



SOURCE TO STREAM

2024 Conference

Canada's Premier
Stormwater and Erosion
and Sediment Control
Conference

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A photograph of the Benjamin Franklin Bridge in Philadelphia at sunset. The bridge's steel structure is silhouetted against a sky of orange, yellow, and blue. The city skyline is visible in the background, and the bridge's reflection is seen in the water below.

Adapting Urban Water Policies and Practices for a Changing Climate

*Howard Neukrug, P.E.
Executive Director*



The Water Center
UNIVERSITY of PENNSYLVANIA



The Water Center

UNIVERSITY of PENNSYLVANIA

“Community. Equity. Science. Resilience. Justice.”



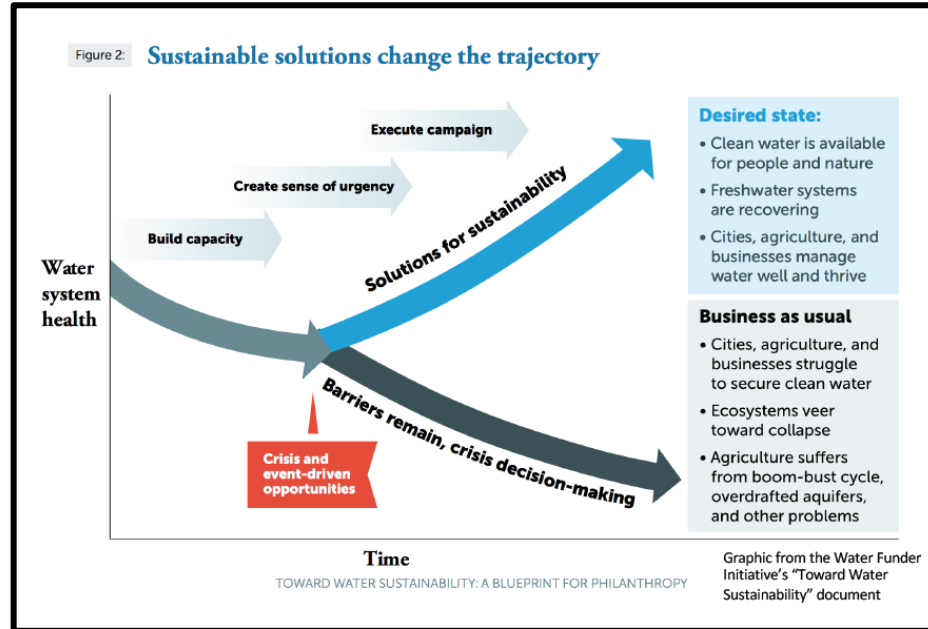
Our Mission

We aim to find resilient, sustainable, equitable, local solutions to our urban water challenges, the watersheds that support them, and the communities that rely on them.



The Water Center
UNIVERSITY of PENNSYLVANIA

Adapting to climate disruption requires disruptive changes in how we think, plan, design, integrate, construct, operate, and fund our work.



Water Systems are adapting and expanding their role from “service providers” to “resource stewards.”



The Water Center
UNIVERSITY of PENNSYLVANIA

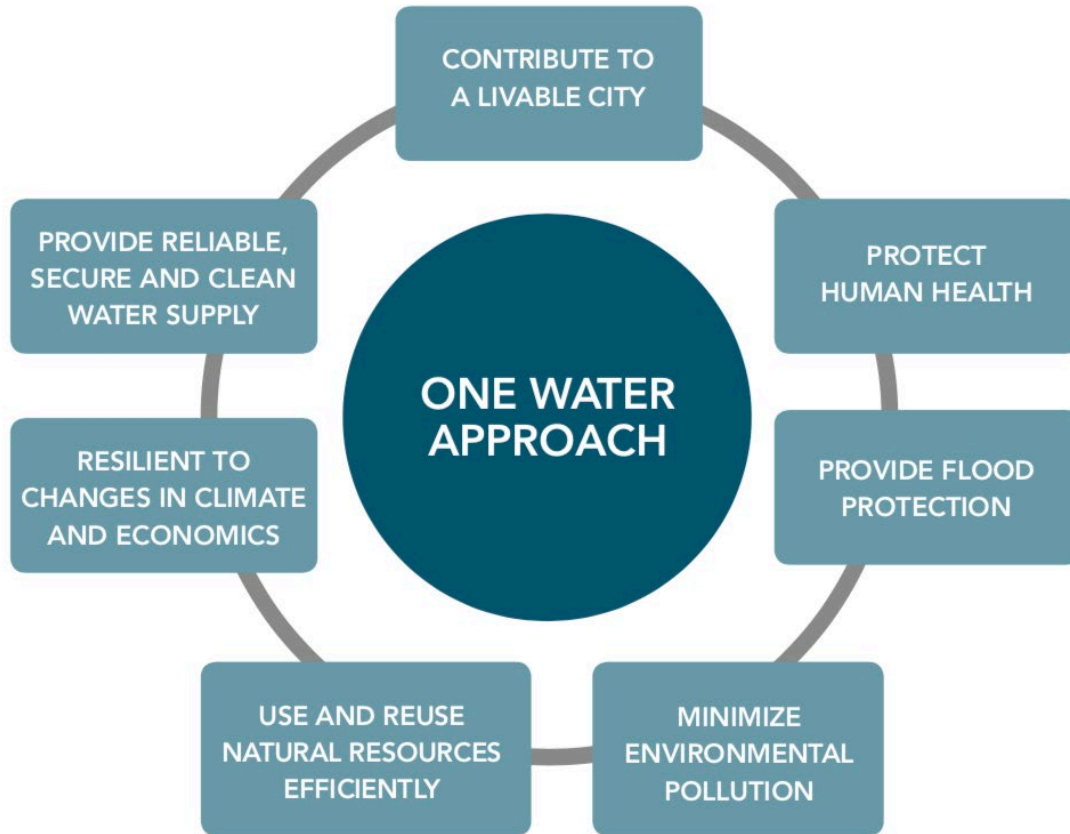
The natural system assumptions upon which we base all water standards, permits, and water use and delivery systems may no longer be valid.



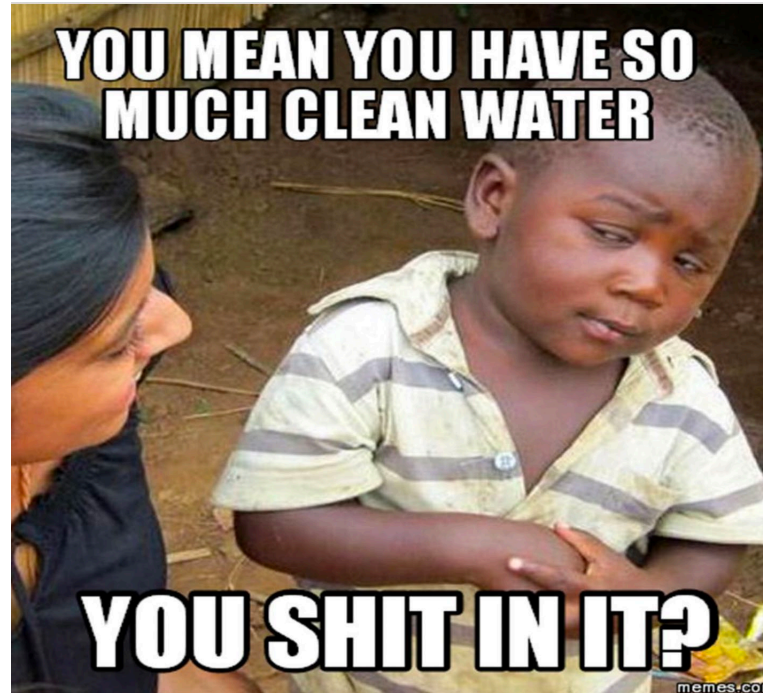
USEPA Climate Ready Water
Utilities Working Group



The Water Center
UNIVERSITY of PENNSYLVANIA

















Water System Challenges and Solutions from Around the World





Global Water Leaders Group

The 70 Leading Utilities of the World



GWI

GLOBAL
WATER
INTELLIGENCE
MAGAZINE

5

MAY 2017

WATER IS OUR CONCERN



WHEN THE BEST IN THE WORLD ISN'T GOOD ENOUGH
SINGAPORE'S PUB CORP FILTERS NO TELLING HOW THE UTILITY IS LOOKING BEYOND ITS GLOBAL REPUTATION

ABENGOA GOES AGAIN
SPANISH FIRM SURVIVAL ONE DEBT WORRIES AND PLOTS A CAPITAL-LIGHT RETURN TO THE TOP TABLE

BRINGING TREATMENT BACK HOME
GWI INVESTIGATES HOW TO MAKE DECENTRALISED WASTEWATER TREATMENT SYSTEMS PAY OFF

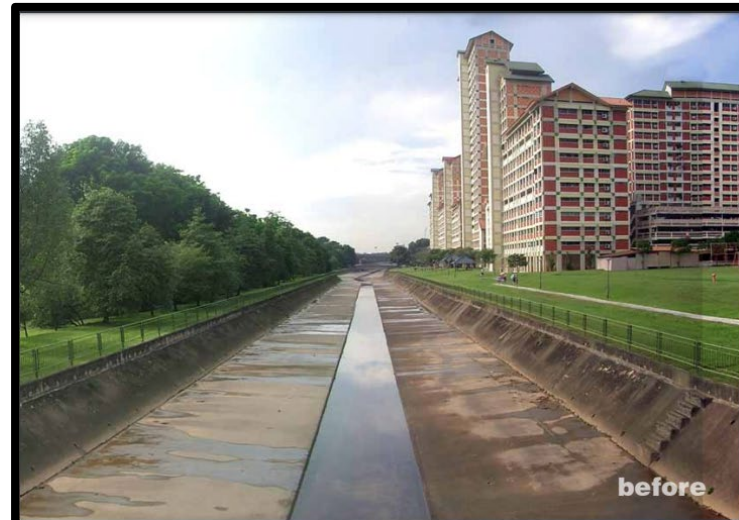
WWW.GLOBALWATERINTELLIGENCE.COM

Bishan - Ang Mo Kio Park and Kallang River

Singapore



PUB Singapore's National Water Agency





During Storm Event



After Storm Event



Singapore's Rooftop Gardens



Singapore Desal





Reverse Osmosis Membranes, Singapore

(AP Photo/David Goldman)



A poster promoting water conservation, Singapore



Ultraviolet (UV) Light Technology, Singapore

(AP Photo/David Goldman)



Singapore draws wastewater from its sewers to deep tunnels. The wastewater is then treated using microfiltration, reverse osmosis, and UV disinfection and discharged to its drinking water reservoirs.



A floating solar panel farm on the Bedok Reservoir,
Singapore.

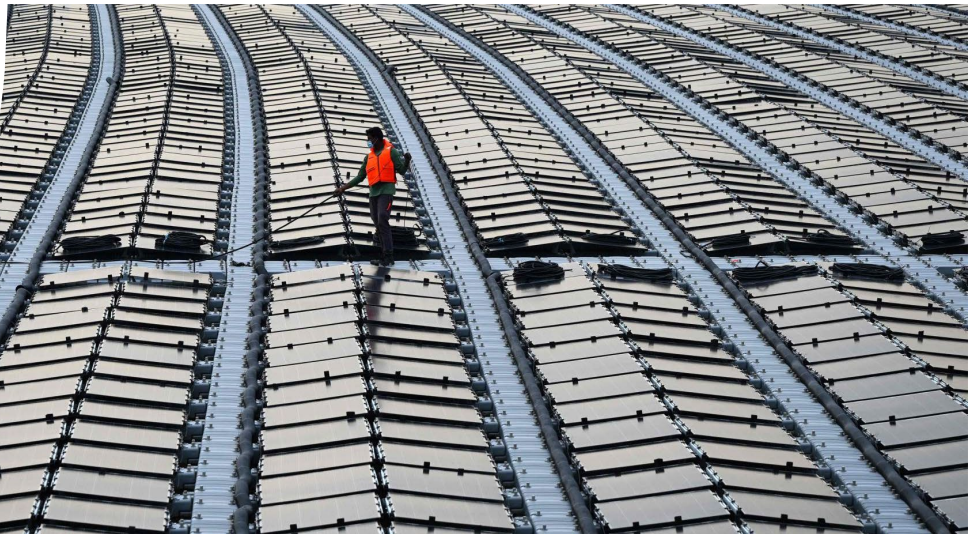
Floating Solar PV Panels – Southeast Asia

The water provides cell cooling and increased energy efficiencies

The Floating Panels prevent evaporative losses and protect water quality

Perfect for where land is scarce and/or expensive

Net-zero energy for Drinking Water Treatment

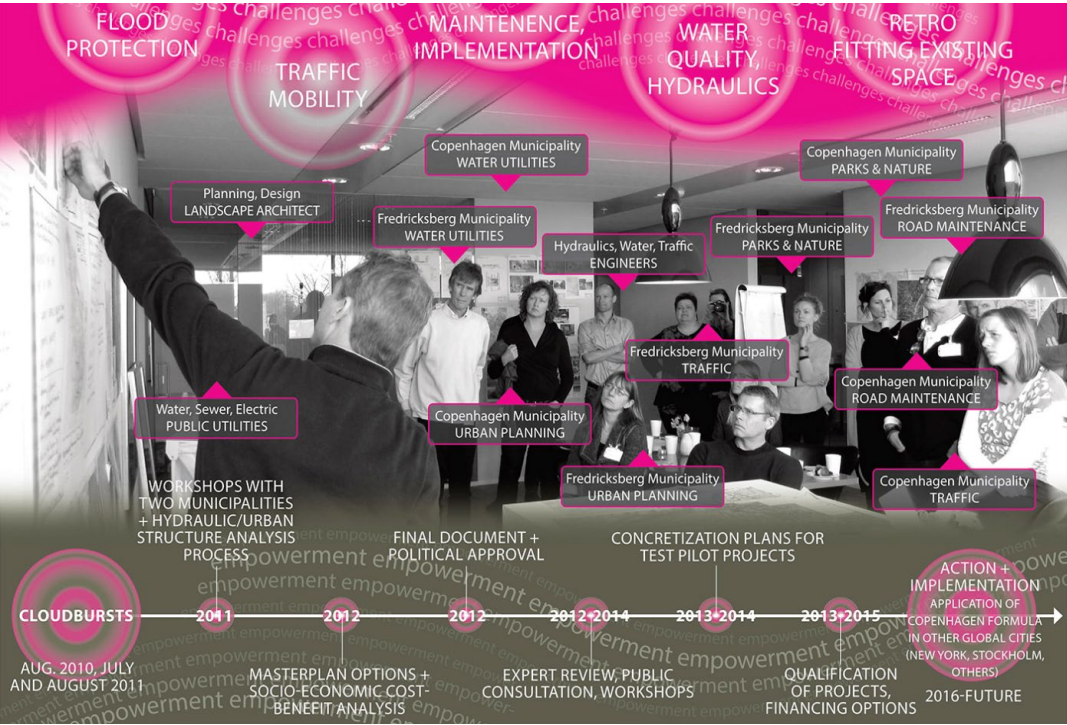




96 million shade balls

Los Angeles Reservoir

Cloudburst Programme Copenhagen, Denmark, 2012



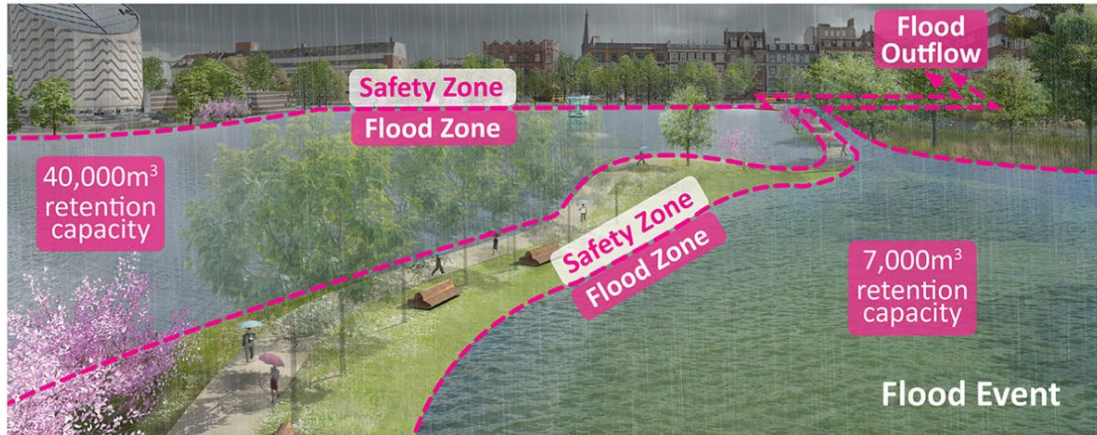
Cloudburst tunnels

Another thing that characterizes the solutions pursued in Copenhagen is multifunctionality. Because heavy rain doesn't happen every day, and so for the investments in the new infrastructure to be worthwhile, they must also serve a purpose at other times. A good example of this is the cloudburst tunnels. Also called highways for stormwater, these tunnels are some of the biggest investments in the cloudburst plan. And while their main purpose is to secure the city during cloudbursts, they also have a climate protection effect on a more regular basis.

"The big challenge by making these cloudburst tunnels is it's a huge investment and you don't want it just to be in function once every 10 years or every 50 years. For example, they are now being used when our sewer system is overloaded just with a normal daily rain, but still sort of a bigger daily rain and they're getting overloaded. We spill it into the tunnels instead, so they become a kind of retention tanks. So, this way they have several functions."

Multi-agency, Multi-functionality

Hans Tavsens Park, Copenhagen, Denmark



Hans Tavsens Park, Copenhagen, Denmark



The park when it is dry. (Image by © Beauty and the Bit, courtesy of SLA)



The park after rainfall. (Image by © Beauty and the Bit, courtesy of SLA)

Multi-Functional Urban Spaces in Copenhagen



The master plan outlines 300 surface solutions to be implemented that incorporate new urban spaces and recreational areas © Carsten Ingemann



The WATER PLUS project in Gladsaxe is normally used as a paddle court but with heavy rains can also detain and store water © Christina Geer Sørensen

Water as the heart of the design Enghaveparken, Copenhagen



Cloudburst, Copenhagen

05 Urban Canal

Existing Street Majorly Flooded in 2011



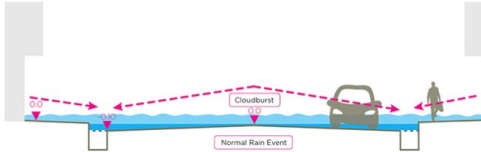
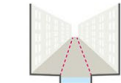
Dry, Normal



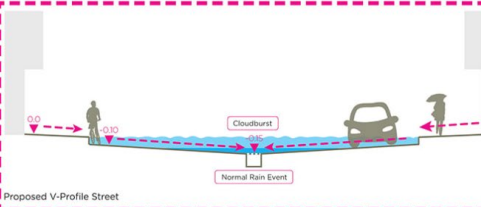
Rain Event



Cloudburst

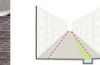


Conventional: Existing Crowned Street

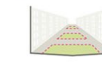


Proposed V-Profile Street

06 Urban Creek



07 Retention Boulevard



08 Boulevard



EVERYDAY RAIN
30% DISCONNECTION
from existing combined
SEWER system.

Driving Investment

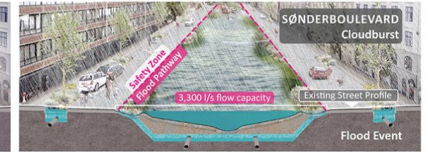
Blue-Green infrastructure helped to lower capital, operational, and maintenance spaces by as much as 75% (Source: American Rivers 2012), while Danish Consultants calculated that USD \$200 million investment costs could be saved by combining Blue-Green solutions with minimized conventional piping.



Rain Event Handled within Multi-Functional Tools including Urban Creek, Retention Boulevard, and Boulevard



SØNDERBOULEVARD Dry



SØNDERBOULEVARD Cloudburst

Flood Event

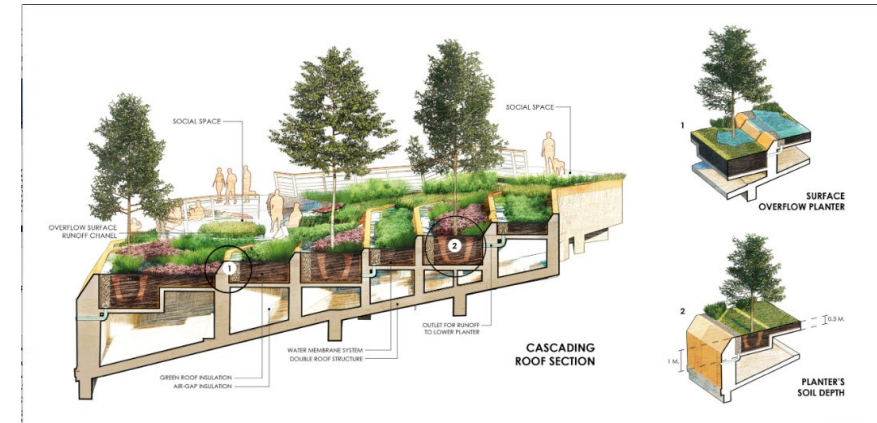
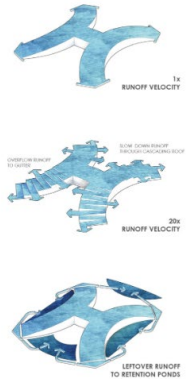
Copenhagen's Harbor



Farm of the Future: Kotchakorn Voraakhom on the Epic Urban Rooftop Farm

LANDPROCESS Brings landscape and architecture together at a grand scale in Thailand.

Eric Baldwin



Bangkok, Thailand

Kotchakorn Voraakhom



Chulalongkorn University Centenary Park
Bangkok, Thailand



Bangkok, Thailand
Kotchakorn Varaakhom

Seoul, South Korea



Bangkok, Thailand





上海市水资源及海绵城市建设情况

Water Resource Management and Shanghai's Sponge City Development

上海市水务局
Shanghai Water Authority

海绵城市概念



海绵城市：是指通过加强城市规划建设管理，充分发挥建筑、道路和绿地、水系等生态系统对雨水的吸纳、蓄渗和缓释作用，有效控制雨水径流，实现自然积存、自然渗透、自然净化的城市发展方式。

Sponge City : Through enhancing urban planning management to fully utilise buildings, roads, green lands, water ways and other ecological systems to absorb, store and drain rainwater . The Sponge City Initiative aims to control stormwater runoff effectively, and allow rainwater in each city to permeate, cleanse and be stored naturally .



1 4 5 T J E 3 Sponge City Concept

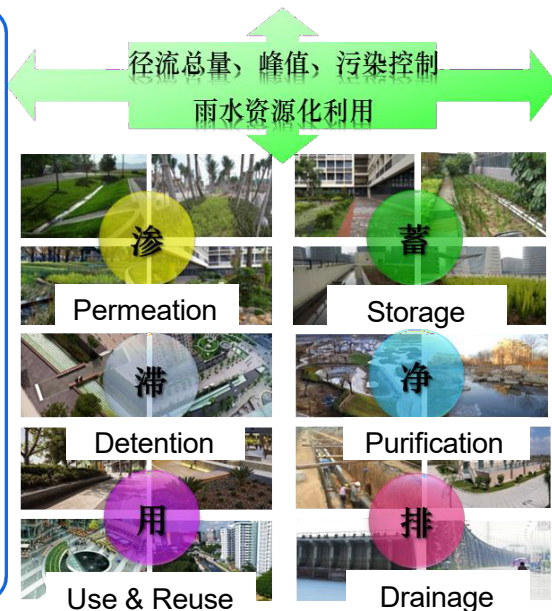


Traditional City Development

传统城市开发

- ✦ 改造自然
- ✦ 填水造地
- ✦ 硬质铺装
- ✦ 快排管网
- ✦ 一次性投资大
- ✦ 兼顾近远期难
- ✦ 运行成本高
- ✦ 效益偏低

Total surface runoff, peak flow, pollution control, rainwater usage



Sponge City Development

海绵城市建设

- ✦ 顺应自然
- ✦ 保护恢复天然河道水系
- ✦ 透水铺装等低影响开发
- ✦ 地上地下蓄排结合
- ✦ 分布式建设系统
- ✦ 兼顾近远期
- ✦ 增加一次性投资
- ✦ 运行成本、效益综合优

- Conforming to Nature
- River Restoration
- Permeable Pavement and LID
- Combining surface and underground storage and drainage
- Distributed Construction System
- Short & Long-term Planning
- Increase Once-off Investment
- High Comprehensive Benefit

- Changing Nature
- Land Reclamation
- Impervious Pavement
- Network to Discharge Stormwater Quickly
- Huge Once-off Investment
- Short-term Planning Only
- High Operational Cost
- Low Returns of Investment



Examples of Sponge City Sites



世博园区 Shanghai Expo Park

——建成雨水利用、低影响

开发理念示范区

Build pilot sites

demonstrating rainwater

usage and LID concepts



杨浦区新江湾城

New Jiangwan Town, Yangpu

District

——体现海绵城市建设理念

Demonstrate the concept

of Sponge City



海洋大学临港校

Shanghai Ocean University
(Lingang Branch)

——体现生态环境保护、雨
水综合利用等理念

Demonstrate the concept
of ecosystem protection
and integrated rainwater
usage

COVID: Resilient Recovery! The BIG7



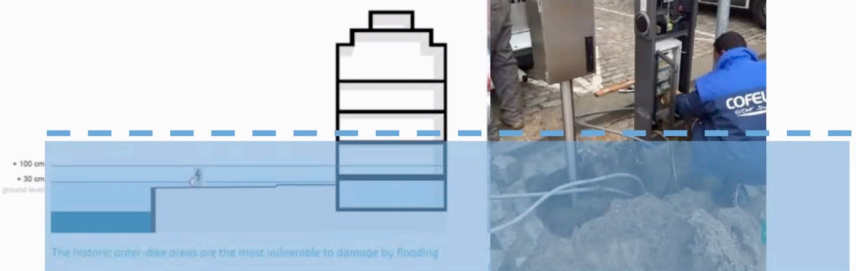
GLOBAL
CENTER ON
ADAPTATION

www.resilientrotterdam.nl



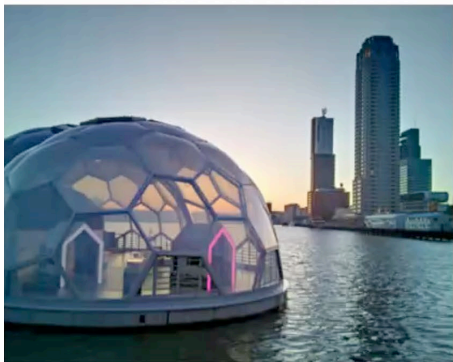
Foto: Public Domain Architecten

FLOODING & VITAL INFRASTRUCTURE: CASCADE EFFECTS



The historic outer-dike areas are the most vulnerable to damage by flooding





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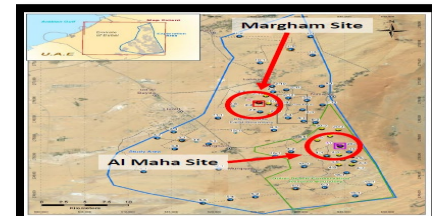
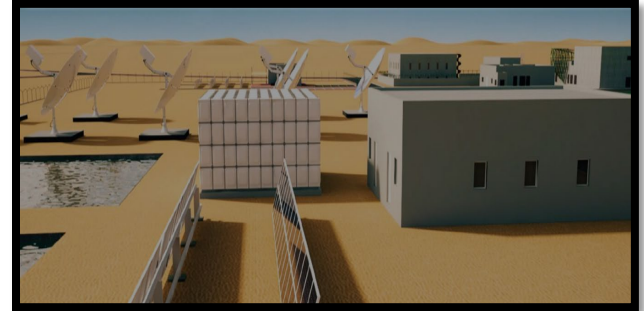
The Water Square in Benthemplein



Rotterdam's response to the dual need for open recreational space and places to store water during heavy rain events

Dubai Electricity and Water Authority (DEWA)

- 100 % DESAL WATER from clean energy technologies by 2030
 - Solar power
 - Waste heat
 - Hydroelectric
- World's largest strategic reserve of DESAL WATER
 - 6,000 MIG
 - Geophysical / hydrogeological field studies
 - Inject DESAL WATER into subterranean basins
 - Use when needed as an energy reserve



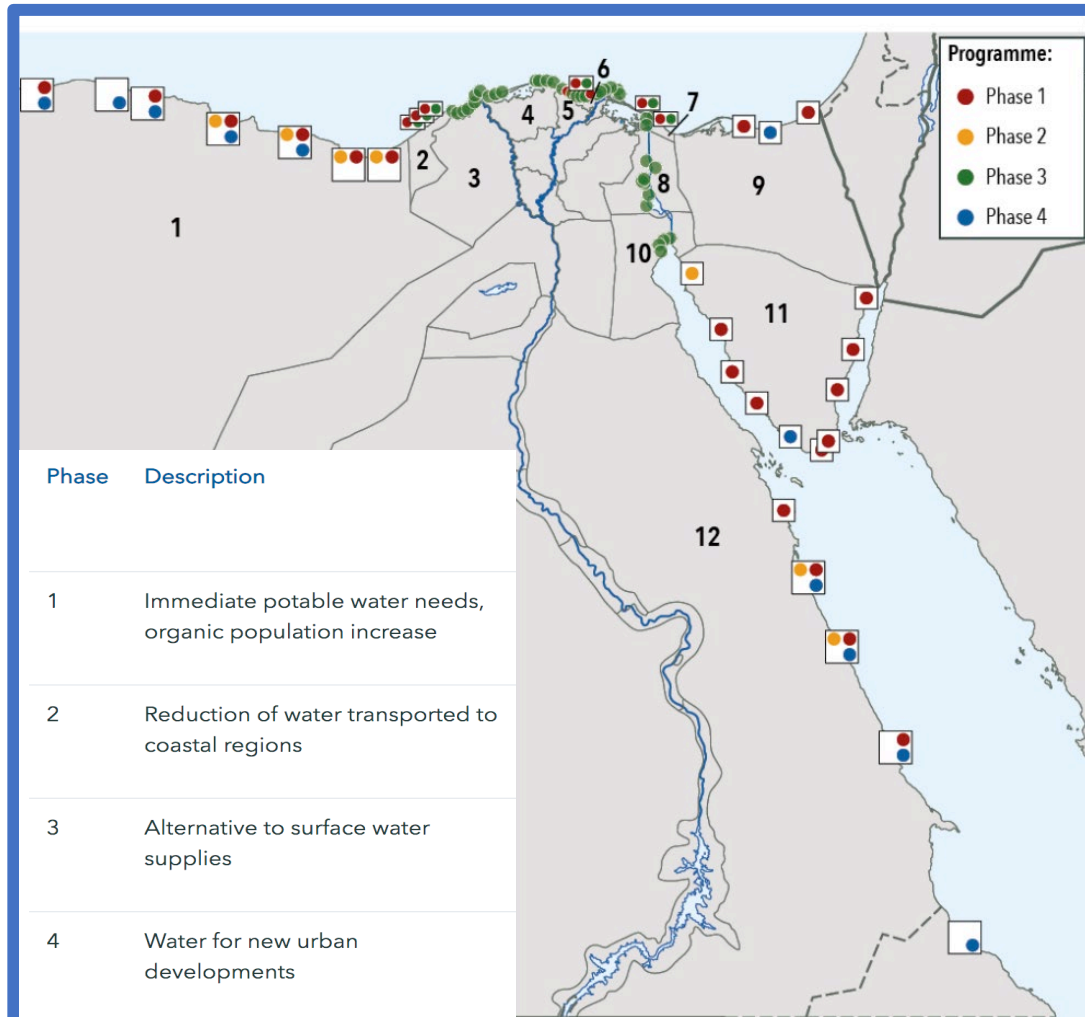
Egypt's Desal Plan: \$15 Billion, 30-years

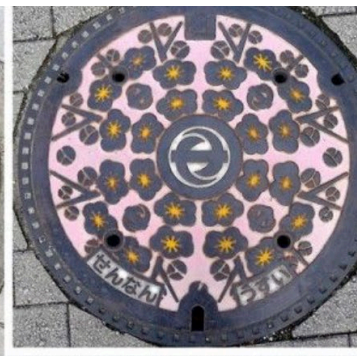


EGYPT'S WATER STARTS TO RUN SHORT

Egypt's booming population is putting its stretched water resources under increasing strain. With the population set to grow by 50% or more over the next 30 years, seawater desalination is seen as a priority.

Source: Shutterstock





Green City, Clean Waters



"This is the most significant use of green infrastructure I've seen in the country, the largest scale I've seen."

Jon Capacasa, EPA regional director of water protection

Breaking ground with a \$1.6 billion plan to tame water

By Sandy Bauers
INQUIRER STAFF WRITER

Philadelphia has announced a \$1.6 billion plan to transform the city over the next 20 years by embracing its storm water — instead of hustling it down sewers and into rivers as fast as possible.

The proposal, which several experts called the nation's most ambitious, reimagines the city as an oasis of rain gardens, green roofs, thousands of additional trees, porous pavement, and more.

All would act as sponges to absorb — or at least stall — the billions of gallons of rainwater that overwhelm the city sewer system every year.

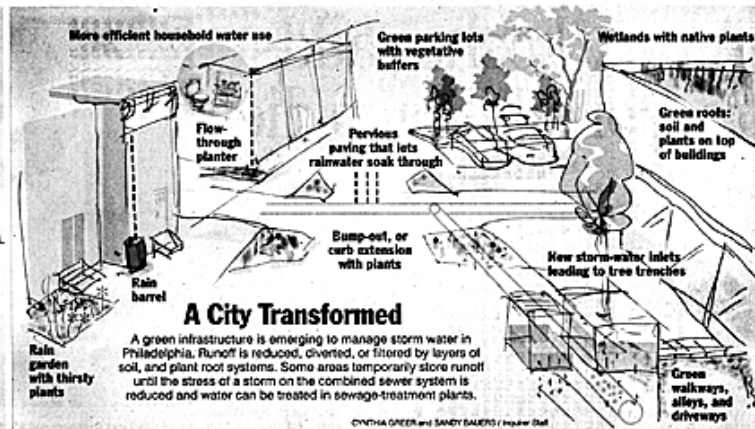
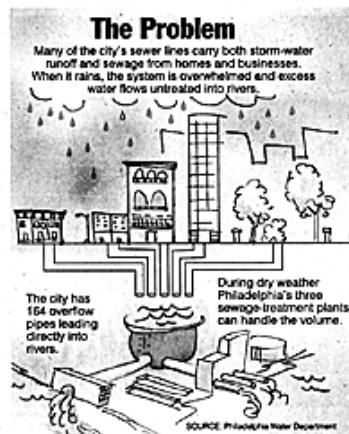
The plan's complex funding formula would raise rates somewhat but also attract grants and encourage private investment.

Further, the Water Department says the city's greening would result in more jobs, higher property values, better air

See **STORMWATER** on A14

The Philadelphia Inquirer

Sunday, Sept. 27, 2009 ★ Locally Owned & Independent Since 2006 ★ \$1.75



A green plan to embrace any deluge

How do you stop flooding and overflowing pipes?

- Make it stop raining so much
- Increase grey infrastructure capacity
- Stop putting rainwater in my sewer

“Once rainwater enters the sewer inlet, it turns from a resource into a waste product.”

Do we expand capacity or reduce demand?



Photo by Jacob
Fenston/WAMU

The Anacostia 26' Diameter Tunnel about to go online

Belarus Nuclear Power Plant #2 about to go online



The Geography of Water Affordability

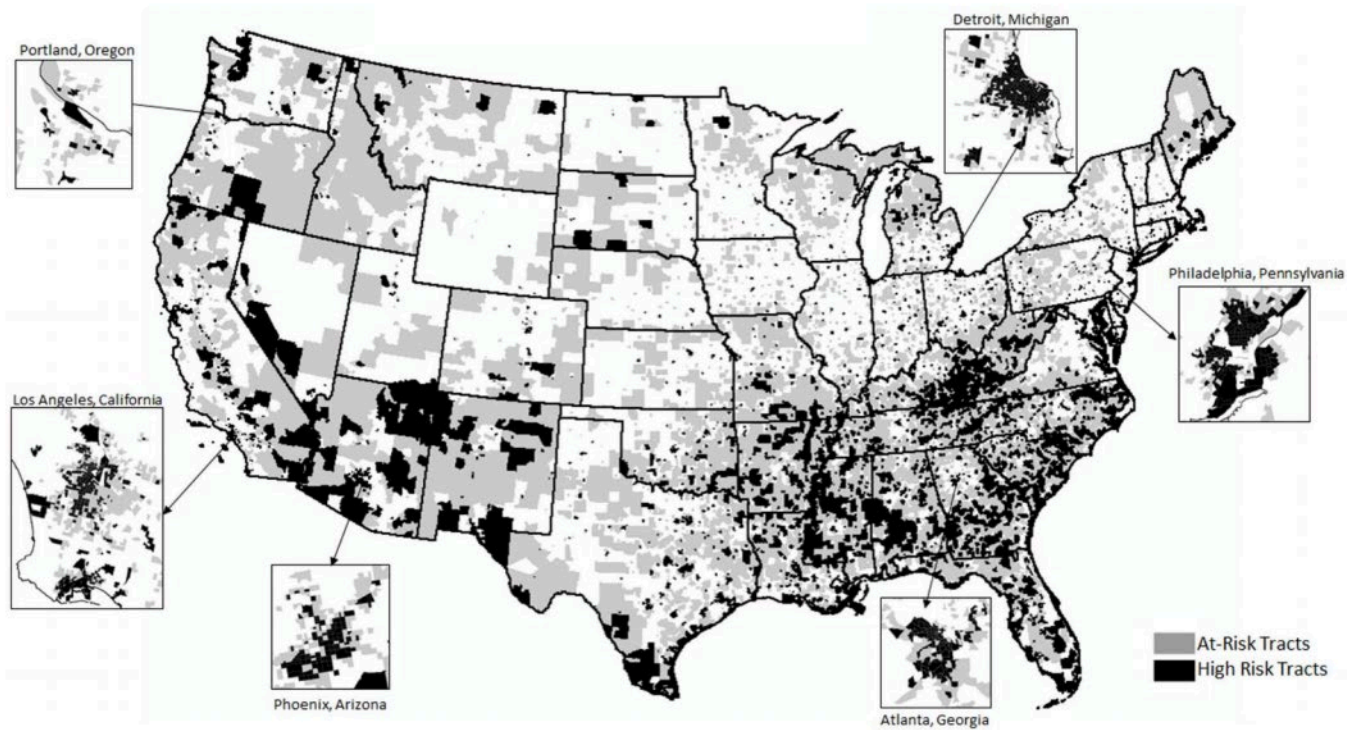


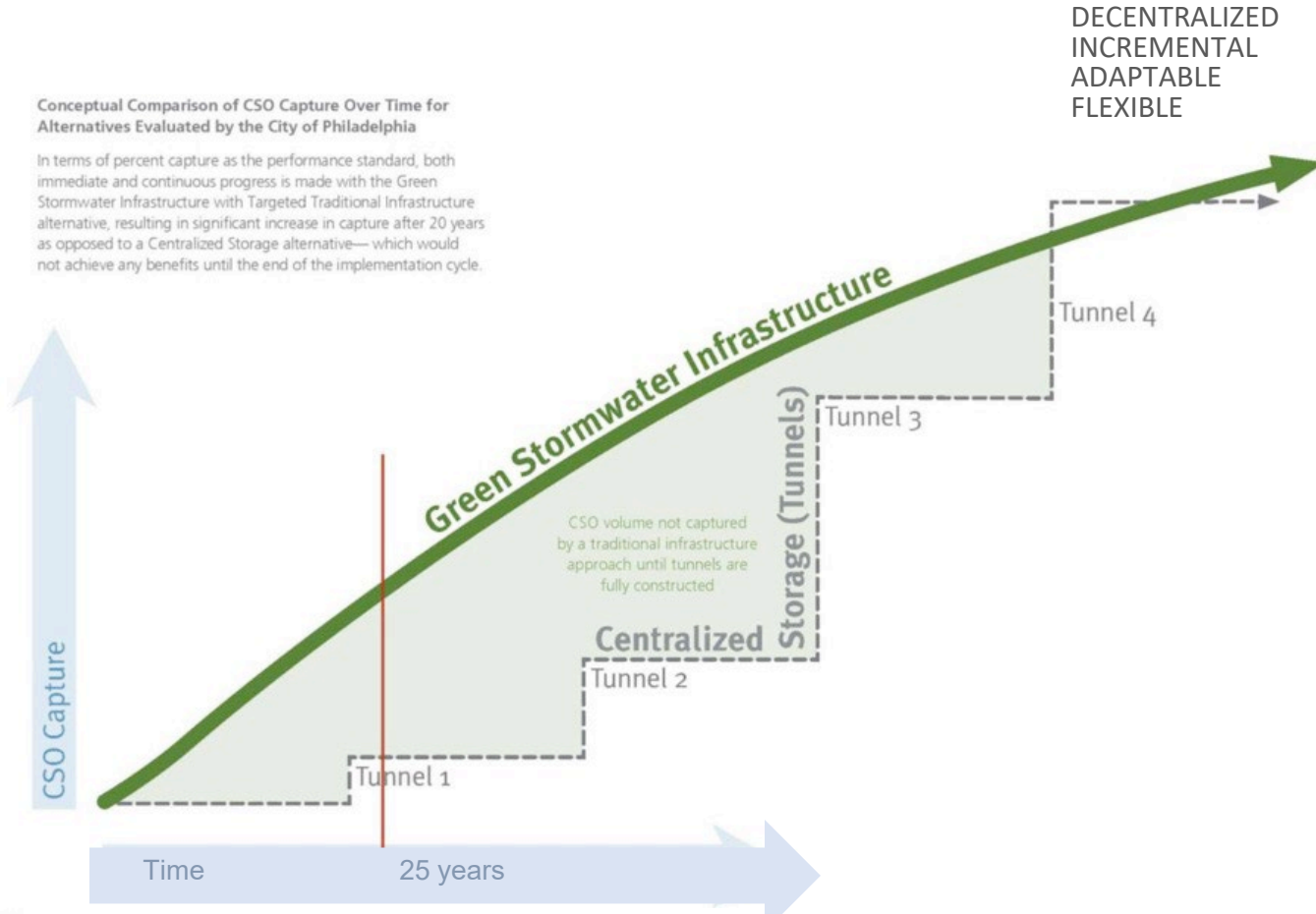
Fig 1. At-Risk and High-Risk Census Tracts.

doi:10.1371/journal.pone.0169488.g001

GSI vs CONVENTIONAL

Conceptual Comparison of CSO Capture Over Time for Alternatives Evaluated by the City of Philadelphia

In terms of percent capture as the performance standard, both immediate and continuous progress is made with the Green Stormwater Infrastructure with Targeted Traditional Infrastructure alternative, resulting in significant increase in capture after 20 years as opposed to a Centralized Storage alternative— which would not achieve any benefits until the end of the implementation cycle.



One Water, One City, Many Places

Changing the Paradigm by which Water Utilities service their cities

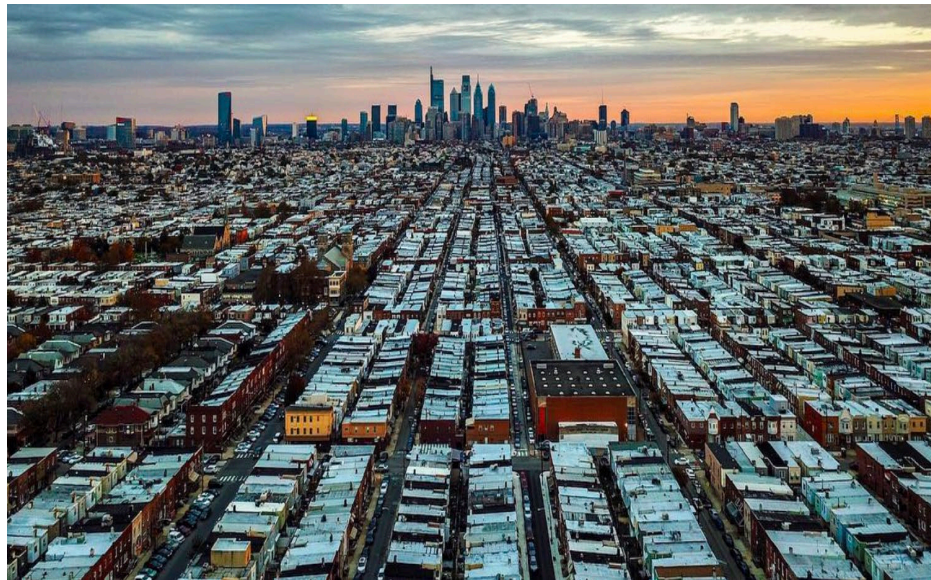
- Communities
- Transit
- Rivers & Streams
- Parks
- Schools
- Streets
- Businesses
- Parking lots
- Universities



Leveraging Water's Capital Dollars for Urban Sustainability, Resilience and Social Justice



Water, Gravity, and the *Incline* of our Cities



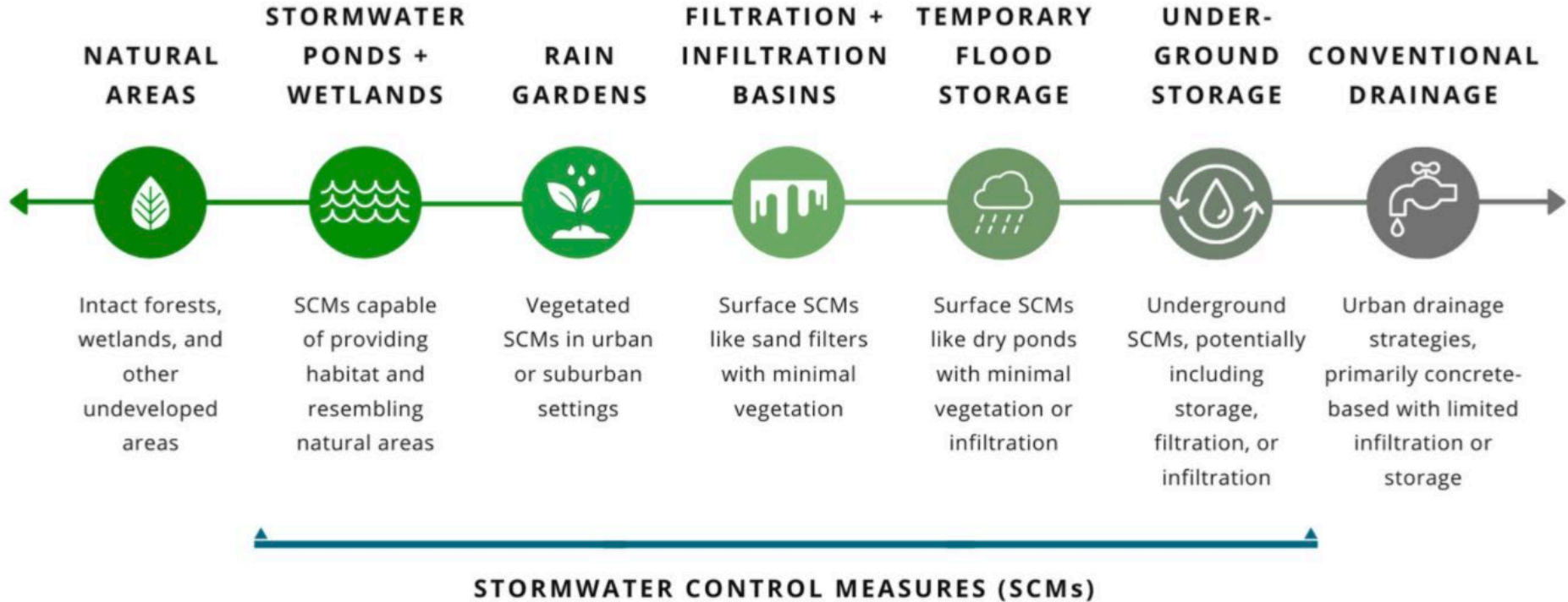
PHOTOLOPE



JESSICA GRIFFIN / Staff Photographer, Billy Penn

"GREEN" INFRASTRUCTURE

"GRAY" INFRASTRUCTURE



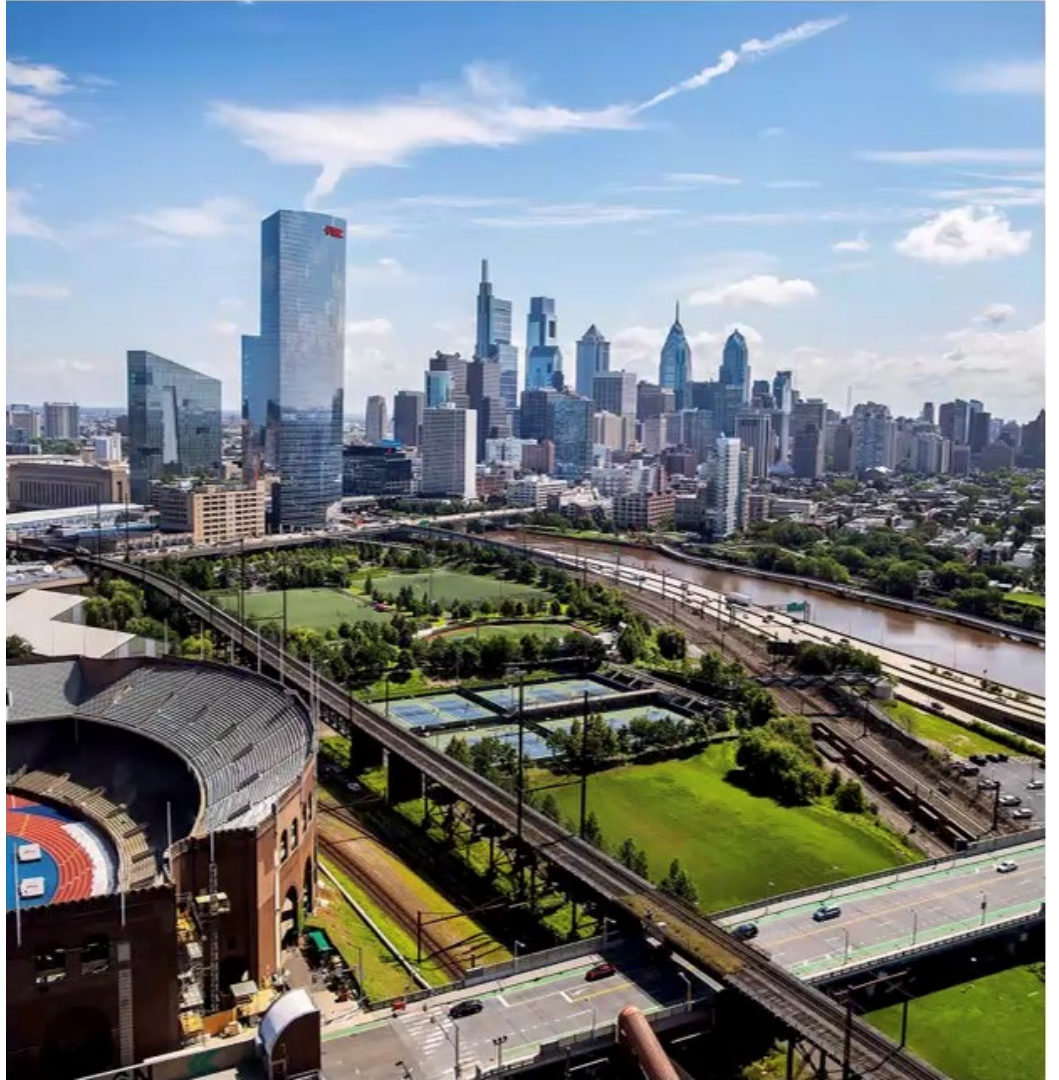


Green Inlets

Cliveden Park, Philadelphia



Penn Park







MALCOM X BARK TREE TRENCH

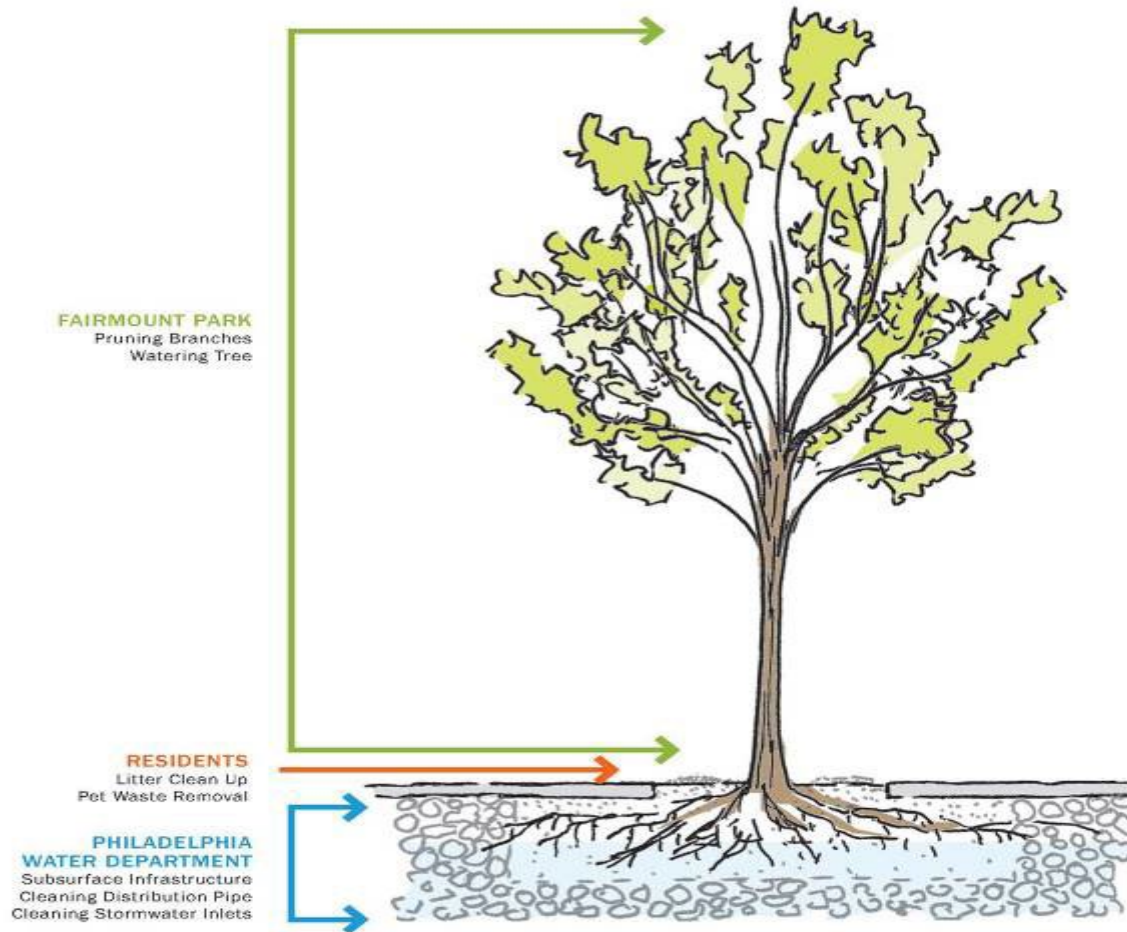


Figure 6: Conceptual rendering showing a proposed rain garden at a playground. Rendering by PWD.



DESIGN PLAYGROUND RAIN GARDEN

STORMWATER TREE TRENCH: Maintenance Responsibilities



Green City, Clean Waters



WRT *Philly's bold plan for urban landscape restoration envisions peeling back the hard surfaces and creating a 'giant sponge'*

Green City Clean Waters

The City of Philadelphia's Program for Combined Sewer Overflow Control
A Long Term Control Plan Update

Submitted by the Philadelphia Water Department
September 1, 2009

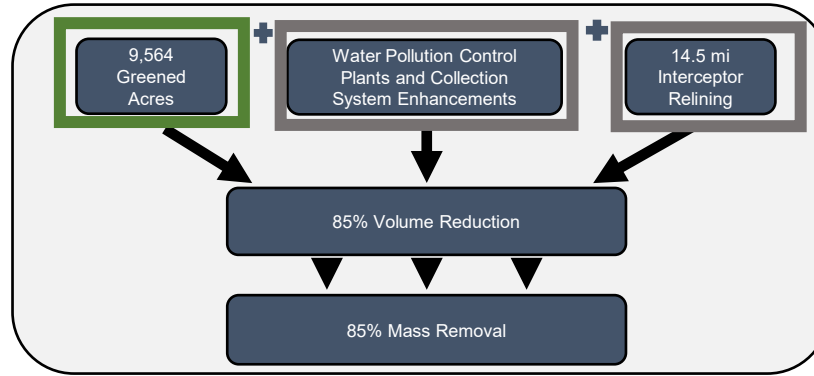


Philadelphia's 25-year Green Stormwater Infrastructure Program

- ✓ 10,000 Green Acres
- ✓ No Storage Tunnel
- ✓ Meet EPA mandates
- ✓ Triple-bottom-line economics
- ✓ \$2.4 billion vs. \$9 billion
- ✓ Upgrades the existing sewer system
- ✓ Institute Parcel-based Stormwater Fees
- ✓ Establish SW Development Regulations
- ✓ Offer Grants / Incentives for Private Retrofits
- ✓ Public engagement
- ✓ Adaptive Management
- ✓ Water Equity, Environmental Justice, Jobs

Green City, Clean Waters

Consent Order and Agreement / Administrative Order for Compliance on Consent
25-year, \$4 Billion Implementation Program



Year	Greened Acres	Square Miles	% Impervious cover managed
5	750	1	3%
10	2,100	3	8%
15	3,800	6	14%
20	6,400	10	23%
25	9,600	15	34%

Green Stormwater Infrastructure | Defined

A range of soil-water-plant systems that *intercept stormwater, infiltrate* a portion of it into the ground, *evaporate and transpire* a portion of it into the air, *harvest and reuse* as a resource, and in some cases *slowly release* a portion of it back into the sewer system



$$GA = IC * Wd$$

Greened
Acre

Impervious
cover

Water
Depth

How is GSI built in Philly?



10000 Green Acres

1230

3060

5710

GSI in Philadelphia: January 2021



Working across programs and implementation pipelines is key.

Public Retrofits + Incentives + Redevelopment = 10,000 acres

Streets	2,960		40	3,000
Parks	1,290	20	40	1,350
Commercial		2,550	460	3,010
Facilities	465	180	255	900
Schools	540	30	130	700
Vacant	445		55	500
Campuses	10	170	210	390
Residential		110	40	150
	5,710	3,060	1,230	10,000

2021 Grants: \$125k / GA

Private property owners have used grants issued through the program to construct more than **750 Greened Acres since 2012**. Each Greened Acre manages nearly **30,000 gallons** of runoff during a **one-inch rainstorm**.



Historic Germantown (left) and Popi's Italian Restaurant (right) are past Stormwater Grant recipients.

Facing a reduced budget following the pandemic, the team reviewing applications for grants reconsidered what made a project stand out as worthy of funding. With many residents working from home and spending more time in neighborhoods, projects rich in secondary benefits like **increased local green space took priority**.

“Providing surface greenery throughout Philadelphia was a priority for us when reviewing applications, especially in this unprecedented year when access to green space in our own neighborhoods close to home has been critical for our mental health,” says *Beth Anne Lutes, Stormwater Billing and Incentives manager*.

As we conclude 2020, we're proud to award **11 resourceful recipients more than \$5 million in grants** with properties adding up to about **40 Greened Acres**.

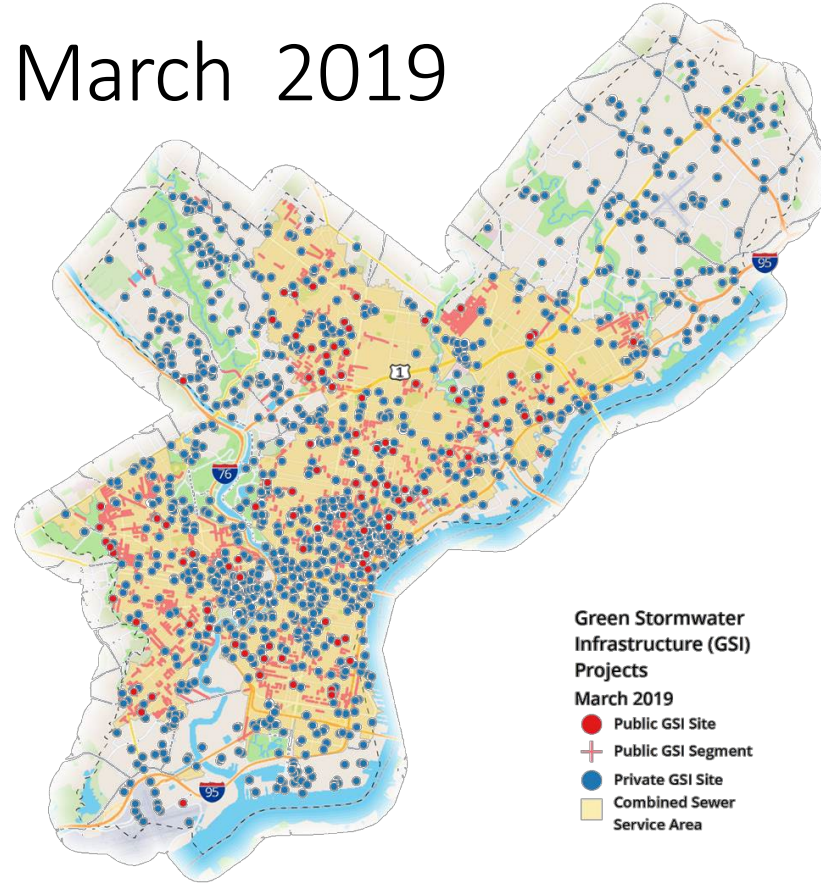


Randy E. Hayman, Water Commissioner

FY2020 Stormwater Grant Awardees December 2020

Project Name	Address	Grant Amount	Project Model	Greened Acres	Project Manager/Consultant	Property Owner
Add B. Anderson School	1034 S. 60th St.	\$195,369	Alt SMIP	0.87	Trust for Public Land	School District of Philadelphia
AMY Northwest Middle School	6000 Ridge Ave.	\$28,650	Alt SMIP	0.17	Trust for Public Land	School District of Philadelphia
Esperanza Headquarters	4231-61 N. 5 th St., 300, 406 W. Bristol St., 301 W. Hunting Park Ave.	\$416,320	Alt SMIP	2.45	The Nature Conservancy	199 Hunting Park
Grover Washington Middle School	201 E. Olney Ave.	\$418,825	SMIP	2.47	KSE (KS Engineers, P.C.)	School District of Philadelphia
James R. Lowell Elementary School	5801-51 N. 5th St.	\$25,811	Alt SMIP	0.16	Trust for Public Land	School District of Philadelphia
Kin Properties	900 Orthodox St.	\$2,655,437	SMIP	14.09	Landcore Engineering Consultants P.C.	Hareff LLC
KIPP Charter School	2600 W. Clearfield St.	\$328,350	SMIP	2.19	Ruggiero Plante Land Design	KIPP Whittier Development LLC
Philadelphia Federal Credit Union	12800 Townsend Rd.	\$167,500	SMIP	3.89	KSE (KS Engineers, P.C.)	Philadelphia Federal Credit Union
Teo Chew	6630 Lindbergh Blvd.	\$629,019	SMIP		Pennoni, Inc.	Teo Chew Association
Thomas Alva Edison High School	151 W. Luzerne St.	\$843,700	SMIP	6.43	KSE (KS Engineers, P.C.)	School District of Philadelphia
Water Reuse System	236-56 E. Hunting Park Ave.	\$166,500	SMIP	1.11	Ruggiero Plante Land Design	Don't Hunt the Whale LLC

GSI Projects: March 2019



10 Miles



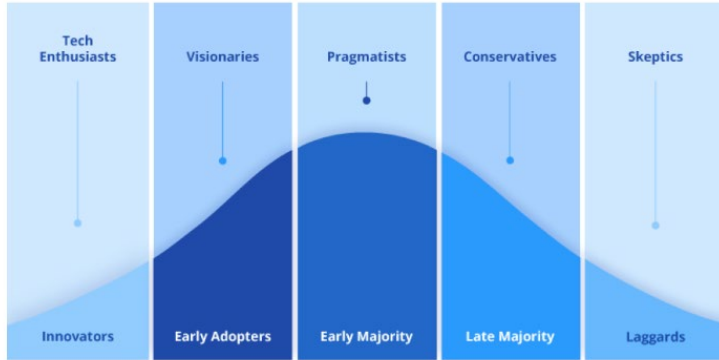
“Philadelphia has earned its place as a national and global leader in sustainable innovation and clean water production.”



-EPA Administrator Lisa Jackson

Driving Green Innovation

Technology Adoption Curve



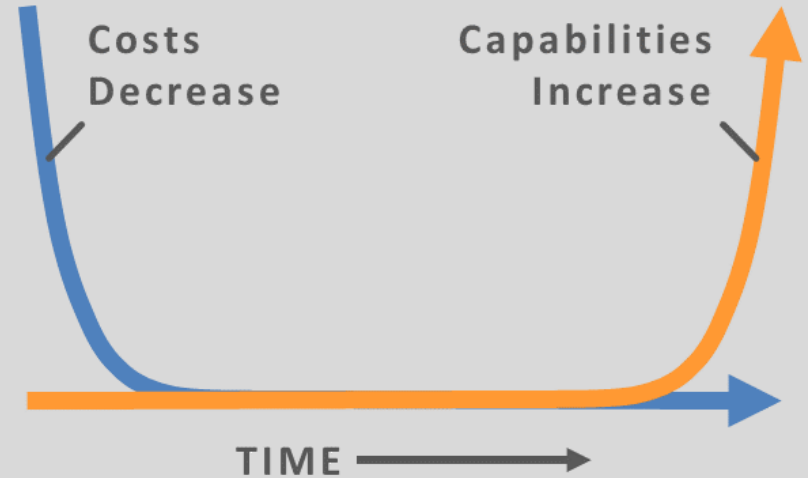
SYDLE

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Stages of decision in the innovation process

- Knowledge
- Persuasion
- Decision
- Implementation
- Confirmation

THE IT CONVERGENCE CURVES



© 2014 RBCS



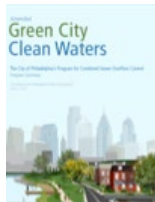
There are many differences between Green City, Clean Waters and other green stormwater programs



Funding



Staffing



Regulatory requirements



Jurisdiction & Authority



Physical landscape & existing infrastructure

Integrated Management



(don't forget about climate change)

We are building the plane
while we are flying.

-Gerald Bright, PWD GSI Maintenance Expert

Keys to GCCW Success

- Create a vision and find the political will
- Lead in technology, expertise, and passion
- Be patient and think long-term
- Leverage partners, funding, expertise
- New development / redevelopment standards
- Raise awareness and communicate
- Identify multiple cross-program benefits
- Become the voice for environmental advocacy
- Reduce poverty, improve quality of life
- One city/one region/one water policy

- Educate ratepayers/bondholders on the benefits
- Strengthen institutions, legislation, and regulation
- Commoditize rainwater through fees and credits
- Demonstrate, innovate and then set standards
- Nurture a new sustainability industry
- Transdisciplinary workforce
- Create a technology/knowledge clearinghouse
- Adaptive Management
- Leverage capital spending
- Build trust – one person at a time

Areas needing new thinking / innovation

- Continuous improvement of GSI techniques
- Optimizing Flood Relief, Scarcity, CSOs and River Water Quality
- Co-benefits vs Co-funding
- Distributed systems
- Making rainwater a commodity through True cost pricing
- One Water Integrated Planning



Image Kadir van Lohuizen



***Thank you for listening!
Have a great conference!***

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The Water Center at Penn

Questions?

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