San Francisco ESTUARY PARTNERSHIP

Innovation in Coastal & Watershed Resilience for Estuary and Delta Cities - Nature Based Solutions at Scale

State of the San Francisco Estuary Conference

Edgar Westerhof, October 29, 2025

ARCADIS

Agenda

1. Global Best Practices, Lessons Learned & Innovations in Flood Protection
    a) Dutch Systems Approach to Flood Control
    b) Governance & Capacity Building: Ecoshape
    c) Integrated, Multifunctional and Watershed Scale Strategies
2. US Case Study: Norfolk, Houston, New York City
3. Conclusions

Nature Based Solutions & Climate Adaptation

Mission Statement:

- Cities need to protect its citizens from climate risks such as extreme weather events, sea level rise, flooding in a cost-effective, sustainable and resilient way.
- Nature based solutions that can be an alternative to civil engineered solutions.
- Make valuable use of ongoing projects and future building plans by incorporating and investing in nature-based solutions.

Nature-based solutions are

"solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience."

European Commission

Goal: integration of NBS and civil engineering solutions for coasts, rivers and cities.

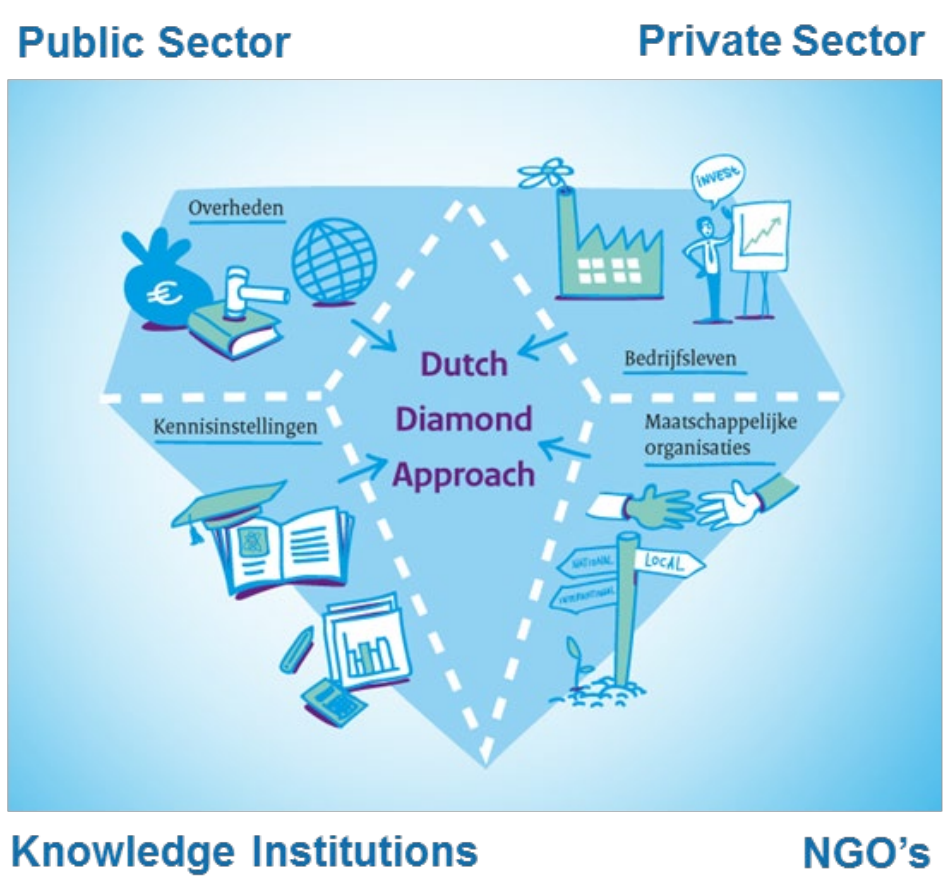
Cities are often located near rivers and coasts and therefore are exposed to a combination of these risks.

A Systems Approach to Water Management in the Netherlands

Image Sources: Rijkswaterstaat, City of Rotterdam

EcoShape Consortium

- Private sector & Public sector & Knowledge Institutes & NGO's
- Sectors working together with a shared ambition
- Formal Consortium – Agreement signed by all partners & acknowledged by government
- Allows for specific prefeasibility market approaches up to € 5M



EcoShape
ARCADIS
Boskalis
Dredging & Marine Experts
Royal HaskoningDHV
Enhancing Society Together
SWECO
TU Delft
Deltares
HKV
LIJN IN WATER
one architecture
Van Oord
Marine ingenuity
WAGENINGEN
UNIVERSITY & RESEARCH
Wetlands
INTERNATIONAL

Ecoshape achievements

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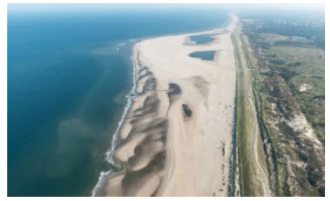
Nature Based Flood Defences

Houtrib Dike Pilot Project



Sand Motor Delfland Coast

Hondsbossche Dunes

Sand engine lake IJssel

Interreg VB North Sea Region project Building with Nature

NatureCoast

Resilient Delta Cities

Werven Park Dordrecht

Tidal park Rotterdam

CityDeal Klimaatadaptatie

Ecosystem Restoration

Sustainable Port Development

Living Lab for Mud

Clay Ripening Pilot Project

Building with Nature in Indonesia

Salt marsh development Marconi Delfzijl

Mud Motor Koehoal salt marsh development

Marker Wadden KIMA

EcoShape

building with nature

Ecoshape – Sand Engine

Building with Nature: Marker Wadden, creating *smart* ecosystems

Natural dike reinforcement, using sandy foreshore
→ Cost-saving and attractive

Island construction, re-using local sediments, goal:
→ Stimulate ecological potential and improve water quality

Small scale applications of the “Sand Engine”, goal:
→ erosion control waterfronts to address flexible future water levels

www.ecoshape.nl

Renovation of the Afsluitdiijk

"Award-winning project with sustainability at the core"

Needs

The Afsluitdijk Closure dike separating the Ijssel lake and the Wadden Sea has stood as a marvel of Dutch engineering since it was completed in 1932. The dike primarily takes care of the floodwaters from the Wadden Sea and drainage from the IJsselmeer, while also providing access between the provinces of North Holland and Friesland and shipping between the Wadden Sea and the Ijssel lake. Due to its age, rising sea levels and more extreme flow rates from land inwards , the dike had to be strengthened and the discharge capacity increased. Preferably in a most sustainable way.

Solutions

The dike will be heightened with 2 meters over a length of 32 kilometers. This is partly done by means of special developed Level-blocks, needing less concrete, leading to 56% CO_2 reduction. Also, less power for the pumps is used by making optimal use of the current. To power the pumping stations, solar energy will be used, and currently trails are done with power generating water turbines inside the dike. A fish migration river will be constructed to allow fish to swim from the Wadden to the IJssel Lake..

Outcomes

When finished, the Afsluit Dike will host one of Europe's largest pumping stations in a single dike and the dike will be able to withstand a storm that occurs once in a 10.000-year period, enhancing the coastal resiliency. Sustainable aspects of this project include, a fish migration river, solar panel fields, energy generating water turbines and the use of more sustainable concrete blocks. The project received a sustainability prize and is now an example for sustainable and resilient development across the world.

Reference: **Arcadis' work on the Afsluit Dike**

Client
Dutch Ministry of Public Works (Rijkswaterstaat)

Location
Ijssel lake, The Netherlands

Period
2018 - present

10

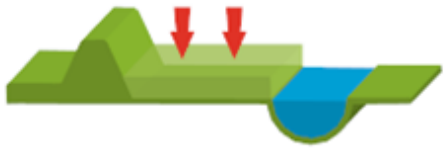
Room for the River – Managed Overflow of River Floodplain

Source Rijkswaterstaat

Room for the River – Managed Overflow of River Floodplain

- Launched in the Netherlands after 1993 and 1995 river floods, forcing evacuation of 250,000 people
- Extreme river discharges become more frequent, higher dikes alone not enough
- Multifunctional River widening as an opportunity to add spatial quality and allow for urban development and public / private funding
- RvR Project Office: combining National, Regional and Local authorities in 1 organisation

Lowering of floodplains



Lowering (excavating) an area of the flood-plain increases the room for the river at high water levels.

Dike relocation

Relocating a dike land inwards increases the width of the floodplains and provides more room for the river.

High-water channel

A high-water channel is a diked area that branches off from the main river to discharge some of the water via a separate route.

Strengthening dikes

Dikes are strengthened in areas in which creating more room for the river is not an option.

Room for the River Nijmegen - Lent

- National authority invested 350 million Euro's in a blue green bypass of the River Waal.
- Based upon reducing flood risk and to avoid future socio-economic losses.
- Nijmegen city used took this momentum to fullfill city's ambition; the river being in the center of its city.
- Investment: national taxes, based upon macroeconomics.

Eendrachtspolder, Willem Alexander Baan, Rotterdam

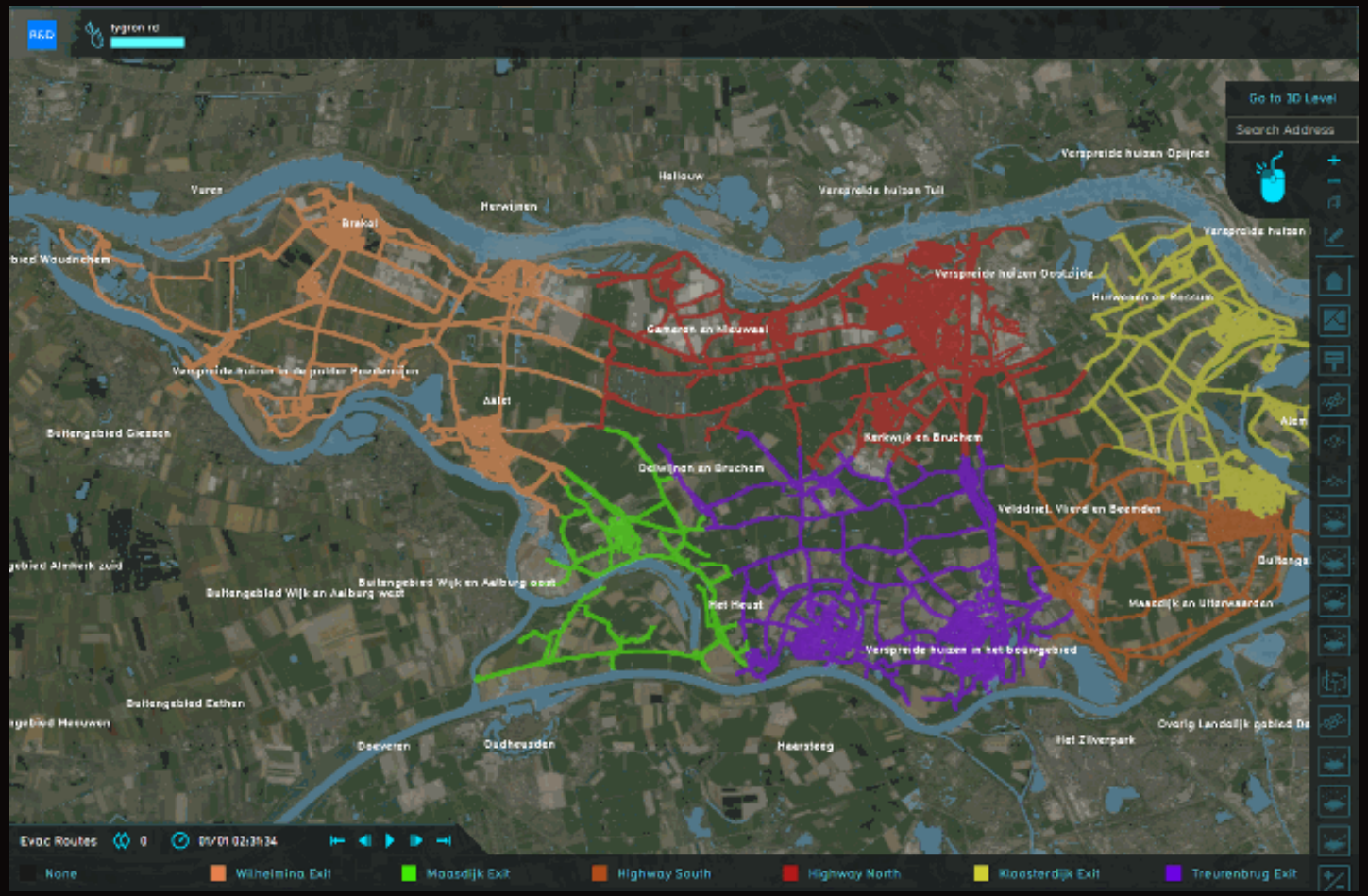
Water Storage and…

- **Residential areas**
- **Ecological corridors**
- **Attractive public area**
- **Recreation / sport facilities**
- **…**

Analytic Capabilities at Waterboard Level

The Tygron digital twin hydro-software handles additional layers, such as those listed below. The video shows a demonstration of the road access functionality in the Netherlands.

- Damage and casualties
- Evacuation
  - Accessibility
  - Evacuation time
- Cascade effects during flood events
  - Road access
  - Electricity and communications



Multi-functional urban flood protection, Rotterdam Roofpark Urban Dike

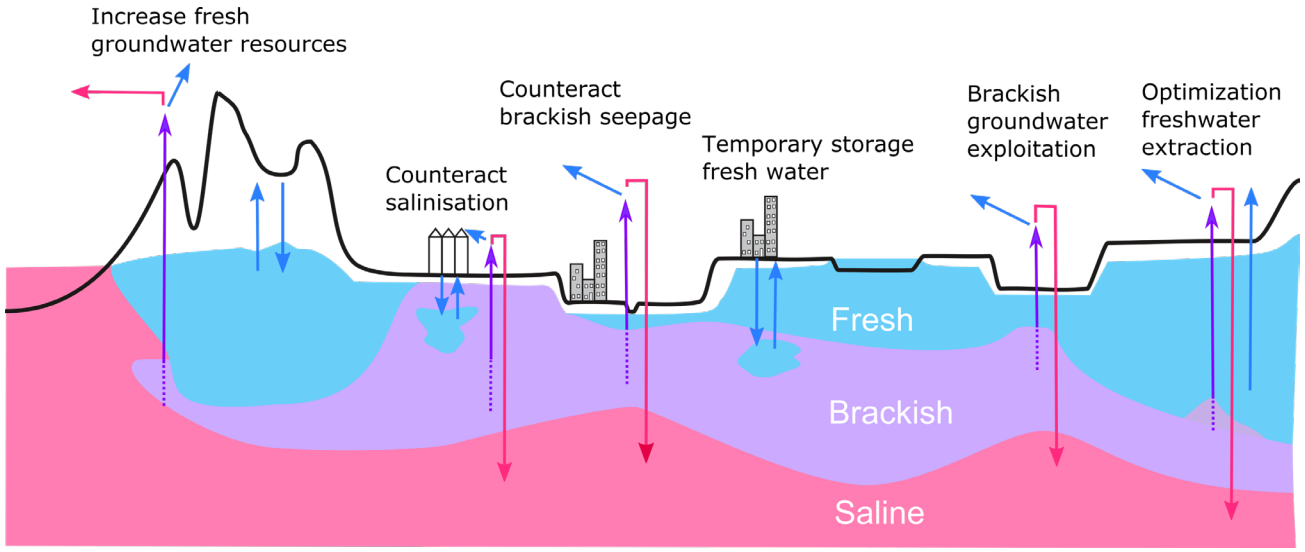
Source City of Rotterdam

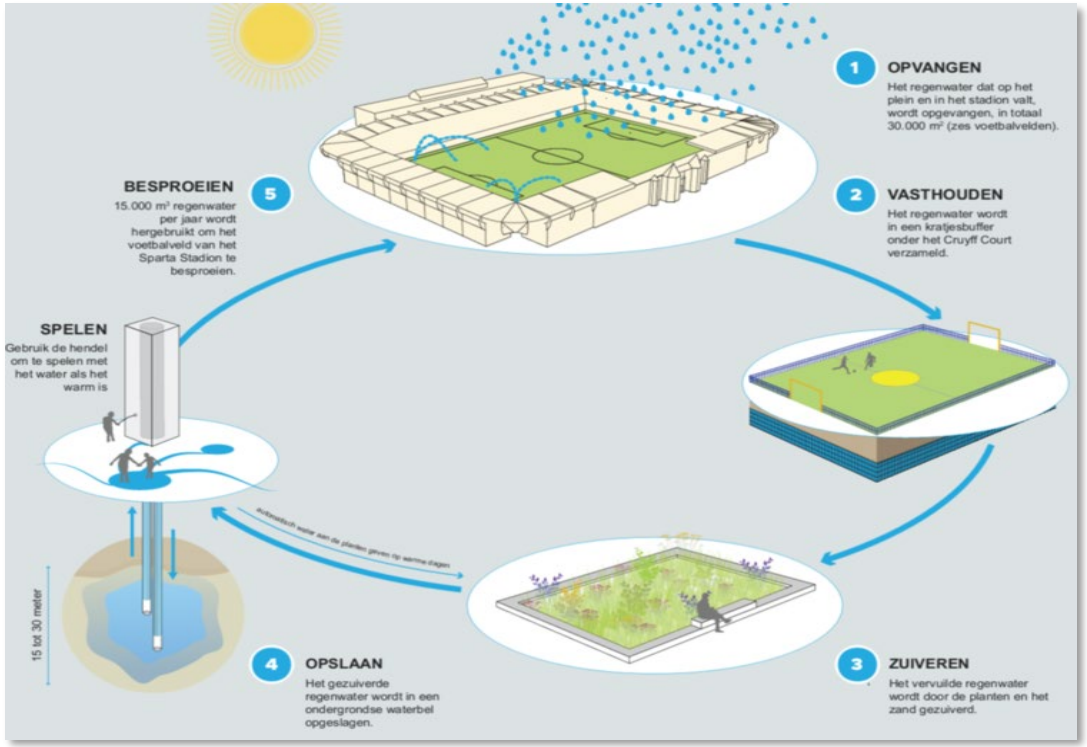
Rainwater harvesting and re-use

COASTAR COastal Aquifer STorage And Recovery in Rotterdam

Increased water demand, and rising sea-levels contribute to increased salinity in coastal areas, leading to shortages of freshwater for drinking water, agriculture, industry, nature and (urban) water management: COASTAR balances aquifer recharge and extraction by infiltrating precipitation surplus utilizing smart sensor technologies.

Water banking and urban water buffers Rotterdam





Deltares KWR ARCADIS

CONNECTING THE PUBLIC & PRIVATE REALM

US Case Studies

Norfolk: Ohio Creek

Houston: Harris County Flood Control District

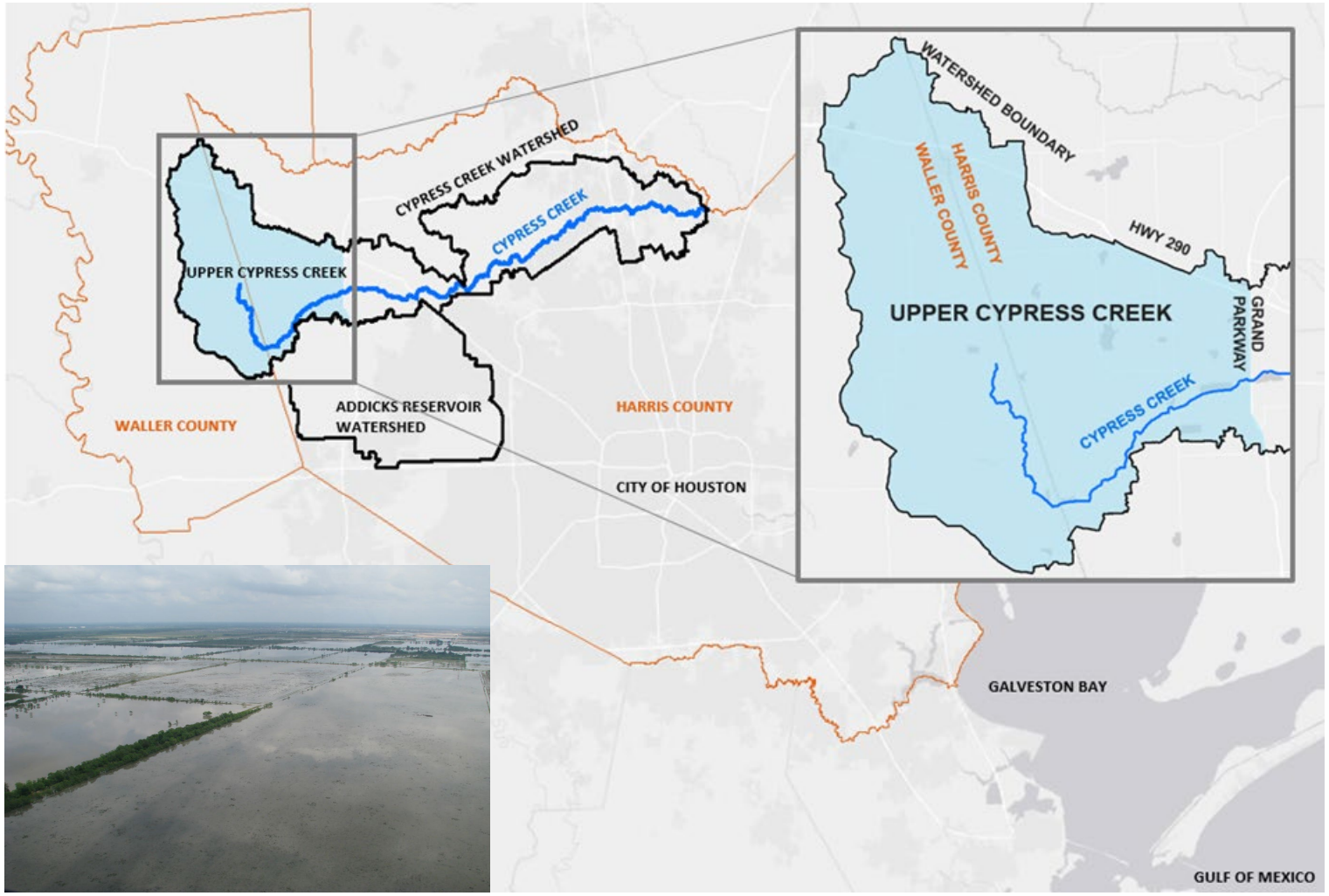
New York City: BIG U, Living Breakwaters, USACE - Hats

Norfolk - Ohio Creek Flood Resilience

Houston Post-Harvey
Upper Cypress Creek / Addicks Reservoir Shallow Storage Areas

HARRIS COUNTY FLOOD CONTROL DISTRICT

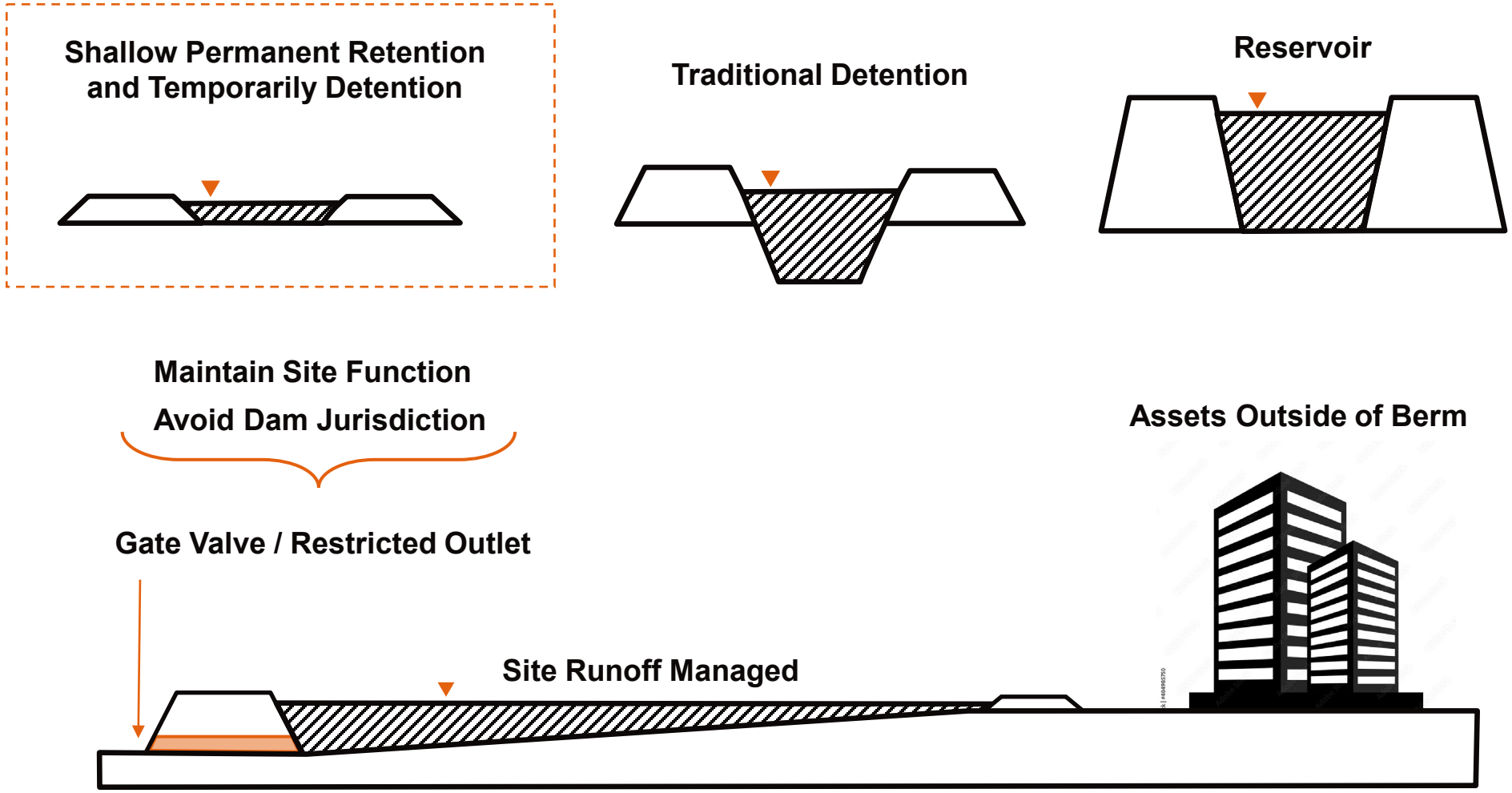
Harris County Flood Control - Project Goals



- Evaluate feasibility of shallow storage areas
- Reduce overflow to Addicks reservoir
- Reduce peak flow rates to Middle Cypress Creek
- Compare to Plan 3 / Plan 5 reservoirs ($650M)
- Feasibility only, not implementation
- Hybrid approach with regional retention

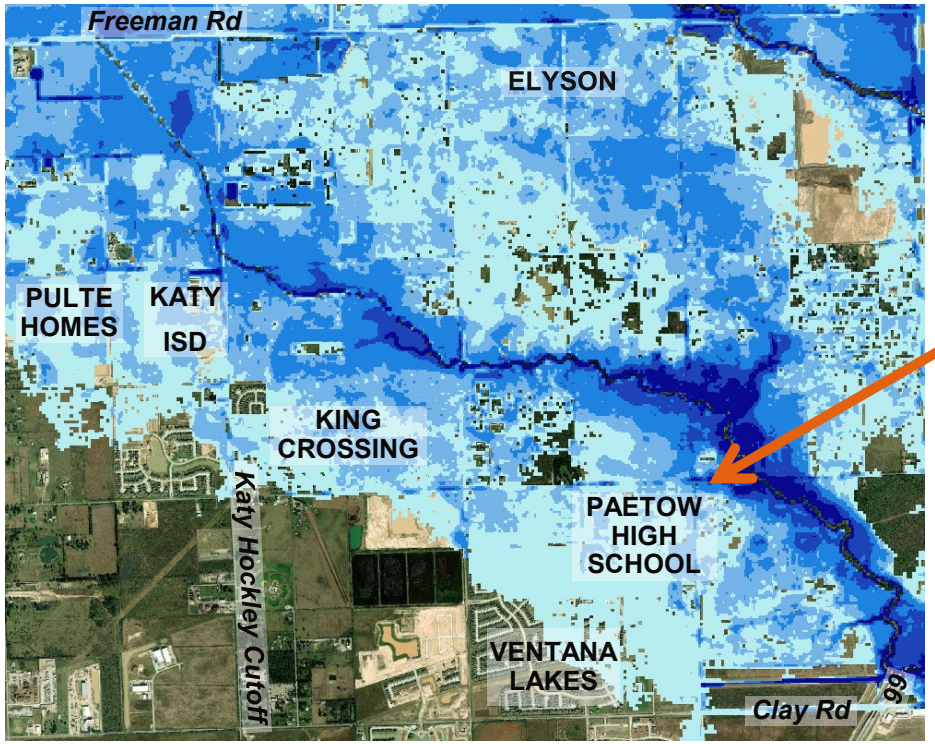
Flood Risk Management Techniques

Through Permanent Retention and Temporary Detention

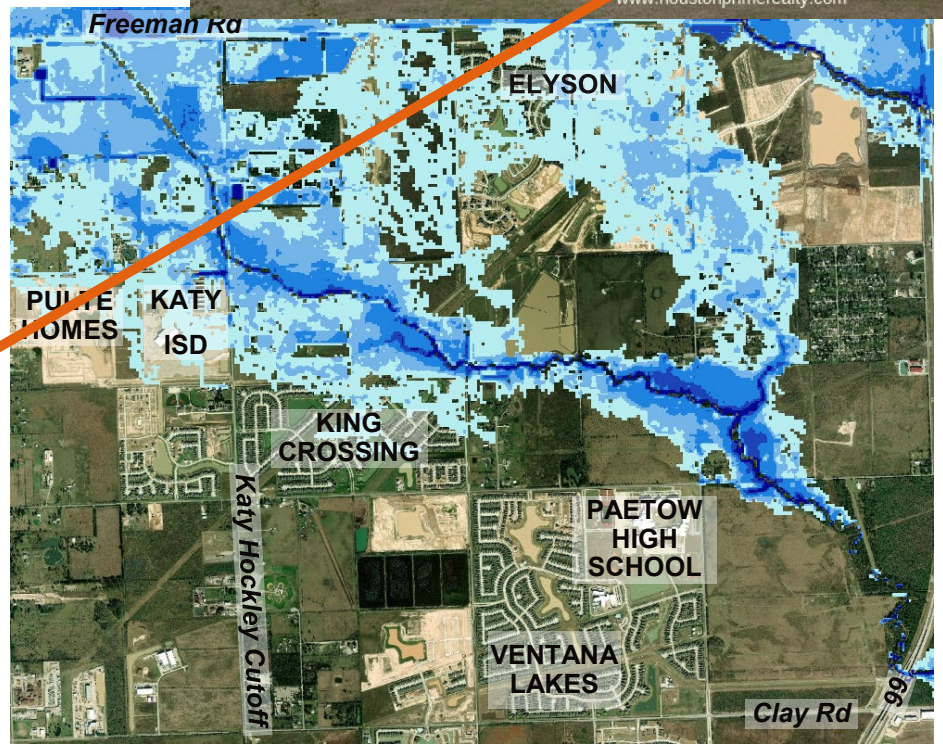


100-Year Property Benefits

100-Year Overflow



Existing performance



Performance with shallow storage

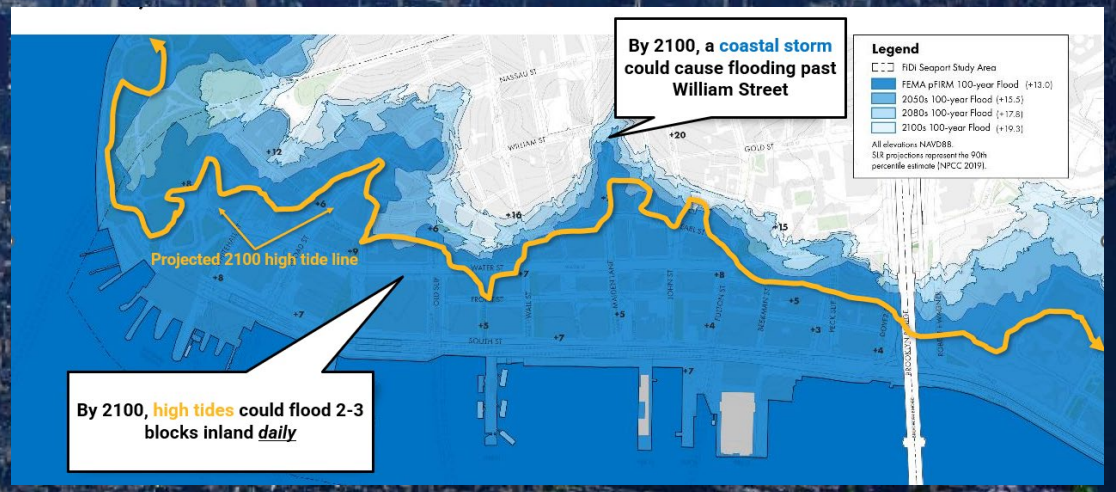
Flood Depth (feet)	0.0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0+

5 - Day Simulation Volume

Manhattan's BIG U Flood Protection Plan

Source Rebuild by Design BIG Team

Two types of climate risks - daily tidal flooding and coastal storms, Lower Manhattan.



Source Rebuild by Design BIG Team

From Concept…

To Realization

East Side Coastal Resilience Project: Quality of Life Outcomes

1. Develop infrastructure solution to ensure equity and environmental justice are fundamental considerations
2. Develop infrastructure solution to fully preserve and protect historic and cultural resources
3. Develop the infrastructure solution to support community needs and goals
4. Consider health and safety improvements beyond minimum requirements established by regulations and laws
5. Develop the infrastructure solution to expand mobility access and choice and improve safety and efficiency

Financial District and Seaport Climate Resilience Master Plan

NYC/EDC

NYC Mayor's Office of Climate & Environmental Justice

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Financial District - Natural World Criteria

1. Locate infrastructure to avoid, or minimize, and/or mitigate adverse impacts on important ecological areas
2. Locate infrastructure on previously developed or disturbed land, or brownfield or greyfield sites
3. Avoid, or minimize, and/or mitigate the effects of increased volumes, pollutants, and temperatures in stormwater runoff
4. Avoid, or minimize, and/or mitigate the effects of site contaminants and pollutants, including pesticides and fertilizers
5. Avoid, or minimize, and/or mitigate adverse impacts on natural systems such as hydrologic and nutrient cycles, habitats including surface and groundwater systems, flood-plains, and soils that provide critical ecosystem functions
6. Avoid, or minimize, and/or mitigate habitat fragmentation while also promoting habitat connectivity
7. Avoid, or minimize, and/or mitigate the introduction of invasive species

Living Breakwaters - From Concept to Construction

Attenuate Wave Energy & Prevent Shoreline Erosion

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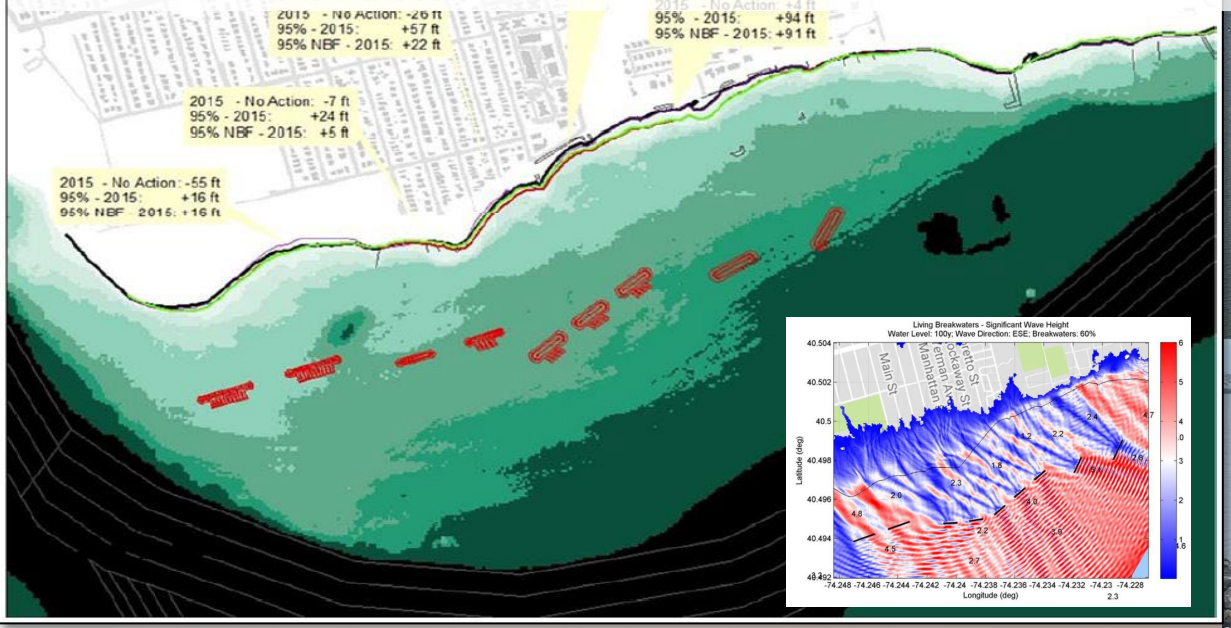
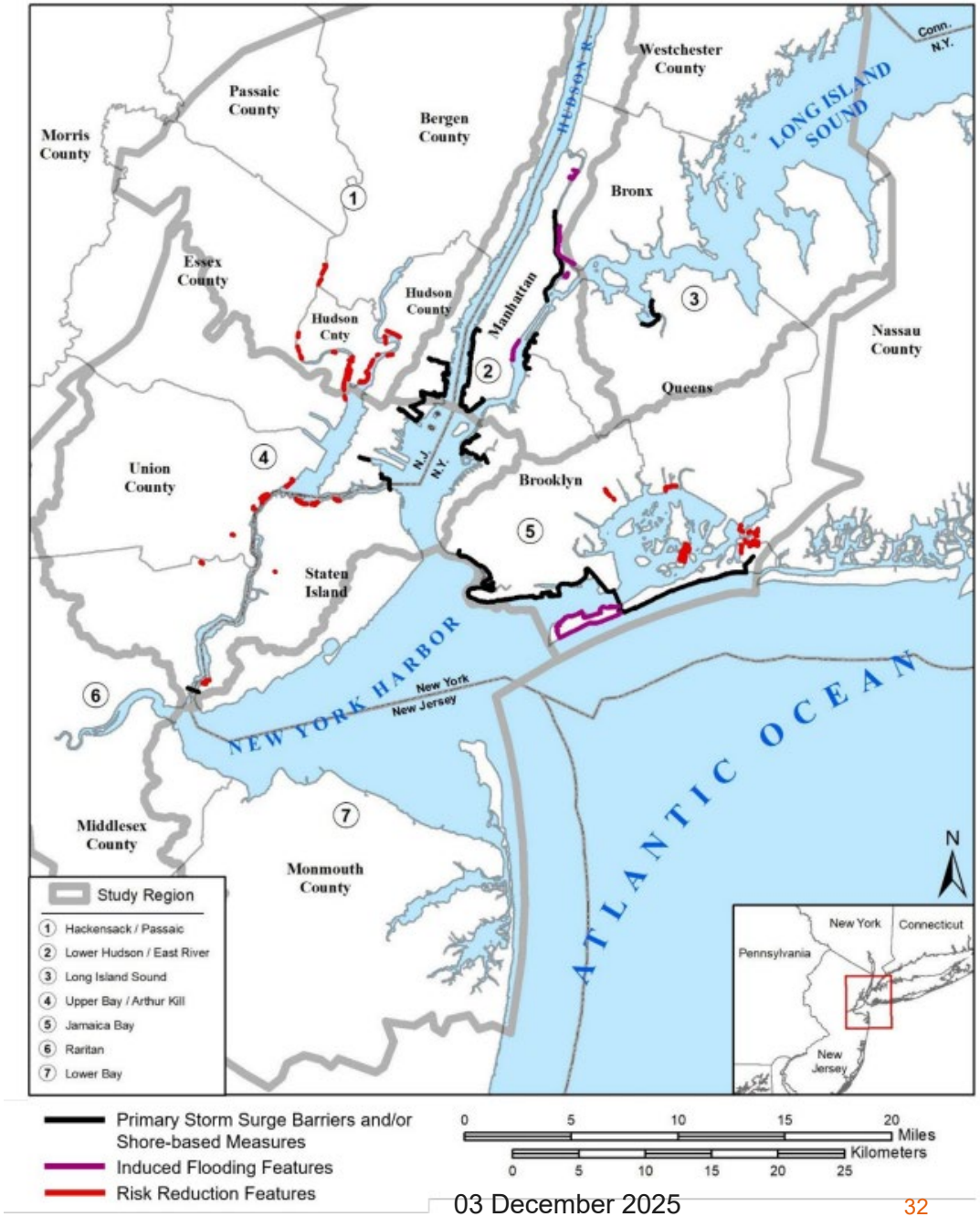


Image Credit Scape

US Army Corps of Engineers®

NY District HATS Observations

- Plan components show high level of integration with existing / planned strategies, a systems approach that gives the study regional potential.
- Coastal protection through shore based and off shore barrier solutions aiming to protect long waterfront stretches of exposed communities.
- The evaluation of applying storm surge barriers has matured.
- The work does not stop if “3B” were to be implemented, what plan components from other strategies may apply over time?
- Drainage outfall and backflow issues, causing severe high tide inundation of low lying communities?
- What is the plan for waterfront communities who currently don’t and may not get have a plan, what will the process of retreat look like?



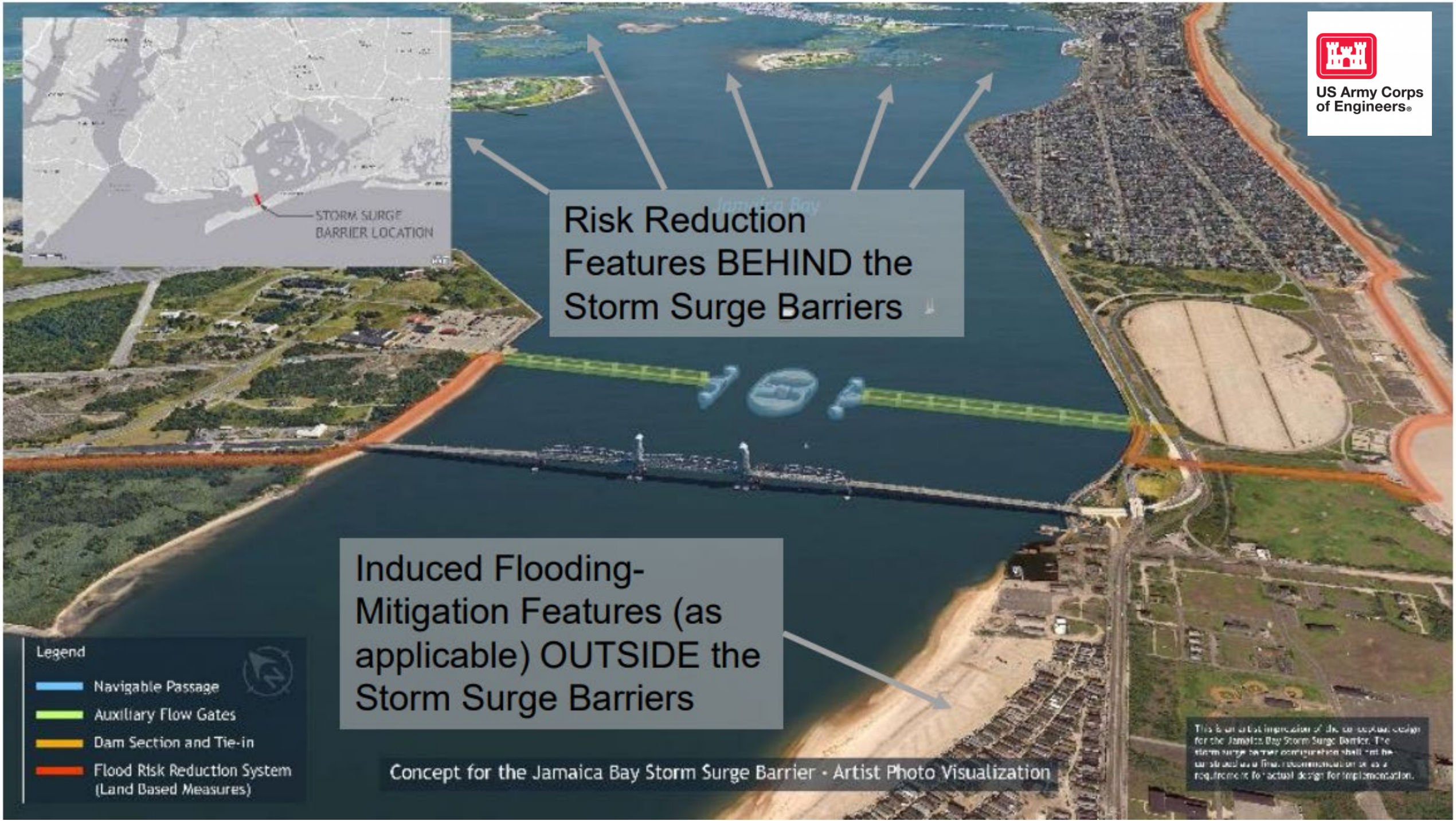

STORM SURGE BARRIER LOCATION
Risk Reduction Features BEHIND the Storm Surge Barriers
Induced Flooding-Mitigation Features (as applicable) OUTSIDE the Storm Surge Barriers
Legend
Navigable Passage
Auxiliary Flow Gates
Dam Section and Tie-in
Flood Risk Reduction System (Land Based Measures)
US Army Corps of Engineers®
Concept for the Jamaica Bay Storm Surge Barrier - Artist Photo Visualization

Image Credit: USACE

Peer-to-Peer Exchange

Metropolitan Water District and Waterschap Hollandse Delta

- A series of virtual peer-to-peer learning sessions with representatives from MWD, CA DWR and WSHD identified many commonalities and areas for further exchange, primarily:
  - Levee monitoring
  - Nature-based solutions
  - Stakeholder engagement and governance

•**Key Insights:** Agencies shared tools and ideas on disaster preparedness and AI-driven modeling improvements.
•**Site Visit:** Participants toured Bay Delta islands to learn about wetlands, levee monitoring, and endangered species efforts while exchanging insights and documents