

FUTURE RISKS

The communities along the Delaware and Lower Schuylkill Rivers are expected to become both hotter and wetter in the future through increased precipitation, rising sea levels, higher air temperatures, and more heat waves. In addition to these changes, extreme weather in the region is projected to continue to increase in frequency and severity, leading to increased riverine and stormwater flooding, among other impacts.¹⁹

1. STORM SURGE AND SEA LEVEL RISE

Extreme events, like hurricanes or nor'easters, will increase the depth of flooding and cause water to reach further inland. As a result of sea level rise, storm surges that occur today are about 8 inches higher than they would have been in 1900.

As seas and tidal rivers continue to rise, daily tidal flooding and storm surge baseline wave elevations will be dramatically amplified, translating into an increased risk and impact on coastal and tidal river communities. By 2100, it is very likely that sea level rise will be between 2 and 5.3 feet.²⁰

2. INCREASED PRECIPITATION

Climate models indicate that rising temperatures will intensify the Earth's water cycle and increase evaporation, resulting in more frequent and intense precipitation and storms.

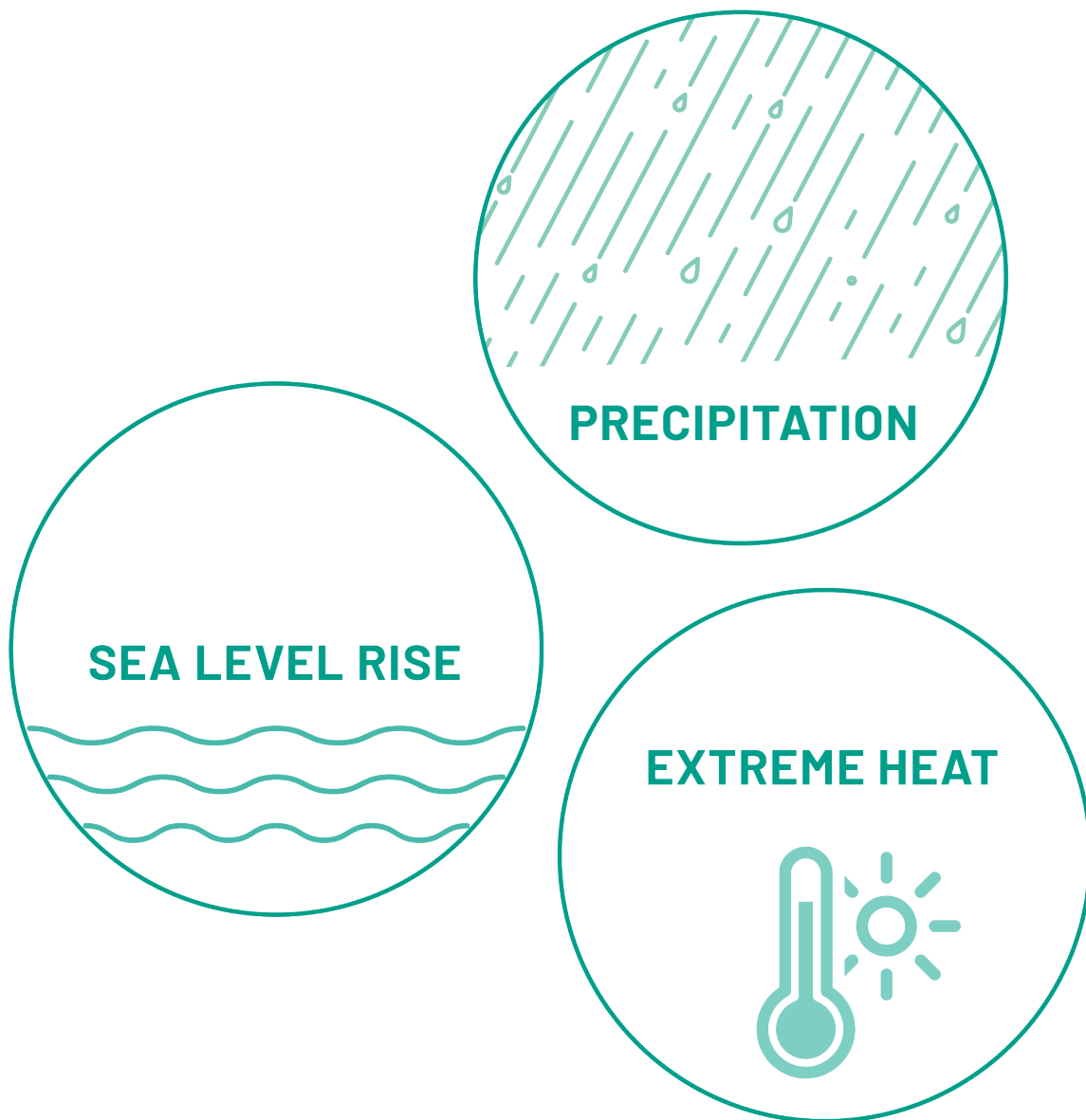
Extreme precipitation events have increased in frequency and intensity across the U.S. since the early 20th century and are projected to keep increasing, with a national average increase of 4% in annual precipitation between 1901 to 2015. The Northeast has experienced the strongest increases in heavy precipitation events.²¹

3. INCREASED HEAT

Extreme heat is increasingly a growing threat across the U.S. and in the Northeast. While extreme heat events have always occurred over the summer months, climate change has made these heat waves more frequent, severe, and longer lasting. The Northeastern climate is experiencing hotter days and longer heat waves. Between 1895 and 2011, temperatures rose by almost 2°F and projections indicate warming of 4.5°F to 10°F by the 2080s.²²

The heat index, also known as apparent temperature, measures how hot a human body feels with relative humidity combined with air temperature. In Philadelphia, a hot day is considered to be a day above a "feels like" temperature of 104°F. There were 7 hot days in 2024 but there are projected to be 15 hot days above 104°F annually in 30 years from now²³ Humidity also reduces a body's ability to cool off.





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By addressing the following climate threats together, we can create resilient solutions to ensure that our communities thrive for generations to come.

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PROJECTED SEA LEVEL RISE

Sea and river level rise will result in daily tidal flooding. National Oceanic and Atmospheric Administration observations indicate that the tidal Delaware River has risen at a rate of about 1.2 inches per decade over the last one hundred years. These rises are projected to continue. By 2100, it is very likely that sea level rise will be between 2 and 5.3 feet.²⁴ The current range reflects the uncertainty of the pace of sea level rise.

For this report, the Consortium for Climate Risks in the Urban Northeast (CCRUN) Sea Level Rise Projections for the Philadelphia Region were used which are based on Coupled Model Intercomparison Projects (CMIP) 6 Projections for future sea level rise derived and downscaled from the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report. These projections are relative to the 1995 -2014 time period. Climate adaptation planning requires continually reviewing the latest local sea level rise projections.

Sea level rise alone is increasing the number of days that Philadelphia experiences high-tide flooding – flooding due to tide levels in the absence of a storm. Coupled with storm surges, sea level rise is causing increased coastal flooding, which is further exacerbated when accompanied by heavy precipitation events.

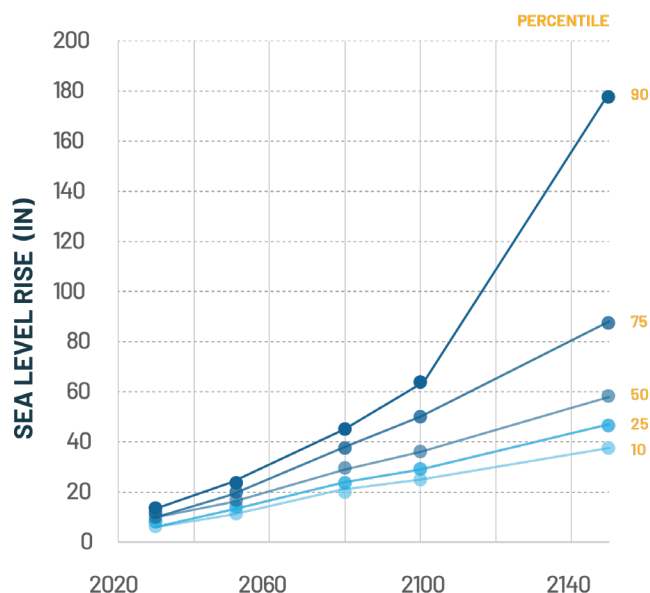


Figure 33. CCRUN Sea Level Rise Projections for the Philadelphia Region based on CMIP6 and derived from the IPCC's 6th Assessment Report. Projections are relative to the 1995-2014 time. Source: OLIN; data from CCRUN, The Climate Resilience Research agenda, 2022



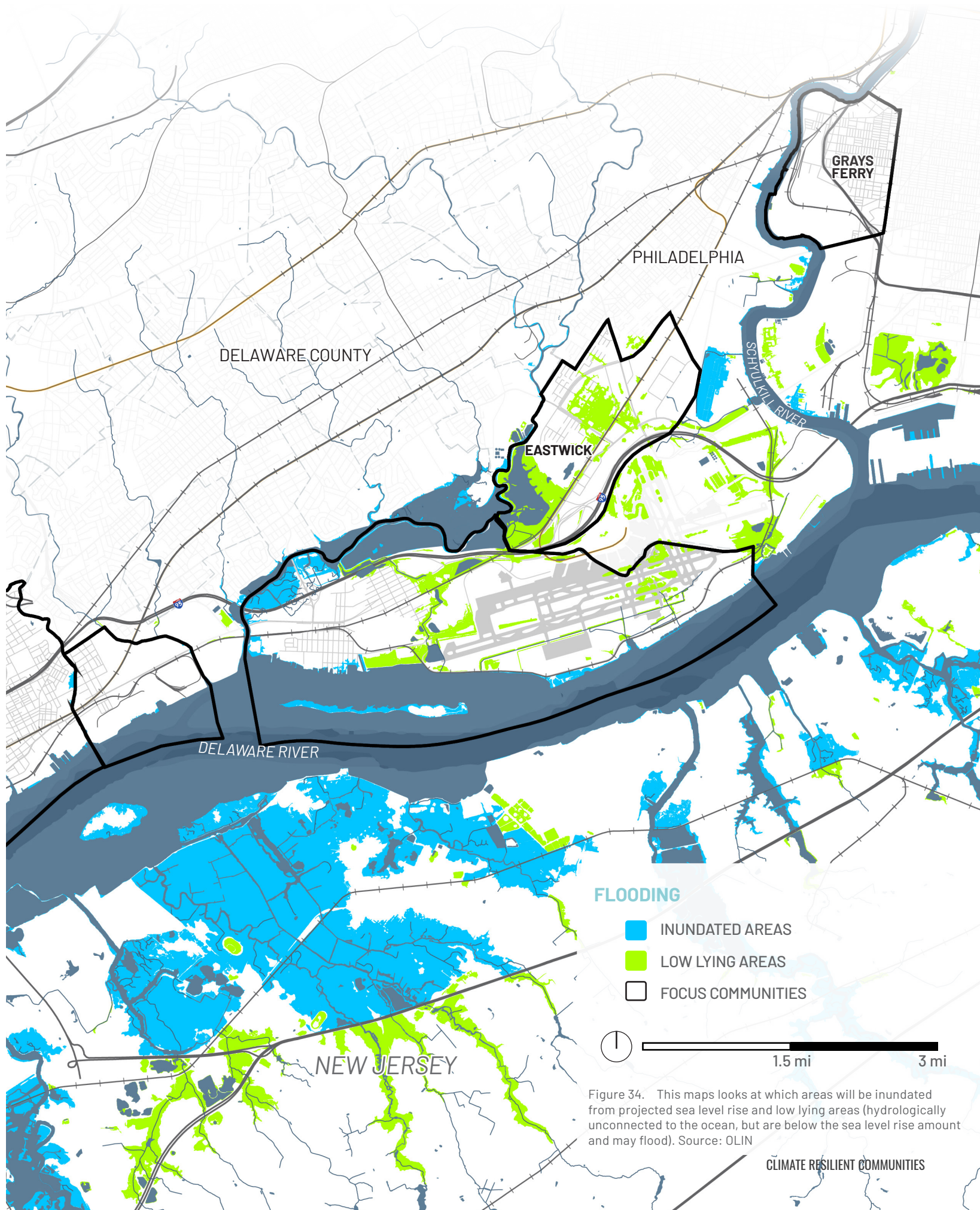


Figure 34. This maps looks at which areas will be inundated from projected sea level rise and low lying areas (hydrologically unconnected to the ocean, but are below the sea level rise amount and may flood). Source: OLIN

INCREASED RAINFALL

Extreme precipitation is expected to be more frequent, resulting in more inland and river or stream flooding. Though periods of severe drought can co-exist, the region is generally expected to see an increase in the duration and intensity of precipitation. Over the past 82 years, annual average precipitation has increased at a rate of 0.82 inches per decade. In the observed record at Philadelphia International Airport, 6 of the 10 wettest years on record have occurred since 1990.²⁵ While annual precipitation in the region is increasing, it is also expected that the frequency and intensity of precipitation events (such as hurricanes, nor'easters, and cloudburst events) will also increase, causing more intense pluvial, riverine, and coastal flooding.

Precipitation Projections for the Philadelphia Region (in)

DECADE	LOW ESTIMATE 10TH PERCENTILE	MIDDLE RANGE 25TH - 75TH PERCENTILE	HIGH ESTIMATE 90TH PERCENTILE
2030s	41.53 IN	42.36 - 44.85 IN	45.68 IN
2040s	41.95 IN	43.19 - 45.68 IN	46.93 IN
2050s	42.36 IN	43.61 - 46.51 IN	47.34 IN
2060s	42.36 IN	43.61 - 46.93 IN	48.59 IN
2070s	42.78 IN	44.44 - 47.34 IN	49.01 IN
2080s	42.78 IN	44.85 - 48.17 IN	50.25 IN
2100	40.70 IN	44.02 - 50.67 IN	53.99 IN

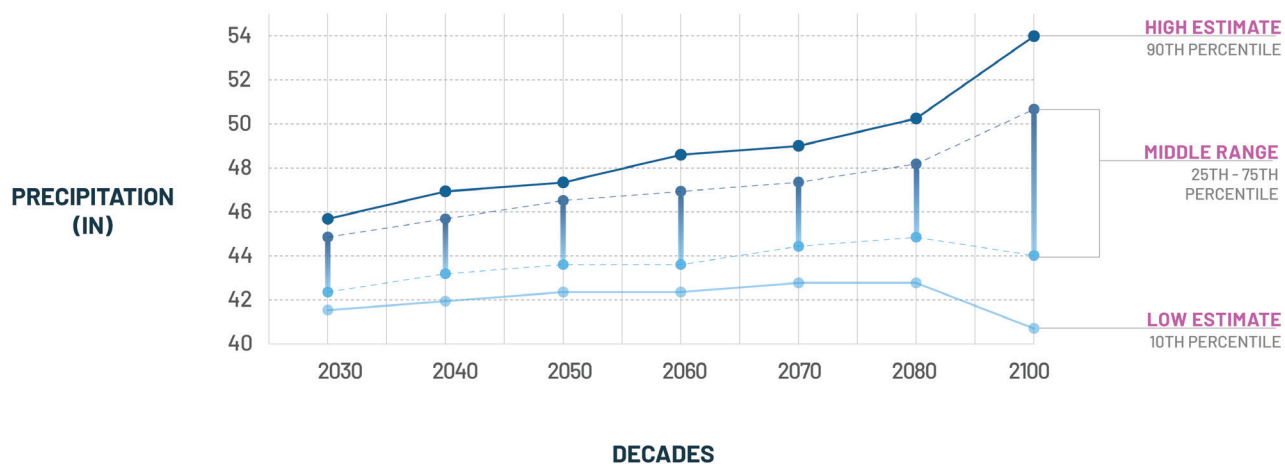


Figure 35. The line graph above shows the projected precipitation amounts over the next century. Source: OLIN, data from CCRUN, The Climate Resilience Research agenda, 2022



EXTREME HEAT

Air temperatures are expected to get hotter. From 1971 to 2000, on average, 4 days a year reached 100°F. By 2099, experts predict 55 days per year will reach 100°F.²⁶ Higher temperatures are likely to increase heat-related deaths and decrease air quality. Children, older adults, those with pre-existing health conditions like asthma, those living alone, those working outdoors, and/or those of lower socioeconomic status are often at higher risk of heat-related illness or death.

Air Temperature Increase Projections for the Philadelphia Region (°F)

DECADE	LOW ESTIMATE 10TH PERCENTILE	MIDDLE RANGE 25TH - 75TH PERCENTILE	HIGH ESTIMATE 90TH PERCENTILE
2030s	57.8°	58.6° - 59.8°	60.6°
2040s	58.5°	59.2° - 60.8°	61.8°
2050s	58.9°	60° - 61.7°	62.7°
2060s	59.5°	60.6° - 62.8°	64.4°
2070s	59.9°	61.2° - 63.9°	65.7°
2080s	60.6°	61.4° - 65.3°	67°
2100	60.8°	61.9° - 66.4°	68.8°

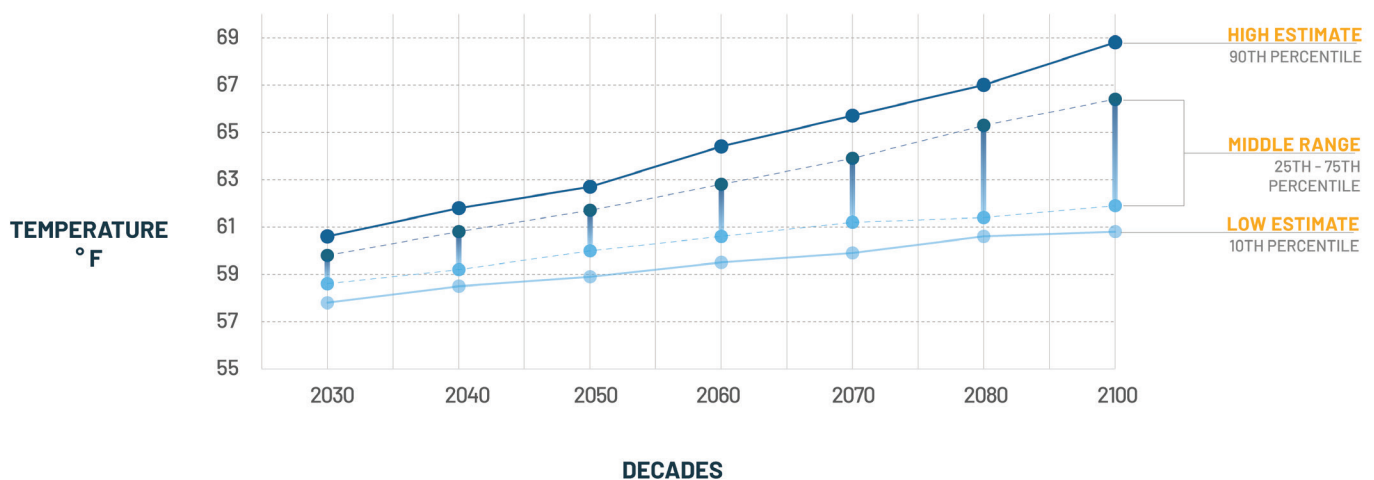


Figure 36. The chart and line graph above show the projected increase in average air temperature through the end of the century. Source: OLIN, data from CCRUN, The Climate Resilience Research agenda, 2022

MODELING THE IMPACTS OF LIKELY FUTURE STORM EVENTS WITH INCREASED SEA LEVEL RISE

As sea levels continue to rise, the Philadelphia region and Delaware River Estuary are expected to experience more frequent and intense flooding events. While rising sea levels will increase the frequency of high-tide flooding over time, the most severe impacts will occur during large storms, such as hurricanes and nor'easters, which bring intense winds, storm surges, and heavy precipitation. There is evidence that future storms may become more frequent and intense due to climate change, leading to an increased risk of severe flooding.²⁷

DEVELOPING A MODEL

Rather than modeling an imaginary future storm event, we chose to model recent past storm events with sea level rise added for two reasons: 1) Because it is likely that these relatively high probability events will occur again in the future, and 2) because understanding future risk relative to previously experienced storms events is a powerful way to communicate risk to community members and local government officials.

Working with engineers Franco Montalto and PhD student Nirajan Adhikari at Drexel University's Sustainable Water Resource Engineering Lab, three recent storm events were chosen: Hurricane Sandy (2012), Hurricane Isaias (2020), and Hurricane Ida (2021). Not only are these storms all recent, but they also exhibited a variety of flooding types and impacted different areas of the region. Based on the latest climate modeling (CMIP6) downscaled from the IPCC's 6th Assessment Report, +1 foot, +2 foot, and +4 foot sea level rise scenarios were studied, with +1 foot considered the likely minimum and +4 foot considered the likely maximum. The +2 foot sea level rise scenario was chosen as the most appropriate scenario for current planning and is shown below. Maps and data associated with the +1 and +4 foot sea level rise scenarios can be found in the Appendix. For each storm event, a Hydrologic Engineering Center

River Analysis System. This model combined was used Delaware River bathymetry data; shoreline delineation; hydraulic inputs from gauges at the Ben Franklin Bridge, Fairmont Waterworks, and Marcus Hook; flow data for ungagged tributaries using a Hydrologic Engineering Center Hydrologic Modeling System rainfall-runoff watershed model; regional landcover and topographic data; and building footprints. Each model was validated by comparing observed versus simulated depth flood depth values. The result of each model is a 3 meter resolution raster for each storm and sea level rise scenario that shows modeled flood depths throughout the study area.

To analyze each storm event with future sea level rise added, flooding was defined as any area with a water depth of greater than 4 inches/100 mm (typical curb height and the value used in NYC Stormwater Resiliency maps). Flooded areas were further classified as: moderately flooded (4 inches–1 foot) or (100 mm–30 cm), extreme flooding (1 foot–2 feet) or (30–60 cm), and very extreme flooding (> 2 feet) or (> 60 cm). Comparing the amount of area flooded in the baseline storm scenario to the area flooded by the same storm with sea level rise added, the potential significant impacts of sea level rise on the region are clear.

Areas of impact

Figure 28 measures the acres of land in each focus community that were impacted by the three storms included in our model (baseline), and then measures the increase of land that would be impacted by an additional 2 feet of sea level rise is added.

The affected land is categorized by different land uses, since each use has different implications and risks associated with flooding. These categories are residential, industrial, commercial, parks and open space, and other.

Figure 37. Chart comparing the modeled impacts of storm events with +2 feet sea level rise added. Land use totals were calculated using DVRPC land use data from 2012. Source: OLIN; Drexel University

MODELED IMPACTS OF STORM EVENTS WITH +2 FEET SEA LEVEL RISE

	ALL STORMS BASELINE		ALL STORMS + 2 FEET SEA LEVEL RISE		INCREASE FROM BASELINE	
	Acres Flooded	Proportion of Category (%)	Acres Flooded	Proportion of Category (%)	Acres Flooded	% Increase
MARCUS HOOK	20.13	2%	74.78	7%	54.65	371%
Residential	0.01	0%	0.30	0%	0.29	2494%
Industrial	15.16	3%	61.61	11%	46.45	406%
Commercial	0.00	0%	0.27	1%	0.27	-
Parks and Open Space	3.99	7%	11.39	19%	7.40	286%
Other	0.97	0%	1.21	0%	0.24	125%
TRAINER	29.83	3%	67.25	8%	37.42	225%
Residential	0.00	0%	0.00	0%	0.00	-
Industrial	4.50	1%	33.45	11%	28.95	743%
Commercial	0.00	0%	0.00	0%	0.00	-
Parks and Open Space	17.76	11%	25.94	17%	8.19	146%
Other	7.57	3%	7.85	3%	0.28	104%
CHESTER	97.44	3%	176.92	5%	79.48	182%
Residential	0.12	0%	0.69	0%	0.58	599%
Industrial	26.18	9%	67.91	23%	41.73	259%
Commercial	9.33	1%	15.48	2%	6.15	166%
Parks and Open Space	46.30	5%	76.11	9%	29.81	164%
Other	15.52	2%	16.74	2%	1.22	108%
EASTWICK	611.52	36%	768.76	46%	157.24	126%
Residential	92.41	43%	98.43	46%	6.02	107%
Industrial	13.18	6%	39.77	17%	26.59	302%
Commercial	26.65	19%	30.19	21%	3.54	113%
Parks and Open Space	263.14	42%	339.48	54%	76.34	129%
Other	216.14	46%	260.89	56%	44.75	121%
GRAYS FERRY	108.37	11%	125.12	12%	16.75	115%
Residential	0.11	0%	0.14	0%	0.03	132%
Industrial	19.60	13%	25.45	17%	5.84	130%
Commercial	0.00	0%	0.00	0%	0.00	-
Parks and Open Space	72.70	24%	81.95	27%	9.25	113%
Other	15.96	7%	17.58	8%	1.61	110%
STUDY AREA TOTAL	1,907.05	13%	2,991.84	20%	1,084.79	157%
Residential	110.55	5%	142.51	7%	31.96	129%
Industrial	179.28	9%	388.99	19%	209.70	217%
Commercial	73.55	6%	124.09	10%	50.54	169%
Parks and Open Space	878.55	29%	1,165.47	38%	286.92	133%
Other	665.12	10%	1,170.78	18%	505.66	176%



FUTURE STORMS WITH SEA LEVEL RISE

Figure 30 shows the combined flooding impact of the three modeled storms - Hurricane Ida (2021), Hurricane Isaias (2020), and Hurricane Sandy (2012) - as well as the increased impact of similar, future storms due to the +2 feet of sea level rise likely by 2080.

Areas of the map that are shaded light blue likely flooded during these past storms, while areas shaded dark blue are those that may flood if and when similar storms occur on top of additional sea level rise in the coming decades. The impacts of sea level rise on these common storms are significant in some low-lying coastal areas and less significant in others. While this analysis focuses on flood risk over the next 50 years, in the long-term more extreme storms and sea level rise will only further increase inland areas' exposure to more moderate and extreme flooding from coastal storms (see figure 29).

The flooding impacts of sea level rise on major storm events is examined in more detail in the individual community plans in the Chapter 6 Recommendations.

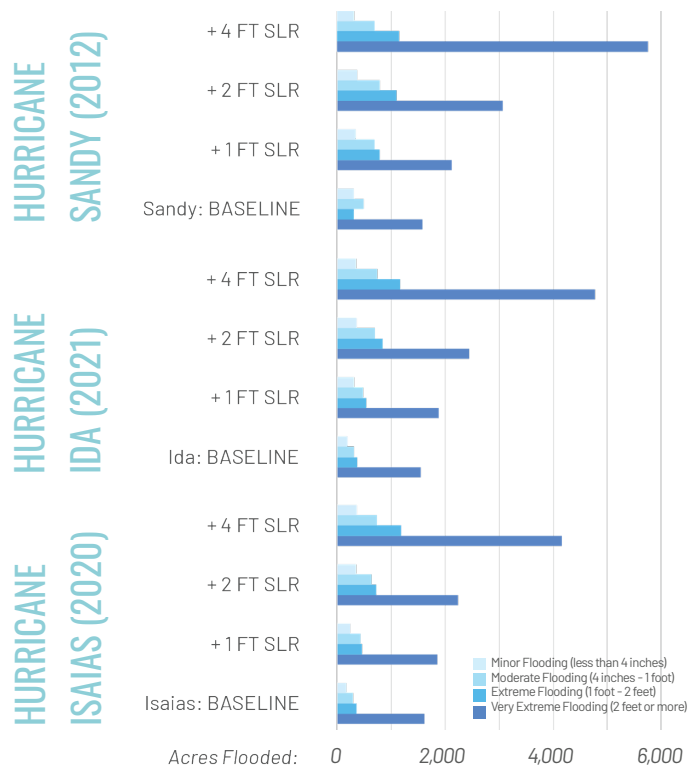
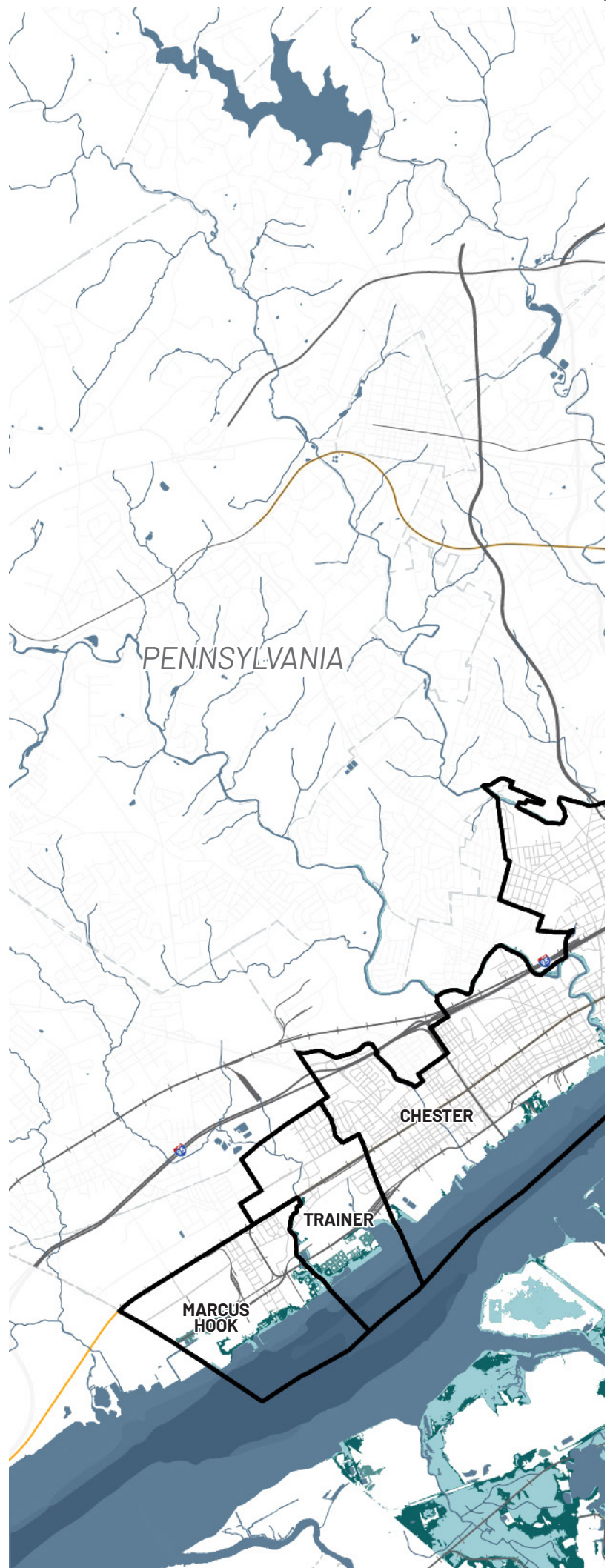


Figure 38. Chart comparing the severity of acres flooded within the project study area for each modeled storm and sea level rise scenario. Source: OLIN; Drexel University



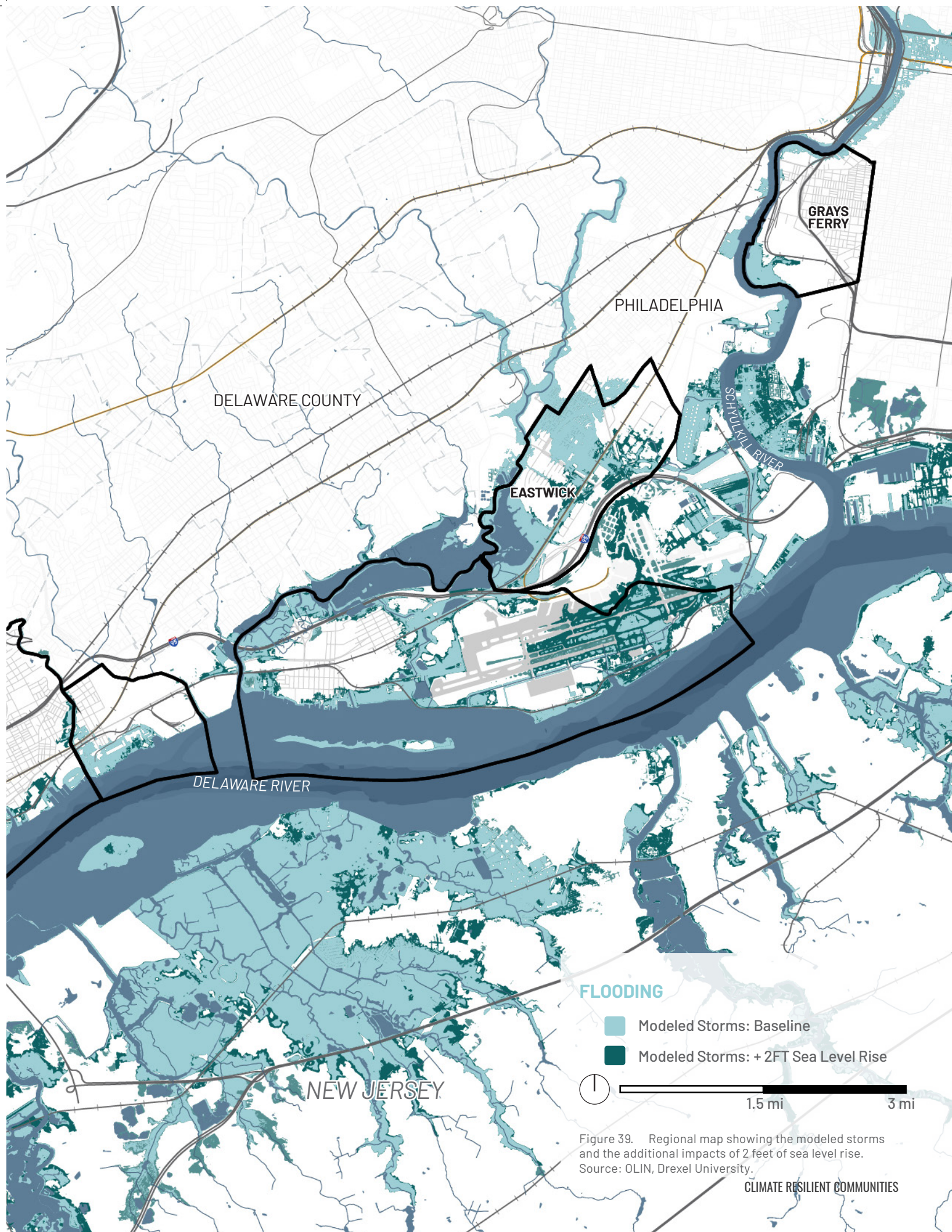


Figure 39. Regional map showing the modeled storms and the additional impacts of 2 feet of sea level rise.
Source: OLIN, Drexel University.