



## DRB2070 Version 1.0 Baseline

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### Product overview:

DRB2070 Version 1.0 represents a baseline forecast of urban land cover in the Delaware River Basin (DRB) out to the year 2070. To develop these forecasts, we calibrated the SLEUTH urban growth model for the entire 43 county region of the DRB over the 2001-2006 time period, and validated the model for the 2006-2011 time period. We used the National Land Cover Database (NLCD) urban classes to represent urban land cover as developed or not developed (**Figure 1**).

The data packaged in the ArcMap document is described in **Appendix 1**, and represents forecasts of urban land cover in 2030 and 2070, summarized by National Hydrography Dataset Plus (NHDPlus, version 2.0) catchments.

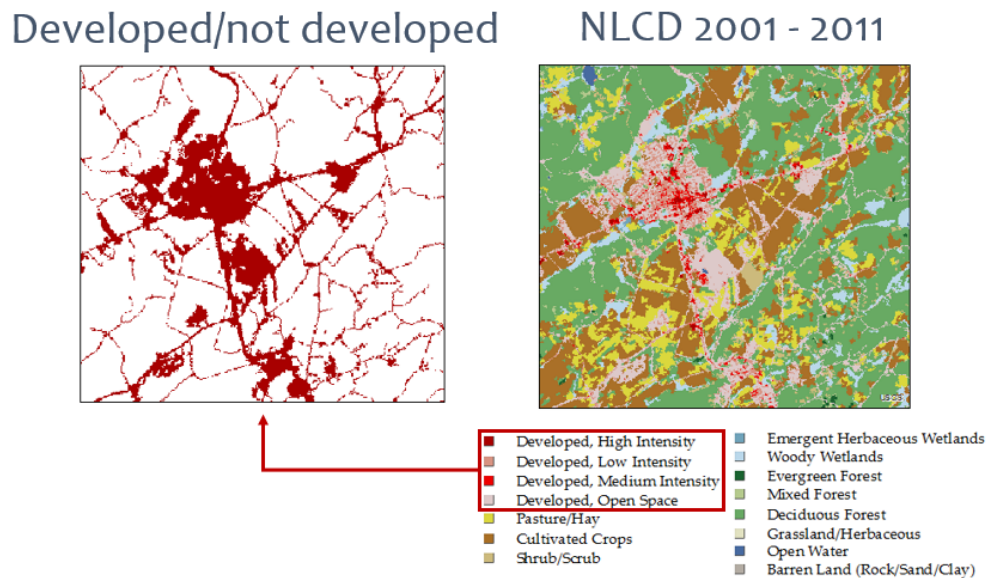


Figure 1: All four NLCD developed classes were consolidated into a single representation to designate developed/non developed as required for SLEUTH input.



The primary input layer to SLEUTH is the exclusion/attraction layer, a layer that describes areas that are more or less suitable for urban development. The exclusion/attraction layer developed for the DRB is the result of statistical and spatial modeling of accessibility, environmental suitability, employment and population spatial dynamics, and land protection (**Figure 2**).

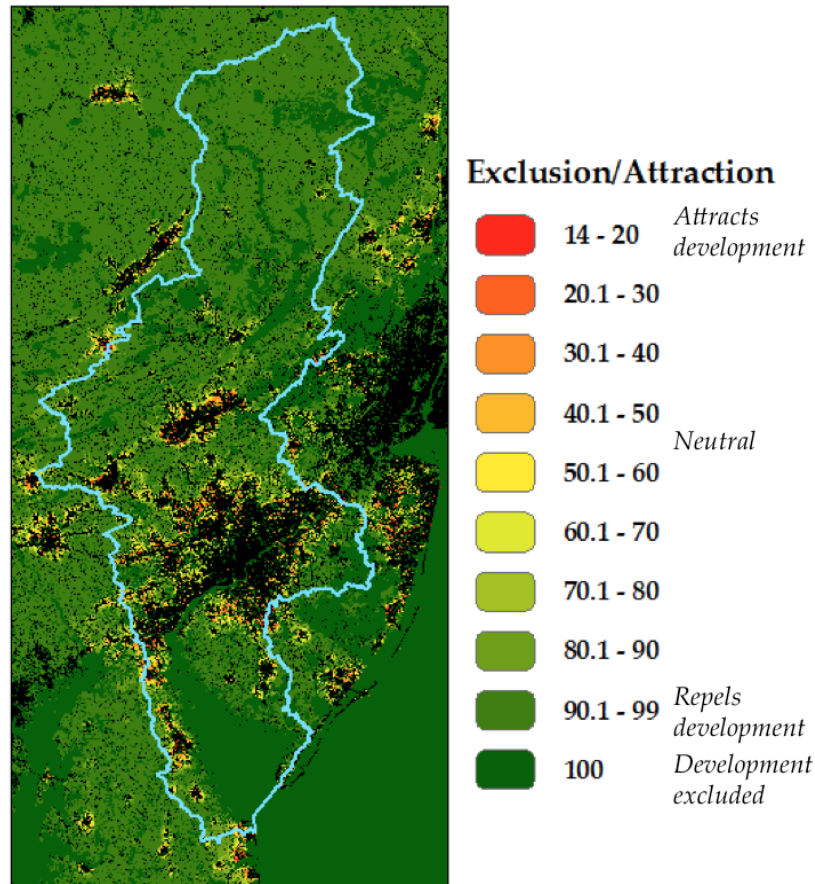


Figure 2: The exclusion/attraction layer used to drive the DRB 2030 and 2070 baseline land cover forecasts

### DRB Modeling Subregions:

The Delaware River Basin is a large area, with the following characteristics:

- 43 overlapping counties in 5 states
- 35,000 sq. km (13,500 sq. miles)
- 8.2 million residents<sup>1</sup>
- 3.6 million payroll jobs<sup>2</sup>
- Provides water resources and ecosystem services to more than 15 million people, or 5% of the US population.<sup>3</sup>

<sup>1</sup> US Census Bureau. American Community Survey Demographic and Housing Estimates, 2009-2013 American Community Survey 5-year Estimates.

<sup>2</sup> US Census Bureau. Longitudinal Employer-Household Dynamics, 2013.

<sup>3</sup> Delaware River Basin Commission. "Basin Information." <http://www.state.nj.us/drbc/basin/>. Accessed March 9, 2017.



We explored trends across all 43 counties in our study area to identify patterns in population, employment, and commuter flows, the main drivers of development on which we focus. Because of heterogeneous land cover dynamics across this large region, we subdivided the region into smaller, homogeneous modeling subregions to improve accuracy. We found that commuter flows between counties allowed us to group counties that share similar characteristics into eight different subregions. These subregions were named after the largest city within the region, where growth was focused, and modeled independently: Albany, Allentown, Baltimore-Annapolis, Delaware, Harrisburg, New York Metro, Philadelphia, and Upper-DRB (**Figure 3**).

Before running the model, the demand for new developed land by 2070 must be estimated. For the baseline land cover scenario, we calculated the average amount of development per person from 2001-2006 using Daily Human Intensity (DHI), or the sum of population and employment density. Finding the relationship between DHI and urban extent allows us to use population and employment projections to estimate the expected amount of development in 2070 for each subregion. For the Upper-DRB and Baltimore-Annapolis subregions, an inverse relationship was seen between urban growth and population growth; in other words, DHI decreased as urban land continued to increase. To model these regions, we linked growth with the region-wide DHI-urban relationship, relying on the assumption that factors other than employment and population affect growth in those regions.

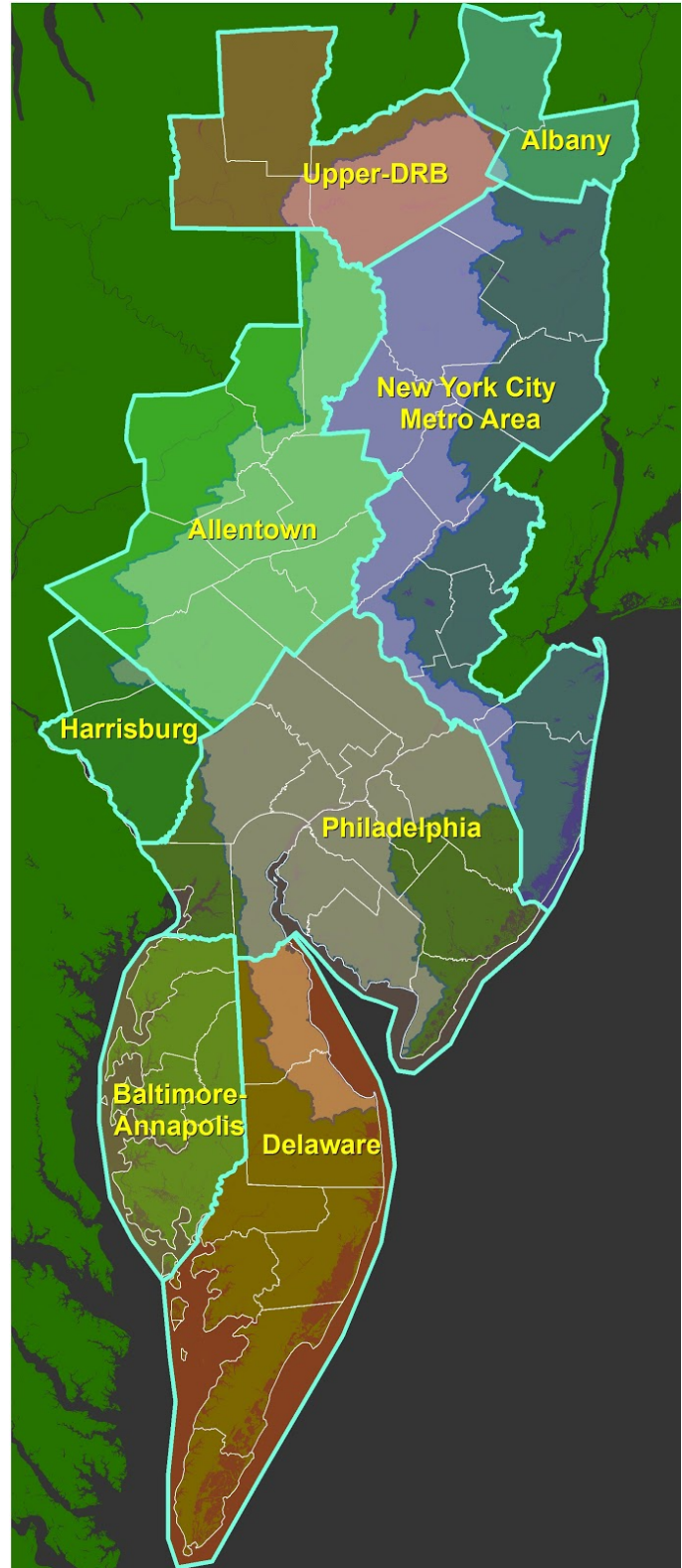


Figure 3: Subregions used to model land cover dynamics in the DRB and DelMarVa Peninsula



### **Baseline Land Cover Scenario:**

The baseline land cover scenario represents recent trends in the Delaware River Basin for population growth, employment, regional build-out, regional infrastructure, and conservation efforts.

- *Population Growth Trajectory:* We based the population trajectory in the DRB on the EPA Integrated Climate and Land-Use Scenarios (ICLUS<sup>4</sup>) Basecase population forecast, which relies on moderate fertility, domestic migration, and net international migration rates, which reflect recent historical rates. Summary statistics for the resulting urban land cover change trajectory are presented for each modeling subregion in **Table 1**.
- *Regional Build-Out Trajectory:* our model considered accessibility to different resources: transportation (e.g. roads and intersections), urban density, and recreational resources (natural areas and water) as positive drivers to attract development.
- *Regional Infrastructure Trajectory:* We did not consider additional regional infrastructure. DRB2070 version 2.0 we plan to include current planned projects for road, rail, and energy infrastructure (electric and pipeline).
- *Conservation Efforts:* Non-forested wetlands are fully protected, forested or shrub wetlands have moderate to weak protection and we included protected lands as indicated in the PAD-US data.
- *Sea Level Rise and Storm Surge Risk:* Sea level rise and storm surge risk were not included in DRB2070 version 1.0. We will account for a global average of 6 feet (2 meters) sea level rise and Category 2 storm surge risk for the basin in DRB2070 version 2.0.

### **Urban land cover trajectory:**

Using the NLCD, we calculated the total urban land cover in 2001 and 2011 for each modeling subregion, not just the portion of the DRB included in each subregion. Future urban land cover projections in 2030 and 2070 were obtained as the average of 100 Monte Carlo trials, and are summarized by subregion in **Table 1**. Our estimates of future land cover are described below, along with graphs of the urban land cover change trajectory calculated for each modeling subregion from 2001 - 2011 (observed from NLCD) and from 2011 - 2070 (DRB2070 Version 1.0 forecast) for the baseline land use scenario (**Figures 4-11**).

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<sup>4</sup> Integrated Climate and Land-Use Scenarios, version 1.3.2. County Population Projections. Environmental Protection Agency. <https://www.epa.gov/iclus>

*Albany:*

- We project a 1.25% increase in developed land cover between 2011 and 2030, with an additional 610 acres of urban land for a total estimate of 49,412 acres.
- By 2070, we project a 4.98% increase over 2011, with an additional 2,428 acres for a total estimate of 51,230 acres.

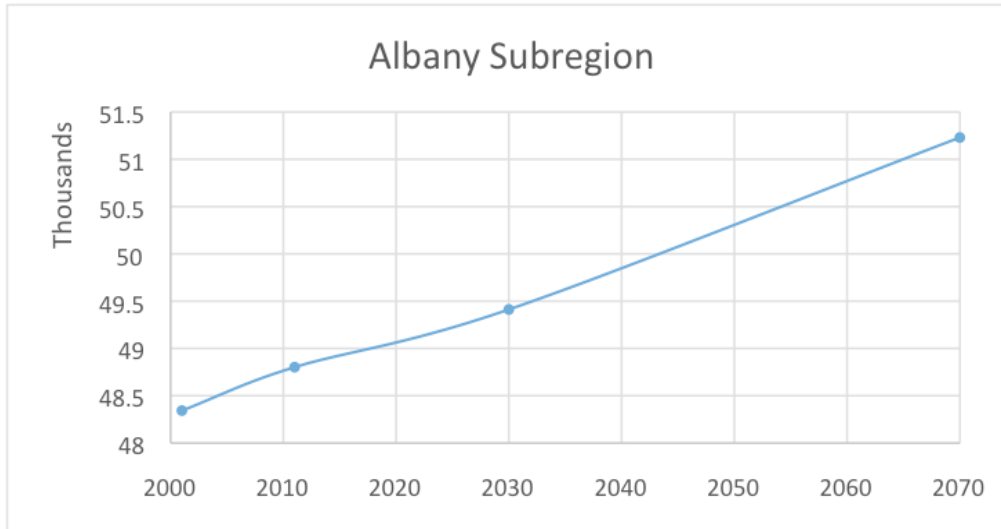


Figure 4: Urban land cover change trajectory for the Albany modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.

*Allentown:*

- We project a 6.68% increase in developed land cover between 2011 and 2030, with an additional 36,767 acres of urban land for a total estimate of 586,991 acres.
- By 2070, we project a 9.65% increase over 2011, with an additional 53,078 acres for a total estimate of 603,302 acres.

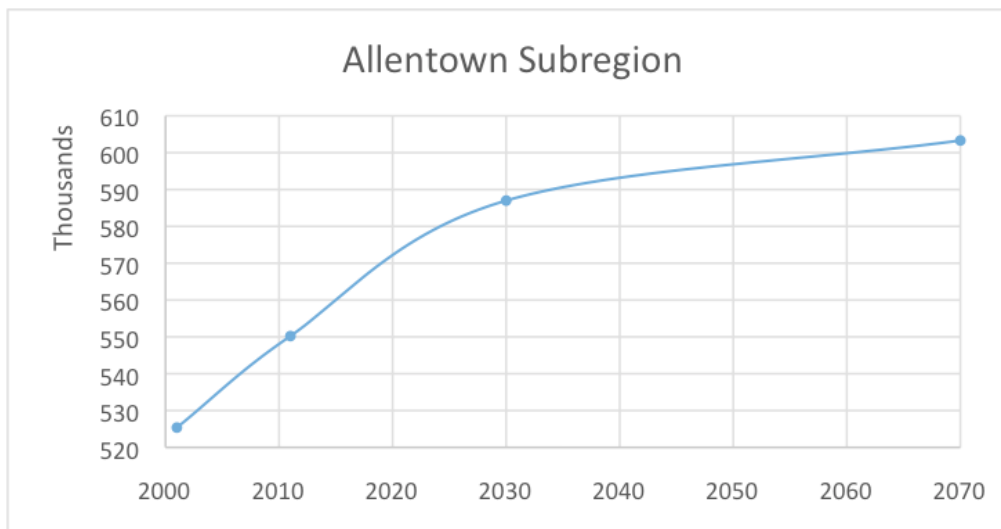


Figure 5: Urban land cover change trajectory for the Allentown modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.



Baltimore-Annapolis:

- We project a 6.33% increase in developed land cover between 2011 and 2030, with an additional 5,967 acres of urban land for a total estimate of 100,201 acres.
- By 2070, we project a 14.05% increase over 2011, with an additional 13,238 acres for a total estimate of 107,472 acres.

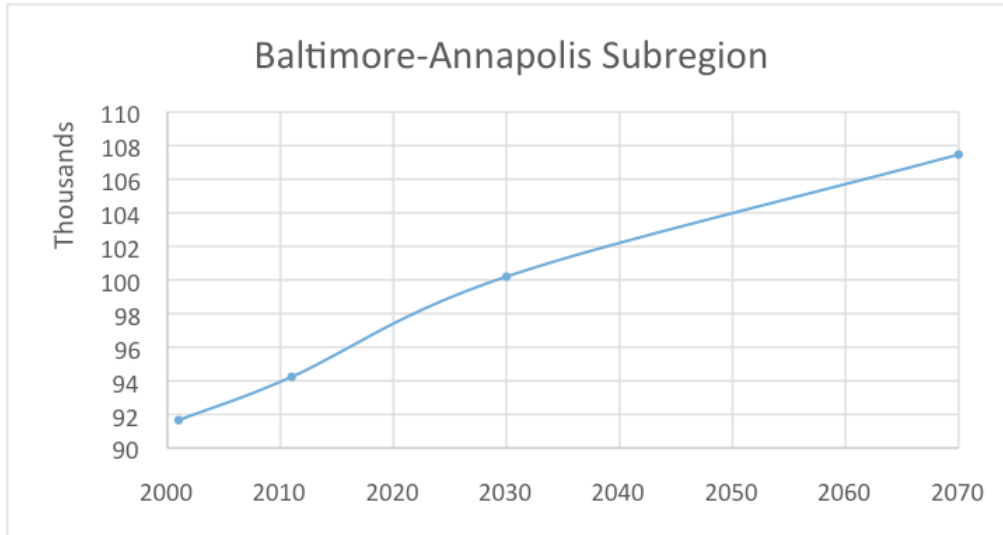


Figure 6: Urban land cover change trajectory for the Baltimore-Annapolis modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.

Delaware:

- We project a 26.43% increase in developed land cover between 2011 and 2030, with an additional 60,894 acres of urban land for a total estimate of 291,254 acres.
- By 2070, we project a 43.67% increase over 2011, with an additional 100,609 acres for a total estimate of 330,970 acres.

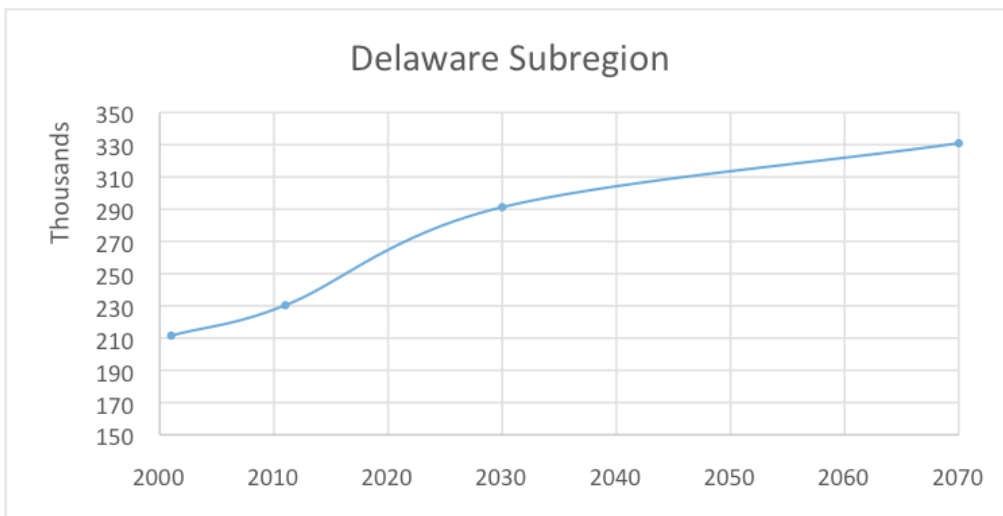


Figure 7: Urban land cover change trajectory for the Delaware modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.

**Harrisburg:**

- We project a 7.03% increase in developed land cover between 2011 and 2030, with an additional 12,025 acres of urban land for a total estimate of 183,084 acres.
- By 2070, we project a 13.66% increase over 2011, with an additional 23,372 acres for a total estimate of 194,432 acres.

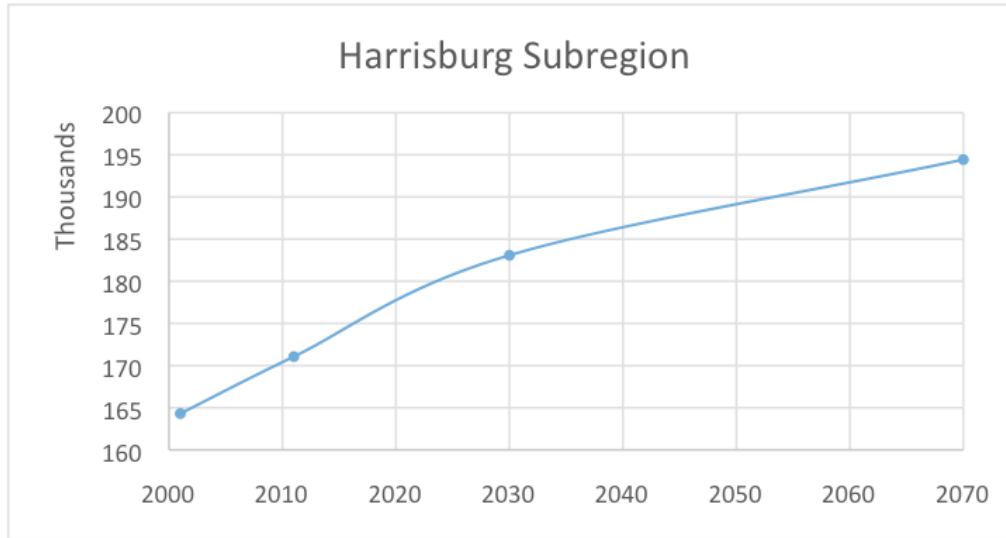


Figure 8: Urban land cover change trajectory for the Harrisburg modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.

**New York Metro:**

- We project a 13.34% increase in developed land cover between 2011 and 2030, with an additional 111,545 acres of urban land for a total estimate of 947,471 acres.
- By 2070, we project a 28.79% increase over 2011, with an additional 240,702 acres for a total estimate of 1,076,629 acres.

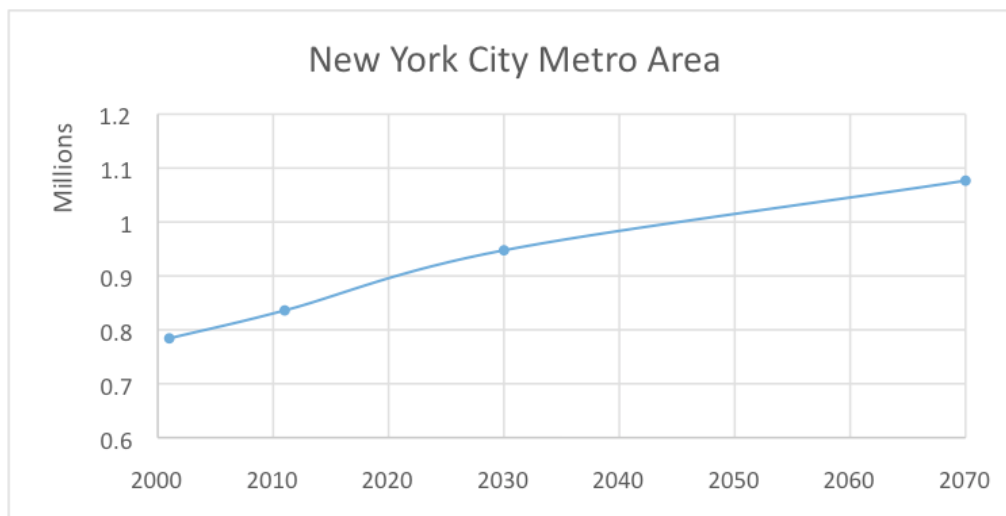


Figure 9: Urban land cover change trajectory for the New York Metro modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in millions of acres of urban land.



Philadelphia:

- We project a 12.73% increase in developed land cover between 2011 and 2030, with an additional 151,629 acres of urban land for a total estimate of 1,343,191 acres.
- By 2070, we project a 34.92% increase over 2011, with an additional 416,098 acres for a total estimate of 1,607,660 acres.

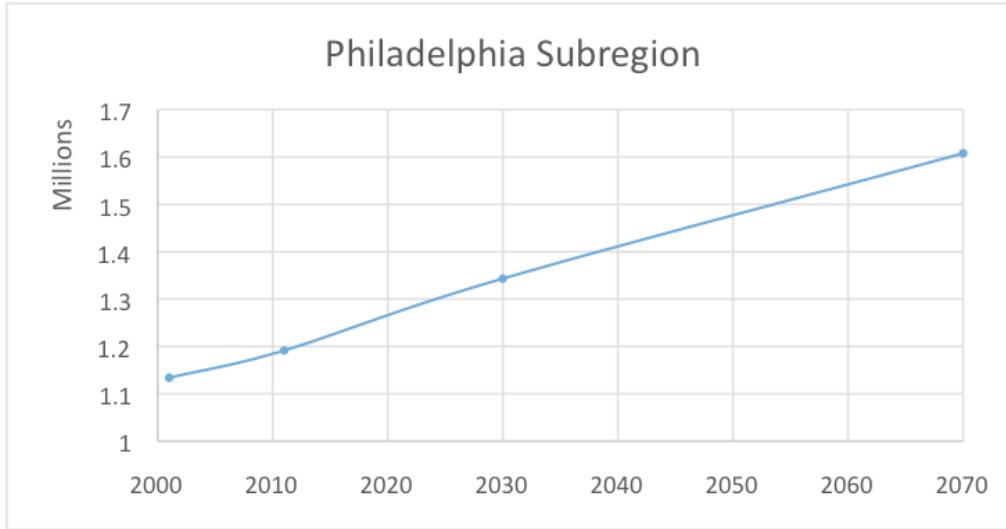


Figure 10: Urban land cover change trajectory for the Philadelphia modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in millions of acres of urban land.

Upper-DRB:

- We project a 1.43% increase in developed land cover between 2011 and 2030, adding an additional 1,425 acres of urban land for a total estimate of 100,913 acres.
- By 2070, we project a 4.06% increase over 2011, adding an additional 4,041 acres for a total estimate of 103,528 acres.

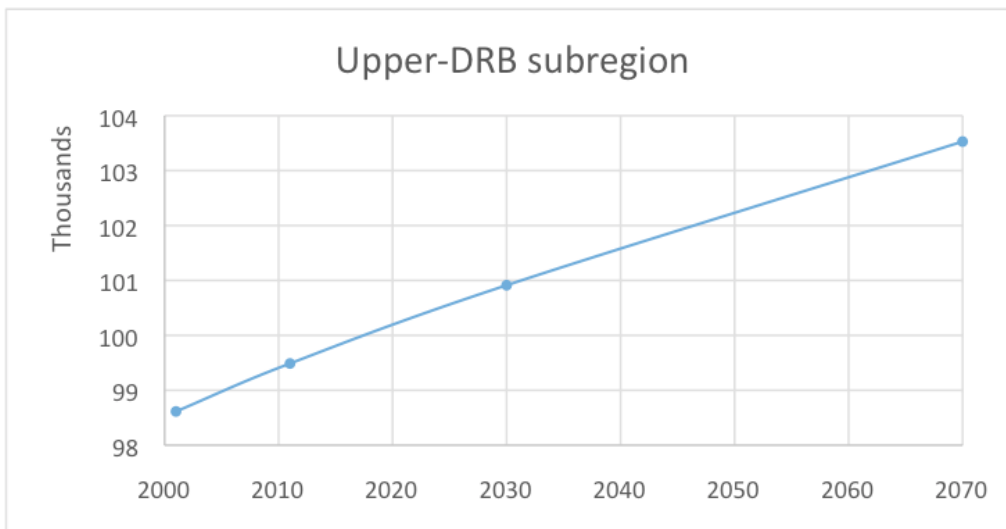


Figure 11: Urban land cover change trajectory for the Upper-DRB modeling subregion from 2001-2011 (observed from NLCD) and from 2011-2070 (DRB2070 Version 1.0 forecast) in thousands of acres of urban land.





Table 1: Developed acres and percent increase for the observational time period (2001-2011) and for forecasts of development in each modeling subregion in 2030 and 2070. For 2011, the increase and percentage is related to 2001. For 2030 and 2070, the increase and percentage are compared to 2011. Standard error is given in acres for the 95% confidence interval over 100 Monte Carlo trials.

<b>Model subregion</b>	<b>Year</b>	<b>Developed land (ac)</b>	<b>Increase (ac) from observational period with standard error</b>	<b>Mean percent (%) increase from observational period</b>
<i>Albany</i>	2001	48,343	-	-
	2011	48,802	459	0.95
	2030	49,412	610 ± 3.4	1.25
	2070	51,230	2,428 ± 13.5	4.98
<i>Allentown</i>	2001	525,379	-	-
	2011	550,224	24,845	4.73
	2030	586,991	36,767 ± 39.8	6.68
	2070	603,302	53,078 ± 49.6	9.65
<i>Baltimore-Annapolis</i>	2001	91,654	-	-
	2011	94,235	2,581	2.82
	2030	100,201	5,967 ± 15.1	6.33
	2070	107,472	13,238 ± 21.9	14.05
<i>Delaware</i>	2001	211,508	-	-
	2011	230,360	18,852	8.91
	2030	291,254	60,894 ± 51.1	26.43
	2070	330,970	100,609 ± 72.0	43.67
<i>Harrisburg</i>	2001	164,308	-	-
	2011	171,059	6,751	4.11
	2030	183,084	12,025 ± 20.6	7.03
	2070	194,432	23,372 ± 30.1	13.66
<i>New York Metro</i>	2001	784,147	-	-
	2011	835,927	51,779	6.60
	2030	947,471	111,545 ± 561.6	13.34
	2070	1,076,629	240,702 ± 1,048.1	28.79
<i>Philadelphia</i>	2001	1,133,757	-	-
	2011	1,191,562	57,805	5.10
	2030	1,343,191	151,629 ± 108.3	12.73
	2070	1,607,660	416,098 ± 250.3	34.92
<i>Upper-DRB</i>	2001	98,614	-	-
	2011	99,488	873	0.89
	2030	100,913	1,425 ± 7.3	1.43
	2070	103,528	4,041 ± 15.7	4.06



### ***Appendix 1. Data Available in the ArcMap Document***

To visualize the results of the 2070 forecasts, we are providing a zip file that includes an ArcMap document and these data sets:

- DRWI cluster boundaries (for reference)
- DRB and county boundaries (for reference)
- National Hydrography Dataset Plus (NHDPlus, version 2.0) catchments symbolized based on the proportion of the catchment that is occupied by developed land cover in 2001, 2011, 2030, and 2070 (e.g. catchments in the <1% category have less than 1% of developed land cover in any given time period). These are the same catchments that are used in SRAT.

We have saved the ArcMap document as version 10.4, 10.3, and 10.1 to ensure compatibility with your version. These are identical except for the version. All data sets include an item description that can be referred to for additional information.