The Times They Are a-Changin'

Preparing for Climate Change at the Philadelphia Water Department

May 9, 2022

AAAEES Technical Workshop

New Jersey Water Environment Association Annual Conference

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PWD Climate Change Adaptation Program | Philadelphia Office of Sustainability

PHILADELPHIA WATER DEPARTMENT

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Philadelphia Water Department

One Water Utility

Drinking Water

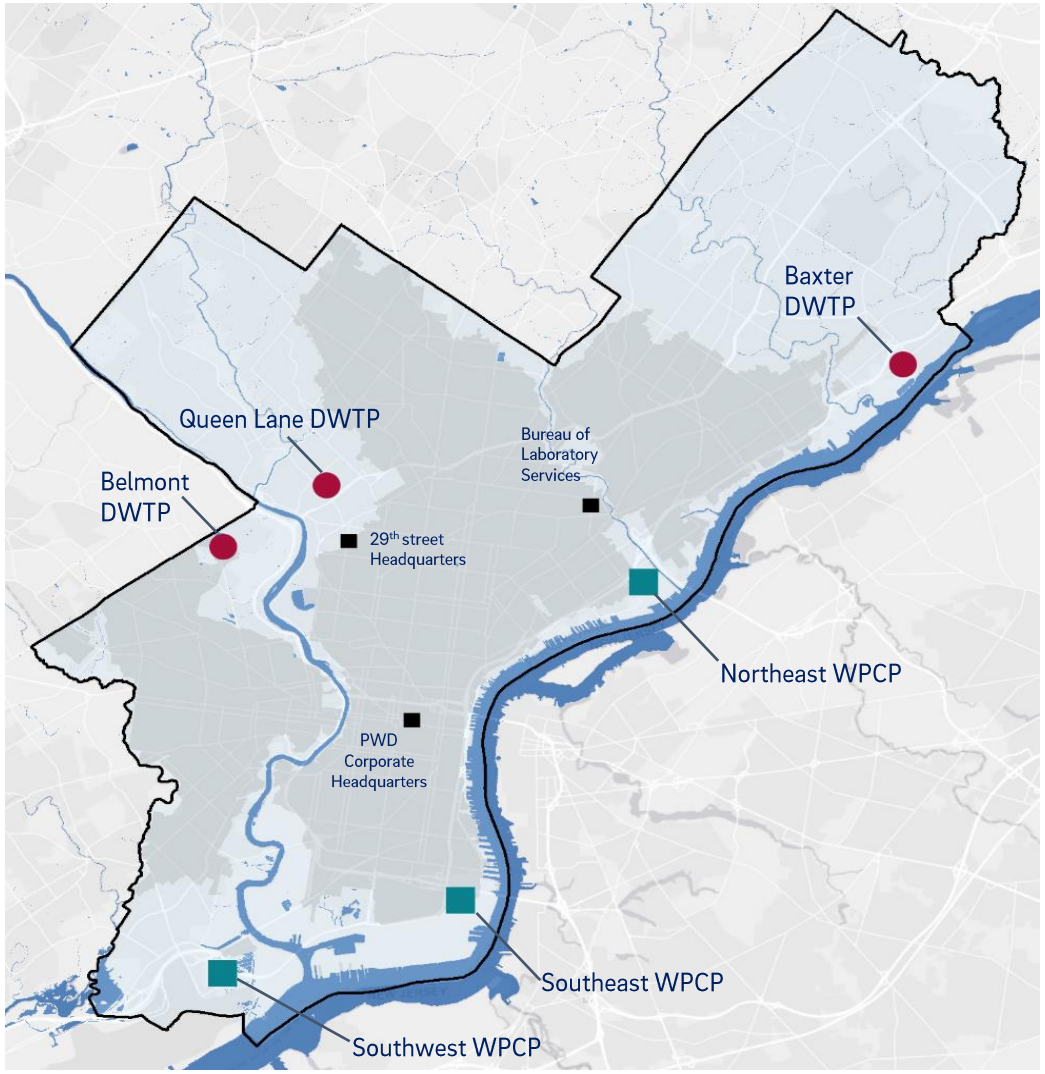
- Source: Delaware and Schuylkill Rivers
- 1.6 million drinking water customers
- Three Water Treatment Facilities
- Over 300 million gallons treated per day
- 3,000 miles of water mains, 25+ pumping stations

Wastewater

- 2.2 million wastewater customers
- 3 Water Pollution Control Plants
- Over 522 million gallons treated per day
- 3,716 miles of sewers, 19 pumping stations

Stormwater

- Roughly 60% Combined Sewer, 40% Separate Sewer
- Green City, Clean Water - Large-scale green stormwater infrastructure program



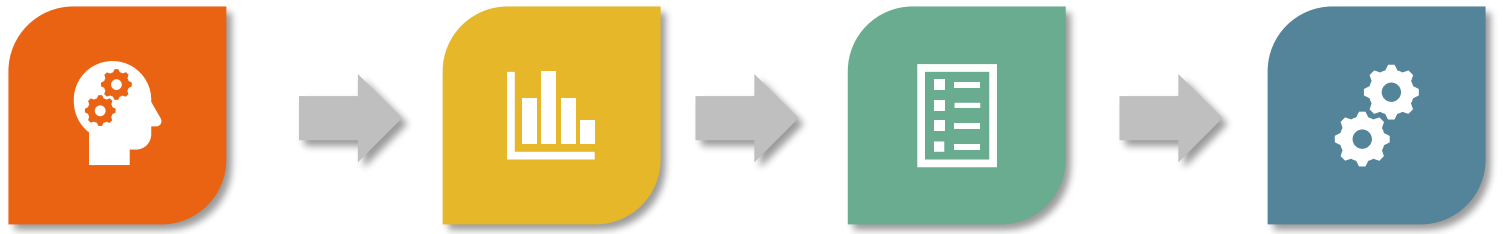
The work we do to achieve our mission is…

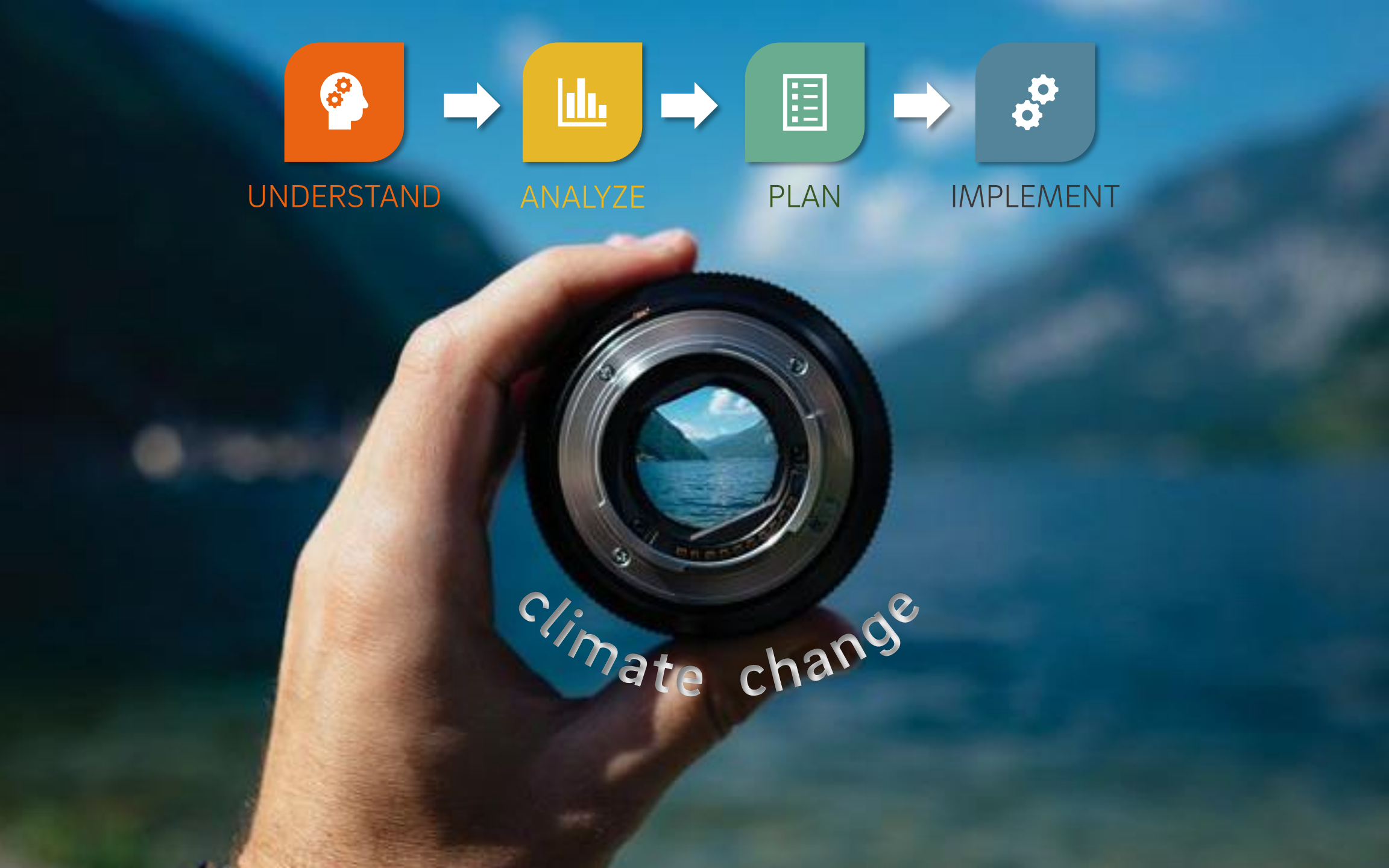
- DRIVEN BY DATA AND BEST AVAILABLE SCIENCE
  - Understand existing conditions and potential future conditions

- BASED ON SOPHISTICATED TOOLS
  - Analyze how our systems and infrastructure perform under a range of conditions

- FOUNDED ON COMPREHENSIVE, WATERSHED-WIDE PLANNING
  - Evaluate risks and develop short and long-term strategies to reduce risks

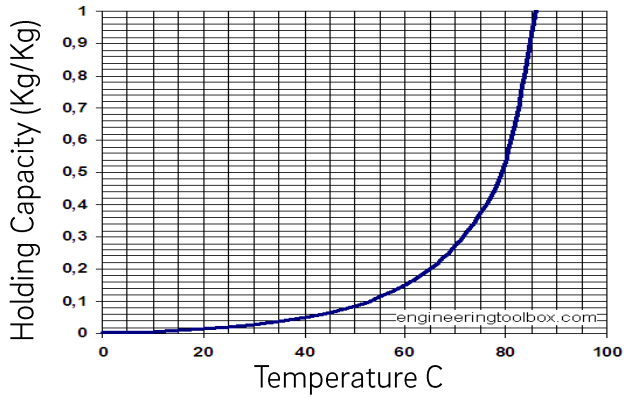
- IMPLEMENTED USING INNOVATIVE APPROACHES
  - Adaptive management, policy changes, advanced technologies, networks & partnerships




UNDERSTAND
ANALYZE
PLAN
IMPLEMENT
climate change

Principle #1

Warm air holds more moisture than cold air.
"Atmospheric holding capacity"

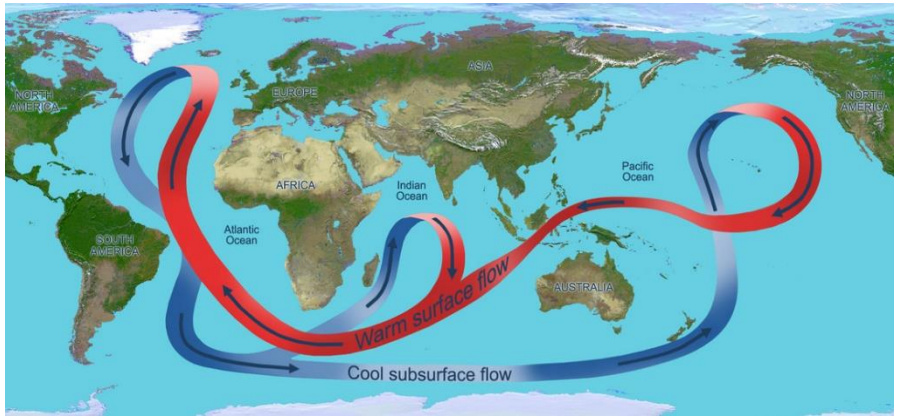


Principle #2

Warm air increases evaporation
and transpiration rates

Principle #3

Temperature changes influence global circulation
patterns (atmosphere & ocean)



PWD's Climate Change Adaptation Program is addressing risks related to:

Precipitation ↑
Sea level ↑
Extreme storm events ↑
} Flood risks ↑

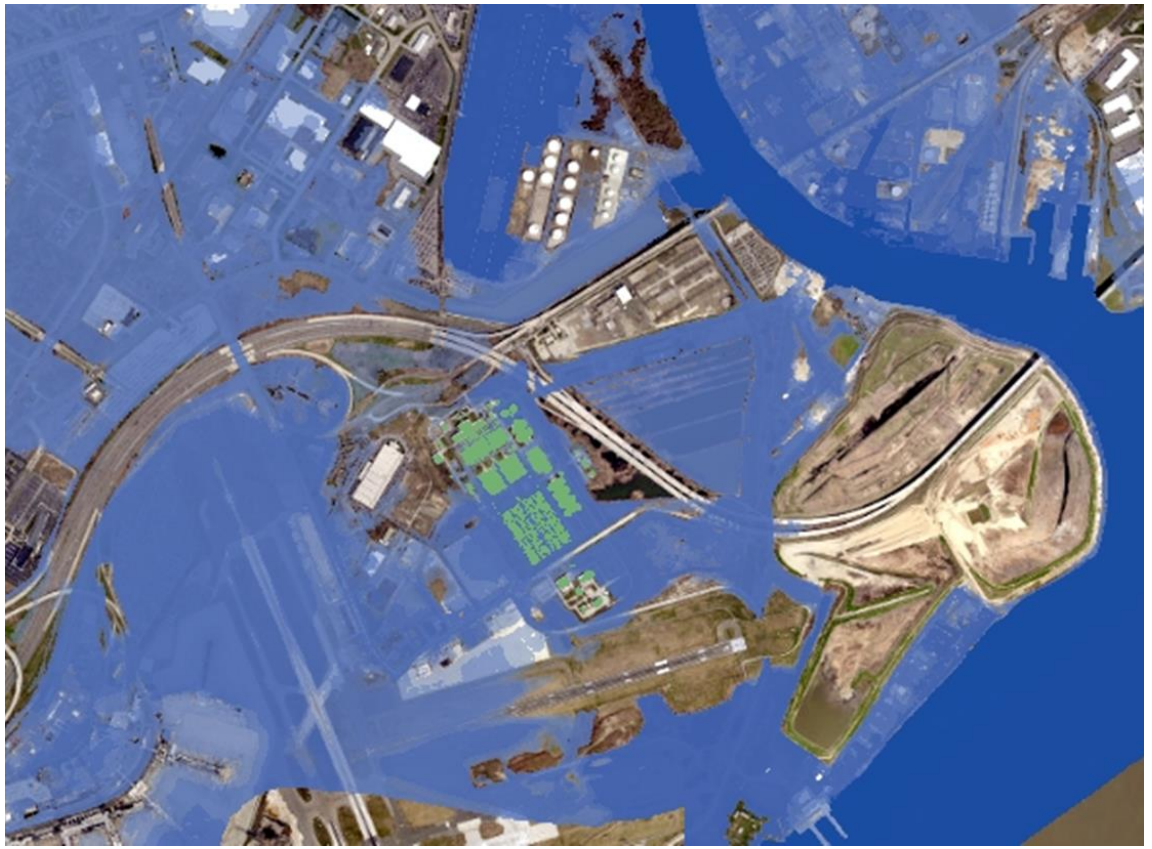
We are concerned about flooding of our critical assets and systems AND the reduced capacity of our drainage system

Air Temperature ↑

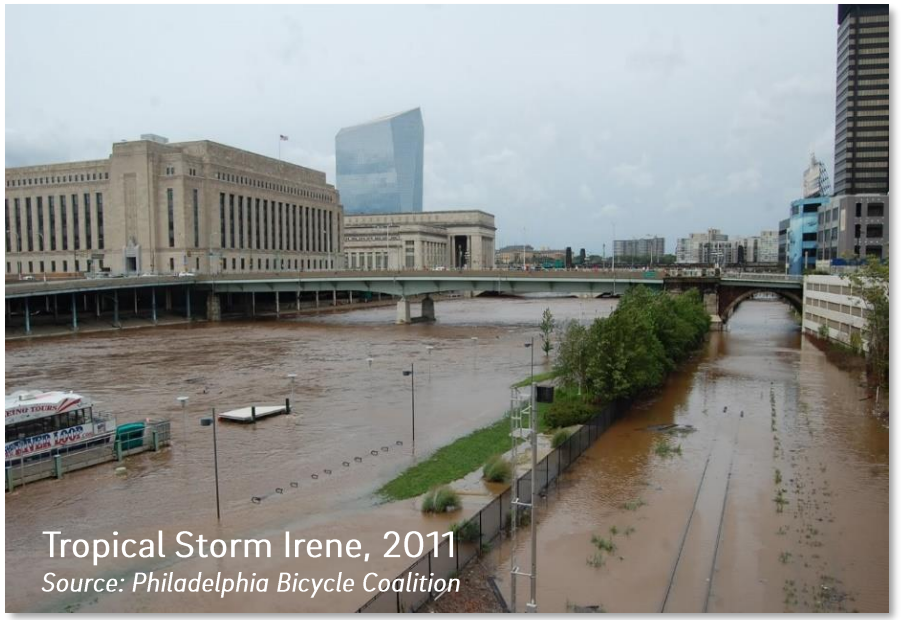
Droughts ↑↓ —

Priority Risks to Address

Coastal, riverine and infrastructure-based flooding



Tropical Storm Ida, 2021
Source: AP/Matt Rourke



Tropical Storm Irene, 2011
Source: Philadelphia Bicycle Coalition

Tropical Storm Isaias

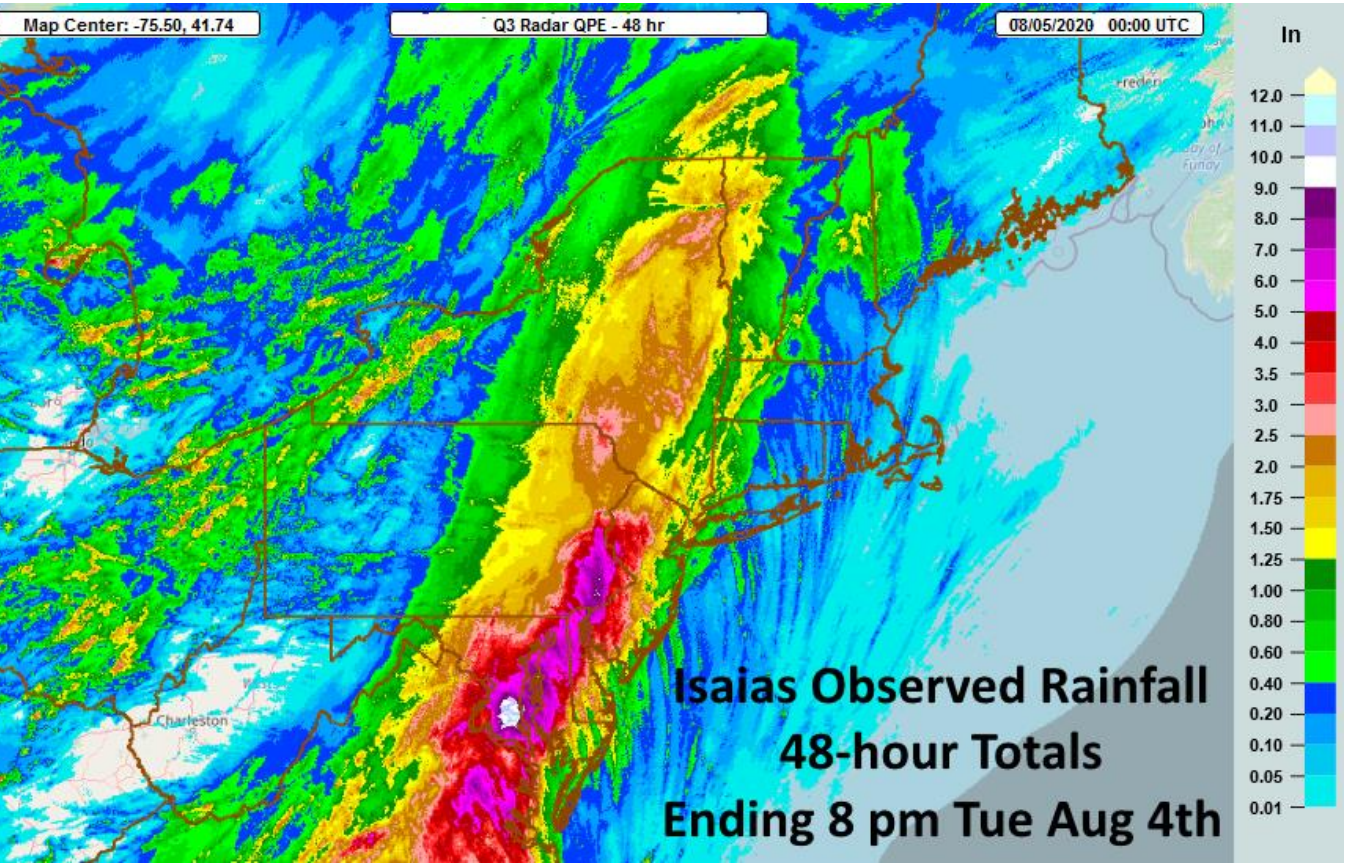
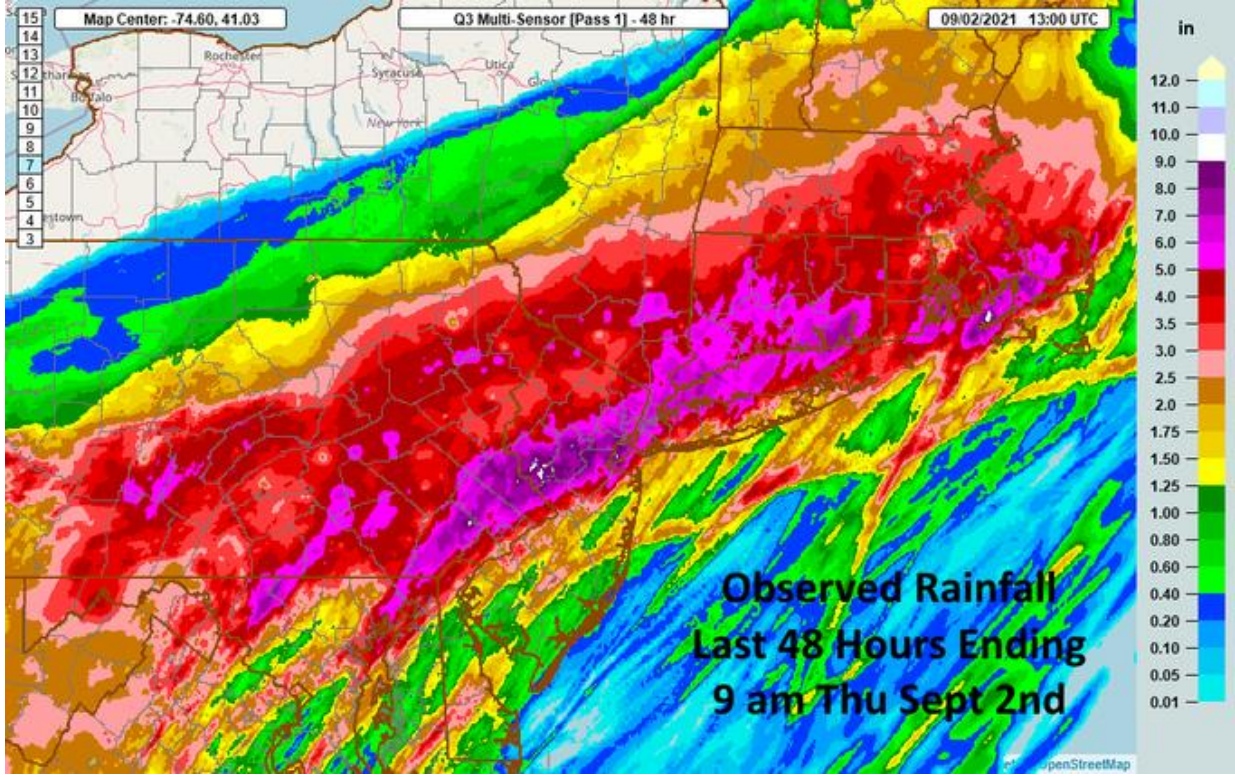
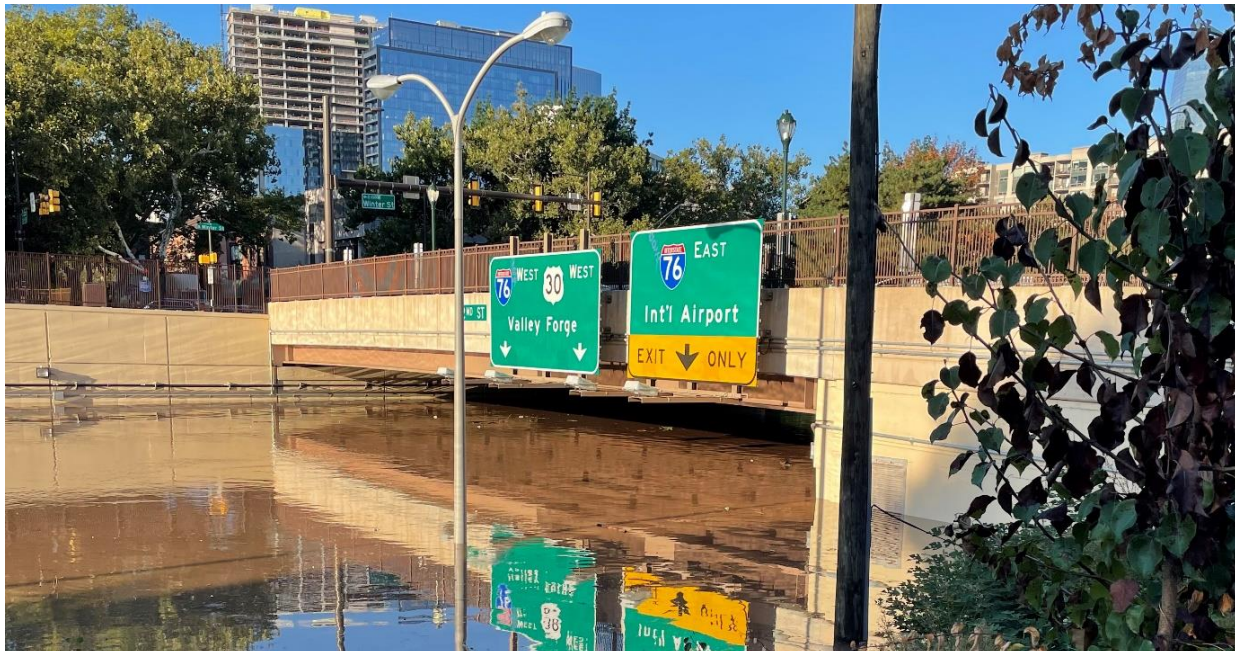


Photo Source: Inquirer



Tropical Storm Ida



Priority Risks to Address

Water quality impacts

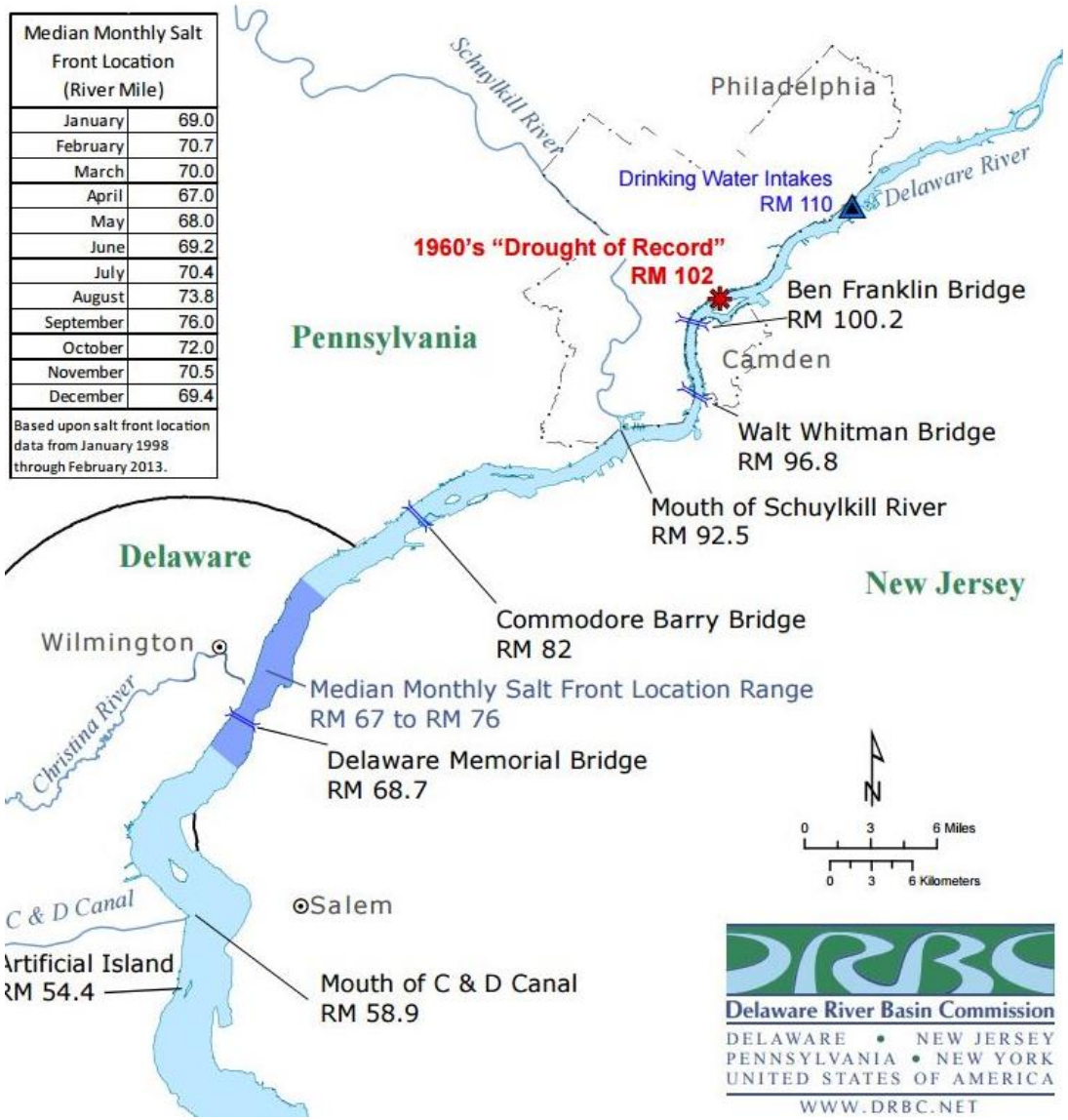
Higher temperatures could lead to decreased dissolved oxygen levels, increased algal growth, and changes to treatment processes

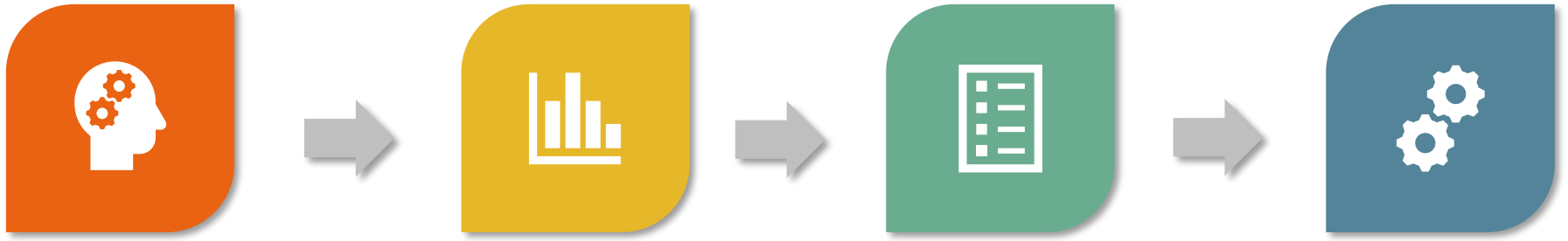
Sea level rise intensified salinity intrusion

Intrusion of ocean salt upstream during drought conditions is a natural process anticipated to become more frequent and severe later this century due to sea level rise

Median Monthly Salt Front Location (River Mile)	
January	69.0
February	70.7
March	70.0
April	67.0
May	68.0
June	69.2
July	70.4
August	73.8
September	76.0
October	72.0
November	70.5
December	69.4

Based upon salt front location data from January 1998 through February 2013.



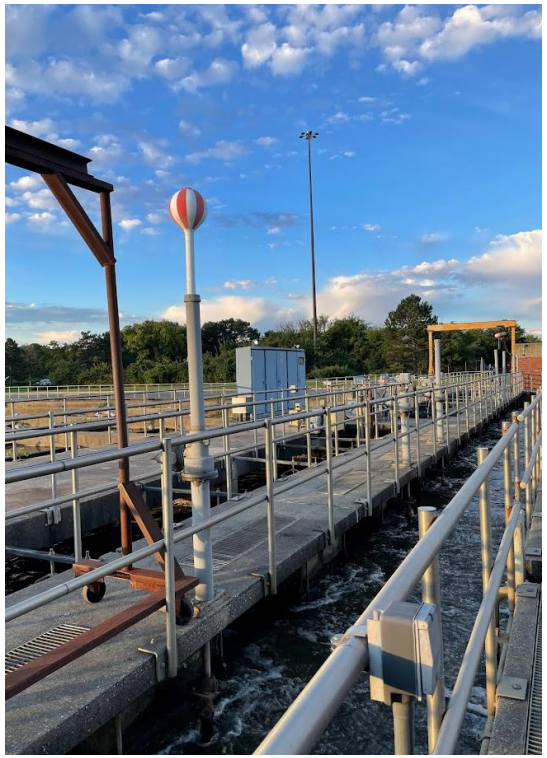


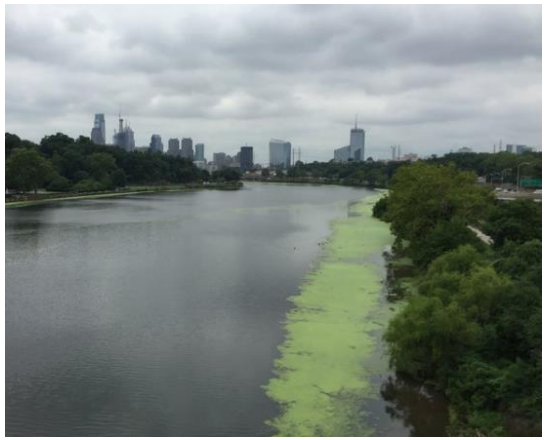
UNDERSTAND ANALYZE PLAN IMPLEMENT

How and when will these impacts affect the operations and management of our systems?
What strategies can we employ to reduce risks and maintain current levels of service?

ACTIONABLE SCIENCE IS REQUIRED

"...data, analyses, projections, or tools that can support decisions regarding the management of the risks and impacts of climate change." *(ACCCNRS, 2015)*

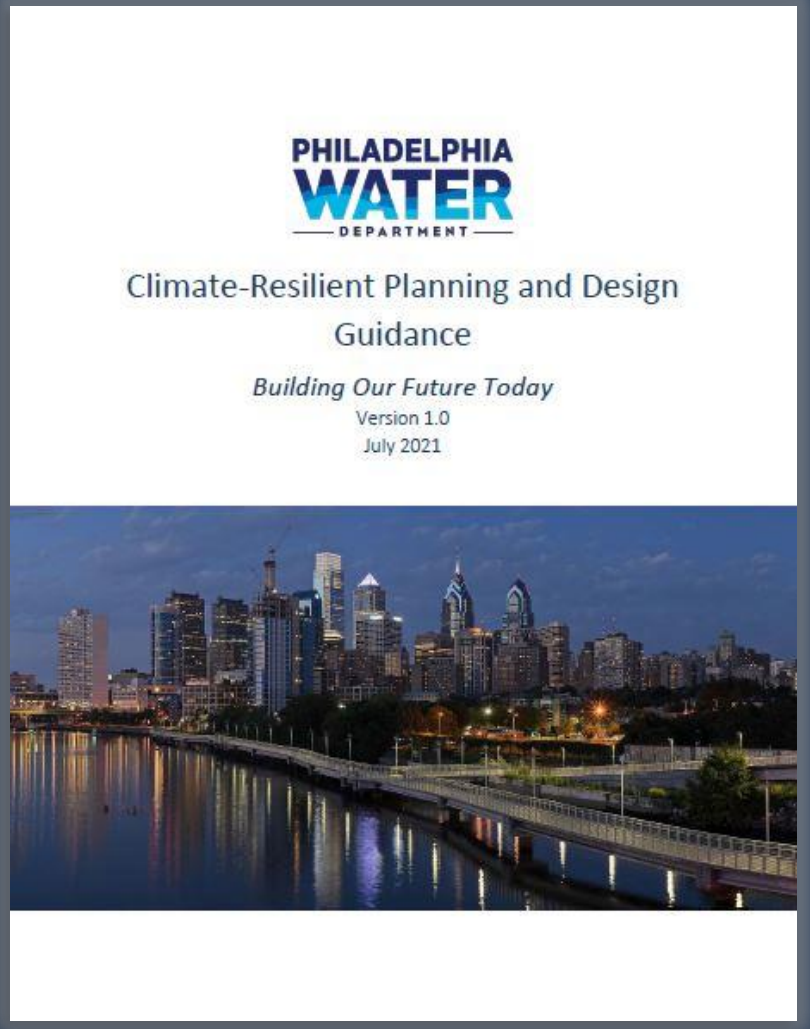




Short and long-term strategies to reduce risk

- **Develop in-house expertise** on climate science and risk-based adaptive management approaches
- **Mainstream** the use of climate change information plans, programs and policies
- **Conduct risk assessments** to inform adaptation strategies
- **Develop adaptation strategies** and **projects**
- **Leverage funds** and **Implement** adaptation projects
- **Partner and coordinate** with internal and external stakeholders

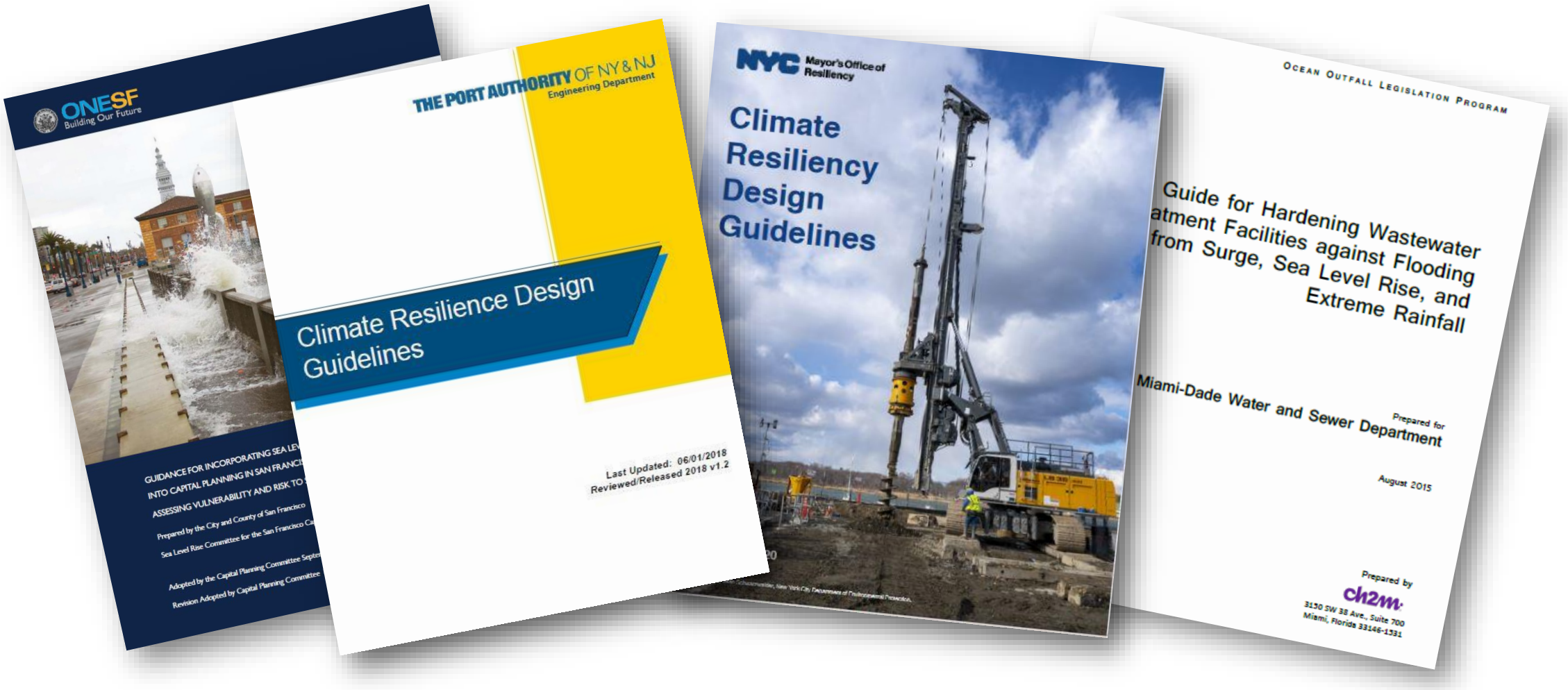
Guidance is PWD's fundamental reference document for mainstreaming the use of climate change information in PWD planning and design processes



- Actionable climate information
- Tools and visuals to better understand risk
- Updated planning guidance and design standards that consider
  - Useful service life
  - Criticality
  - Risk Tolerance
  - Adaptive Capacity
- Adaptive management approaches

Publicly available version of the guidance document is available here: *https://water.phila.gov/pool/files/climate-resilient-guidance.pdf*

Climate-informed Planning & Design Guidance Examples



Sea Level Rise and Storm Surge

Philadelphia's two main rivers are tidal – we will be impacted by sea level rise

Potential risks include:

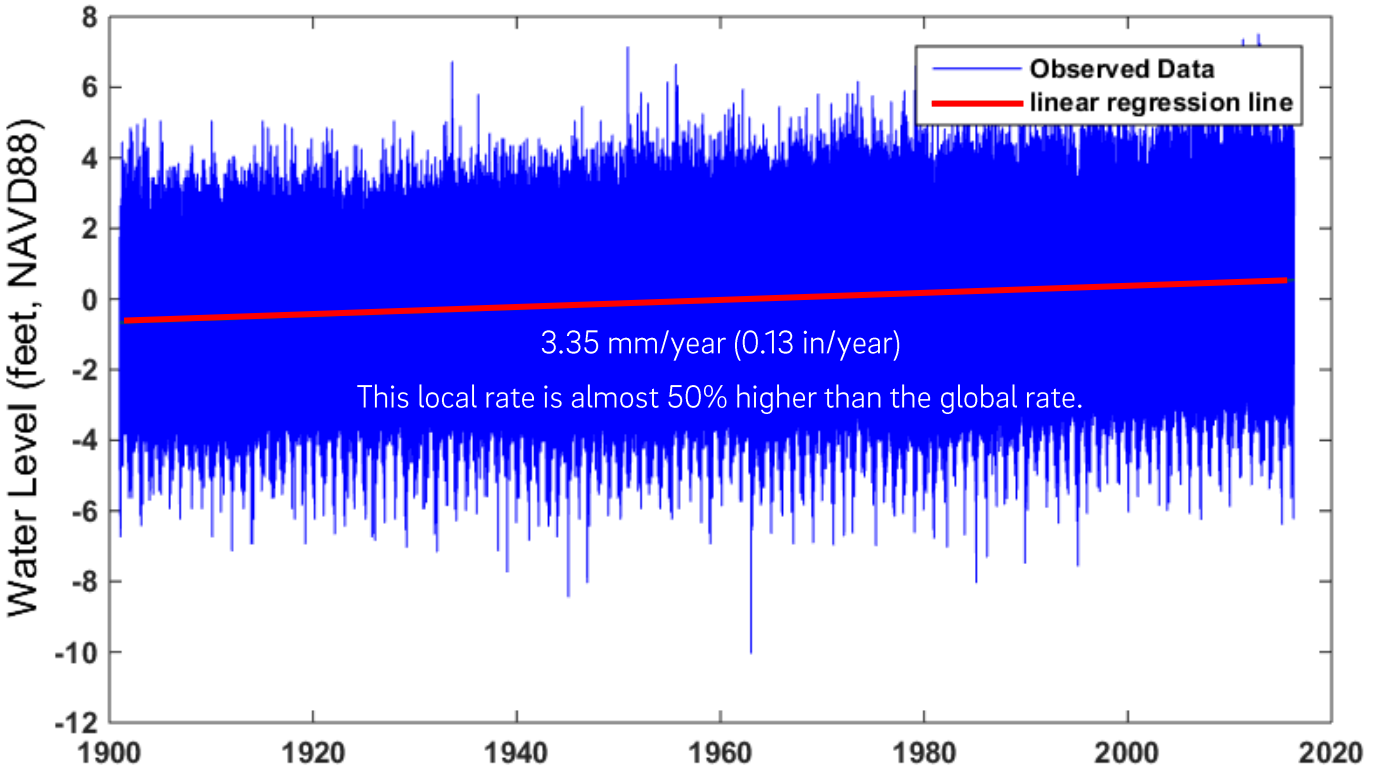
- Flooding of PWD assets
  - Surface and below-grade
  - Treatment plants and pump stations
- Increased energy demand (pumping and treatment)
- Degraded source water quality (salinity)

Actionable science developed includes:

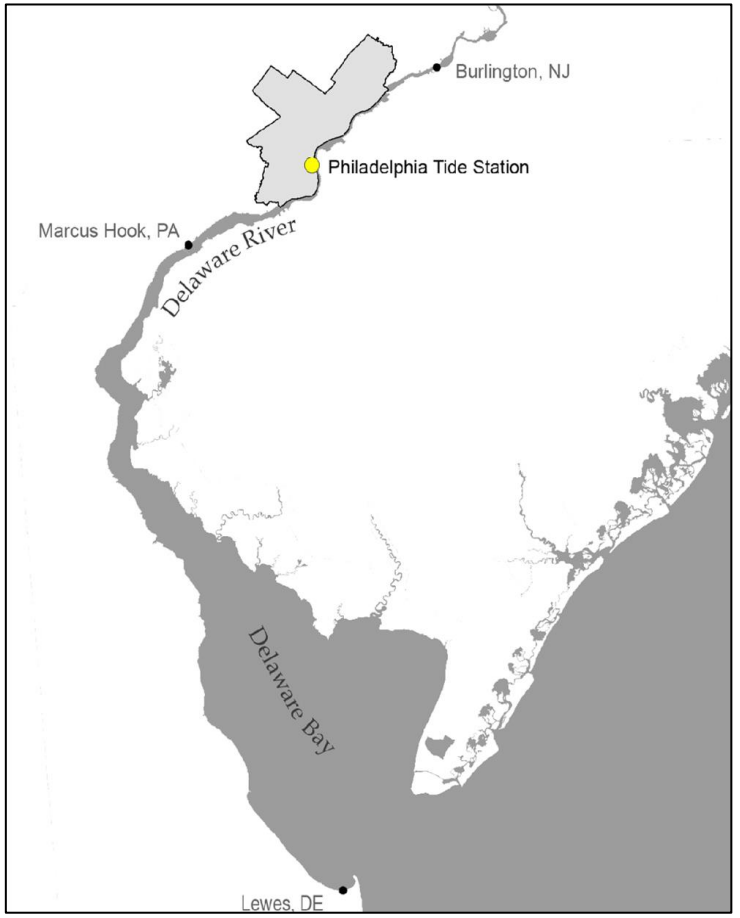
- Analysis of SLR projections and storm surge elevations on Delaware River
- Customized GIS screening tool for PWD assets
- Updated design starndards – climate-informed design flood elevation (DFE)
- Analysis with PWD 3-D model of salinity intrusion under current and future sea level conditions

Philadelphia is already experiencing climate change

SEA LEVEL RISE – LOCAL TRENDS

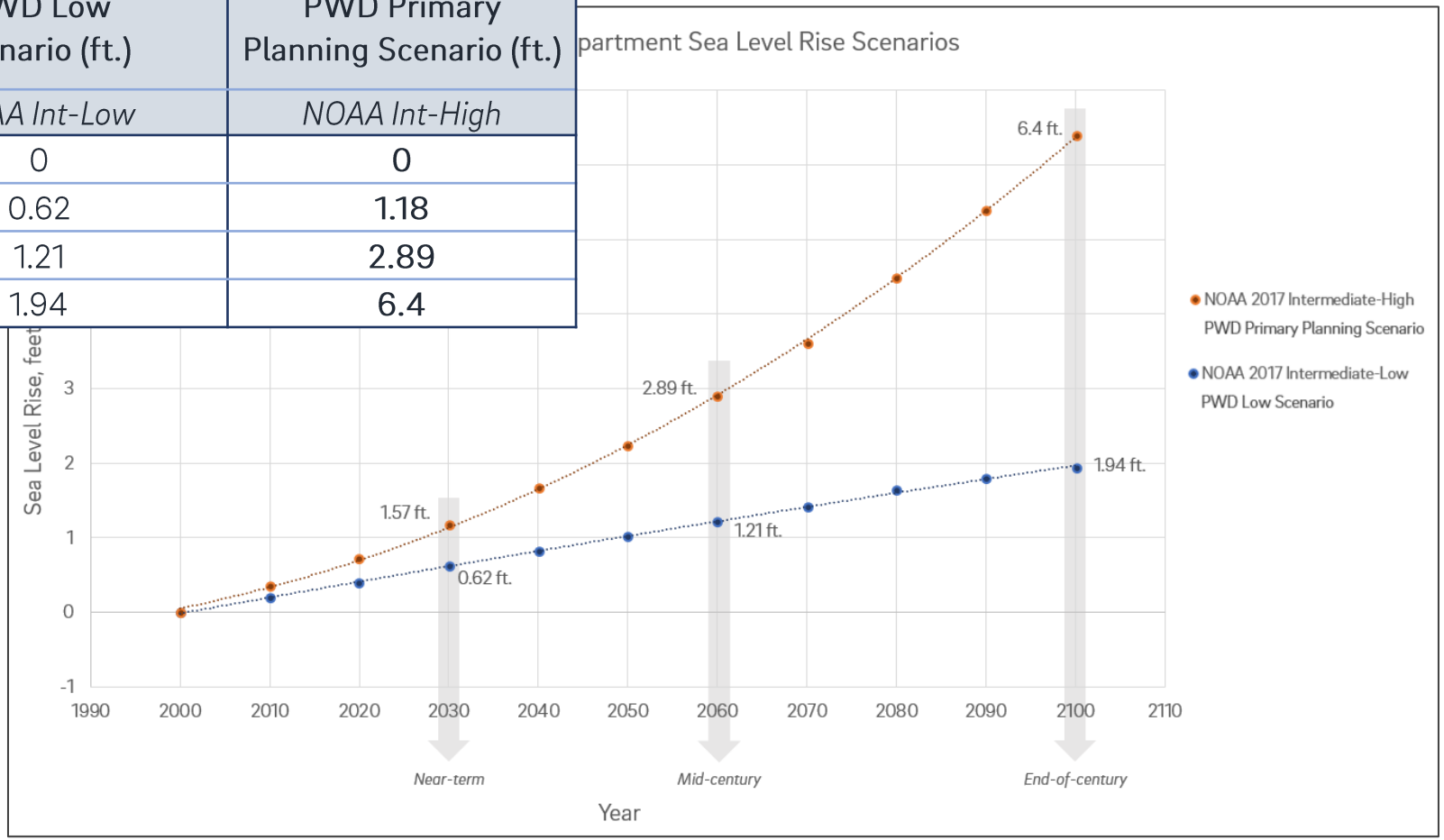


1901-2016 continuous tide lelvel data from Philadelphia's NOAA gauge 8545240

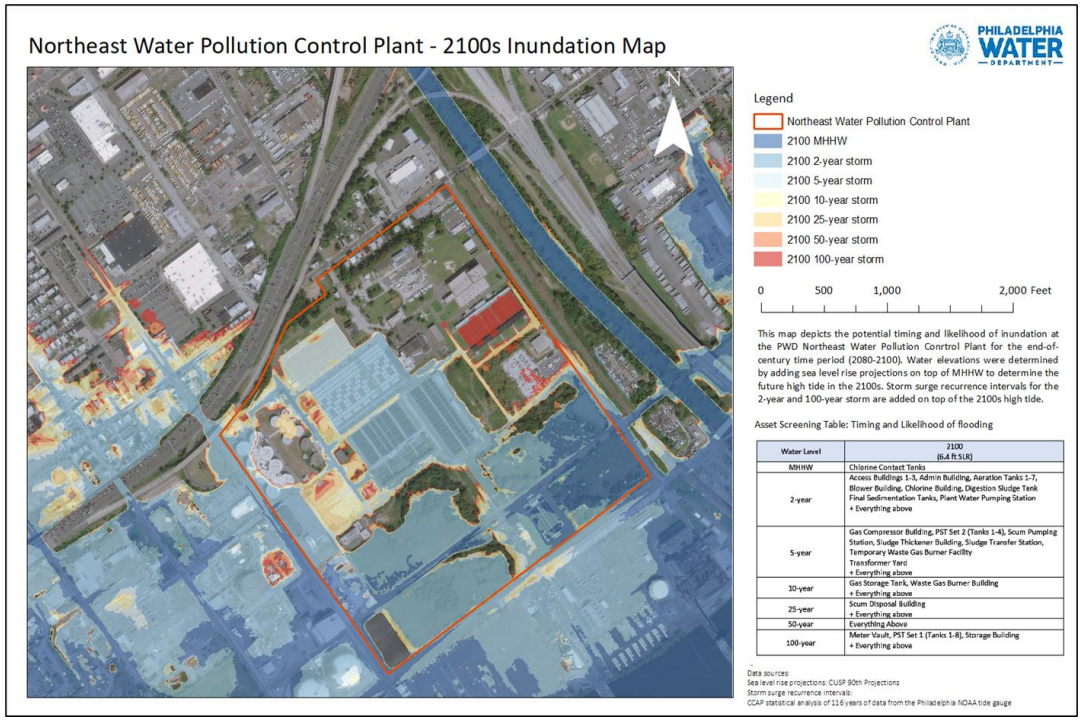


Sea Level Rise Projections

Philadelphia Water Department Sea Level Rise Planning and Design Scenarios		
Year	PWD Low Scenario (ft.)	PWD Primary Planning Scenario (ft.)
	NOAA Int-Low	*NOAA Int-High*
2000 (baseline)	0	0
Near-term (2030s)	0.62	1.18
Mid-century (2060s)	1.21	2.89
End-of-century (2100s)	1.94	6.4



PWD Inundation Model



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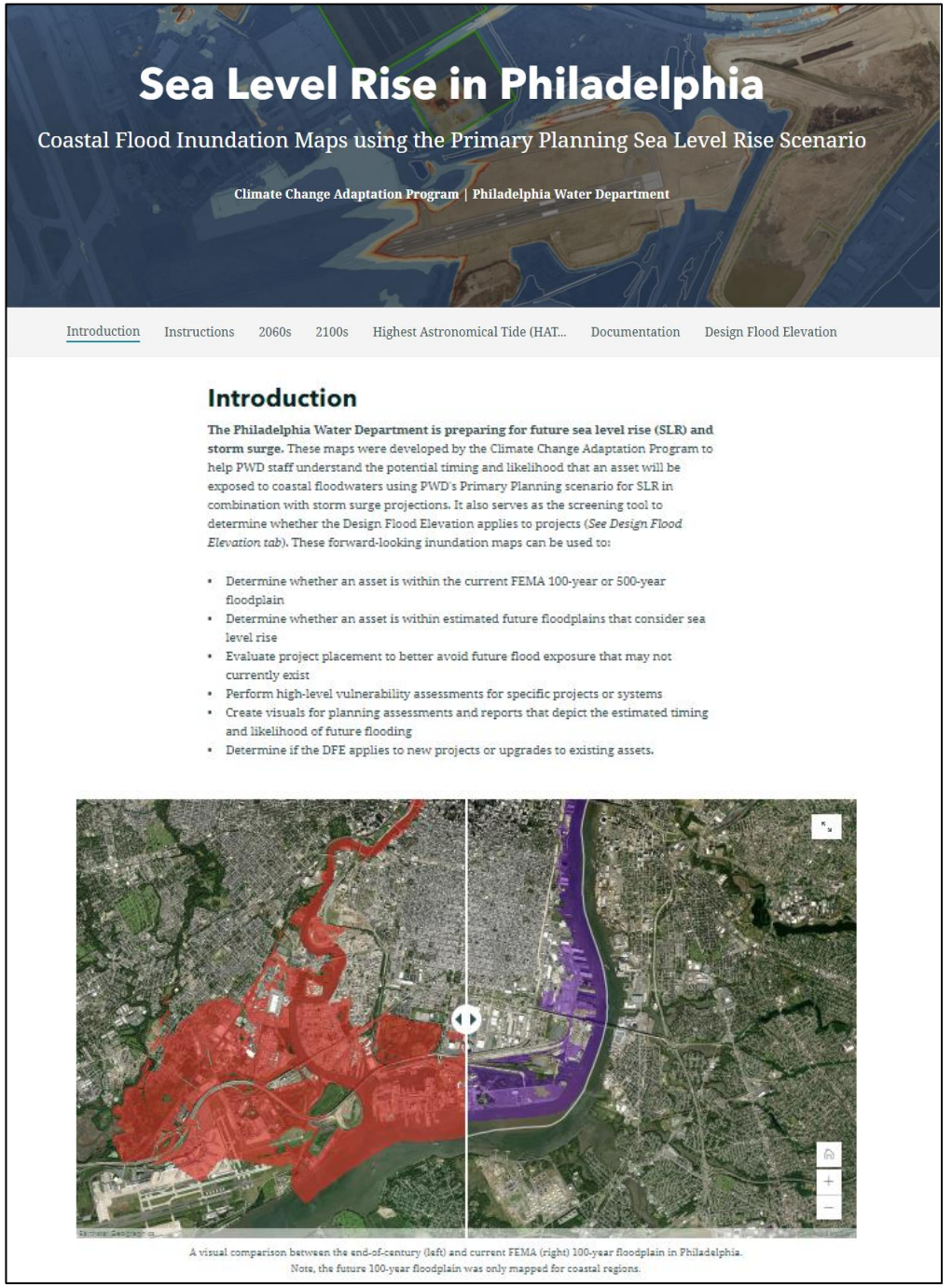
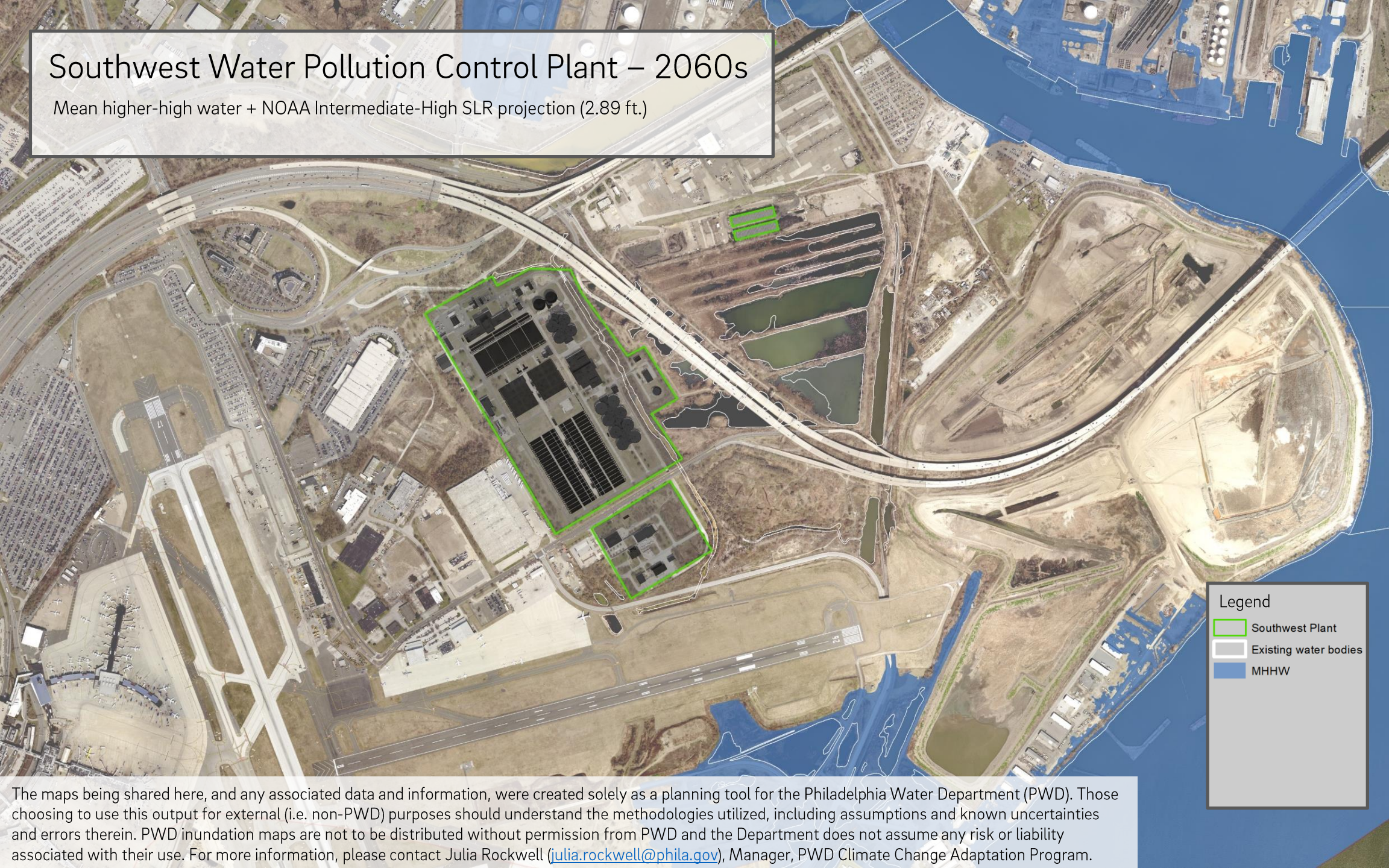


Southwest Water Pollution Control Plant
Mid-century, 2060s

Southwest Water Pollution Control Plant – 2060s

Mean higher-high water + NOAA Intermediate-High SLR projection (2.89 ft.)



Southwest Water Pollution Control Plant – 2060s

Mean higher-high water + NOAA Intermediate-High SLR projection (2.89 ft.)
+ 2 through 100-year storm tides

Southwest Water Pollution Control Plant
End-of-century, 2100s

Southwest Water Pollution Control Plant – 2100s

Mean higher-high water + NOAA Intermediate-High SLR projection (6.4 ft.)

Southwest Water Pollution Control Plant – 2100s

Mean higher-high water + NOAA Intermediate-High SLR projection (6.4 ft.)
+ 2 through 100-year storm tides

Coastal Design Flood Elevation

PWD Design Flood Elevations

Asset Type	Near-term *End of useful life does not extend beyond 2050*	Mid-century *End of useful life: 2050-2075*	End-of-century *End of useful life: 2075 +*
non-critical assets	Current floodplain regulations apply	12.0 ft. NAVD88, *or the protective elevation established by local regulations, whichever is higher*	
critical assets	Current floodplain regulations apply	13.75 ft. NAVD88	End-of-Century DFE ***OR*** 13.75 ft. NAVD88 **+ *Adaptive Management Plan***

Criticality

Useful Service Life

Adaptive Capacity
is considered when developing the AMP

Coastal Design Flood Elevation

MHHW	SLR	100-year (Stillwater)	Wave Effects	Freeboard	Total
3.66 ft.	2.89 ft.	3.95 ft.	1.5 ft.	1.75 ft.	13.75 ft.

Risk Tolerance
Accepted risk tolerance is storm surge associated with 100-year event)

Uncertainty
Safety factor accounts for multiple sources of uncertainty

A conservative sea Level rise projection (NOAA 2017 Intermediate-High scenario) was chosen for the DFE considering PWD's low **adaptive capacity**, low **risk tolerance**, generally long **useful service life** of assets and the **criticality** of facilities in the floodplain.

However, given the large **uncertainties** associated with sea level rise projections, assets with a useful service life beyond 2075 can still use the mid-century projection (2060s), as long as an adaptive management plan is developed in tandem.

Does the Design Flood Elevation Apply

There are three components that determine whether the DFE is requi your project: exposure, criticality and useful lifespan. The floodplain maps found in this tab are necessary for determining your project's ***exposure*** *to coastal flooding and ultimately, if the DFE requirement applies to your project or asset.*

Because this requirement goes above and beyond current floodplain regulations, an asset that is designed, constructed, or flood-proofed to the DFE, it is likely to be protected from coastal flooding through mid-century (2050-2075).

The map to the left contains the DFE Screening Layer (magenta) as well as FEMA's 100-year (blue) and 500-year floodplains (orange).

How to use this tool for the DFE

How can I use this tool to determine if the DFE applies?

This guide supplements information in the flow chart, providing planners and designers with the steps necessary to determine if a DFE applies to a particular project.

Determine asset exposure to inundation

It is first necessary to determine whether the project location is within a current or future floodplain. A project location may not currently be located within a floodplain, but due to SLR, may be within a future floodplain. If the project is within a current or future floodplain, one of the DFEs applies.

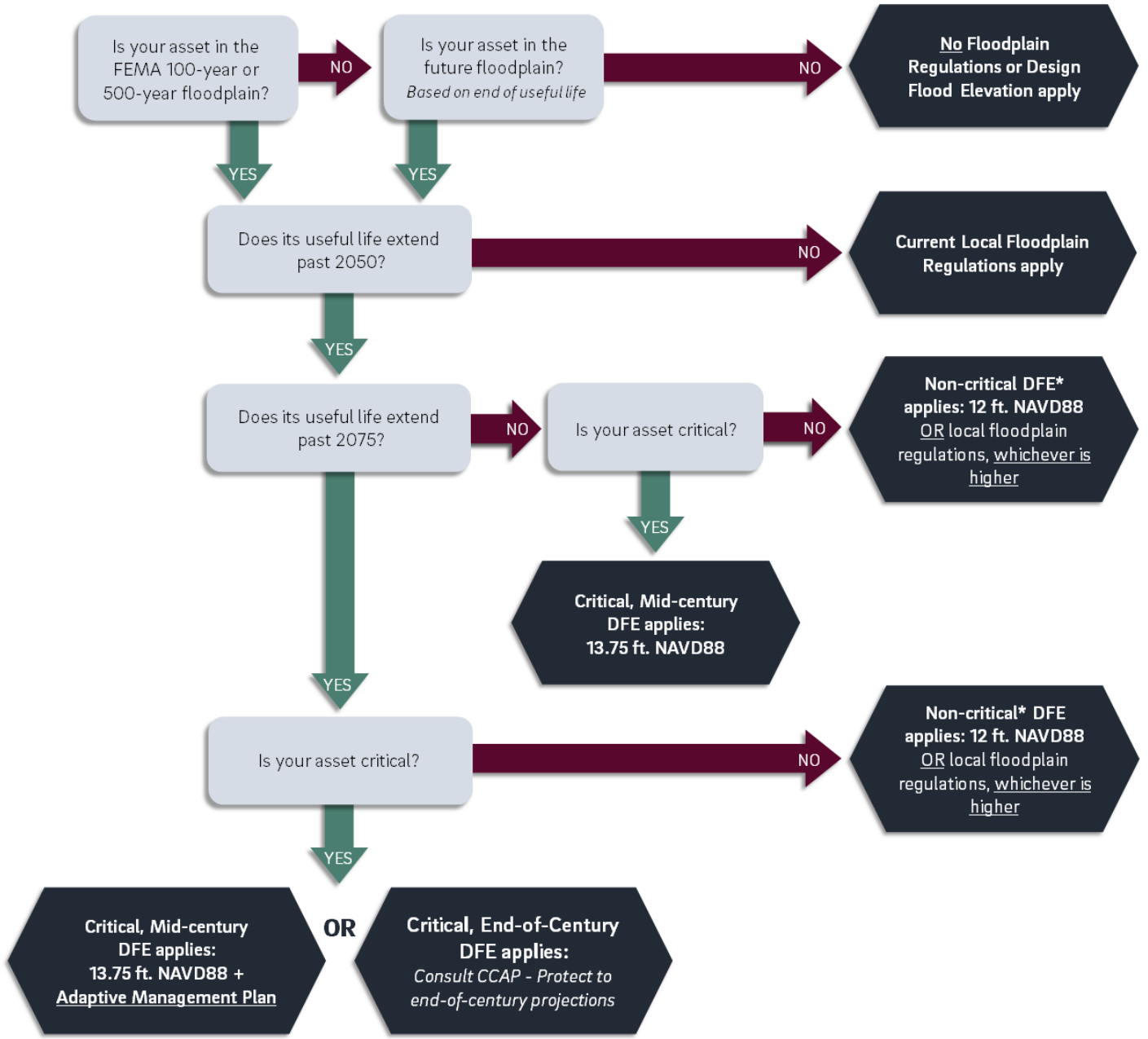
How does the DFE apply to my project?

Learn more

Planning and Design DFE flowchart

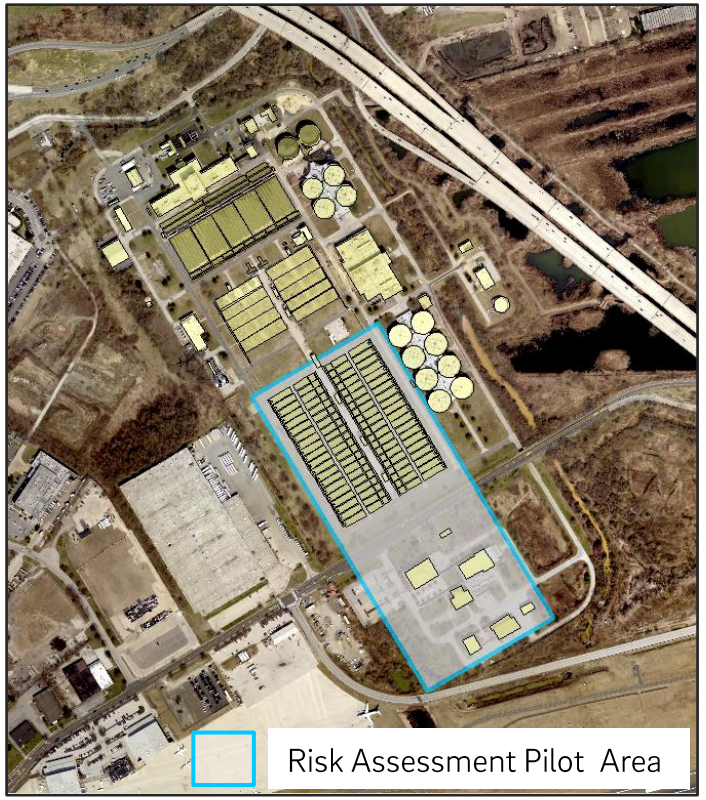
Learn more

Coastal DFE Decision Tree



Facility-based Coastal Flood Risk and Resiliency Assessments

Pilot Risk Assessment at the Southwest Water Pollution Control Plant



1. Asset Characterization
2. Threat Characterization and Analysis
3. Consequence Analysis
4. Vulnerability Analysis
5. Risk Analysis
6. Risk Management

CONSEQUENCE SCORE

Level of Service Disruption Score _____
+ Impact to Regulations Score _____
+ Danger to Staff Score _____
+ Cost to Repair/Replace Score _____
+ Dependency Score _____
+ Resiliency Score _____
TOTAL CONSEQUENCE SCORE _____

LIKELIHOOD

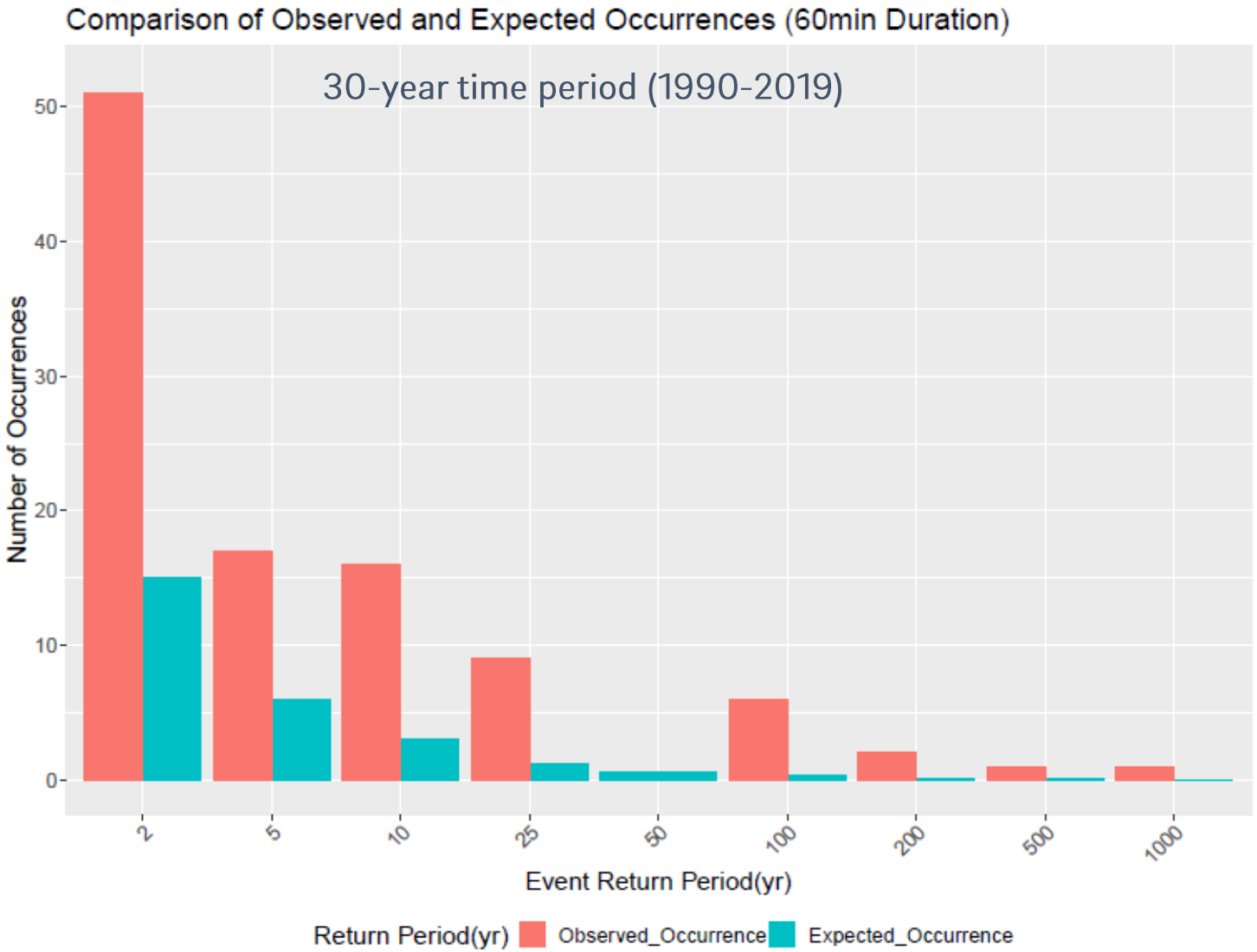
Exposure Frequency - In this risk assessment exposure frequency is a measure of the likelihood, in any given year, that the asset will be exposed. This risk assessment looks at two time periods, the 2060s and 2100 and the exposure frequency score is based on the earliest flooding scenario to inundate the asset and the return period.

	2060s	2100
The asset will not be exposed to future coastal flooding in the scenarios considered here.	☐ 0	☐ 0
The asset will be exposed to flooding, but only during rare storms (50-yr to 100-yr storms).	☐ 1	☐ 1
The asset will not be exposed to flooding during the normal tide cycle but it will be exposed to flooding during storm events that are somewhat likely to happen (5-yr storm to 25-yr storm).	☐ 2	☐ 2
The asset is highly exposed to flooding and water will reach this asset during the normal high tide cycle (mean higher-high water) and/or during a storm that is very likely to happen (2-yr storm). Flooding will be sever during less-likely to occur storms (>2-yr events).	☐ 3	☐ 3

TOTAL RISK SCORE

2060s	2100
Vulnerability Score _____	Vulnerability Score _____
+ Consequence Score _____	+ Consequence Score _____
TOTAL	TOTAL
X Likelihood _____	X Likelihood _____
TOTAL RISK SCORE _____	TOTAL RISK SCORE _____

Philadelphia is already experiencing climate change

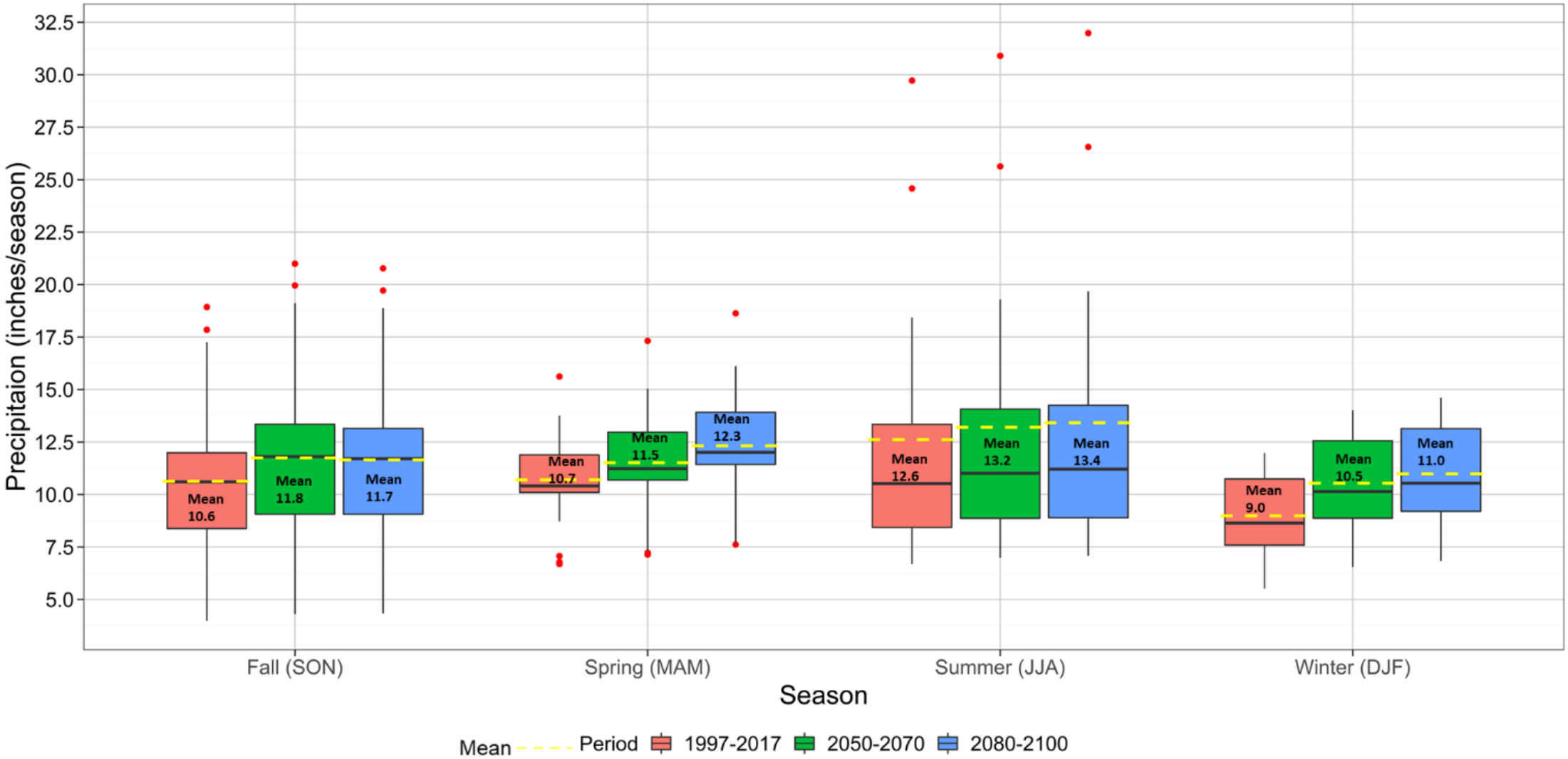


Precipitation Projections

Time Period	Average Annual Total (in./yr.)	Max. Annual Total (in./yr.)	Min. Annual Total (in./yr.)	Mean Event Depth (in./event)	Max. Event Depth (in./event)	Max Intensity (in./hr.)	Mean Intensity (in./hr.)
1997-2017	43.01	64.33	30.41	0.41	8.27	1.36	0.06
2050-2070	47.10	70.22	33.22	0.45	8.58	1.55	0.07
2080-2100	48.49	72.28	34.50	0.46	9.06	1.52	0.07
% Change 2050	9.5%	9.2%	9.2%	9.5%	3.7%	14.0%	7.6%
% Change 2080	12.7%	12.4%	13.4%	12.7%	9.5%	11.7%	9.7%

Statistical parameters for the PHL 1997-2017 observed time series compared to the PHL 2050-2070 and 2080-2100 projected (i.e. climate-adjusted) time series.

Precipitation Projections



Seasonal precipitation for observed PHL gauge data (1997-2017) and climate-adjusted future time periods for mid (2050-2070) and end-of-century (2080-2100).

Increasing Precipitation

In Philadelphia, rainfall is expected to increase in intensity, with the largest increases occurring for the biggest storms

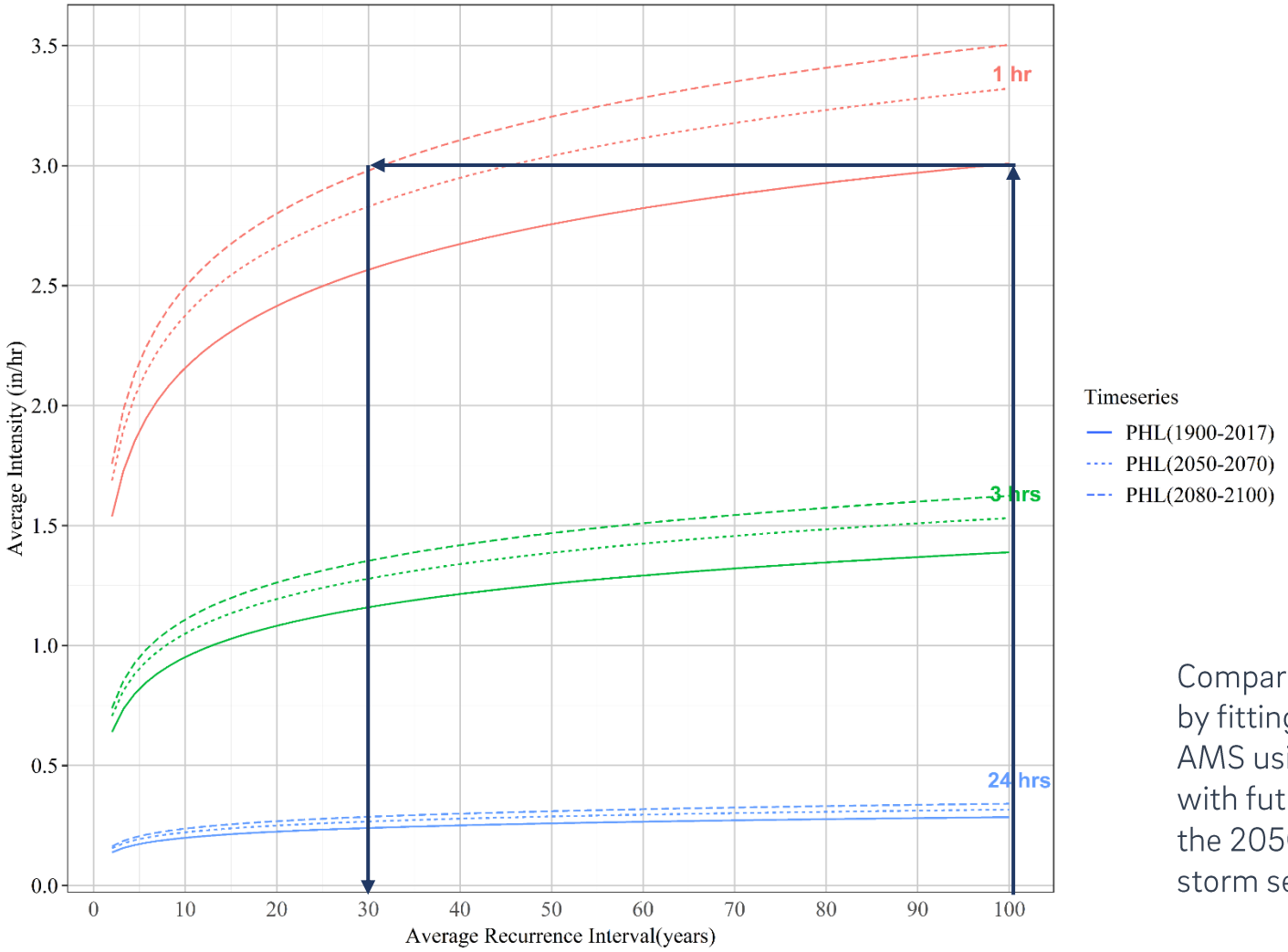
Potential risks include:

- More frequent combined sewer overflows (CSOs)
- Increased erosion and sediment transport
- Increased riverine flooding
- Increased infrastructure-based flooding (basement/sewer back-ups)

Actionable science developed includes:

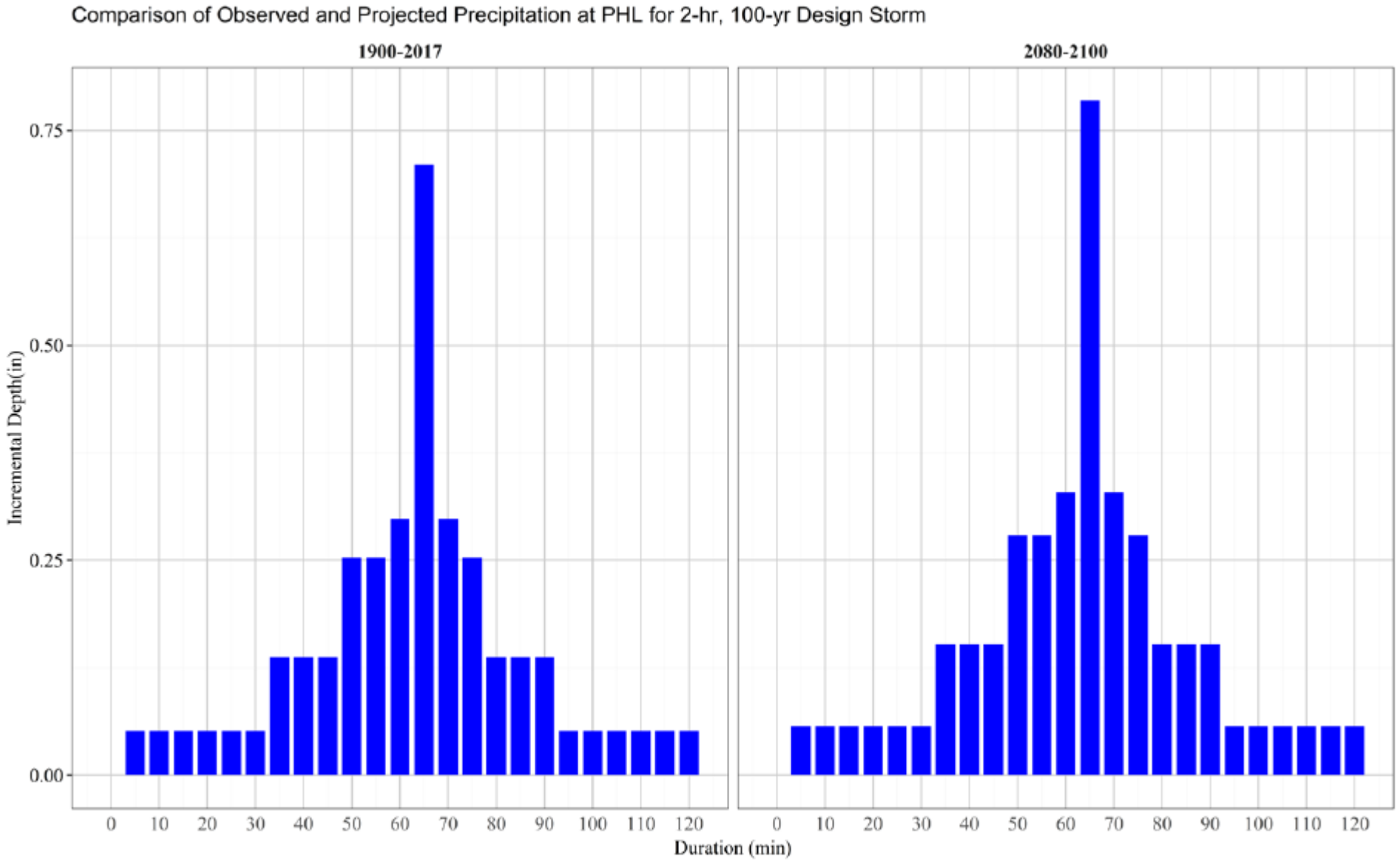
- High resolution precipitation projections for use in modeling applications
- Future design storm events (common tool in infrastructure design)
- Stochastic rainfall generator to evaluate current and future precipitation variability

Intensity-Duration-Frequency Curves



Comparison of IDF curves generated by fitting GEV Type II distribution on AMS using PHL data (1900-2017) with future PHL time series based on the 2050-2070 and 2080-2100 storm sets for RCP8.5

Current and Future Design Storms



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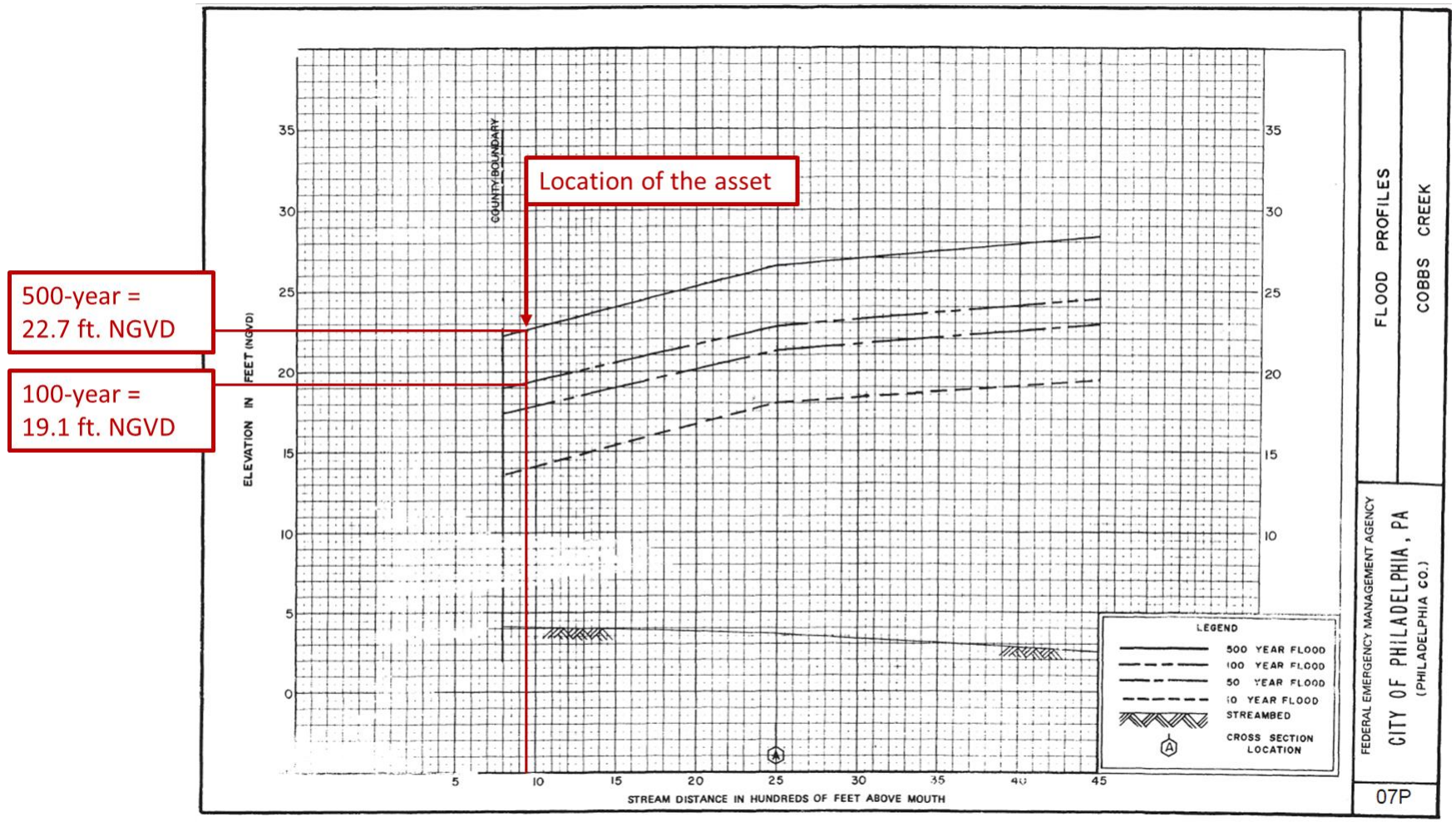
Technical Papers

Transforming Global Climate Model Precipitation Output for Use in Urban Stormwater Applications

M. Maimone, Ph.D., P.E., D.WRE, M.ASCE; S. Malter; J. Rockwell; and V. Raj

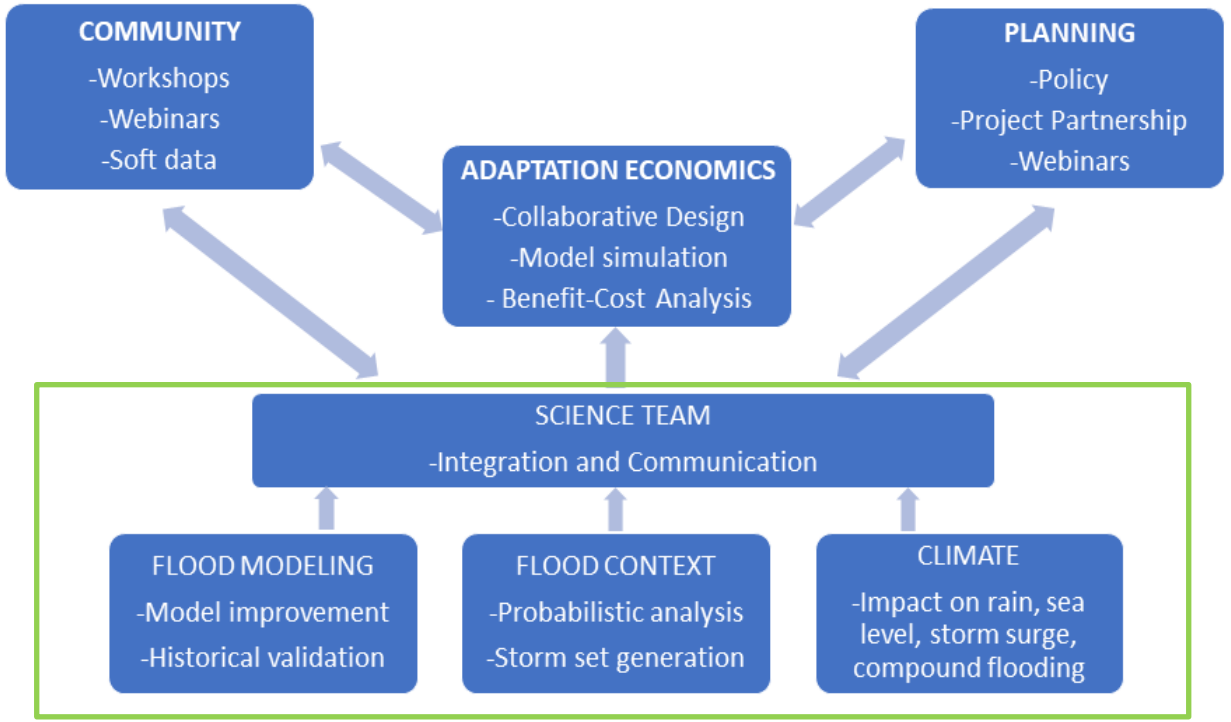
Riverine Flood Resiliency Guidance

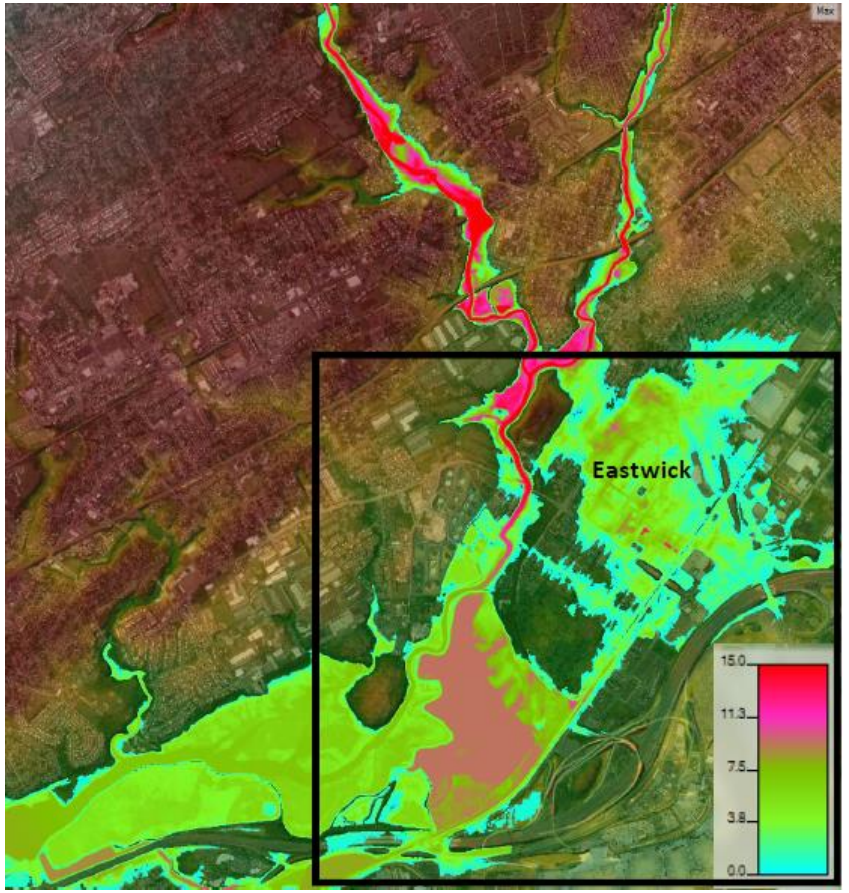
In riverine floodplains, CCAP recommends using the 500-year flood elevation



NOAA COCA/SARP Project

Compound Fluvial-Coastal Flood & Climate Adaptation: A Transferable Framework of Engagement, Modeling & Cost-Benefit Analysis





Modeled flooding for synthetic event: Hurricane Sandy's Delaware River water levels + Hurricane Irene's Darby-Cobbs stream flows

Project leads:
Philip Orton (PI), Stevens Institute of Technology
Franco Montalto (Co-PI), Drexel
Julia Rockwell, Marc Cammarata (Co-PI), PWD

Building Resiliency

Green City, Clean Waters Program

Green City, Clean Waters continues to make tremendous progress since launching in 2011. We exceeded our 10-year pollution reduction goal, with new infrastructure investments now keeping nearly **three billion gallons** of stormwater runoff and sewer overflow out of local waterways.

We've installed more than
2,800 green tools...

...at nearly
800 sites
throughout the city...

...keeping more than
2.7 billion gallons
of polluted water out of our rivers.

PWD Internal Flood Risk Management Coordination

Flood Relief Program

PWD Design

Development Services (Private development)

Public Affairs

Sewer System Modeling (hydrologic & hydraulic modeling)

Climate Change Adaptation Program

Watershed protection

Green stormwater infrastructure program

Water Quality Modeling Group

Capital Planning Program

Operations – Collection System

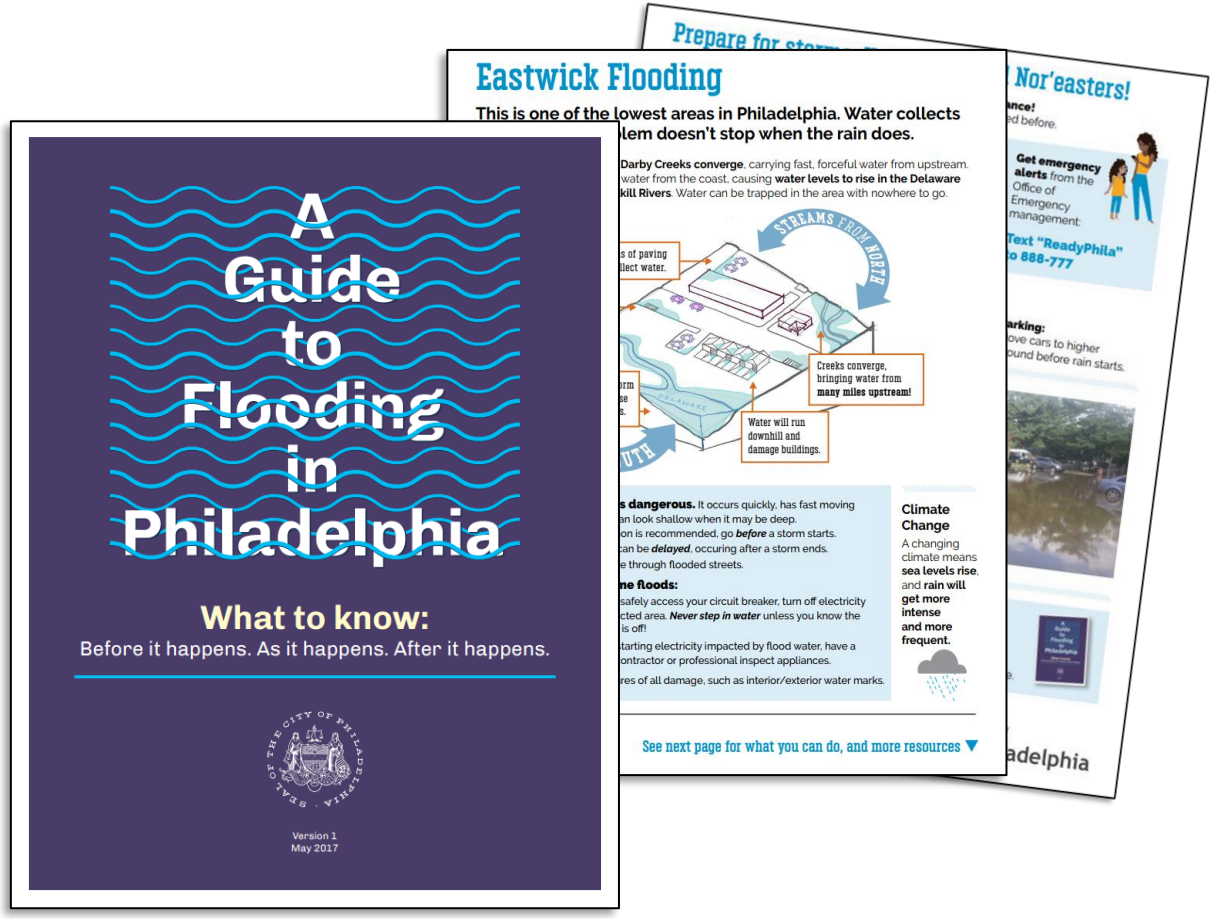
Sewer Planning Program

City of Philadelphia Flood Risk Management Program

The Philadelphia Flood Risk Management Program is led by a task force comprised of more than 15 City departments/agencies as well as state and federal partners

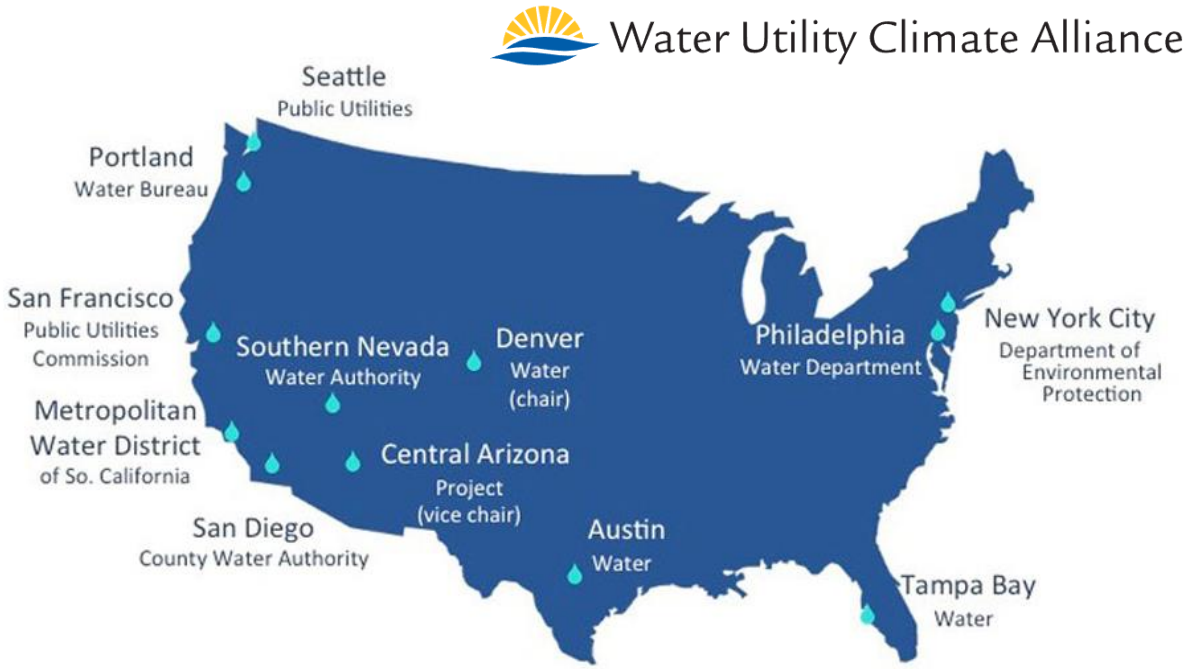
FRMTF
FLOOD RISK MANAGEMENT TASK FORCE
CITY OF PHILADELPHIA

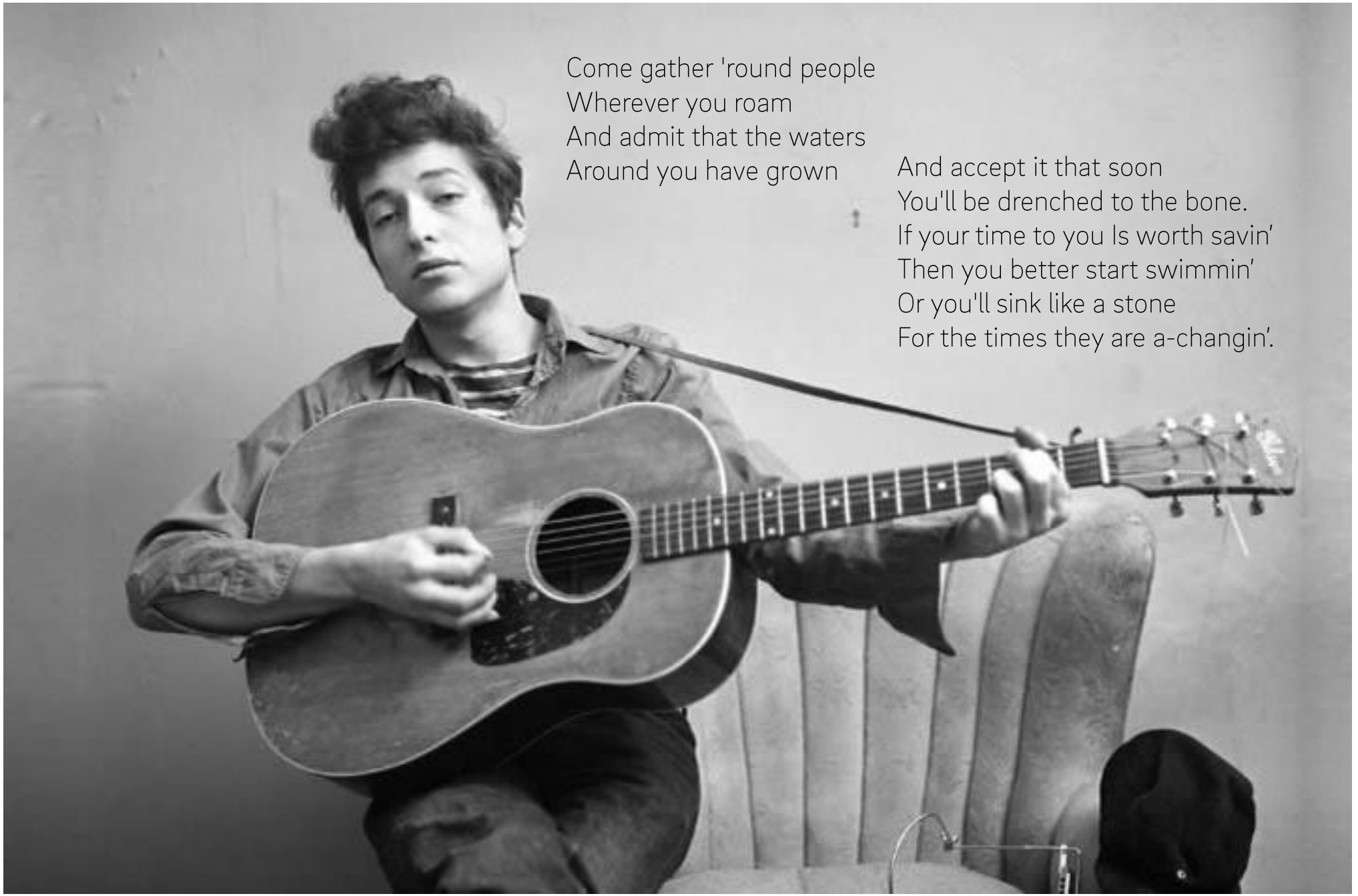
- Provide public information
- Update and enforcing flood maps & regulations
- Reduce flood damages
- Increase flood preparedness



Where we're headed

- Continue work on priority initiatives that will help mainstream the use of climate information (risk assessments, climate planning & design guidance)
- Move from planning to implementation of adaptation strategies
- Continue building internal capacity and engaging with city and regional partners
- Continue partnering with and leveraging knowledge from peer cities/utilities




Come gather 'round people
Wherever you roam
And admit that the waters
Around you have grown
And accept it that soon
You'll be drenched to the bone.
If your time to you Is worth savin'
Then you better start swimmin'
Or you'll sink like a stone
For the times they are a-changin'.

Thank You!

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PHILADELPHIA WATER DEPARTMENT