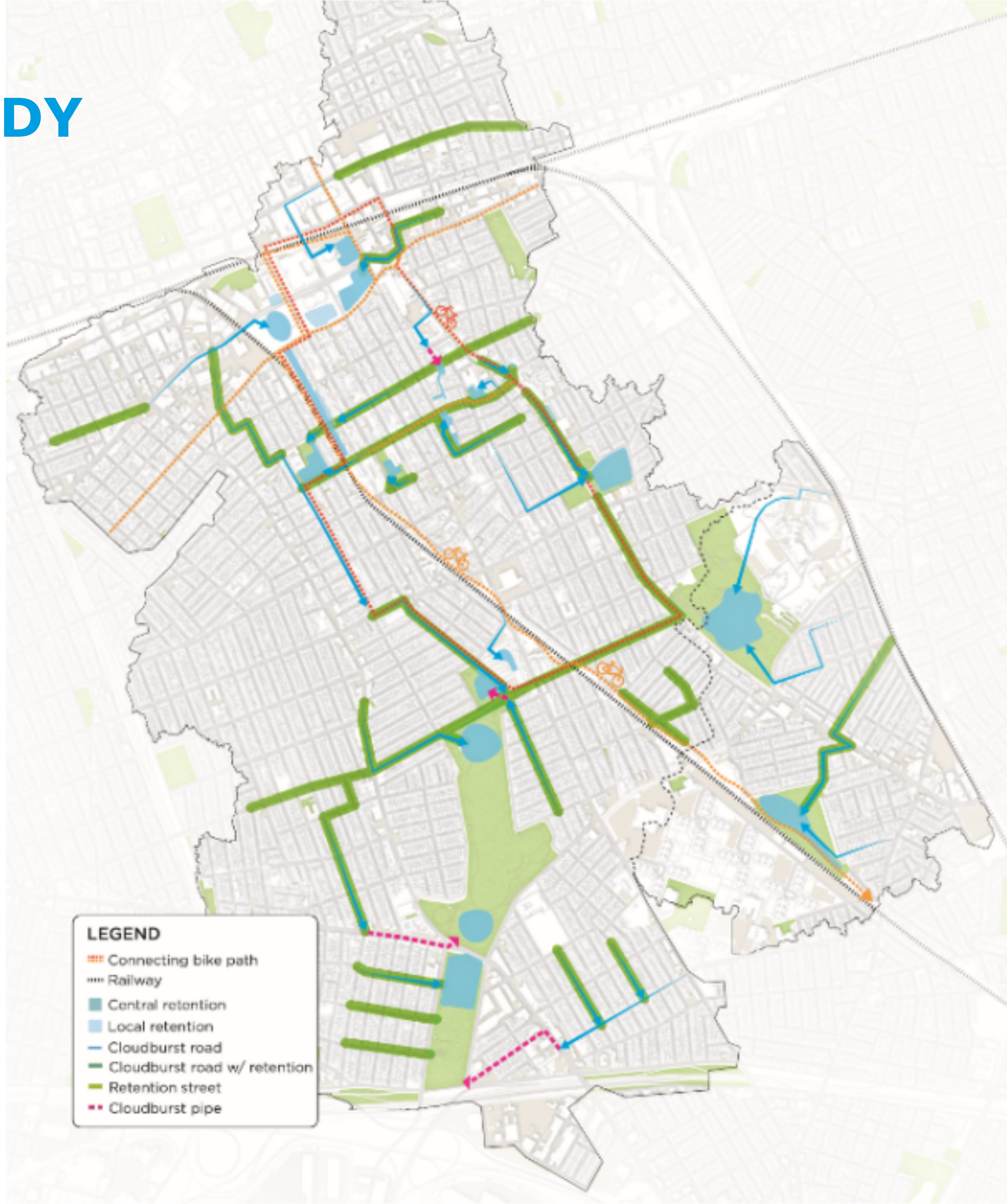
NYC – CLIMATE RESILIENCY STUDY

- Masterplan (68 projects)
  - 11 cloudburst roads
  - 16 cloudburst roads with retention
  - 15 retention streets
  - 4 cloudburst pipes
  - 18 central retention
  - 4 local retention



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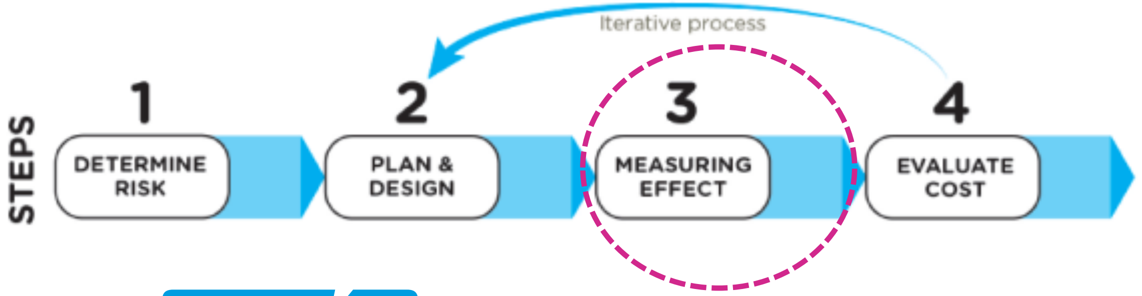
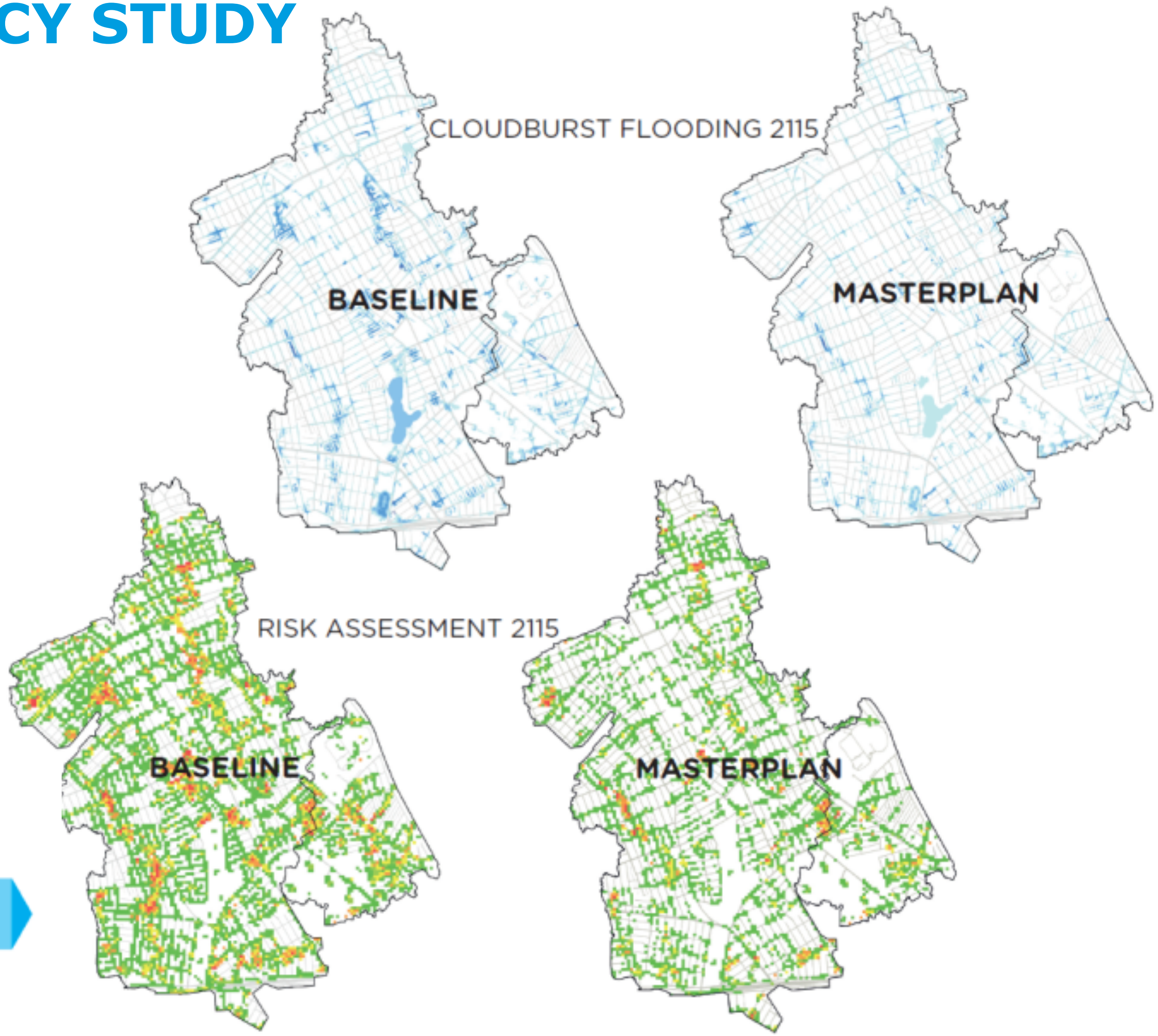
NYC – CLIMATE RESILIENCY STUDY

- Considerable less flooding
- Considerable lower damage costs





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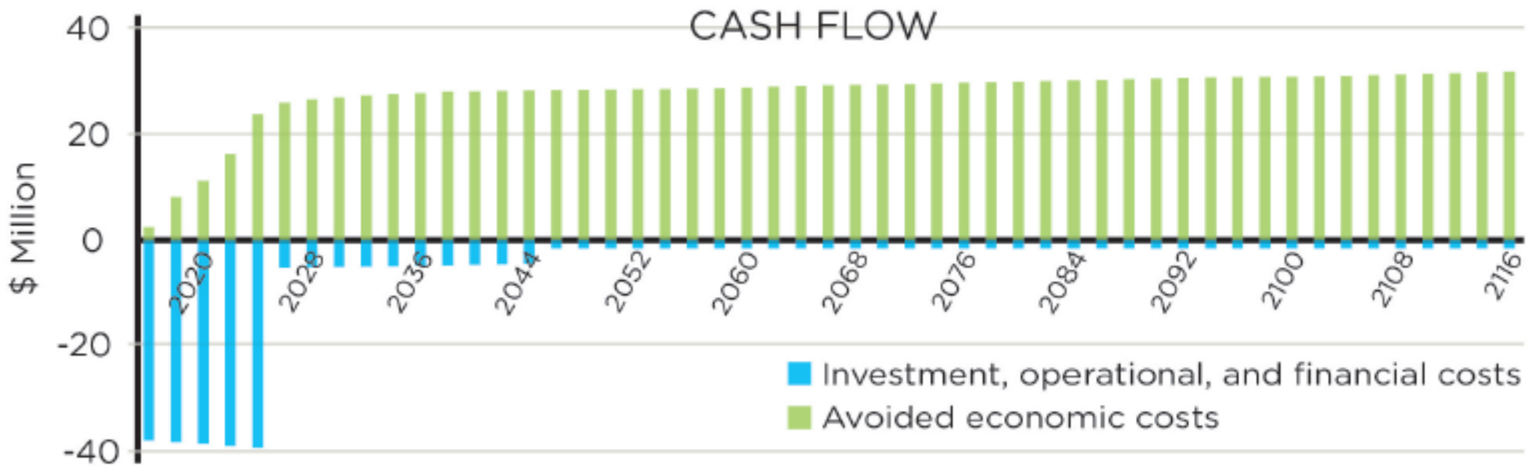
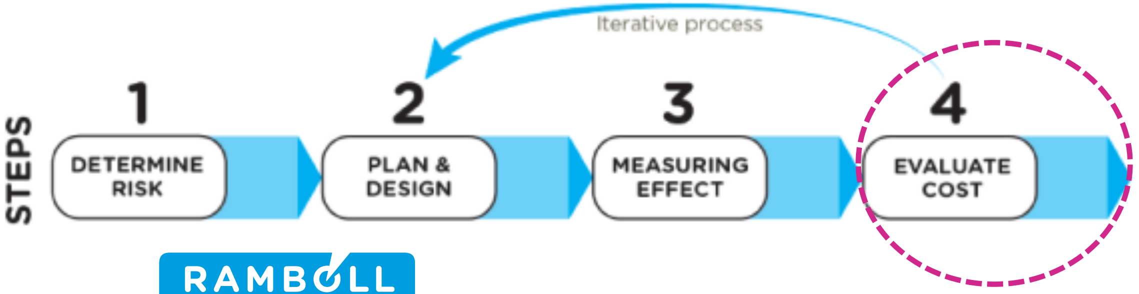
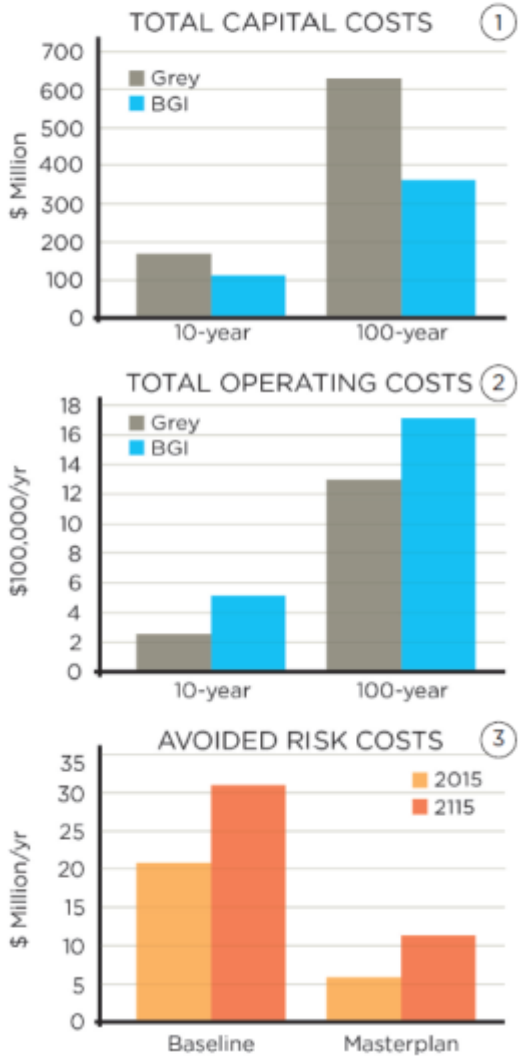
NYC – CLIMATE RESILIENCY STUDY

- Capital investment: $330 million
- Avoided risk costs: $310 million
- Net loss: $-20 million







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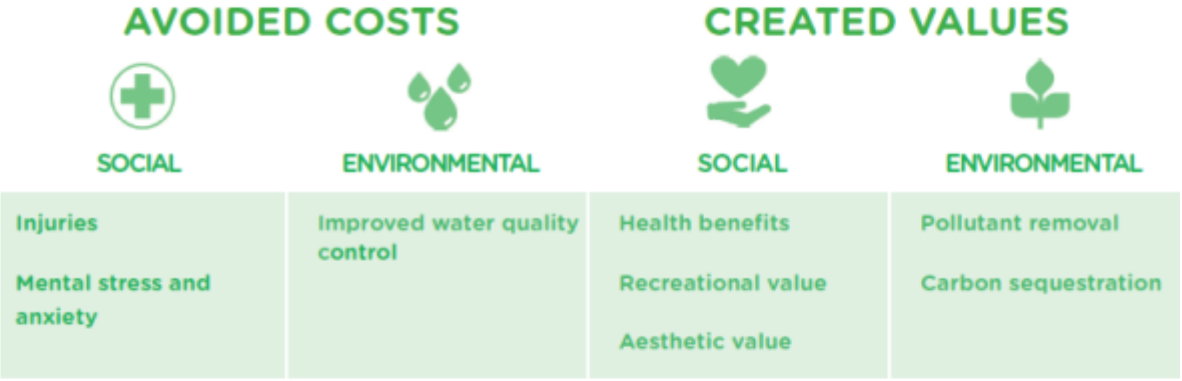
NYC – CLIMATE RESILIENCY STUDY

- CBA
  - Aesthetic values
  - Air quality
  - Health benefits
  - Etc.
- Avoided social and environ. costs: $290 million
- Created social and environ. Values: $3 million



The **BENEFIT-COST RATIO** indicates that for every $1 the City invests in BGI, the City makes $1.9 in return in generated co-benefits in the local area.

KEY FIGURES	
Total Costs	$-20M
Total Benefits	$293M
Net Present Value	$273M
Benefit-cost ratio	1.9
Internal rate of return	14%

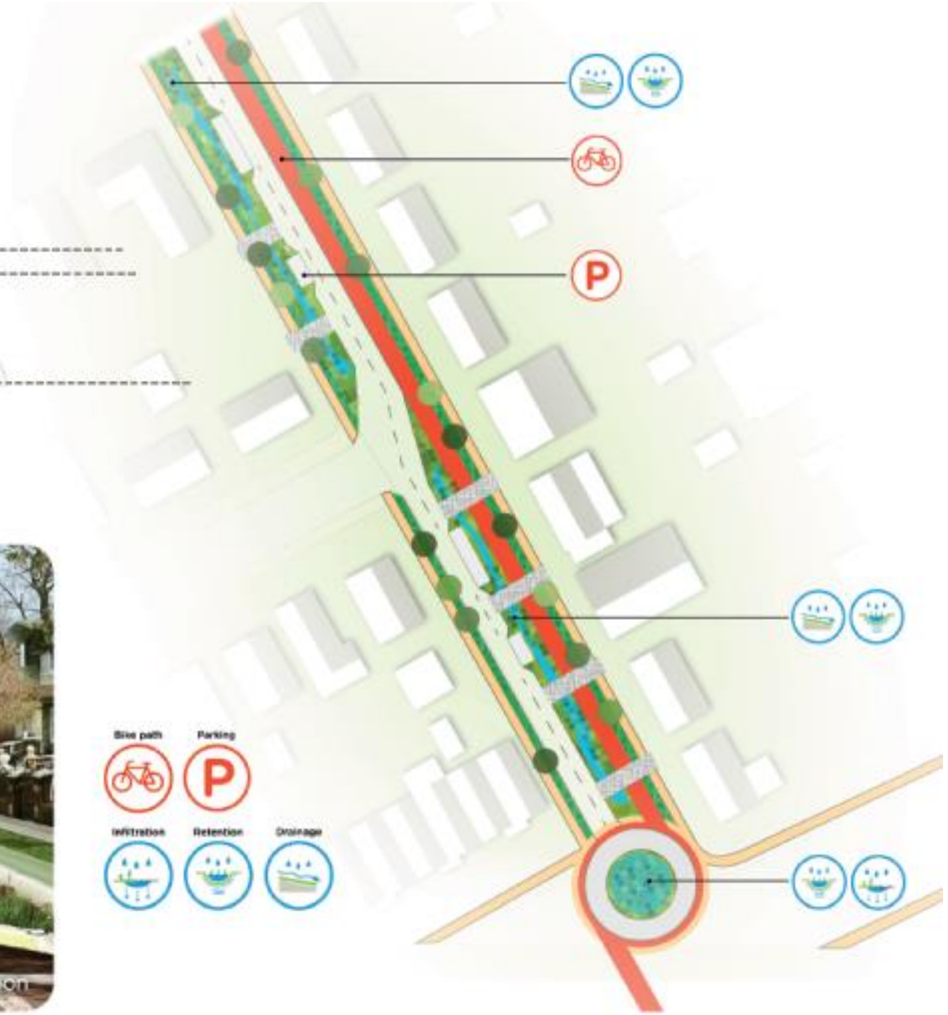
NYC – CLIMATE RESILIENCY STUDY

- Pilot project:

Conceptual cloudburst road

A generic road profile is redesigned 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 and replace full stop crossings.

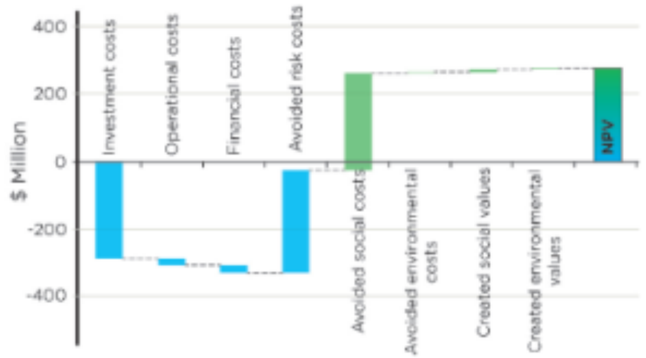
A conceptual cloudburst road with rain gardens for retention



NYC – CLIMATE RESILIENCY STUDY

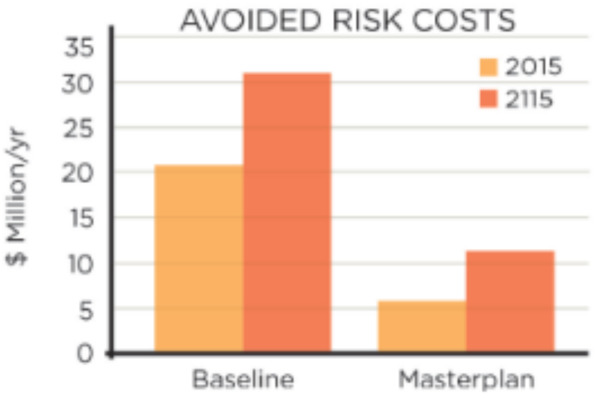
- Pilot project: South Jamaica Houses

NYC – CLIMATE RESILIENCY STUDY



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 reduce risks 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 maximise 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.

NYC – CLIMATE RESILIENCY STUDY

- Challenges
  - Changing the Level of Service
  - Bringing agencies together
  - Data protection (reluctant to share)
  - Political concerns
  - Stakeholder involvement

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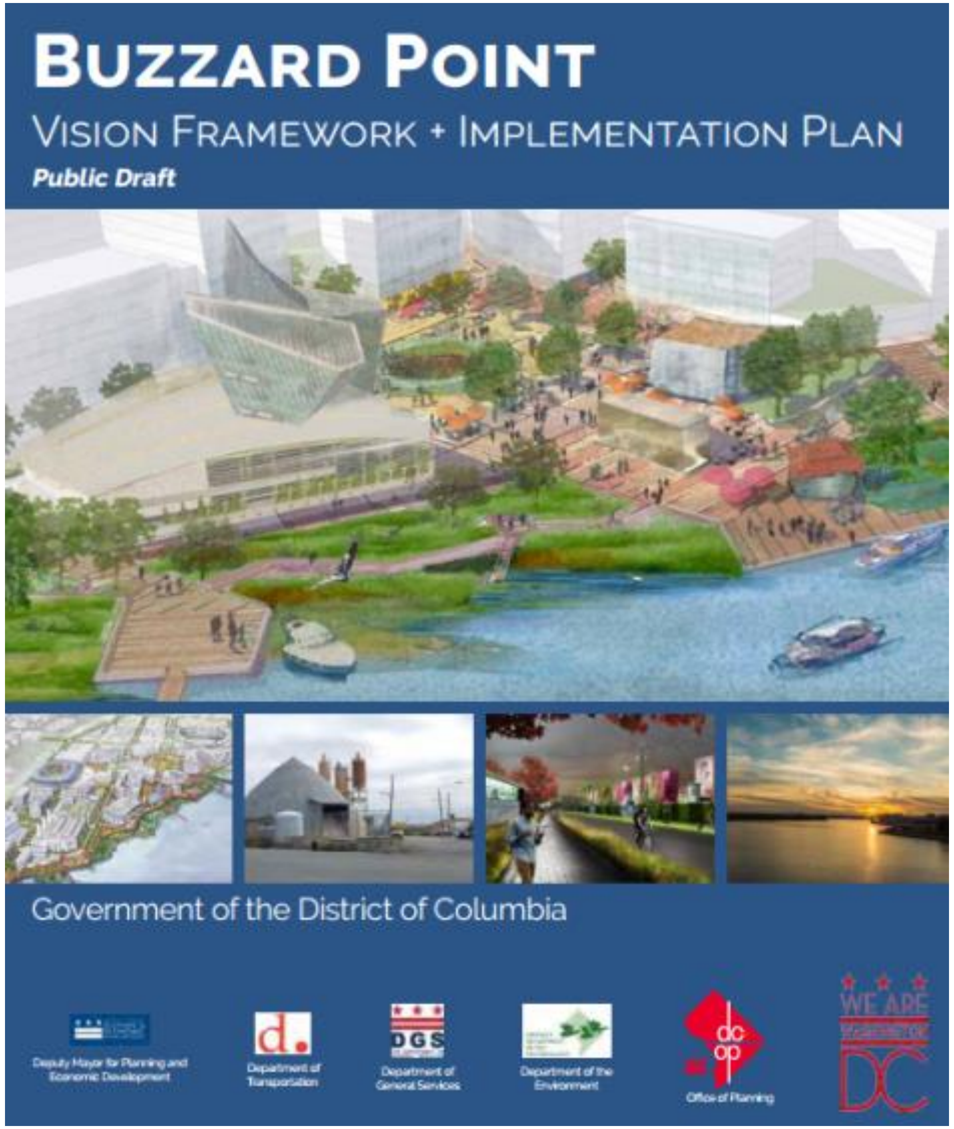
BUZZARDS POINT, WASHINGTON D.C.
BACKGROUND FOR PROJECT

- **A comprehensive climate resilience plan and design**
- **Includes flood mitigation vision, but no measures**
  - Portions of Buzzard Point are identified as a highrisk flood zone in the effective Flood Insurance Rate Map (FIRM)
  - Current District regulations require that the lowest floors of residential structures be 1.5 feet above the 100-year flood elevation
  - Vision to maintain first floor elevations above the level of the 500-year flood event for residential buildings

The vision for Buzzard Point focuses on four key concepts:

- A vibrant mixed-use neighborhood
- Dynamic parks and public spaces
- An improved multi-modal transportation system
- A living and sustainable environment

This document outlines the vision, key design concepts and strategies, the planning context, regional influences, and implementation measures to make the vision a reality.



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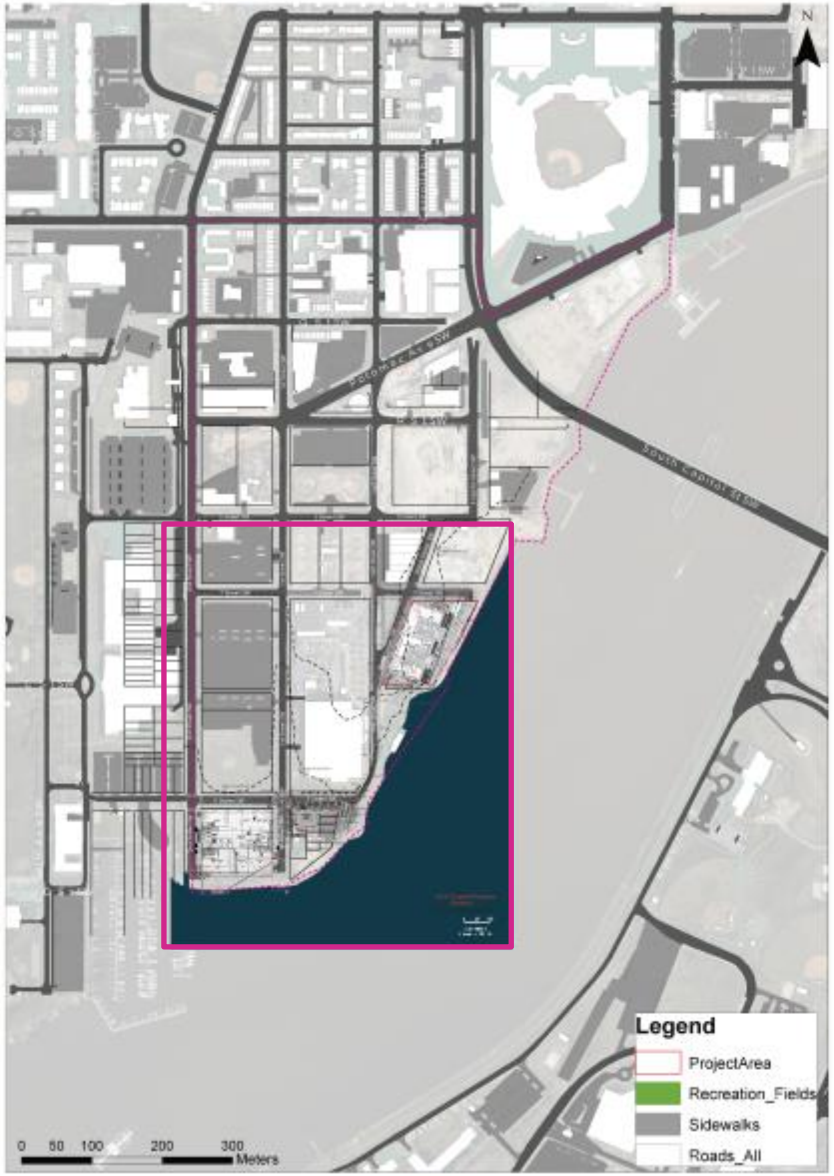
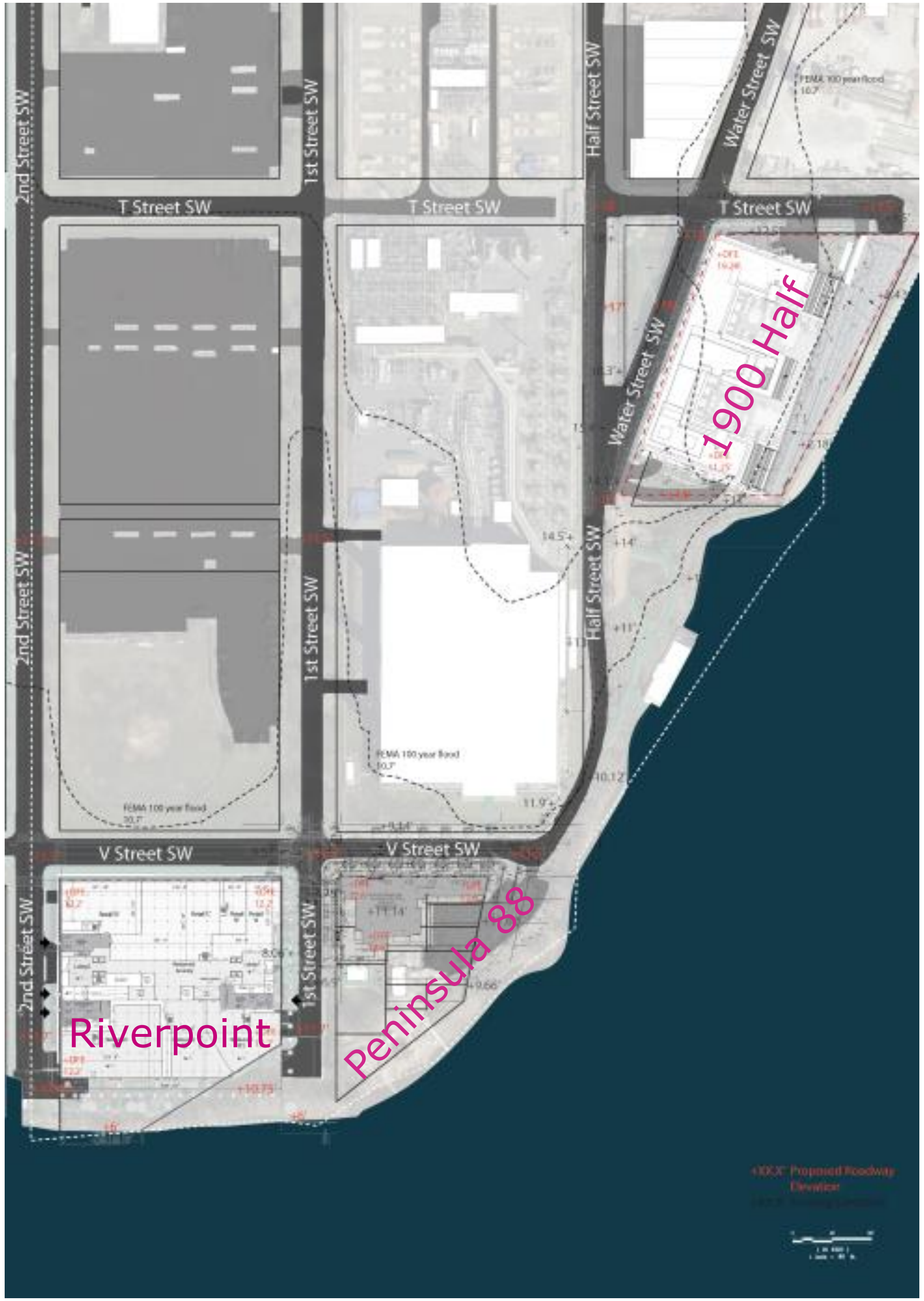
Existing Proposals

3 Developments along the water edge :

- Riverpoint
- Peninsula 88
- 1900 Half





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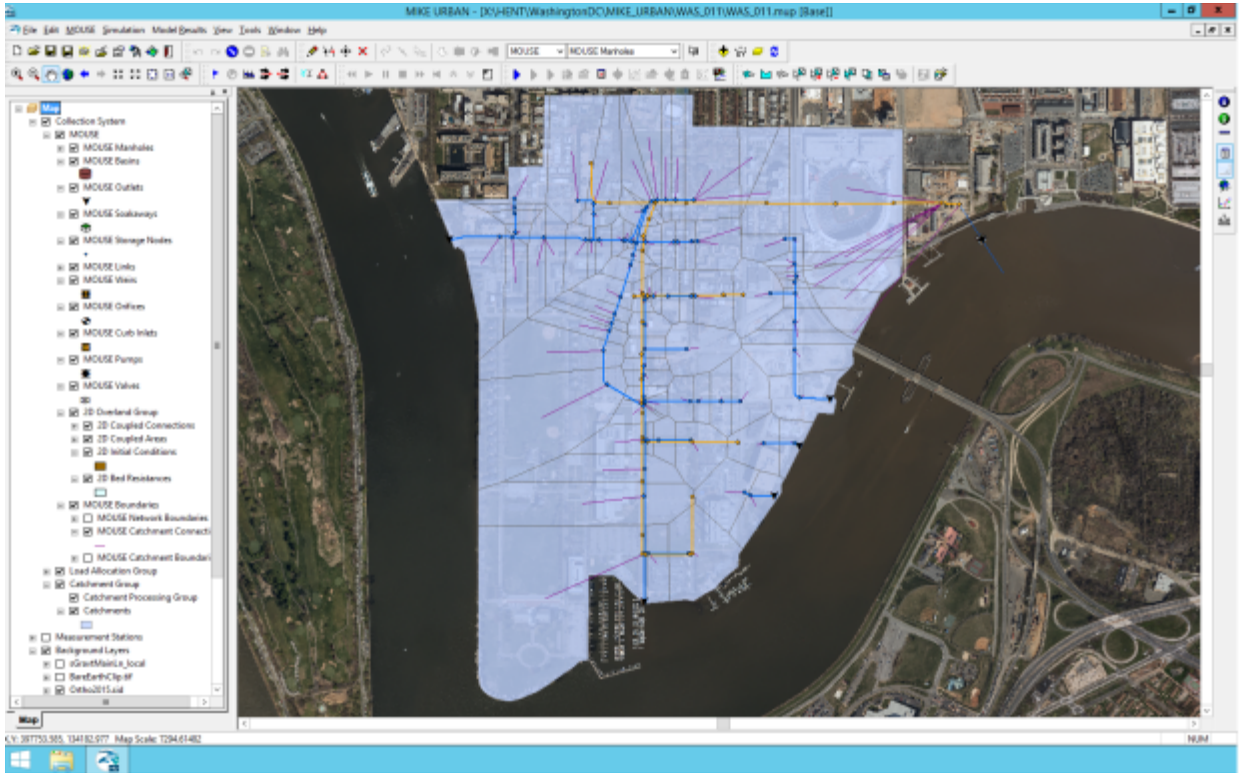
BACKGROUND FOR PROJECT

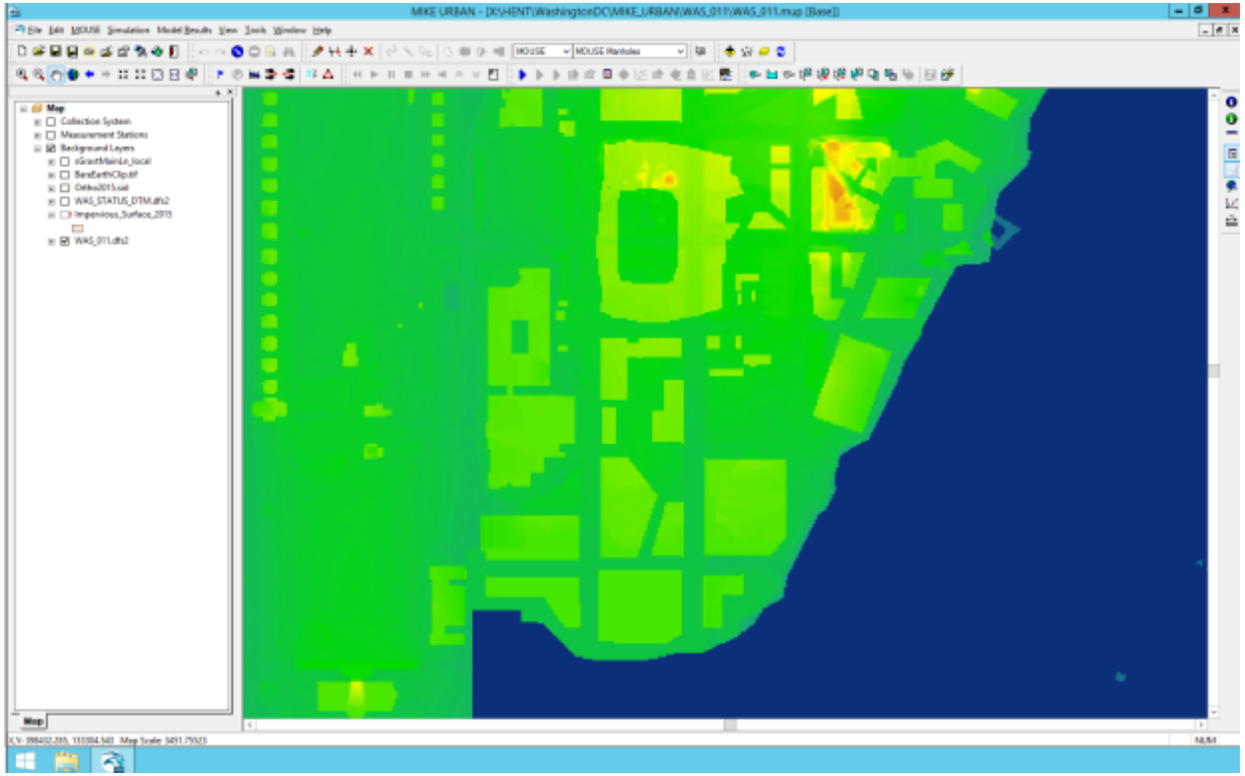
- Lack of overall plan for development and resilience for area
- Need for validation or new recommendation of acceptance criteria related to flood protection
- A proposal to raise the streets as flood mitigation strategy is the only suggestion at present – this proposal is not analyzed in depth:
  - Is it resilient, flexible and robust against climate change and extreme events
  - How does raised streets impact the urban plan, architecture, accessibility etc.
  - Is it the most cost-efficient way and who pays for construction and operation?

MODELLING APPROACH

MIKE FLOOD: MIKE Urban connected to MIKE 21



MIKE Urban – hydrological and hydraulic model

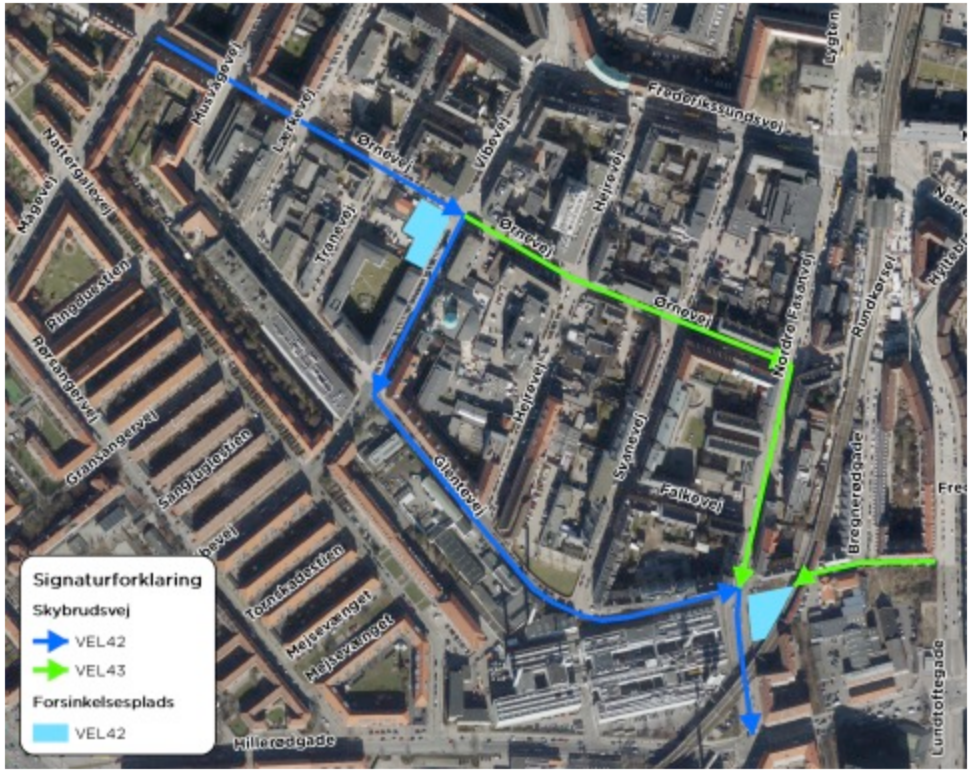


MIKE 21 – 2D overland model

EXAMPLE OF FLOOD SIMULATION OF A FLUVIAL AND TIDAL STORM SURGE EVENT

POTENTIAL OF IMPROVEMENTS

- Detail the sewer system to include smaller sewer pipes and thus get more detailed results
- Divide the catchments into the actual catchment of each manhole to the more accurate distribution of water
- Find the whole catchment area of the pumping station to simulate the correct boundary conditions
- Find the exact pumping capacity in order to simulate when the capacity of the pumping station is exceeded
- Perform simulations with proposed cloud burst solutions (cloud burst roads, channels, retention ponds etc.)



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FLOOD ANALYSIS SCENARIOS

Cloudburst

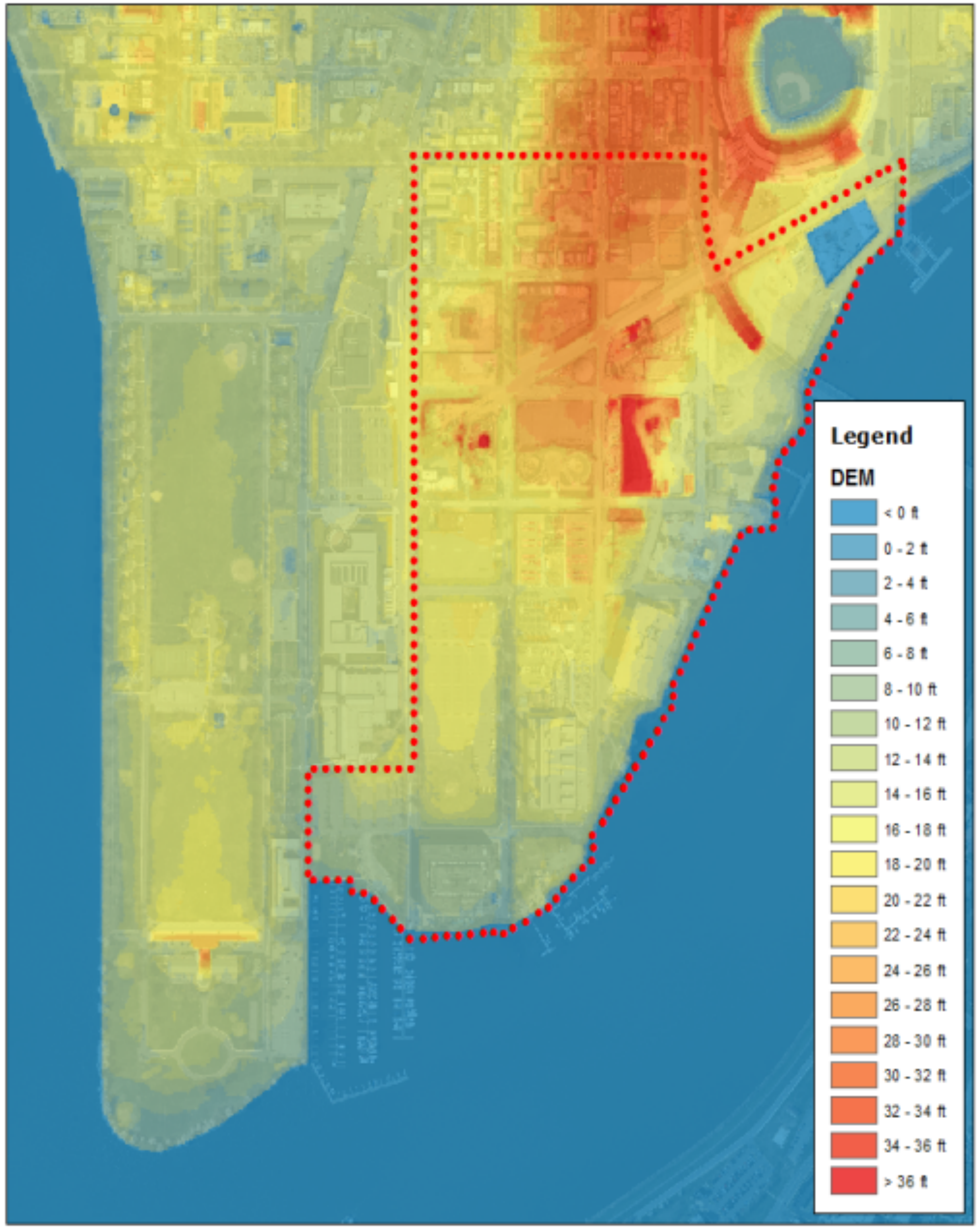
- 1/10 year today
- 1/100 year today

Fluvial and tidal storm surges

- 1/100 year today
- 1/500 year today*
- 1/1000 year today*

** expert judgement, outside statistics*

Existing conditions, proposed development and alternative plan.



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100 YEAR EVENT IN 2017 UNDER EXISTING CONDITIONS

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100 YEAR EVENT IN 2100 UNDER EXISTING CONDITIONS

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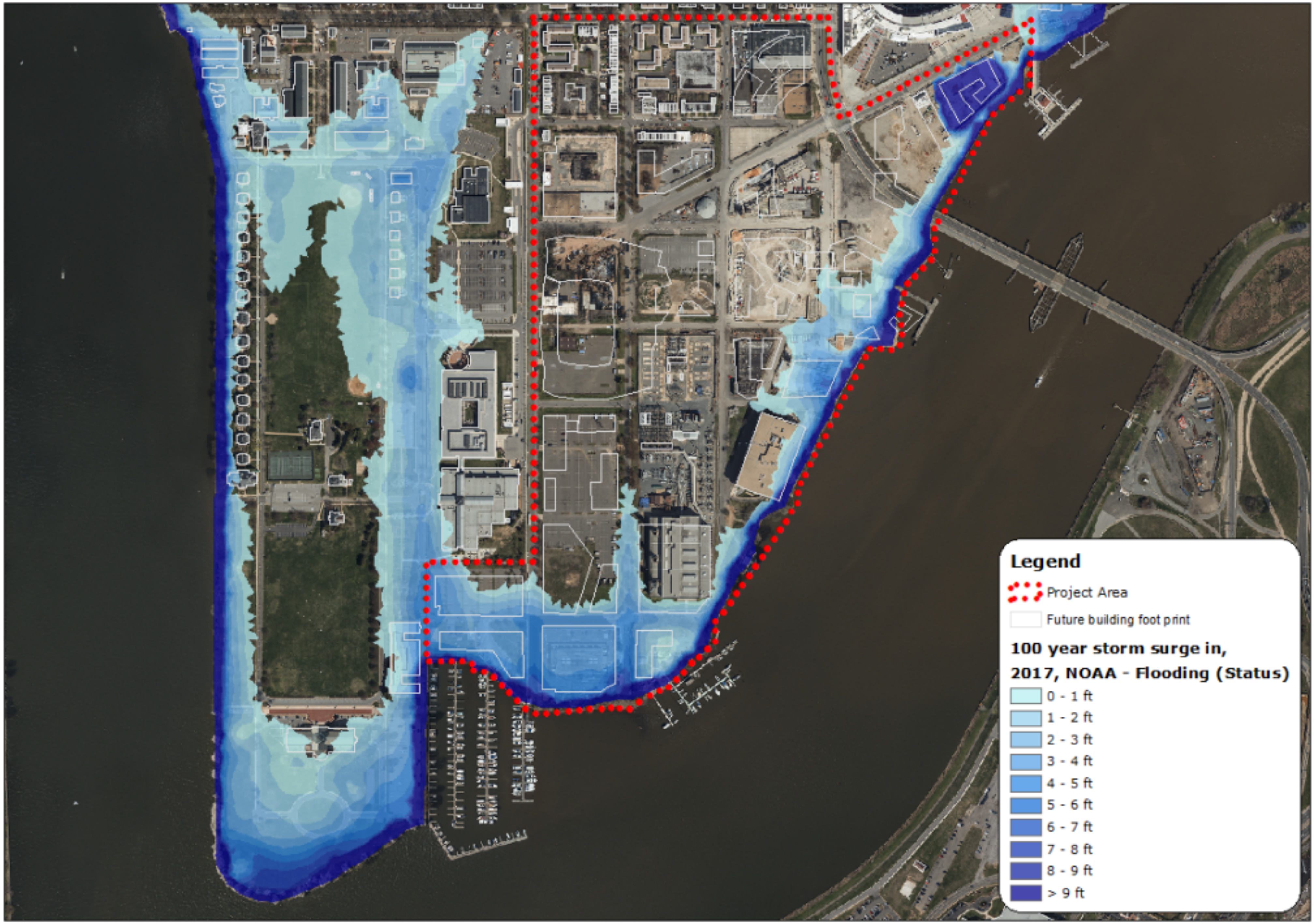
100 YEAR EVENT IN 2017 UNDER EXISTING CONDITIONS



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100 YEAR EVENT IN 2100 WITH CURRENT PROPOSAL

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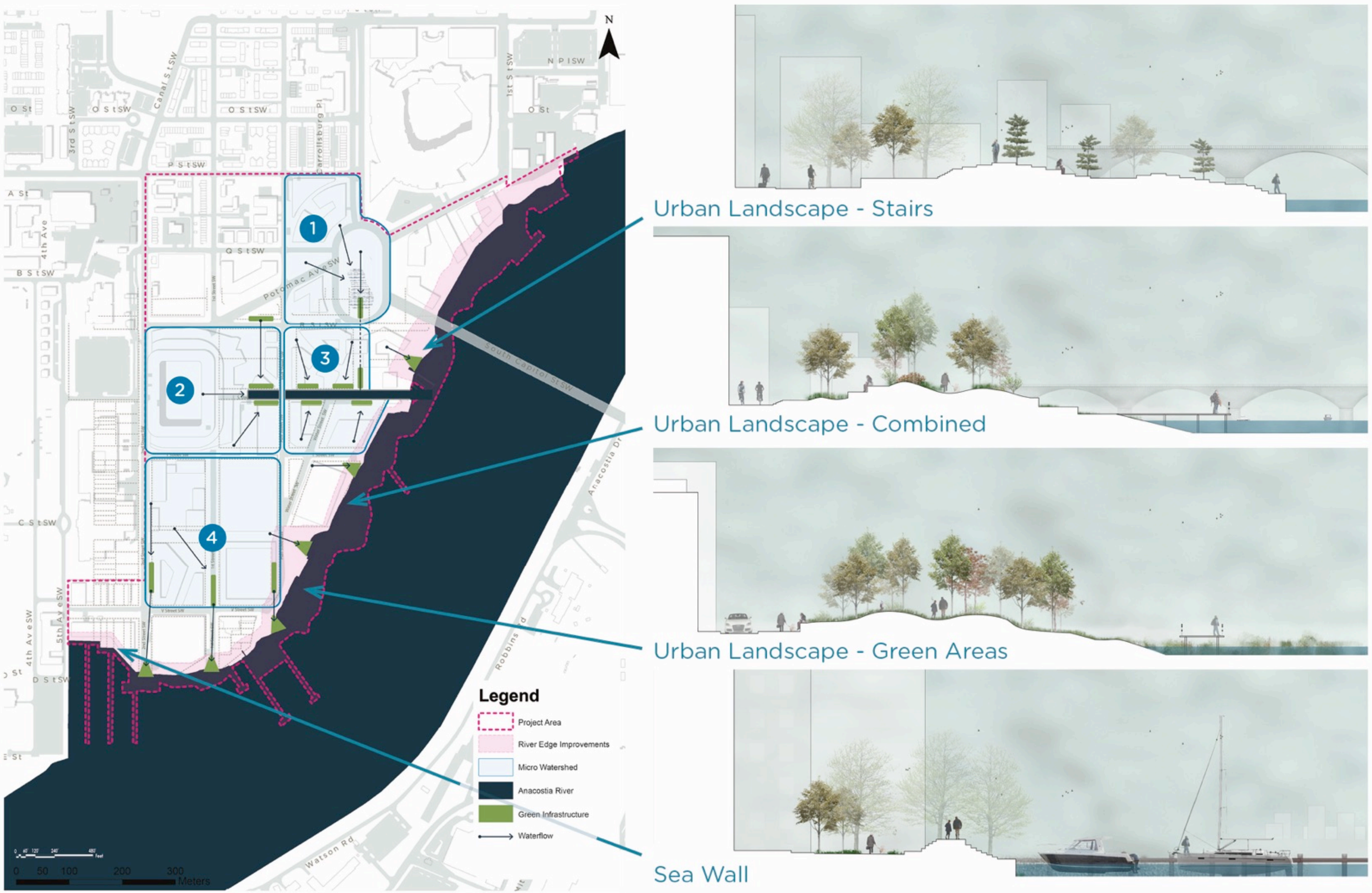
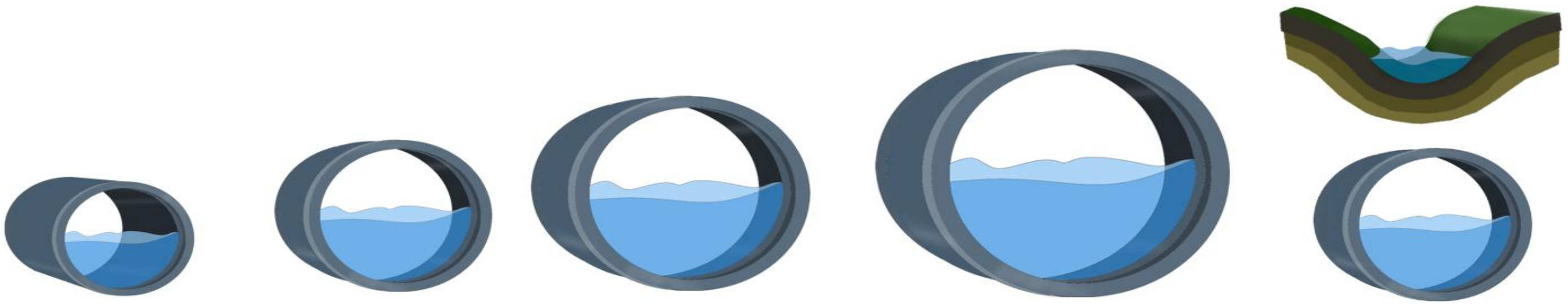

N
Legend
Project Area
River Edge Improvements
Micro Watershed
Anacostia River
Green Infrastructure
Waterflow
1
2
3
4
0 50 100 200 300 Meters
Potomac Ave SW
South Capitol St SW
Anacostia Dr
Robbins Rd
Watson Rd
Urban Landscape - Stairs
Urban Landscape - Combined
Urban Landscape - Green Areas
Sea Wall

RAMBOLL

VISION PLAN, REVISED

RAMBOLL

REDUCING INFRASTRUCTURE COSTS AND INCORPORATING CLIMATE RESILIENCY WITH BLUE-GREEN SOLUTIONS



1 year

3 years

5-10 years

10-15 years

Combined blue green solutions 10 years

Effect of combined Blue Green solutions with conventional (grey) pipes

THANK YOU

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