



**CHOOSING TRAJECTORIES: AN
AIDE FOR MODELING FUTURE
LAND USE SCENARIOS IN THE
DELAWARE RIVER BASIN**

DRB PROJECT- LAND USE DYNAMICS

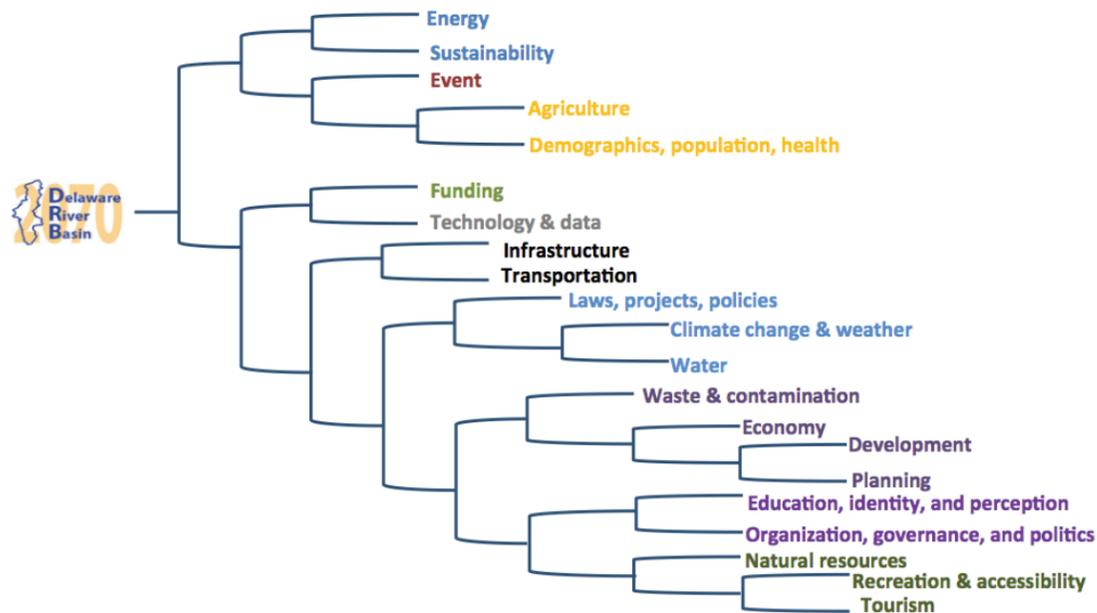
BACKGROUND

The Delaware River Basin (DRB) provides water resources for roughly 5% of the US population – over 15 million people. There are significant challenges facing water resources in the DRB including water quality, population growth and associated land cover change, emerging energy industries, and the potential for sea level rise, flooding, and drought with climate change.

To address these challenges and to account for an uncertain future, we aim to develop a land cover mapping, modeling, and monitoring system for the DRB in support of maintaining and restoring water resources. Our team is based out of Shippensburg University, with collaborators at the USGS and UVM Spatial Analysis Lab. Our funding comes from the William Penn Foundation.

DRB2070 WORKSHOPS

From October 2015- February 2016, we held a series of workshops throughout the basin to understand the regional vision and values for the DRB. Workshops were held in Pennsylvania (Philadelphia and Reading), New Jersey (Washington), New York (Narrowsburg), and Delaware (Dover). In total, we had 70 participants from a range of backgrounds that provided input on drivers of land use change. They also identified current strengths and weaknesses in the basin, as well as future opportunities and threats.



GROUP REPORT-OUTS AND MAP ANNOTATIONS FROM THE DRB2070 WORKSHOPS WERE COMPARED USING WORD FREQUENCY ANALYSIS. THE CLUSTERING PATTERN (ABOVE) DEMONSTRATES SIMILARITIES IN THEMES DISCUSSED.

BASIN-WIDE LAND USE SURVEY

In Summer 2016, we provided a summary of our DRB2070 workshops in the form of a survey and asked participants to confirm or refute our initial findings. Our survey had over 440 views and received 120 responses. In the survey, we requested feedback on the following statements, compiled from the workshop SWOT analyses:

Current strengths of the DRB include water quality, natural areas and resources, tourism and recreational opportunities, and extensive organizational efforts to protect and restore resources within the region. (86% agreement)

Current weaknesses of the DRB include increased storm intensity, lack of access to services and education, legacy of poor planning, fragmented approach to water resource management, uneven access to water resources, and limited communication between the various organizations and efforts to protect and restore resources within the region. (68% agreement)

Future opportunities for the DRB include changing population dynamics and demographics, new technologies and infrastructure, and economic opportunities related to new development, forestry, tourism, agriculture, and energy. (71% agreement)

Future challenges for the DRB include population growth and development pressures, aging infrastructure, and increased severity and frequency of storms with flooding, sea level rise, and salt line intrusion. (77% agreement)

DRB PROJECT- LAND USE DYNAMICS

DRIVERS OF LAND USE CHANGE

In our basin-wide land use survey, participants were asked to rank drivers of land use change and protection. A development catalyst was defined as something that will stimulate population growth, economic growth, or land development. A catalyst for land protection was defined as something that will lead to more protected land, such as land preservation programs or incentives to redevelop existing urban land.

Examples were provided for each catalyst (e.g. schools, medical facilities, and universities were listed under public service infrastructure). Finally, survey respondents were asked to rank the importance of exploring various future land use scenarios. A brief description of each scenario was given, along with text with the importance of exploring multiple land use scenarios to visualize the range of futures.

	Very or extremely influential (%)	Not at all influential (%)
New/expanded transportation infrastructure	71	<1
Population growth	65	<1
New public service infrastructure	54	5
New energy infrastructure	49	6
Change in real estate taxes	43	4
Expanded tourism	42	3
New energy resources	42	7
New transportation technology	25	16
Expansion/improvement of cell service	23	18
Casinos	11	24

DRIVERS OF LAND DEVELOPMENT, RANKED BY SURVEY PARTICIPANTS IN SUMMER 2016

	Very or extremely influential (%)	Not at all influential (%)
New land acquisitions	69	3
Regulations or incentives to protect water	69	5
"Smart growth" style planning	61	4
Payment for ecosystem services	54	3
Land use planning for climate change	48	9

DRIVERS OF LAND PROTECTION, RANKED BY SURVEY PARTICIPANTS IN SUMMER 2016

	Very or extremely important (%)	Not at all important (%)
Cities/towns build up, not out	71	2
Opportunistic growth	64	3
Forest as infrastructure	62	<1
Recent trends	61	3
Reduction of protected lands	58	7
Regional self-reliance	57	3
National emergency	57	6
Increased technology/infrastructure	55	3

FUTURE SCENARIO THEMES, RANKED BY SURVEY PARTICIPANTS IN SUMMER 2016

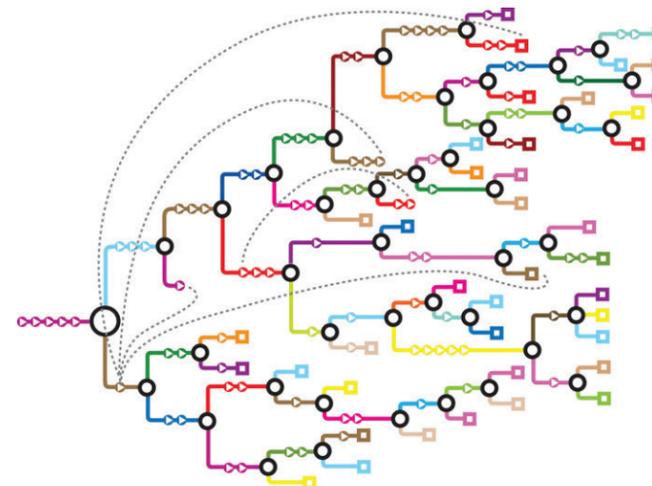
OUR MODEL:

Our future land use change model is based on three sub-models: environmental suitability, socio-economic "drivers," and planning & policy. Some model layers are static, such as soil suitability and slope. Other layers can be adjusted, like "knobs," which allow us to visualize a range of possible futures.

Example "knobs" in our model include population growth rate, extent of conservation or preservation, amount of sea level rise, and areas excluded from development.



HOW TO USE THIS GUIDE...



The purpose of this guide is to walk you through the scenario development process. The concept is similar to a "choose your own adventure" story, where a reader makes choices that determine the character's actions and the plot's outcomes.

Each page covers a specific topic related to the future. You will find background information, options, and an area to elaborate or describe your choice. The more information you provide, the better we will be able to understand your choice.

POPULATION GROWTH TRAJECTORY

WHAT IS THE POPULATION MOMENTUM IN THE DRB?

The figures below show how the US population and labor force changed between 1950 and 2000, and how they are expected to change by the year 2050 (US Census Bureau, US BLS). They provide us with a baseline. For alternatives, the EPA has developed Integrated Climate and Land-Use Scenarios, which rely on different assumptions about the components of population growth and change, which propagate into differently sized populations and labor forces.

PICK ONE...

BC: "BASE CASE," MIDLINE US CENSUS PROJECTIONS.

Business-as-usual development patterns, middle series projections for fertility, mortality, domestic migration and net international immigration.

B1: ENVIRONMENTALLY-DRIVEN DEVELOPMENT

Fertility is assumed to be low due to higher incomes and economic development. International migration is expected to be high due to widespread economic development and freer global flows. Domestic migration, however, is lower due to a combination of factors. First, an increased focus on sustainability leads to a reduction of subsidies for development in previously rural counties with significant natural amenities. Second, the information oriented economy increases demand for specialized labor pools and increases the number of high paying jobs in traditional large urban centers.

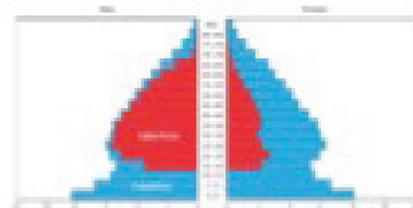
A1: HIGHEST RATES OF TECHNOLOGICAL CHANGE & GLOBAL ECONOMIC DEVELOPMENT

A1 represents a world of fast economic development, low population growth, and high global integration. In this storyline fertility is assumed to decline and remain low in a manner similar to recent and current experience in many European countries. Substantial aging resulting from the combination of low birth rates and continued low death rates raises the demand for immigration. Domestic migration is anticipated to be relatively high as well, as economic development encourages a flexible and mobile workforce.

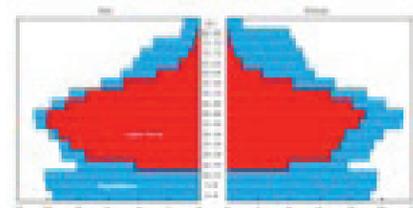
A2: REGIONAL ECONOMIC DEVELOPMENT

The A2 storyline represents a world of continued economic development, yet with a more regional focus and slower economic convergence between regions. Fertility is assumed to be higher than in A1 and B1 due to slower economic growth, and with it, a slower decline in fertility rates. International migration is assumed to be low because a regionally-oriented world would result in more restricted movements across borders. Domestic migration is high because, like in A1, the continued focus on economic development is likely to encourage movement within the United States.

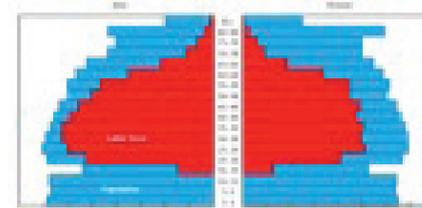
SOURCES: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SPECIAL REPORT- EMISSIONS SCENARIOS 2000 ([HTTPS://WWW.IPCC.CH/PDF/SPECIAL-REPORTS/SPM/SRES-EN.PDF](https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf))
 EPA INTEGRATED CLIMATE AND LAND-USE SCENARIOS- WILL USE ICLUS 2.0 ([HTTPS://WWW.IPCC.CH/IPCCREPORTS/TAR/WG1/O29.HTM](https://www.ipcc.ch/ipccreports/tar/wg1/o29.htm); [HTTP://WWW.IPCC.CH/IPCCREPORTS/SRES/EMISSION/INDEX.PHP](http://www.ipcc.ch/ipccreports/sres/emission/index.php))



POPULATION & EMPLOYMENT PYRAMID FOR 1950



POPULATION & EMPLOYMENT PYRAMID FOR 2000



POPULATION & EMPLOYMENT (PROJECTED) PYRAMID FOR 2050

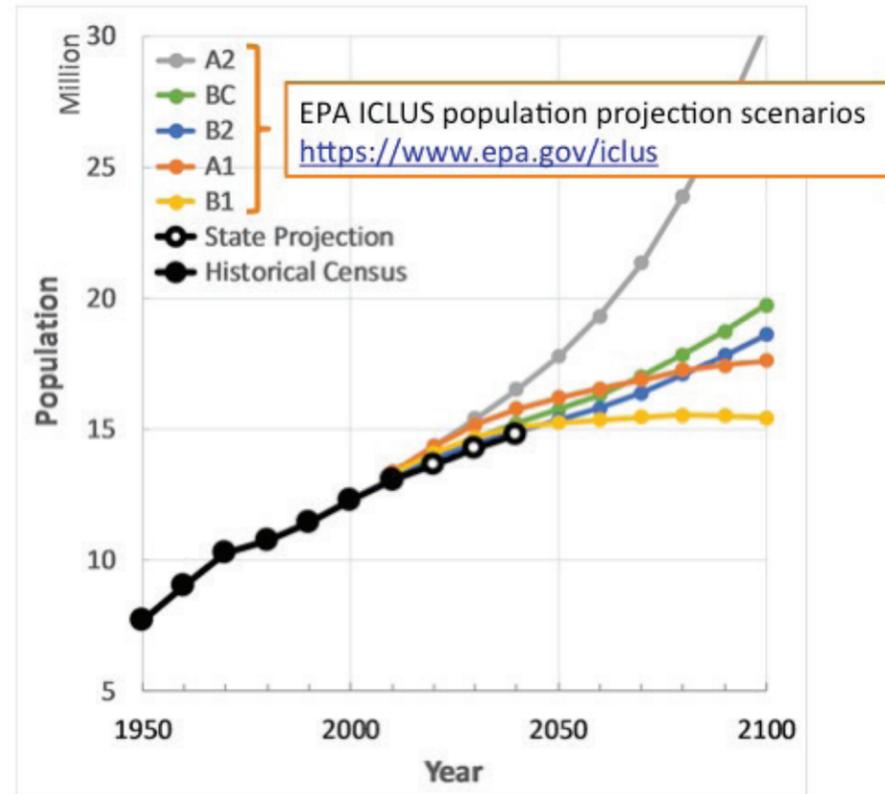


POPULATION & EMPLOYMENT PYRAMID FOR 2070?

POPULATION GROWTH TRAJECTORY

“_____” ICLUS GROWTH TRAJECTORY

Population projections



- Will this pattern be expressed uniformly across the basin?
- What would an aging population structure look like?
- What effects would this growth trajectory have on employment? On social structure?
- Other considerations... ?

ELABORATE...

Baseline: The US Census Bureau's "base case" scenario, which relies on moderate fertility, domestic migration, and net international migration rates, which reflect recent historical rates.

Please note: The ICLUS v1 scenario data above are placeholders for our modeling work, as ICLUS v2 is not yet available. We will find analogs of your choices once we are able to access the ICLUS v2 data.

REGIONAL BUILD-OUT TRAJECTORY

WHAT FORM WILL DEVELOPMENT TAKE AS WE MOVE TOWARD 2070?

PICK ONE...

SPRAWL

OR

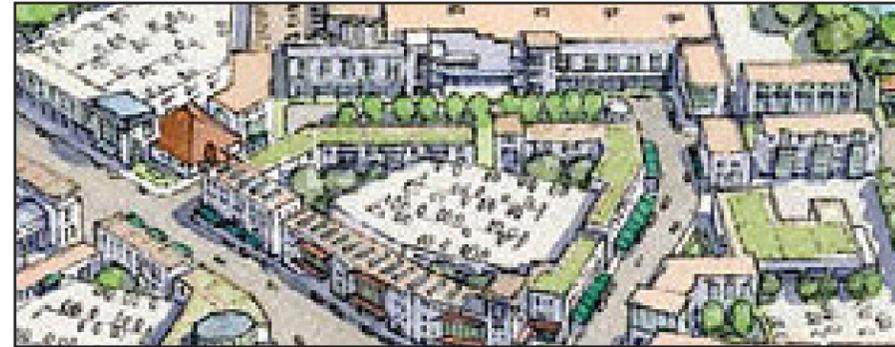
“SMART GROWTH”

OR

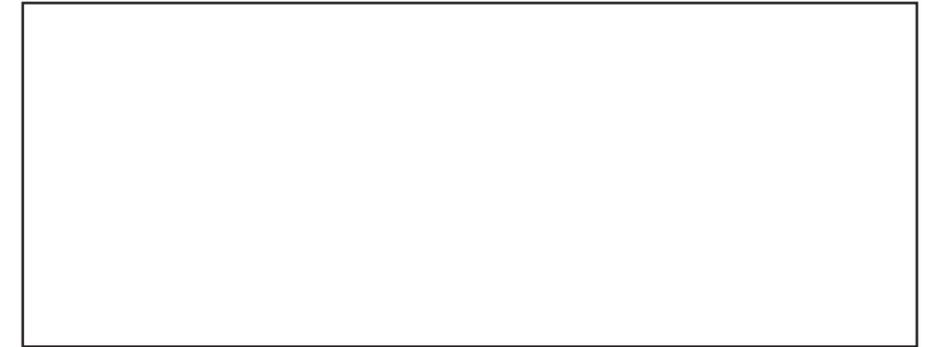
OTHER?



Large metropolitan areas with low population densities, interconnected by roads. Residents tend to live in single-family homes and commute to school, work, and other activities by automobile. Maximizes “greenfield” development; development on new land.



High population density, walkable and bikeable neighborhoods, preserved green spaces, mixed-use development, available mass transit, limited road construction. Maximizes “infill” development- adaptive reuse, redevelopment, densification.



“Small-town urban”/“big-city” urban, walkable urbanism/driveable suburbia, etc.?

SOURCES: SMART GROWTH ONLINE ([HTTP://SMARTGROWTH.ORG/FOUR-TYPES-OF-SPRAWL/](http://smartgrowth.org/four-types-of-sprawl/))
RESNIK, DAVID B. “URBAN SPRAWL, SMART GROWTH, AND DELIBERATIVE DEMOCRACY.” AMERICAN JOURNAL OF PUBLIC HEALTH 100.10 (2010).
THE CITY FIX ([HTTP://THECITYFIX.COM/BLOG/NEW-CLIMATE-ECONOMY-SPRAWL-CITIES-SUSTAINABLE-URBAN-DEVELOPMENT-HELEN-MOUNTFORD-ROBIN-KING/](http://thecityfix.com/blog/new-climate-economy-sprawl-cities-sustainable-urban-development-helen-mountford-robin-king/))

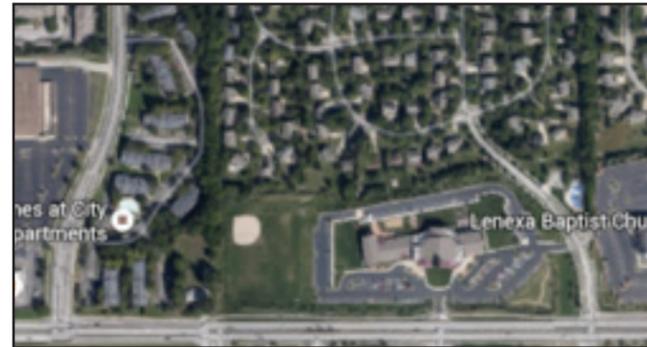
- What is the balance of development on new land vs. infill?
- Is this pattern uniform across the basin?
- What would you expect to see in urban/metro, suburban, and rural areas?
- What effects would this policy have on employment and transportation?
- Is this pattern amenity driven? If so, by what types?
- What impacts might this have on different types of land (agricultural, natural, etc.)?
- Do you expect similar patterns as seen historically, or radically different policies?
- What environmental impacts might this type of development have (e.g. on air and water quality)? What infrastructure might be necessary to support this policy?
- Other considerations... ?

REGIONAL BUILD-OUT TRAJECTORY

EXAMPLE DEVELOPMENT PATTERNS:



"PRE-INTERSTATE SUBURBIA"



"STANDARD SUBDIVISION SUBURBIA"



"MASTER-PLANNED COMMUNITIES"



"RURAL/EXURBAN SPRAWL"

ELABORATE... " _____ " **BUILD-OUT TRAJECTORY**

Baseline: Greenfield development in metropolitan areas with minimal/moderate infill; in northern basin, very low population-driven land use change rates.

REGIONAL INFRASTRUCTURE TRAJECTORY

WHAT INFRASTRUCTURE PROJECTS MIGHT IMPACT DEVELOPMENT PATTERNS ACROSS THE DRB?

DESCRIBE ONE (OR MORE)...

ROAD

Bus-rapid transit, self-driving cars, highways & bridges, street design...

RAIL

High speed rail, rail-to-trail, returning to rail transportation, lightrail/streetcar, subway/metro rail, intercity rail...

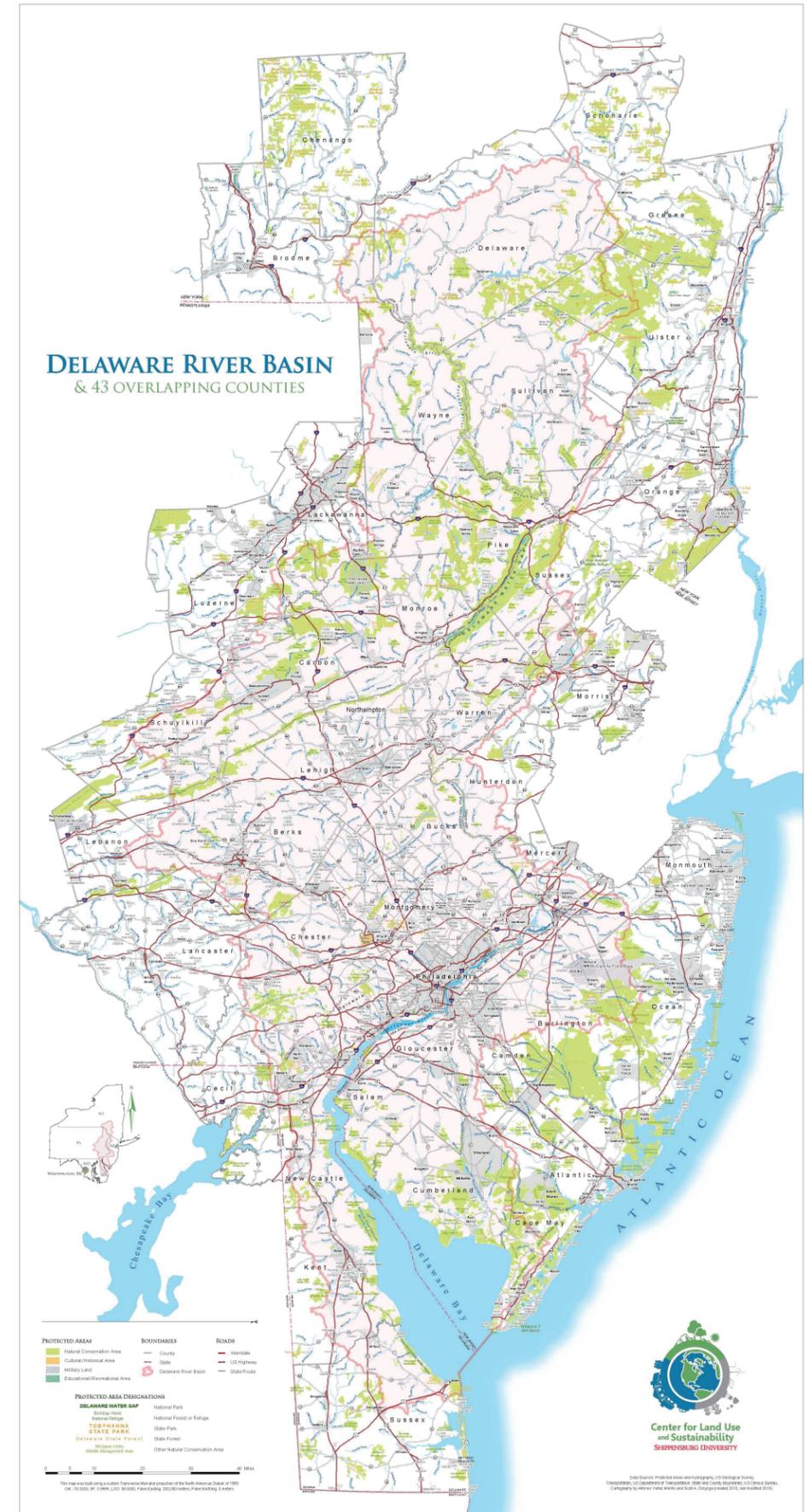
ENERGY

Natural gas pipelines, transformer stations, hydroelectric dams, oil and gas wells...

OTHER

Landfill/waste management facilities, wastewater treatment, sewer treatment, water desalinization, canals & freight, airports, colleges & universities, hospitals, schools, public services, third bay bridge...

- Where are these projects located?
- Who will be affected by these projects, and how? What changes do you expect to see relative to historical patterns?
- What are the impacts to urban/metro, suburban, and rural areas?
- What effects would this policy have on the economy, employment, transportation, etc.?
- Are these projects amenity driven? If so, by what types?
- What technologies emerging now might be common in 2070?
- What regulations or policies should we expect regarding development close to these projects?
- Other considerations... ?



REGIONAL INFRASTRUCTURE TRAJECTORY

DESCRIBE & ELABORATE...

ROAD

Baseline assumptions: Static road network. US remains automobile oriented.

RAIL

Baseline assumptions: Current planned projects, including Lackawanna cutoff.

ENERGY

Baseline assumptions: Current planned projects.

OTHER?

Baseline assumptions: N/A.

CONSERVATION EFFORTS

WHAT CONSERVATION EFFORTS (WATER, FORESTS, OTHER) MIGHT IMPACT DEVELOPMENT PATTERNS ACROSS THE DELAWARE RIVER BASIN?

CONSIDERATIONS AND EXAMPLES OF CONSERVATION EFFORTS:

WATER: Riparian buffers, conservation/protection corridors, impervious surface limits...

FOREST: fragmentation vs. preservation, patch size and number, Habitat corridors

OTHER?: Agricultural land, wetlands, zoning laws, restrictions, etc.

- + THE BASIN HAS ONE OF THE NATION'S GREATEST CONCENTRATIONS OF HEAVY INDUSTRY INCLUDING CHEMICAL, OIL, AND REFINING. THE DELAWARE RIVER PORT COMPLEX IS THE LARGEST FRESHWATER PORT IN THE WORLD, AND IMPORTS STEEL, PAPER, MEAT, COCOA BEANS, AND FRUIT FOR THE EAST COAST.
- + AGRICULTURAL USES IN THE DELAWARE BASIN INCLUDE DAIRY FARMING, POULTRY FARMING, AND RELATED INDUSTRIES SUCH AS EGG, MILK, CHEESE, AND ICE CREAM PRODUCTION. MUSHROOMS ARE A MAJOR CROP IN PENNSYLVANIA, WHERE CHRISTMAS TREE FARMING IS A MAJOR INDUSTRY.
- + THE TIMBER INDUSTRY HAS FLOURISHED AND FED PAPER MILLS AND SHIPYARDS. IRON BUILT LOCOMOTIVES; SHIPS WERE BUILT AT THE YARDS IN PHILADELPHIA, CHESTER, AND WILMINGTON; AND CABLES FOR BRIDGES CAME FROM THE AREA.

SOURCES: DELAWARE RIVER BASIN FACTS ([HTTP://DCNR.PA.GOV/CS/GROUPS/PUBLIC/DOCUMENTS/DOCUMENT/DCNR_20031252.PDF](http://dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20031252.pdf))
WORLD WILDLIFE FUND ([HTTP://WWW.WORLDWILDLIFE.ORG/THREATS/DEFORESTATION](http://www.worldwildlife.org/threats/deforestation))
KEEP EARTH BEAUTIFUL ([HTTP://WWW.NATURE-EDUCATION.ORG/WATER-POLLUTION.HTML](http://www.nature-education.org/water-pollution.html))

-
- How might these efforts vary across the DRB?
 - What would we see in urban/metro, suburban, and rural areas?
 - What kinds of new conservation policies are emerging now, and where might they be concentrated or common in the future?
 - What new agricultural practices do we expect to see in the next 50 years?

CONSERVATION EFFORTS

SELECT LEVEL...

WATER

AGGRESSIVE OR WEAK



FOREST

AGGRESSIVE OR WEAK



OTHER: _____

AGGRESSIVE OR WEAK



DESCRIBE...

Baseline assumptions: Non-forested wetlands are fully protected, forested or shrub wetlands have moderate to weak protection. We are not considering impervious surface limits or additional riparian protections.

We are relying on the Protected Areas Database of the US (PAD-US) to identify protected lands and easements. Easements are considered to have moderate to weak protection, while lands owned outright by local, state, or federal agencies are fully protected.

Baseline assumptions: Forests that are within protected areas as identified in PAD-US are protected. We are not considering additional protections on forest lands.

Baseline assumptions: Aside from lands identified in PAD-US or wetlands, we are not incorporating protections on any other land types (i.e. agriculture).

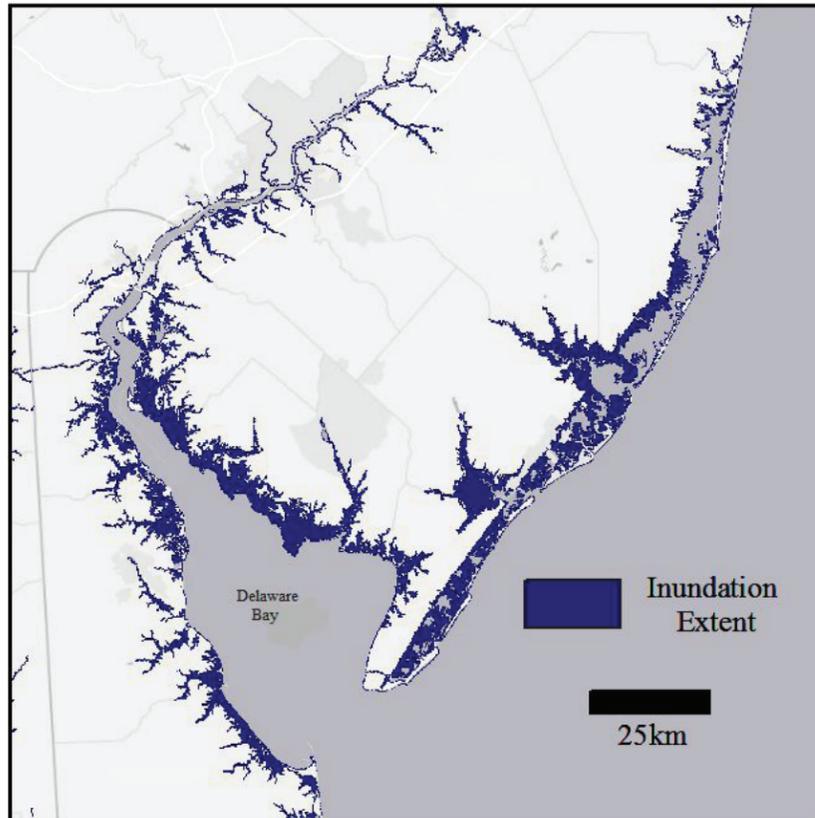
SEA LEVEL RISE & STORM SURGE RISK

WHAT CLIMATE CHANGE IMPACTS DO YOU EXPECT TO SEE IN THE DRB?

PICK A LEVEL...

NO CHANGE

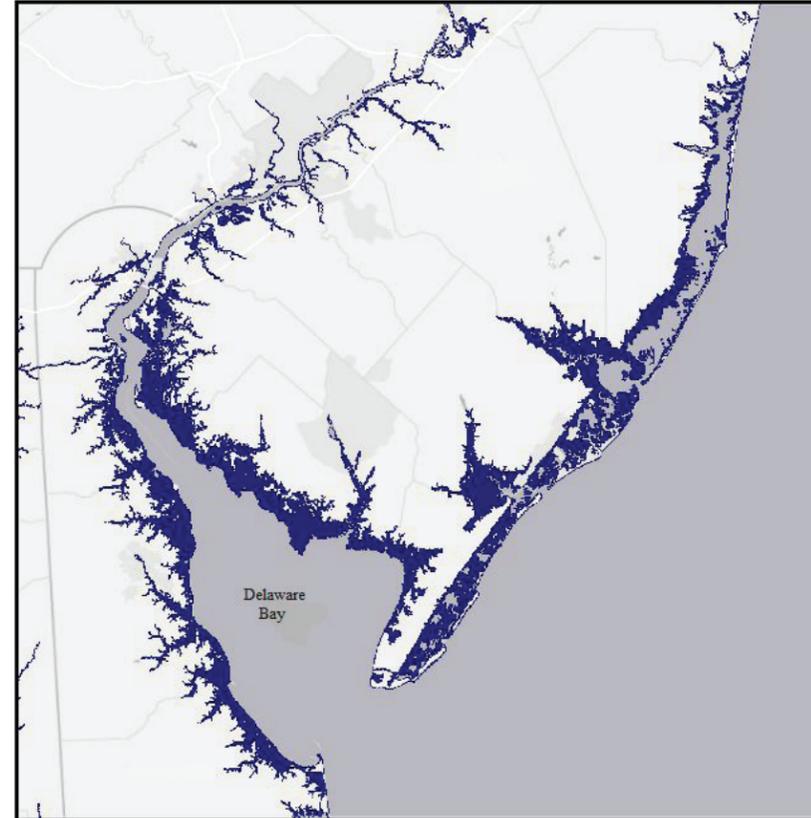
0 FEET SLR (GLOBAL AVG)



OR

CONSERVATIVE INCREASE

2 FEET SLR (GLOBAL AVG)



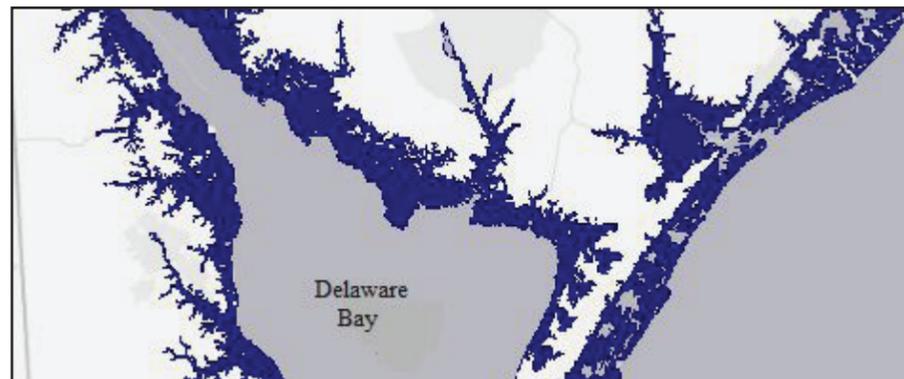
OR

MODERATE INCREASE

6 FEET SLR (GLOBAL AVG)



HURRICANE CATEGORY 1



AND

OR

HURRICANE CATEGORY 4



SEA LEVEL RISE & STORM SURGE RISK

- + GLOBAL SEA LEVEL HAS RISEN BY ABOUT 8 INCHES SINCE RELIABLE RECORD KEEPING BEGAN IN 1880
- + FROM 1958-2012, THE NORTHEAST EXPERIENCED A 71% INCREASE IN THE AMOUNT OF PRECIPITATION FALLING IN VERY HEAVY EVENTS (HEAVIEST 1%)
- + MODELS BASED ON GLOBALLY AVERAGED TEMPERATURE CHANGE AND SEA LEVEL RISE SUGGEST A RANGE OF ADDITIONAL SEA LEVEL RISE FROM ABOUT 2 FEET TO AS MUCH AS 6 FEET BY 2100, DEPENDING ON THE EMISSIONS SCENARIO
- + 40% OF THE U.S. POPULATION LIVES IN A COASTAL AREA THAT MAY BE VULNERABLE TO SEA LEVEL RISE
- + NUISANCE FLOODING IS 300%-900% MORE FREQUENT THAN IT WAS 50 YEARS AGO

- How will this combination affect different parts of the basin?
- What effects will we see in coastal vs. inland communities?
- Would you expect any changes in development patterns?
- What effects would these levels of sea level rise and storm surge have on commuting and transportation?
- What roads, bridges, subways, water supplies, oil and gas wells, power plants, sewage treatment plants, landfills, etc. might be impacted? What might be done about this infrastructure?
- What would happen to the populations in the areas affected by increasing sea levels and storm surge risk?
- Other considerations... ?

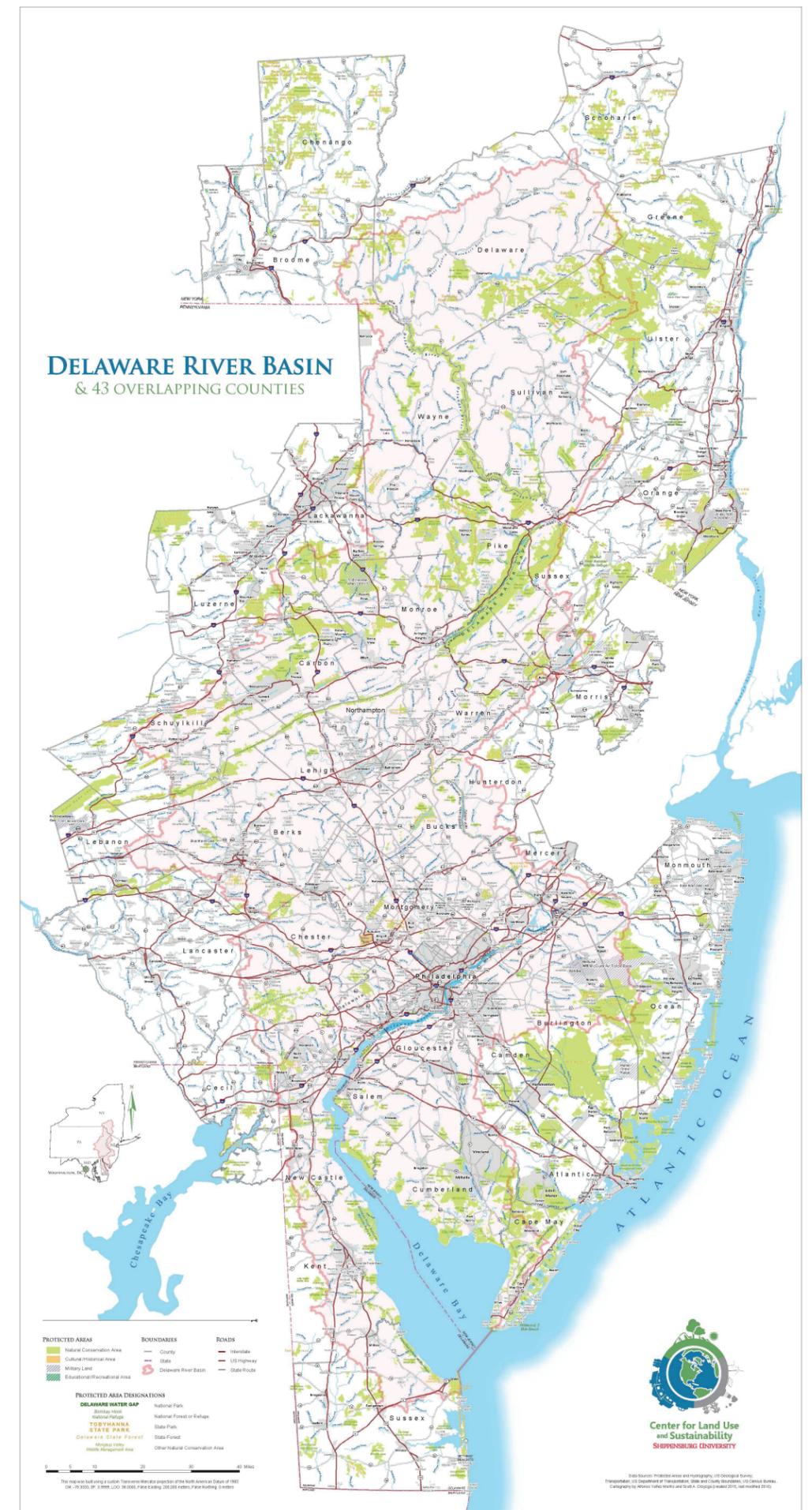
“ _____ ” **SEA LEVEL RISE & HURRICANE CATEGORY “ _____ ”**

DESCRIBE...

Baseline assumptions: Conservative increase of sea level rise (2 feet) and hurricane Category 1 storm surge risk.

2070 Delaware River Basin

Population Growth Trajectory
 Regional Build-out Trajectory
 Regional Infrastructure Trajectory
 Regional Conservation Efforts
 Sea Level Rise & Storm Surge Risk



SCENARIO NARRATIVE:

“

”

DESCRIBE YOUR FUTURE:

.....
: *“Baseline Scenario:” In our baseline scenario, we incorporate midline population projections and currently planned infrastructure projects. We expect business-as-usual development and build-out :
: patterns across the basin. This is the future without additional policy changes and restrictions. We assume a conservative increase in sea-level rise, but do not make assumptions that would change :
: anticipated development patterns.*

MAPPING, MODELING, AND MONITORING LAND USE CHANGE IN THE DELAWARE RIVER BASIN



WWW.DRBPROJECT.ORG



FUNDING FOR THIS PROJECT COMES FROM THE WILLIAM PENN FOUNDATION. THE WILLIAM PENN FOUNDATION, FOUNDED IN 1945 BY OTTO AND PHOEBE HAAS, IS DEDICATED TO IMPROVING THE QUALITY OF LIFE IN THE GREATER PHILADELPHIA REGION THROUGH EFFORTS THAT INCREASE EDUCATIONAL OPPORTUNITIES FOR CHILDREN FROM LOW-INCOME FAMILIES, ENSURE A SUSTAINABLE ENVIRONMENT, FOSTER CREATIVITY THAT ENHANCES CIVIC LIFE, AND ADVANCE PHILANTHROPY IN THE PHILADELPHIA REGION. IN PARTNERSHIP WITH OTHERS, THE FOUNDATION WORKS TO ADVANCE OPPORTUNITY, ENSURE SUSTAINABILITY, AND ENABLE EFFECTIVE SOLUTIONS. SINCE INCEPTION, THE FOUNDATION HAS MADE NEARLY 10,000 GRANTS TOTALING OVER \$1.6 BILLION. THE FOUNDATION'S ASSETS EXCEED \$2.3 BILLION AS OF NOV. 30, 2014.

MORE INFORMATION ABOUT THE FOUNDATION IS AVAILABLE ON ITS WEBSITE AT WWW.WILLIAMPENNFUNDATION.ORG.