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Watersheds & Landscapes

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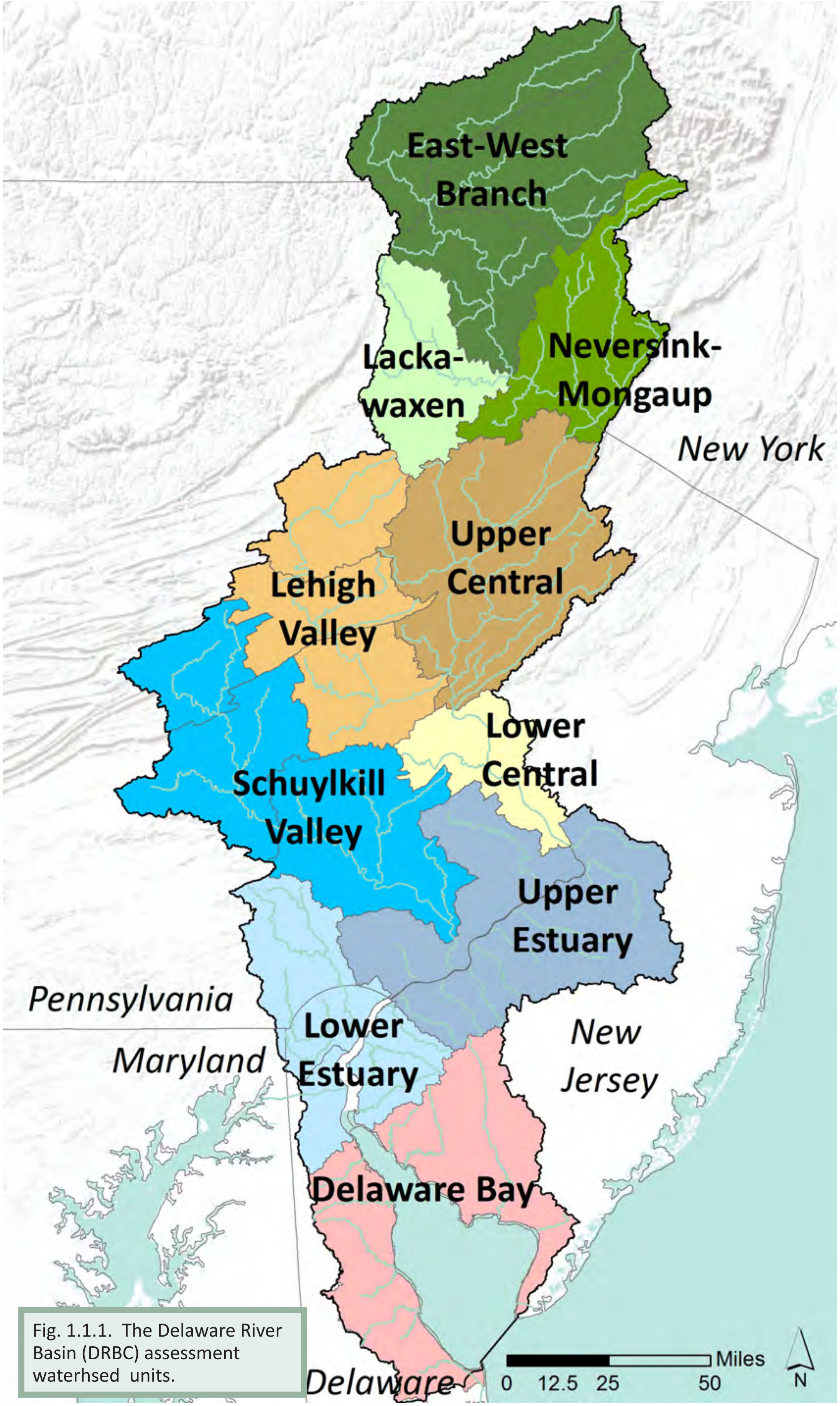


Fig. 1.1.1. The Delaware River Basin (DRBC) assessment waterhsed units.

Chapter 1 – Watersheds & Landscapes

1 – Population

1.1 Description of Indicator

This indicator quantifies the human population within the Delaware River Basin based on data from the U.S. Census. Water quality (pollution) and quantity (water supply and flooding) impacts in the watershed are directly proportional to the size of the population.

1.2 Present Status

The Delaware River Basin occupies 12,769 sq mi (33071 km²) (not including the river and bay) in Delaware (8% of basin), New Jersey (23%), New York (20%), and Pennsylvania (49%). Population data from the 2010 U.S.Census (Table 1.1.1) indicates 8,256,005 residents live in the basin including 703,963 people in Delaware (9%), 6,339 in Maryland, 1,945,966 in New Jersey (24%), 121,160 in New York (1%), 5,478,577 in Pennsylvania (66%), and 6,339 in Maryland (<1%). In 2009, nearly 3,500,000 people worked in the Delaware Basin with 316,014 jobs in Delaware (9%), 1,172 jobs in Maryland, 823,294 jobs in New Jersey (24%), 69,858 jobs in New York (2%), and 2,271,317 jobs in Pennsylvania (65%).

Table 1.1.1. Land area, population, and employment in the Delaware River Basin

State	Area in mi² (km²)	Population[1] 2010	Employment[2] 2009
Delaware	965 (2498)	703,963	316,014
Maryland	8 (21)	6,339	1,172
New Jersey	2,961 (7666)	1,945,966	823,294
New York	2,555 (6615)	121,160	69,858
Pennsylvania	6,280 (16,259)	5,478,577	2,271,317
Total	**12,769 (33,059)**	**8,256,005**	**3,481,655**

1. U.S. Census Bureau 2010. 2. U.S. Bureau of Labor Statistics

The population of the Delaware Basin now exceeds 8 million people which if considered a single jurisdiction, would be the 11th most populous state in the U.S. after North Carolina and New Jersey but ahead of Virginia and Massachusetts. Table 1.1.2 summarizes the area, population, and employment by state and county in the Delaware Basin. In Delaware, the basin covers 50% of the State's area yet includes 74% of the First State's population. The New Jersey portion of the basin covers 40% of the State's land area and includes 22% of the Garden State's population. The New York portion covers 5% of the State's land area and includes 0.7% of the Empire State's population. The Pennsylvania part of the basin covers just 14% of the State's area yet includes 43% of the Keystone State's population.

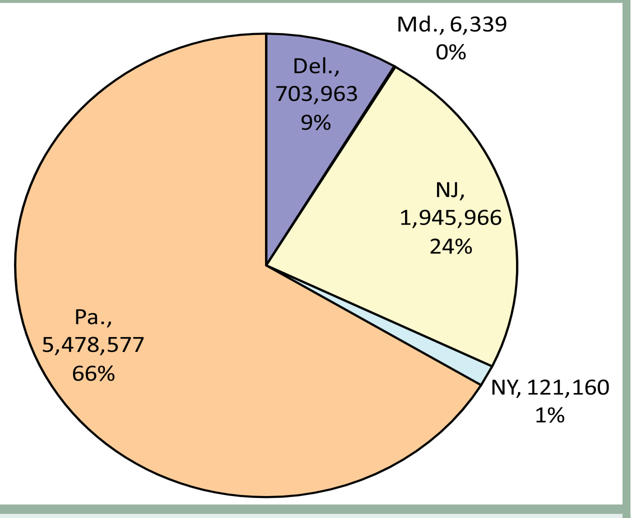


Fig. 1.1.2. Population in the Delaware River Basin by state.

1.3 Past Trends

Between 2000 and 2010, the population in the Delaware Basin increased by 6.3% or 492,942 people (Table 1.1.3). This population increase is equivalent to adding the cities of Dover and Wilmington, DE; Camden and Trenton, NJ: Allentown, Bethlehem, Easton, and Stroudsburg, PA; and Port Jervis, NY to the basin, in just 10 years! Over the last decade, population increased by over 30% in Kent and Sussex counties, Del. and by over 20% in Pike County and Monroe County, PA Philadelphia gained population for the first time in half a century. Several counties in the basin slightly lost population since 2000: Cape May, NJ; Ulster and Broome counties, NY; and Schuylkill County, PA. Eight counties gained over 30,000 people: New Castle and Kent counties, DE, and Berks, Chester, Montgomery, Monroe, Northampton, and Lehigh counties, PA.

Table 1.1.2. Land area, population, and employment by county in the Delaware River Basin

State/county	Area 2005[1] in mi² (km²)	Population[2] 2010	Employment[3] 2009
Kent	389 (1007)	141,346	50,412
New Castle	381 (986)	519,130	252,534
Sussex	195 (505)	43,487	13,068
Delaware	**965 (2498)**	**703,963**	**316,014**
Cecil	**8 (21)**	6,339	**1,172**
Maryland	**8 (21)**	**6,339**	**1,172**
Atlantic		5,470	
Burlington	495 (1282)	439,697	187,758
Camden	123 (318)	442,152	169,909
Cape May	104 (269)	30,845	14,545
Cumberland	490 (1269)	156,901	61,868
Gloucester	279 (722)	258,306	89,183
Hunterdon	215 (557)	35,139	23,650
Mercer	180 (466)	269,344	178,320
Monmouth	20 (52)	12,360	9,864
Morris		30,575	
Ocean	30 (78)	11,724	7,495
Salem	347 (898)	65,976	21,900
Sussex	320 (828)	78,917	23,302
Warren	358 (927)	108,559	35,500
New Jersey	**2,961 (7666)**	**1,945,966**	**823,294**
Broome	85 (220)	2,292	11,292
Chenango		103	
Delaware	1,295 (3353)	32,865	14,240
Greene	25 (65)	236	572
Orange	65 (168)	18,250	10,456
Schoharie		135	
Sullivan	940 (2434)	66,332	25,511
Ulster	145 (375)	946	7,787
New York	**2,555 (6615)**	**121,160**	**69,858**
Berks	777 (2012)	397,634	150,665
Bucks	607 (1572)	622,157	244,453
Carbon	381 (986)	65,979	16,730
Chester	616 (1595)	453,757	212,996
Delaware	184 (476)	553,166	201,208
Lackawanna	25 (65)	6,426	4,830
Lancaster		1,086	
Lebanon	20 (52)	17,021	2,750
Lehigh	347 (898)	343,054	166,932
Luzerne	50 (129)	23,161	8,074
Monroe	609 (1577)	169,172	56,025
Montgomery	483 (1250)	802,342	453,771
Northampton	374 (968)	304,002	96,536
Philadelphia	135 (350)	1,525,400	619,396
Pike	547 (1416)	57,177	9,874
Schuylkill	420 (1087)	85,893	27,077
Wayne	705 (1825)	51,151	14,114
Pennsylvania	**6,280 (1825)**	**5,478,577**	**2,271,317**
Delaware Basin	**12,761 (16,259)**	**8,256,005**	**3,481,655**

1. NOAA CSC 2005. 2. U. S. Census Bureau 2010. 3. U. S. Bureau of Labor Statistics 2009.

Table 1.1.3. Population change in the Delaware River Basin, 2000-2010 (U. S. Census)

State/County	2000	2010	Change	%
Kent	107,850	141,346	33,496	31.1%
New Castle	486,336	519,130	32,794	6.7%
Sussex	29,622	43,487	13,865	46.8%
Delaware	**623,808**	**703,963**	**80,155**	**12.8%**
Cecil	5,496	6,339	843	15.3%
Maryland	**5,496**	**6,339**	**843**	**15.3%**
Atlantic	4,766	5,470	704	14.8%
Burlington	413,729	439,697	25,968	6.3%
Camden	440,664	442,152	1,488	0.3%
Cape May	31,758	30,845	-913	-2.9%
Cumberland	146,771	156,901	10,130	6.9%
Gloucester	231,921	258,306	26,385	11.4%
Hunterdon	32,555	35,139	2,584	7.9%
Mercer	259,121	269,344	10,223	3.9%
Monmouth	9,850	12,360	2,510	25.5%
Morris	27,023	30,575	3,552	13.1%
Ocean	10,228	11,724	1,497	14.6%
Salem	64,553	65,976	1,423	2.2%
Sussex	76,429	78,917	2,488	3.3%
Warren	101,846	108,559	6,713	6.6%
New Jersey	**1,851,214**	**1,945,966**	**94,752**	**5.1%**
Broome	2,364	2,292	-72	-3.0%
Chenango	120	103	-17	-13.9%
Delaware	32,448	32,865	418	1.3%
Greene	224	236	12	5.2%
Orange	17,693	18,250	557	3.1%
Schoharie	124	135	11	8.8%
Sullivan	63,440	66,332	2,893	4.6%
Ulster	1,040	946	-94	-9.0%
New York	**117,453**	**121,160**	**3,708**	**3.2%**
Berks	361,361	397,634	36,273	10.0%
Bucks	593,922	622,157	28,235	4.8%
Carbon	59,011	65,979	6,967	11.8%
Chester	396,849	453,757	56,908	14.3%
Delaware	544,561	553,166	8,605	1.6%
Lackawanna	5,597	6,426	829	14.8%
Lancaster	737	1,086	349	47.4%
Lebanon	14,981	17,021	2,040	13.6%
Lehigh	305,656	343,054	37,398	12.2%
Luzerne	21,373	23,161	1,789	8.4%
Monroe	137,583	169,172	31,589	23.0%
Montgomery	751,287	802,342	51,055	6.8%
Northampton	273,549	304,002	30,453	11.1%
Philadelphia	1,518,220	1,525,400	7,180	0.5%
Pike	46,493	57,177	10,684	23.0%
Schuylkill	87,298	85,893	-1,405	-1.6%
Wayne	46,613	51,151	4,538	9.7%
Pennsylvania	**5,165,092**	**5,478,577**	**313,485**	**6.1%**
Delaware Basin	**7,763,062**	**8,256,005**	**492,942**	**6.3%**

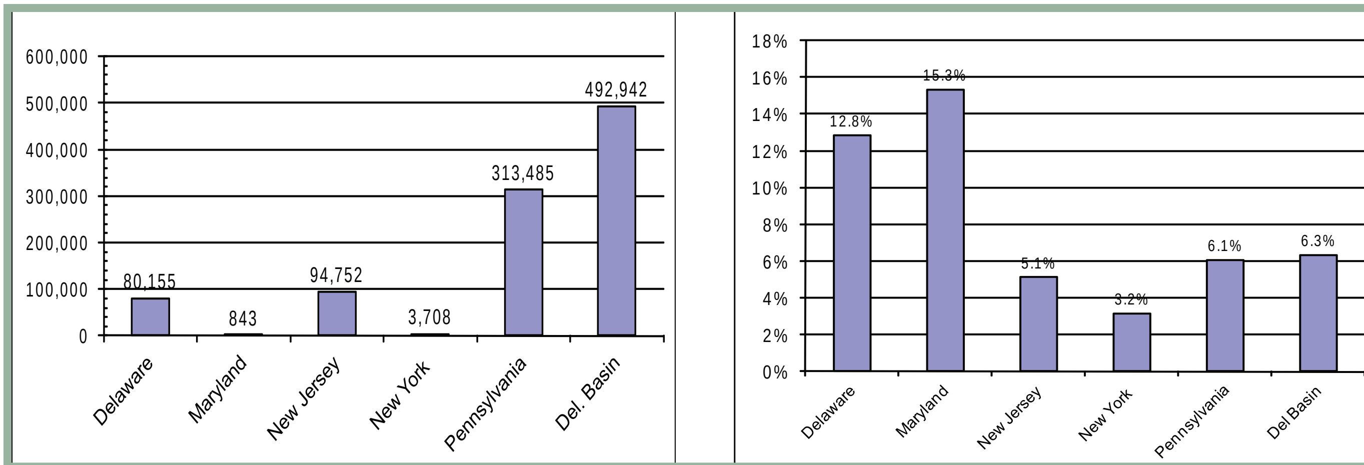


Fig. 1.1.3. Population change in the Delaware River Basin, 2000-2010 (U.S. Census)

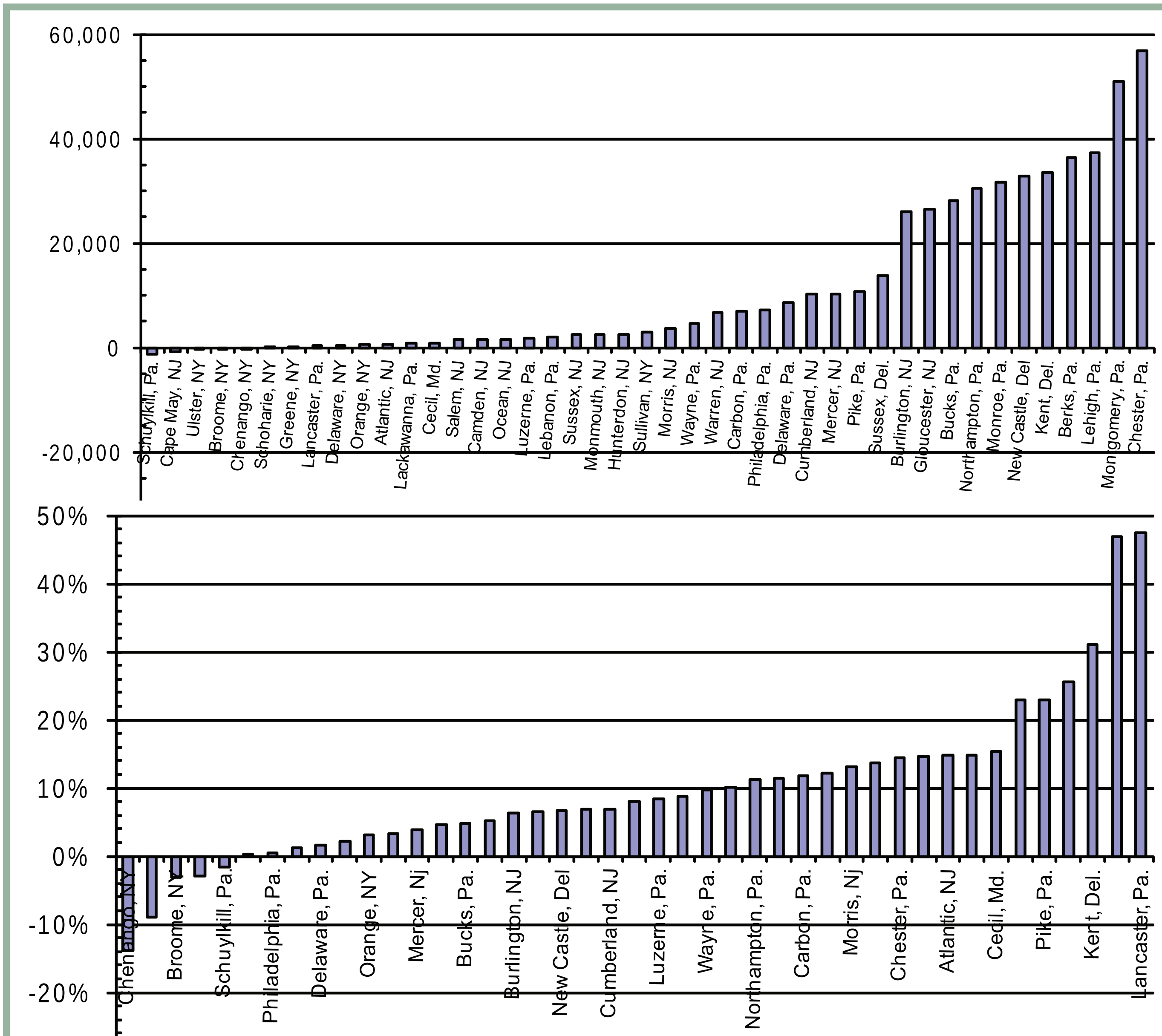
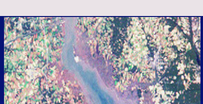


Fig. 1.1.4. Population change in Delaware Basin counties, 2000-2010 (U.S. Census)



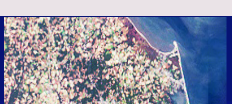
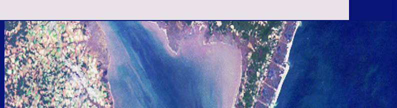
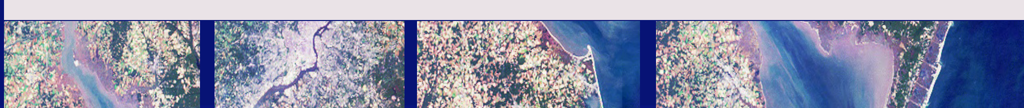



Table 1.1.4. Watersheds in the Delaware River Basin

Watershed	Area in mi^2 (km^2)	Population 2000	Population 2010	Change	%
LE1 Brandywine/Christina	187 (484)	424694	430615	5921	1.4%
LE2 C&D Canal	152 (394)	57613	83428	25815	44.8%
DB1 Delaware Bay	626 (1612)	141472	189891	48419	34.2%
Delaware	**965 (2498)**	**623,779**	**703,934**	**80155**	**12.8%**
LE 1 Maryland	**9 (23)**	5496	6339	843	15.3%
Maryland	**9 (23)**	**5496**	**6339**	**843**	
UC2 NJ Highlands	745 (1929)	218808	232511	13,703	6.3%
LC1 Del. R. above Trenton	159 (412)	58146	57828	-318	-0.5%
UE2 New Jersey Coastal Plain	1,021 (2643)	1292170	1353930	61,760	4.8%
LE3 Salem River	254 (658)	54518	59457	4,938	9.1%
DB2 Delaware Bay	782 (2025)	234537	249785	15,248	6.5%
New Jersey	**2,961 (7666)**	**1,858,179**	**1,953,511**	**95,331**	**5.1%**
EW1 East Branch Del. R.	666 (1724)	22155	22791	637	2.9%
EW2 West Branch Del. R.	841 (2177)	19222	18789	-433	-2.3%
EW3 Del. R. above Pt. Jervis	314 (813)	11188	11298	110	1.0%
NM1 Neversink R.	734 (1900)	64982	68352	3,370	5.2%
New York	**2,555 (6615)**	**117,546**	**121,230**	**3,684**	**3.1%**
EW3 Del. R. above Pt. Jervis	210 (544)	8633	9030	398	4.6%
NM1 Neversink R.	82 (212)	12136	13053	917	7.6%
LW1 Lackawaxen R.	598 (1548)	49736	56502	6,765	13.6%
UC1 Pocono Mt.	779 (2017)	208525	251121	42,596	20.4%
LV1 Lehigh River above Lehighton	451 (1168)	37667	48120	10,454	27.8%
LV2 Lehigh River abv Jim Thorpe	430 (1113)	88387	99152	10,765	12.2%
LV3 Lehigh River above Bethlehem	480 (1243)	478573	529935	51,362	10.7%
LC1 Del. R. above Trenton	295 (764)	101683	107933	6,250	6.1%
SV1 Schuylkill above Reading	338 (875)	88741	87033	-1,708	-1.9%
SV2 Schuylkill above Valley Forge	649 (1680)	321337	354874	33,537	10.4%
SV3 Schuylkill above Philadelphia	874 (2263)	952451	1010730	58,279	6.1%
UE1 Penna Fall Line	693 (1794)	2573270	2625750	52,480	2.0%
LE1 Brandywine/Christina	401 (1038)	235237	276033	40,796	17.3%
Pennsylvania	**6,280 (16,259)**	**5,156,376**	**5,469,266**	**312,890**	**6.1%**
Delaware Basin	**12,761 (33,038)**	**7,755,881**	**8,247,941**	**492,060**	**6.3%**

The Delaware Basin includes 21 watersheds that flow to the river and bay (Table 1.1.4).



1.4 Future Predictions

Based on past growth (1990-2020), the population of the Delaware River Basin is projected to grow from 8.2 million in 2010 to 8.7 million people by 2020 and 9 million by 2030. Every million adds approximately 100 mgd to public water supply demand and wastewater treatment needs in the basin with accompanying water resources infrastructure.

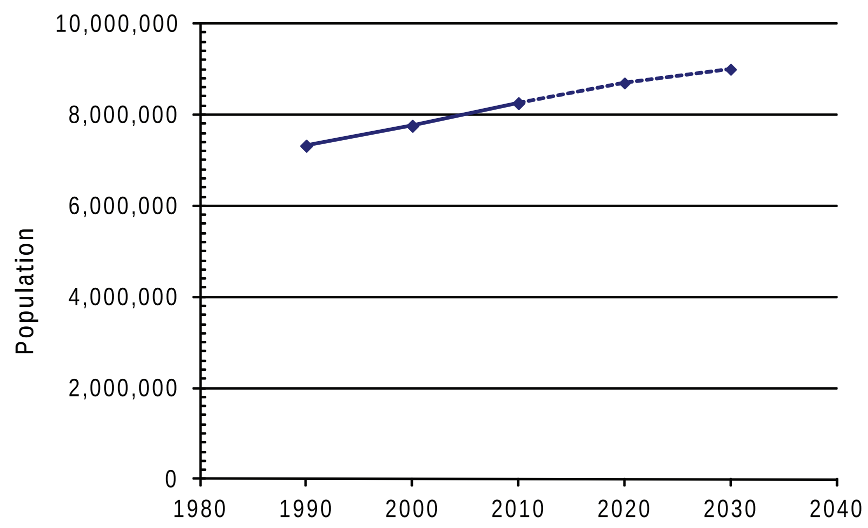


Fig. 1.1.5. Population in the Delaware River Basin

1.5 Actions and Needs

To accomodate the projected population growth, 5-year watershed master plans should be prepared for each of the 10 watersheds in the basin. The master plans should incorporate population projections and impact on drinking water demands, wastewater treatment, water quality, stormwater, and flood control.

1.6 Summary

Population data from the 2010 U.S.Census (Table 1.1.1) indicates 8,256,005 residents live in the basin including 703,963 people in Delaware (9%), 6,339 in Maryland, 1,945,966 in New Jersey (24%), 121,160 in New York (2%), and 5,478,577 in Pennsylvania (66%). Between 2000 and 2010, the population in the Delaware Basin increased by 6.3% or 492,942 people. The population of the Delaware River Basin is projected to grow from 8.2 million in 2010 to 8.7 million by 2020 and 9 million by 2030.

2 – Land Use/Land Cover

Data Sources and Processing

There are several potential sources of land use/land cover data. One is satellite imagery, another is aerial photography. The classification of land cover from satellite imagery is based on multi-spectral analysis of physical properties of reflectance at 30m by 30m resolution (The terms "land use" and "land cover" will be used interchangeably in this report. However, reflectance-based satellite imagery is more accurately a land *cover* data set, and may underestimate, for example, low density land use or cover [e.g., wetlands] under tree canopy). Aerial photography, while usually of higher resolution, is also highly idiosyncratic and not comparable across state lines—each of the four basin states has different policies and timeframes for their photogrammetry and divergent methodologies for assessment. For these reasons, this analysis is based on satellite imagery which offers a higher degree of consistency and replicability across a large study area. It is also available at regular time intervals from one provider employing dependable analytical methods.

The US Geological Survey (USGS) produces the National Land Cover Dataset (NLCD) which was used for parts of the land use assessment issued in the State of the Estuary 2008 and State of the Basin 2008. The NLCD is produced approximately every 10 years. A change in assessment methodology created comparison issues for the 1992 and 2001 data sets and another data set from The National Oceanic and Atmospheric Administration (NOAA) was considered.

The data set from NOAA is produced by the Center for Coastal Services (CSC). However, until 2010 their analysis area excluded a sizeable portion of the basin (approximately 750 $mile^2$, 1942 km^2) straddling the Central and Upper regions, an artifact of capturing the Atlantic and Great Lakes coastal regions. We are grateful to NOAA's CSC for generously agreeing to revisit the three most recent assessment years to incorporate that missing area, and to continue to include the entire Delaware River Basin in their analyses into the future, funding permitting. The CSC dataset has been available in five- year increments. A comparison of the NLCD and the NOAA-CSC data sets is shown in Figure 1.2.1. The NOAA-CSC data set appears to present a more consistent and reasonable trend in land cover change over the decade 1996-2006 than the NLCD presents for 1992-2001.

The NOAA-CSC data set was chosen for this assessment based on the frequency of publication and the consistency of the assessment methodology, availability, and reliability. NOAA-CSC expanded their area of coverage to include a previously missing area in the center of the basin in order to provide three assessment years of land use data: 1996-2001-2006. NOAA employs 21 classifications of land cover/land use, which have been consolidated into 6 categories for this analysis:

- Developed: low, medium, and high intensity development and developed open space
- Agriculture: cultivated lands, pasture, grasslands and transitional land
- Forest: deciduous, evergreen and mixed forest
- Wetlands: palustrine and estuarine emergent, scrub/shrub and forested wetland types
- Open Water: open water and palustrine aquatic beds
- Barren land: unconsolidated shore and barren land

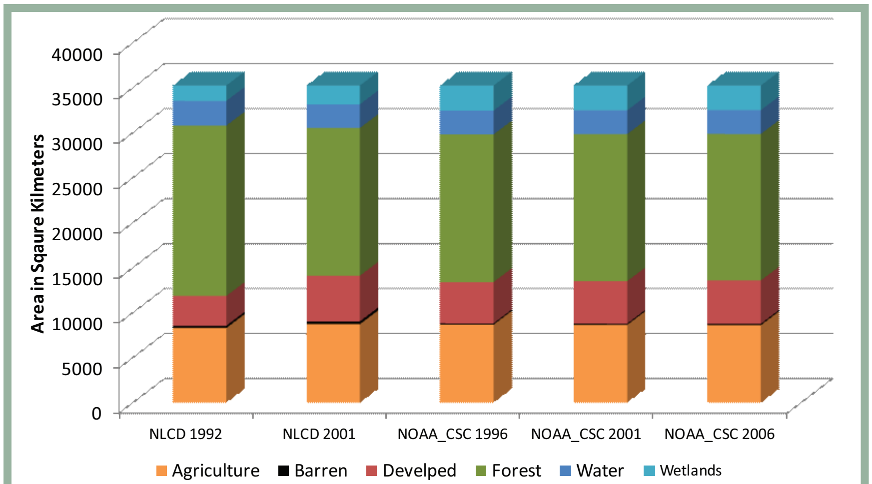


Fig. 1.2.1. LULC Data Set Comparison. The NOAA-CSC data set was chosen for this assessment based on frequency and consistency.

The NOAA-CSC data was developed to meet an 85% overall target accuracy specification, but can vary by geography and date. The NOAA-CSC data was parsed by the Delaware River Basin Commission (DRBC) and the University of Delaware into 21 sub-watershed groups and subsequently aggregated into 11 watersheds, 4 regions, and the basin for analysis. Additionally, the Upper and Central Regions combined drain into the non-tidal river, while the Lower and Bayshore regions drain to the tidal river and the bay, or Delaware Estuary. This distinction is included as an additional geographic unit of analysis. See Fig. 1.2.1 for basin assessment unit heirarchy.

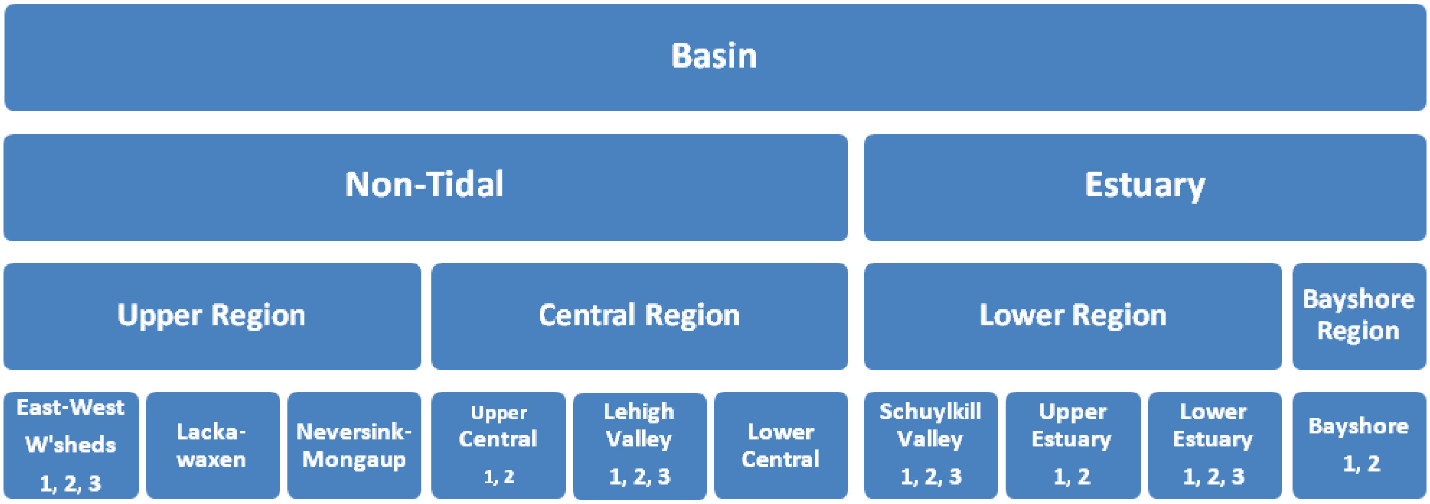


Fig. 1.2.2. Basin Assessment Units & Reporting Hierarchy. The basin can be subdivided into regions and watershed groups for more definitive reporting. See map for watershed units Fig. 1.1.1.

See watershed map Fig. 1.1.1, Table 1.2.1 , and Fig. 1.2.3 for geographic location and relative sizes.

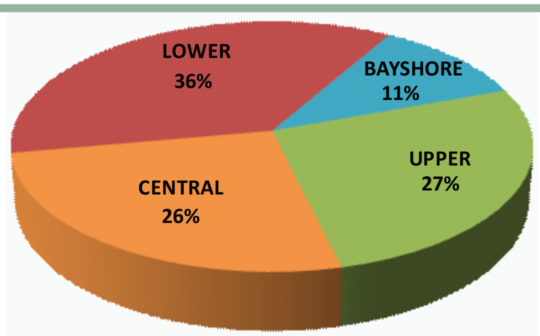


Fig. 1.2.3. Basin Regions. The four regions of the basin cover varying amounts of land area.
Note: Delaware Bay is not included in the analysis.

2.1 Description of Indicator

Land use/Land cover is a way to characterize the landscape; it includes both natural land cover (such as forests and wetlands) as well as the use of land for human habitation, commerce, and industry. The presence of land cover and land use types, as well as changes over time, often correlate to the condition of water resources and habitat.

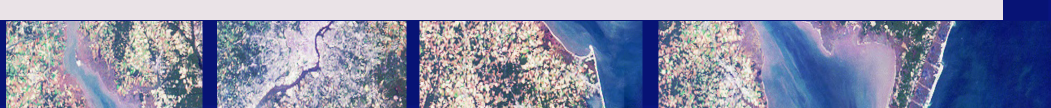
Forest cover is a natural land cover strongly associated with pre-development conditions of water quality and hydrology. Forests cycle nutrients and carbon dioxide, capture rainfall and inhibit erosion, playing an important role in the supply and quality of water for streams and wetlands; they also provide forage and habitat for wildlife. Large areas of forested land are associated with water supply and water quality (Barnes et al. 2009) and forested watersheds are often routinely used to define natural reference conditions for streams. Mature forest is considered to be the main benchmark for defining pre-development hydrology within a subwatershed (Center for Watershed Protection 2003).

Value of Forest Cover as an Indicator

It should come as little surprise that the progressive loss of Forest Cover has been linked to declining stream quality indicators, given that forested watersheds are often routinely used to define natural reference conditions for streams . . . Mature forest is considered to be the main benchmark for defining pre- development hydrology within a subwatershed, as well. ***Consequently, forest cover is perhaps the most powerful indicator to predict the quality of streams within the "sensitive"category (i.e., with zero to 10% impervious cover).***

Impacts of Impervious Cover
Monogrqaph No. 1
Center for Watershed Protection 2003

Similarly, wetlands are positively associated with water resource quality and abundance, although that positive relationship can be dependent on size, connectivity, and functional integrity. Less is documented on the relationship of grasslands on water resources, and the effects of agricultural land uses can vary greatly—from benign to detrimental—depending on crop, intensity of use, degree of soil compaction, and the application of nutrient amendments and pesticides.



Agricultural lands include cultivated cropland, pasture, grasslands, and lands in transition (scrub/shrub). Abandoned agricultural lands may, through natural succession, return to more naturalized conditions, or they may be developed for more intense human use and habitation. The suitability as habitat and impacts on water resources are commensurate with the intensity of use.

Development or degree of urbanization, and its corollaries of population density, road network density, and impervious cover, are associated with the loss of native land cover and change (usually deleterious) to water quality and hydrology. Land uses, such as residential development or agriculture, may correlate to demand for water and an increase in potential water quality impacts through wastewater discharge and surface runoff.

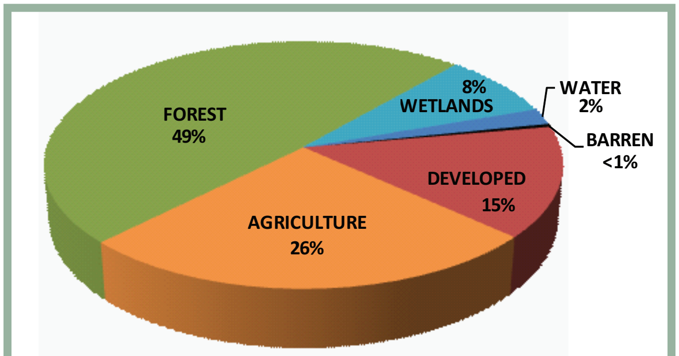


Fig. 1.2.4. Basin Land Cover 2006. The predominant land cover in the basin is forest. About 15% of the basin is classified as developed.

Knowledge of the proportion and distribution of land use and land cover types is one way to assess the conditions of watersheds and identify potential long-term concerns. This indicator is most effectively used in combination with population. Land cover and land use are also used as a basis for estimating impervious cover (IC), another indicator of potential degradation in water quality and hydrologic condition that is assessed in Section 5: Impervious Cover. Much research exists correlating the degree of land cover and intensity of use with water quality, stream flow, and habitat for aquatic and terrestrial communities. The US Geological Survey routinely assesses water quality and aquatic community impairment along an urban gradient (Ayers, et al. 2000).

At this aggregated scale, the proportion of land use can be a very general indicator of potential water resource quality and use issues that may need to be addressed. However, given the unit of analysis (30m^2), standard error, and aggregation of land use types, the results are general and suggestive across a broad landscape area. Definitive watershed analyses require aerial photography and field checks to ground-truth actual conditions.

2.2 Present Status

Basin Landscape

The basin has approximately 12,866 miles^2 (33,323 km^2) of land area within the states of Delaware New Jersey, New York, and Pennsylvania. (This does not include approximately 8 miles^2 (20.7 km^2)of land in the state of Maryland). More than half (53%) of the land area drains to the non-tidal Delaware River above the fall line near Trenton. The Delaware Bay adds 747 mi^2 (1,936 km^2) of area to the basin increasing the total to 13,614 miles^2 (35,268 km^2). With the bay included, more than half (50.2%) of the basin is part of the Delaware Estuary in the National Estuary Program. The following analysis reflects only that area (land and water) considered as part of the land cover assessment; the area of the bay has not been included in this landscape analysis. See Table 1.2.1.

Table. 1.2.1. Watershed Regions of the Basin – Land Area

Region	Upper			Central			Lower			Bayshore	
Water-shed	East-West	Lackwax.	N-M	Lehigh Valley	Upper Central	Lower Central	Schuyl. Val.	Upper Estuary	Lwr. Estuary	DE	NJ
Area in mi^2 (km^2)	2030 (5256)	598 (1548)	816 (2113)	1362 (3526)	1524 (3946)	454 (1175)	1892 (4898)	1745 (4518)	1021 (2643)	634 (1641)	790 (2045)
% of Region	59 %	17 %	24 %	41 %	46 %	14 %	41 %	37 %	22 %	45 %	55 %
% of Basin	27 %			26 %			36 %			11 %	
% of Estuary	NA						77 %			23 %	

Fig. 1.2.4 and Table 1.2.2a illustrates the amount and percentages of landscape types in the basin. The predominant land cover is forest which overlays 6,288 mi^2 (16,280 km^2) or 48.9 % of the basin land area; nearly three quarters of forested landscapes are found in the Upper and Central regions. Agricultural use and grasslands cover about 3,325 mi^2 (8,608 km^2) or 25.8% of the landscape. Wetlands and water combined account for an additional 10 % (1,334 mi^2, 3,454 km^2), although freshwater wetlands, especially in forested areas, may be under-reported in satellite imagery analysis. Developed landscapes—a combination of low, moderate, and high density residential,

Table. 1.2.2. Land use and land cover for the enitre basin, rounded to the nearest mi^2 (km^2)

	DEVELOPED	AGRICULTURE	FOREST	WETLANDS	WATER	BARREN	TOTAL AREA
UPPER	48 (124)	437 (1131)	2,778 (7192)	95 (247)	76 (197)	9 (23)	3,443 (8913)
CENTRAL	327 (847)	815 (2110)	1,925 (4983)	197 (510)	62 (161)	15 (40)	3,341 (8651)
LOWER	1,352 (3500)	1,514 (3919)	1,351 (3498)	334 (865)	82 (213)	22 (58)	4,656 (12053)
BAYSHORE	134 (347)	559 (1447)	234 (607)	434 (1124)	53 (137)	9 (23)	1,424 (3686)
BASIN	1,861 (4818)	3,325 (8608)	6,288 (16279)	1,061 (2746)	273 (708)	56 (144)	12,863 (33303)
% Cover	14.5%	25.8%	48.9%	8.2%	2.1%	0.4%	100%

commercial, and industrial development – cover 1,861 mi^2 (4818 km^2) or 14.5% of the basin.

Types of land cover are not equally distributed across the basin, as Fig. 1.2.5 illustrates. See also Table 1.2.2. The Upper and Central regions are dominated by forest cover and account for about 75% of the basin's forested area. The Lower region is the most heavily developed and populated area of the Basin, as reflected in the predominance of human use—development (29%) and agriculture (33%); indeed, nearly three-quarters of all development within the basin is found in the watersheds of the Lower region, a factor that can be related to the water quality of the region's tributaries and the mainstem Delaware River here. Wetlands are found throughout the basin, but their presence is most notable as the tidal wetlands in the Upper Estuary and Bayshore watersheds. See Chapter 5B for more detail on tidal wetlands. Along with population density and development patterns, the varying combinations of land cover and land use in each region and each watershed affect the way and the amount of water use and the ways water quality can be affected by point and non-point sources of pollution.

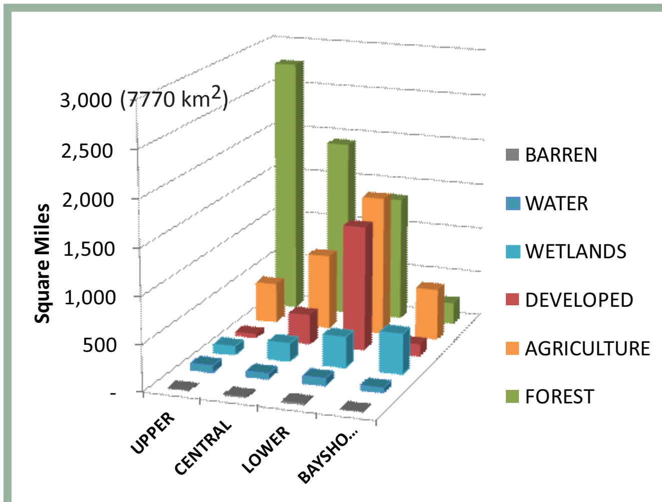


Fig. 1.2.5. Land Cover 2006 by Basin Region. Forest cover predominates in the Upper and Central Regions. The Lower Region is a mix of agriculture, forest and developed lands. the The Bayshore Region is characterized by coastal wetlands and agricultural land use.

Similarly, watershed groups within regions exhibit notable variation in land cover and use. Fig. 1.2.6 illustrates the variation in the landscape characterisitics of watershed from north (East-West) to south (Bayshore). While forest dominates the landscape of the watersheds from the headwaters down through the Lehigh Valley, its presence is considerably muted in the watersheds of the Lower Central and south to the Bayshore watersheds. Agriculture is a dominant use in the Schuylkill valley, the Lower Estuary and the Bayshore watersheds. The population centers of in the Lehigh, Schuylkill, Upper and Lower Estuary watersheds are also very visible. In the Upper Estuary, development dwarfs all other land cover.

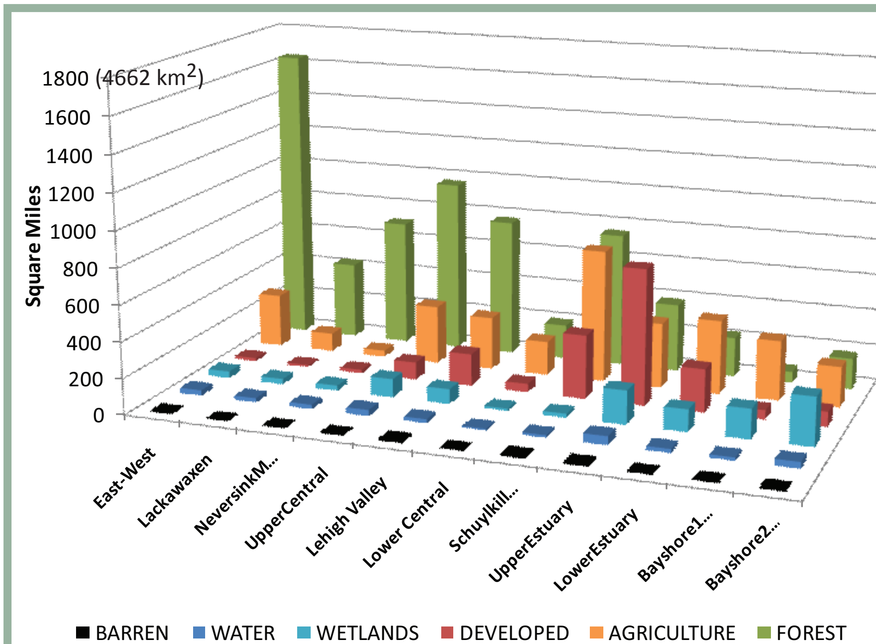


Fig. 1.2.6. Land Cover 2006 by Watershed Group. The variation of land cover across the basin is most evident when viewed from a watershed perspective.

The Delaware Estuary

The land area of the Delaware Estuary is nearly 6,100 mi^2 (15,793 km^2), comprised of the five watershed groups of the Lower and Bayshore regions which drain the Schuylkill Valley, the Upper Estuary, the Lower Estuary and the eastern (NJ) and western (DE) Bayshore. Although the Estuary contains slightly less than half (47%) of the basin's land area, it accounts for 79.9% of all developed land, 62.3% of cultivated and scrub land, and 72.4% of the basin's wetlands. See Fig. 1.2.7, and Table 1.2.3 for details. Next to agriculture, wetlands are the notable and most important feature of the Estuary, especially of the Bayshore watersheds where they ring the Bay, functioning as nursery, nutrient sink, sediment source, temperature-moderating, and flood-regulating system. See Chapter 5B for additional information on wetlands.

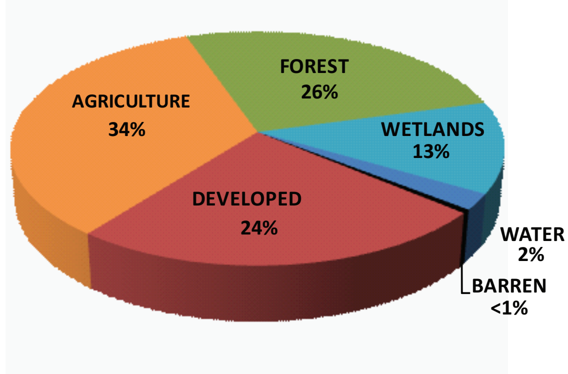


Fig. 1.2.7. Estuary Land Cover 2006.

Table 1.2.3a Estuary Land Cover & Use in mi^2

	DEVELOPED	AGRICULTURE	FOREST	WETLANDS	WATER	BARREN	ESTUARY
SV	356.45	739.10	749.46	22.20	13.23	10.55	1,890.99
UE	755.34	362.86	379.49	187.96	48.15	9.34	1,743.14
LE	240.22	411.83	222.20	123.78	20.90	2.49	1,021.42
DB1-West	51.98	333.87	61.62	166.02	17.45	3.46	634.40
DB2-East	82.04	225.22	172.78	268.29	35.53	5.43	789.29
ESTUARY	1,486.03	2,072.88	1,585.55	768.25	135.25	31.28	6,079.24

Table 1.2.3b Estuary Land Cover & Use in km^2

	DEVELOPED	AGRICULTURE	FOREST	WETLANDS	WATER	BARREN	ESTUARY
SV	923.18	1,914.19	1,941.04	57.49	34.26	27.33	4,897.48
UE	1,956.26	939.78	982.84	486.80	124.69	24.20	4,514.57
LE	622.14	1,066.61	575.48	320.57	54.13	6.45	2,645.38
DB1	134.62	864.69	159.59	429.97	45.18	8.97	1,643.03
DB2	212.48	583.29	447.48	694.84	92.01	14.07	2,044.17
ESTUARY	3,848.68	5,368.55	4,106.42	1,989.68	350.28	81.02	15,744.63
% of ESTUARY	24.4%	34.1%	26.1%	12.6%	2.2%	0.5%	100.0%
% of Basin LC/LU	79.9%	62.3%	25.2%	72.4%	49.5%	56.2%	

2.3 Past Trends

While satellite imagery has enabled the consistent measurement of land use change over time, it is a relatively new tool. The first land use imagery base was generated in 1972 based on multispectral imagery from Landsat1. Technological innovations, improvements in methodology, and cost confound a quantitative assessment of landscape change over a broad time frame, and is therefore not within the scope of this report. However, historic evaluation of landscape change can help identify the proximate causes of current conditions that are linked to antecedent land use and management. A description of land use and land cover change between 1996 and 2006 is found in Section 3.

2.4 Future Predictions

It is expected that as population increases, developed (urban) land will continue to increase and forests, grasslands and fields will be converted for human habitation, commercial and industrial uses. The rate of change will be dependent on demand and how intensely land is used—that is, how many acres are developed for each net increase in population, economic growth or shift in resource needs. While filling and conversion of wetlands for agricultural and urban development has generally decreased over time, the loss of coastal wetlands is expected to continue exacerbated by sea level rise and the inability of wetlands to migrate. See Chapter 5. While agricultural use has shown a generally decreasing trend, the demand for locally-sourced produce and meat may enhance the economic viability of small farm agriculture. Longer growing seasons—a condition expected to accompany climate change—could stabilize or even increase the amount of land in agricultural use. As the effects of climatic changes are realized, the ecological service value of wetlands and forests – especially their ability to sequester carbon, might alter the economic valuation of these landscapes and, in turn, how they are used. Ideally, we will accommodate population increases with improved efficiency, which would result in the amount of developed land holding steady—or decreasing—over time. In addition, water supply and quality issues, coupled with a desire to reduce energy consumption, could result in the "greening" of urban areas to offset the adverse impacts of dense human settlement patterns on air and water temperature, air quality and surface water flow and quality. Significant challenges exist—political, economic and cultural—before positive land use outcomes can be realized. See Section 3.4.

2.5 Actions and Needs

The satellite imagery data set is the only one that offers consistent evaluation of land cover across the basin. As long as NOAA-CSC is able to include full basin coverage in their analyses, this will continue to be the data set of preference for land cover analysis at the basin scale. However, the 30m resolution, while adequate for the basin in aggregate, is not ideal for capturing land cover change at a smaller sub-basin scale. The use of vector-based land cover data from aerial photography may be preferable for watershed-scale analyses, but is not possible under current conditions; each basin state has differing schedules for their photogrammetry and differing methods of analysis. Until synchronized and normalized across the basin, the state-based information, while more detailed, is not useful for any comparative analyses.

2.6 Summary

The basin land cover and land use includes forest (49%), agriculture (26%), developed (15%), wetlands (8%), water (2%), and barren (1%). This varies significantly by region. The dominant feature of the Upper region is forest (80%) and that region has the least amount and percentage of developed land. The landscape of the Lower regions is more or less equally divided into agriculture, forest and developed land. This is the most highly developed region of the basin, accounting for nearly 73% of all development. The Estuary area, that is the Lower and Bayshore regions combined, accounts for nearly 80% of all developed land in the basin, as well as about 72% of the basin's wetlands visible via satellite imagery. The Bayshore and Central regions exhibit similar levels of development (about 9% and 10% respectively), although they are each unique. The Central region is still slightly dominated by forest (58%) and nearly a quarter of the landscape is in agriculture. The Bayshore region landscape is best characterized by a mix of agricultural use and coastal wetlands; approximately 16% of the Bayshore landscape is forested.

3 – Land Use /Land Cover Change

This analysis considers the *net* change in land cover based on the dates of the NOAA-CSC data for 1996, 2001, and 2006. It includes changes across the basin, among regions and across watersheds by the six land cover types defined earlier in Chapter 1.2: developed, agriculture, forest, wetlands, water and barren land.

3.1 Description of Indicator

Land cover changes over time. It may change by natural succession—as when woody plants volunteer and eventually replace grasslands and abandoned fields—or by other natural processes—erosion or inundation of shoreline and wetlands, for example. Disasters notwithstanding, landscape changes due to natural causes generally occur at a very slow pace, especially in comparison to the relatively rapid changes wrought by human activity. In general, however, land cover changes relatively slowly in the aggregate, landscape scale. Scale plays a role in our perception of change, as well as our ability to capture it. For example, while one may notice the lot or parcel being cleared in a community for new housing or stores, that change of a few acres may not be sufficiently significant to register in an analysis of net change.

Tracking land cover change at a watershed level is valuable for planning and protection efforts, and for correlating with water use and water quality. It is not simply the change of land classification that is of interest, but the potential change or loss of the function of the natural landscape that makes this indicator worth tracking. However, statements of aggregated "net" change can yield only a very general assessment of conditions at large scales and may mask significant land cover change at the watershed or local level.

Relative changes, trends, and rates of change may be useful for indicating potential impairments to water quality or hydrology and where additional assessment work would be beneficial. Change in land cover and use, in tandem with changes in population, can indicate a need for re-visiting plans for water supply and wastewater to ensure the maintenance of adequate stream flow and quality.

3.2 & 3.3 Past Trends & Present Status

Land Cover Change in the Basin and Regions

Historically, land use change has occurred in a stepped process, generally increasing in intensity over time, as land has first been cleared (forest) or filled (wetlands), then put to a succession of uses that serve community needs and the demands of commerce and industry. It is far less likely that developed land will revert back to a natural, undeveloped landscape. As former Secretary of Agriculture Rupert Cutler noted, "Asphalt is the land's last crop" (R. Cutler, 1984).

Table. 1.3.1. Net Land Cover Change 1996-2006 by Regions

	DEVELOPED	AGRICULTURE	FOREST	WETLANDS	WATER	BARREN
Percent Change	**4.7%**	**-0.7%**	**-0.8%**	**-1.8%**	**-0.7%**	**7.1%**
Net Change in mi²						
UPPER	1.69	8.74	-10.14	0.03	-1.27	0.95
CENTRAL	20.75	-5.36	-11.06	-4.26	-2.16	1.70
LOWER	61.11	-25.18	-25.07	-8.94	-2.52	0.62
BAYSHORE	4.04	-0.02	-2.90	-5.77	3.97	0.68
BASIN	**87.59**	**-21.83**	**-49.17**	**-18.94**	**-1.98**	**3.95**
Total Land Cover	1,860.83	3,324.71	6,287.91	1,060.75	273.42	55.64
Net Change in km²						
UPPER	4.38	22.62	-26.27	0.09	-3.28	2.46
CENTRAL	53.73	-13.88	-28.64	-11.03	-5.60	4.41
LOWER	158.26	-65.23	-64.94	-23.17	-6.53	1.60
BAYSHORE	10.47	-0.06	-7.50	-14.94	10.27	1.76
BASIN	**226.84**	**-56.54**	**-127.35**	**-49.05**	**-5.14**	**10.22**
Total Land Cover	4,819.36	8,610.68	16,285.06	2,747.23	708.14	144.11
Net Change in Acres						
UPPER	1,082	5,591	-6,492	22	-810	608
CENTRAL	13,277	-3,429	-7,078	-2,727	-1,384	1,089
LOWER	39,108	-16,118	-16,047	-5,724	-1,614	395
BAYSHORE	2,588	-15	-1,854	-3,691	2,538	435
BASIN	**56,055**	**-13,971**	**-31,471**	**-12,120**	**-1,270**	**2,527**
Net Change in Hectares						
UPPER	438	2,262	-2,627	9	-328	246
CENTRAL	5,373	-1,388	-2,864	-1,103	-560	441
LOWER	15,826	-6,523	-6,494	-2,317	-653	160
BAYSHORE	1,047	-6	-750	-1,494	1,027	176
BASIN	**22,684**	**-5,654**	**-12,735**	**-4,905**	**-514**	**1,022**

We know from historic description that the Delaware basin was predominantly forested at the time of European colonization and that there were also significant areas of marshes and wetlands, especially throughout the estuary and including the vicinity of Philadelphia. We also know that forests throughout the basin have been successively and extensively cleared for use in shipbuilding, glass manufacturing (fuel), and for construction. Currently, forested area exceeds what was present in the early 20th century. The Interstate Commission on the Delaware River Basin (INCODEL) reported that only 4,117 square miles (10,659 km2) were forested in 1930 (INCODEL 1940). Human encroachment on the basin's wetlands, especially in the estuary, has been substantial; remaining wetlands are but a fraction of original estimates. See Chapter 5B.

During the decade between 1996 and 2006:

- Approximately 88 mi^2 (228 km^2) were developed across the basin, an increase of 4.7%. The *State of the Basin Report 2008* (DRBC 2008, p. 71) overestimated the net change in developed area between and the net loss of forested land between 1996 and 2001.
- Twenty two mi^2 (57 km^2) of cultivated or scrub land were converted to another use or succumbed to natural succession and reverted to forest, a net loss of 0.7 %.
- Nearly 20 mi^2 (52 km^2) of wetlands were developed or otherwise lost, perhaps through inundation, a net loss of 1.8%.
- The basin also experienced a net loss of nearly 49 mi^2 (127 km^2) of forest (-0.8%).

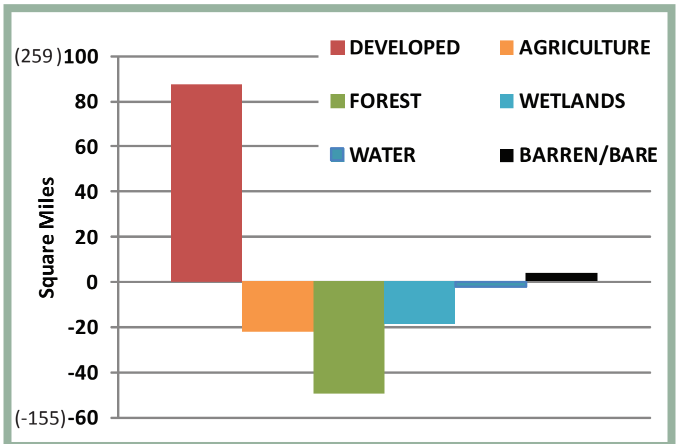


Fig. 1.3.1. Basin Land Cover Change 1996-2006. During the decade between 1996 and 2006, approximately 88 square miles (128 km2) of development was added across the basin. Overall, almost 50 square miles (127 km2) of forest was lost during the same time period. Changes in wetlands and barren land, although reported for completeness, are *de minimus* and within the margin of error of the analysis.

Change in Large Watersheds

The net changes that are calculated in aggregate are the result of changes in land cover within watersheds. As previously noted, the satellite imagery is most robust for large landscape analysis. If not particularly accurate for absolute change, such analyses can illustrate relative change among the watersheds. Figure 1.3.3 illustrates the relative net change in land cover type across the basin by the 10 watershed groups arranged north to south. Although not normalized for total area, the predominant type of land cover change is clear. Development is occurring in the Upper Central, Lower Central, and Lehigh watersheds, and is continuing in the Schuylkill, the Upper Estuary, and the Lower Estuary watersheds. At the northern end of the basin, the East-West, Lackawaxen, and Neversink-Mongaup watersheds are experiencing less development, but a net loss of the forested landscape, the hallmark landscape of the basin's headwater region. In the Bayshore watersheds, development increased and the net loss of wetlands continued, while the amount of agricultural landscape remained stable.

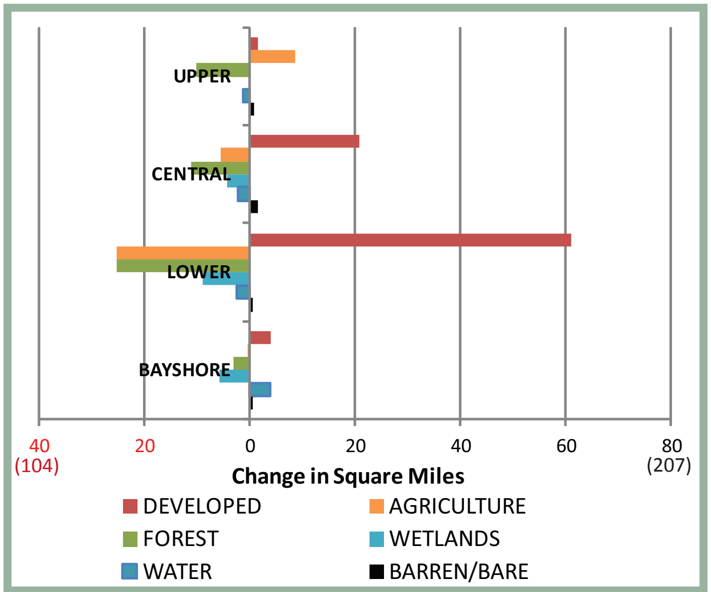


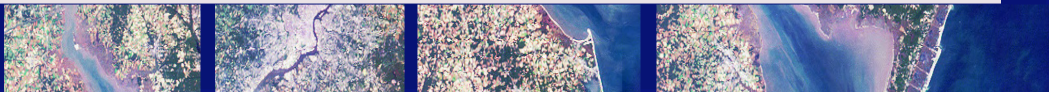
Fig. 1.3.2. Net Land Cover Change by Region 1996-2006. The Lower Region experienced three times the development of the Central Region

Change in Developed Area

Developed land increased in every watershed of the basin in the decade between 1996 and 2006. The greatest increase in development occurred in the Lower Region where more than 60 square miles (158 km^2) of land were developed, and a combined total of more than 50 square miles (130 km^2) of agricultural land and forest were lost. The Central Region had the second greatest gain of developed land (more than 20 square miles, about 54 km^2) and a proportionately larger loss of forest than agricultural land.

Change in Agricultural Area.

A net decrease in the basin's agricultural land (22 mi^2, 57 km^2) occurred with major losses in the Lower Region (25 mi^2, 65 km^2). However, the Upper Region shows a net increase in agricultural landscapes (nearly 9 mi^2 or 29 km^2). There was also loss of agriculture in the Central Region (5 mi^2, 14 km^2) where a modest increase in crop and pasture land was overshadowed by a loss of scrub/shrub lands. Change in agricultural land in the Bayshore Region was unremarkable.



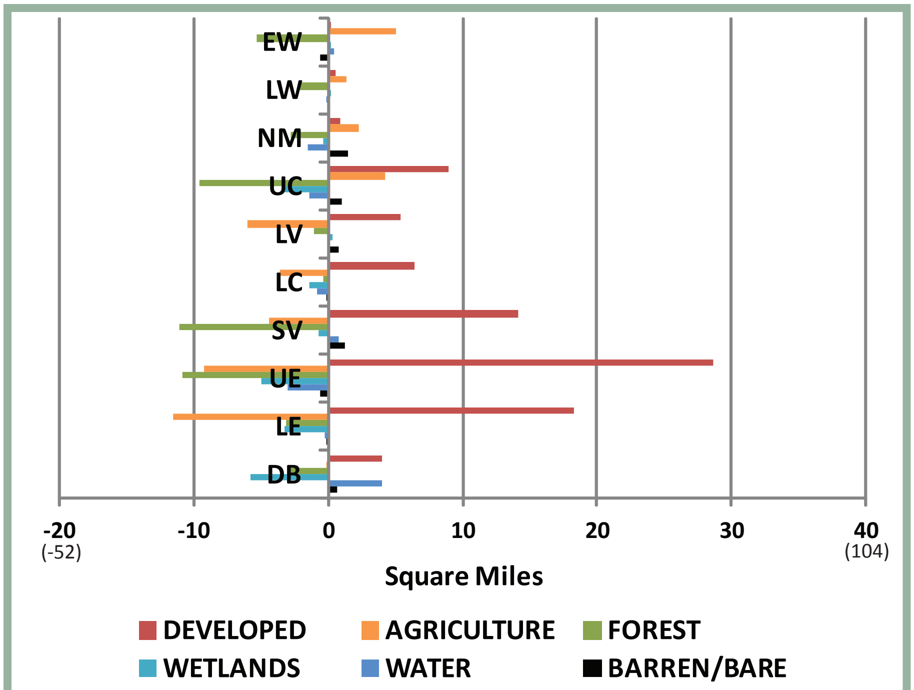


Fig. 1.3.3. Change in Land Cover 1996-2006 by Watershed. Land cover change analysis based on satellite imagery is better for indicating relative not absolute change, especially at the watershed scale. Because of scale and accuracy issues involved with satellite imagery, small changes should be considered suggestive and not definitive. Additional information would be required to support the changes suggested by this analysis.

Table. 1.3.2 Rate of Net Forest Loss 1996-2006

Net loss per decade	-31,471 ac (12733 ha)
Net loss per year	-3,147 ac/yr (1273 ha/yr)
Net Loss per Month	-262.25 ac/mo (106 ha/mo)
Net Loss per Week	-60.52 ac/wk (-24 ha/wk)
Net Loss per 5-Day Work Week	-12.10 ac/day (5 ha/day)
Football field	~1.3 ac (0.53 ha)
Forest Loss Equivalent	-9.2 football fields/day
8-hour work day	-1.2 football fields/hour

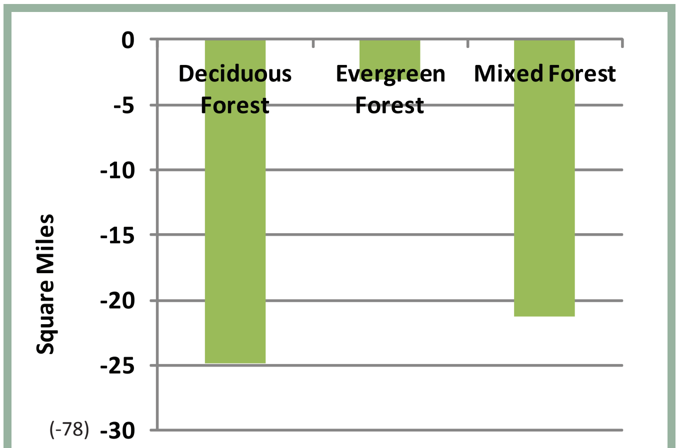


Fig.1.3.4. A decade of Forest Change. Bar graph of change in 3 forest types

Change in Forest Area

Between 1996 and 2006, there was a net loss of nearly 50 square miles (127 km^2) across the basin. Just slightly less than one percent (0.8%) of the forest existing in 1996 was lost in 10 years. A net loss was found in each of the 21 assessment units, and in every region. The greatest loss (25 mi^2, 65 km^2) occurred in the largest (Lower) Region. In the Central Region, modest gains in deciduous and evergreen forest were offset by greater losses in mixed forest. Even the Upper Region, which experienced very little development, had a net loss of more than 10 square miles (26 km^2) of forest.

Rate of Forest Change

Understanding the scale of landscape change over a long period of time can be confounding, so expressing that change in as a "comparable" can be helpful. A football field is a useful comparison, since a football field is just slightly larger than an acre. (An acre is 43,560 square feet. A football field is 360 ft by 160 feet, or 57,600 square feet, or 1.32 acres.) The estimated net loss of forest across the basin can be expressed as an average net loss over the decade, a year or even shorter time frame. For example, assuming 52 weeks per year, and an average of five 8-hour workdays per week, the average rate of net forest loss was approximately 9 football field per day, or about 1 per hour. See Table 1.3.3.

The net loss of forest in the time frames 1996-2001 and 2001-2006 were very similar (-16,082 ac/-6507 ha and -15,389 ac/-6226 ha, respectively), indicating a fairly constant rate of loss over the decade. Additional years of data will aid in the establishment of a trend.

Change in Forest Types

There is a difference in the change of types of forests. The NOAA-CSC data set classifies forest cover as one of three types: deciduous forest, evergreen forest, or mixed forest. Deciduous forests areas are dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover where more than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

Evergreen forests areas are dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover where more than 75 percent of the tree species maintain their leaves all year and the canopy is never without green foliage.

Mixed forest areas are dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

The greatest amount of net loss was seen in deciduous and mixed forest types. See Fig 1.3.4. The change was differentiated across the basin regions. Deciduous forest decreased in every region but the Central Region, where slight net gains were calculated for deciduous and evergreen forests. See Fig 1.3.6

3.4 Future Predictions

Landscape change is only part of the suite of indicators that are needed to a) depict how efficiently and effectively we are using land, and b) predict issues of concern that may warrant further investigation. For example, the density of development and per capita land conversion, landscape change relative to population, are indicators of how efficiently we are using land. Lower density "suburban" development, also known as sprawl, is typical of the development pattern across the basin and is associated with greater travel times for work commutes and access to community services, as well as greater per capita loss of natural landscapes.

Pennsylvania's growth opportunity is green and walkable. Changing demographics suggest there is an emerging market for development that is green (energy and environmentally conscious) and walkable (compact, affordable, mixed-use, and favoring pedestrians). This is a win-win scenario. Pennsylvania CAN attract growth AND sprawl less.

State Land Use & Growth Management Report
Executive Summary
Governor's Center for Local Government Services (PA)
2010

"Since there is a cause-and-effect link between land development and [vehicle miles traveled] VMT, land use is directly and synergistically linked to the transportation sector…[I]t will be difficult for New Jersey to meet its statewide GHG [green house gasses] limits without a fundamental shift in the state's historic development patterns."

Global Warming Response Act Recommendations
NJ Department of Environmental Protection 2009

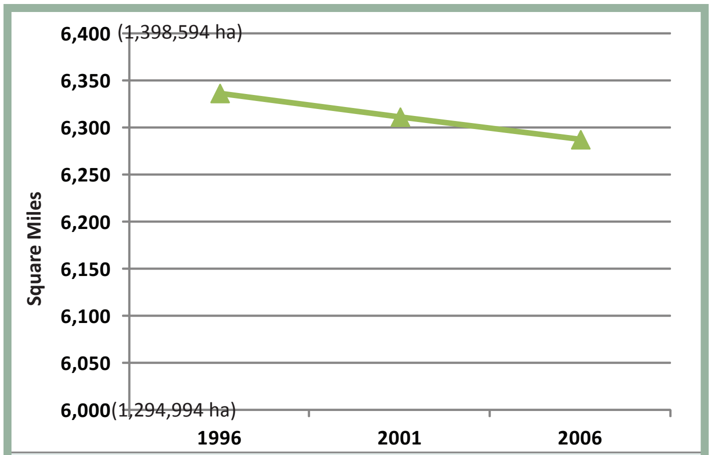


Fig. 1.3.5. Basin Forest Change 1996-2006. The net loss of forest between periods were similar 1996-2001= - 25.13 mi^2 ; 2001-2006 = - 24.04 mi^2 (-16,082 acres and -15,389 ac respectively; -41,636 and -39,842 ha respectively)

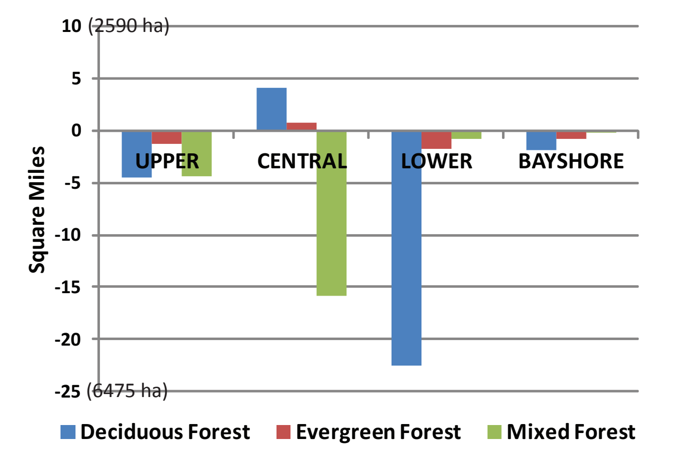


Fig. 1.3.6. Forest change by region 1996 - 2000

When compared to an array of known or perceived threats, landscape change has been identified as producing the "largest negative ecological and socio-economic impacts" including: habitat loss and fragmentation; permanent ecosystem destruction; increases in stormwater flows and flooding; skewed employments patterns and property values detrimental to older communities; traffic congestion; and public health impacts (NJDEP 2003).

In at least two basin states, recent reports recommend a focus on green, walkable (more compact—greater density) communities to reduce loss of natural lands and decrease traffic and vehicular trips while correspondingly improving air quality and public health. To date, no significant policy actions have been taken to advance this goal and amend the historic trends in land development.

Development patterns are affected by regulatory and economic forces. While the regulation of land use—how densely and for what uses land can be developed—remains delegated to local governments and largely uncoordinated across watersheds and states and effectively independent of broad transportation and environmental policies and state-wide programs, other economic factors may provide an impetus to change. Among them are higher energy costs—for gasoline in particular—and changing demographics—increased cohort of healthy retirees—which may create a resurgence of demand for urban living, the subsequent revitalization of older communities, and a reduced pressure to convert forest and field to buildings and asphalt. Anecdotal reports on housing and population trends from some cities, including Philadelphia, support this as a potential future trend in land use change.

In addition to the influence of population growth, economic development and climate on land use (see Section 2.4) emerging energy and industry trends may prove to have significant impact on the character of the landscape and possibly on the water resources of the basin. Marcellus shale, a geologic formation more than a mile below the surface, holds a significant reserve of natural gas which recently has become economically viable to extract. Marcellus shale underlays nearly 5,000 square miles, or approximately 36% of the basin, almost exclusively in the Central and Upper Region watersheds. However, less than a third of that area is above the "northern structural front" (the boundary of the Ridge and Valley physiographic province) and thought to be viable. Evolving technologies are making extraction more efficient: horizontal drilling and hydraulic fracturing can be used to extract more gas from a larger supply area from a single well, and several wells on a single pad can significantly reduce the amount of landscape disturbance.

Landscape changes can be expected as multi-well pads, staging areas, water supply facilities, wastewater holding and transfer areas, access roads, pipelines and compressor stations are developed to access, extract and distribute the natural gas. The introduction of this new industry to the upper basin is expected to increase demand for both temporary and permanent housing, and may accelerate the conversion of seasonal housing for year-round use.

Both the Delaware River Basin Commission and New York State have prepared new regulations to address natural gas extraction via high volume hydraulic fracturing. While the regulations may differ and neither has been adopted, it is possible that the portion of the basin associated with New York City watersheds will be off limits from that activity. The extent and rate of natural gas development will be dependent on many variables, including market price, lease conditions, pipeline access and capacity, and the resource potential of other shale formations, such as the Utica.

3.5 Actions and Needs

- Coordinated geospatial data and technologies to better inform and assist local governments in land use decision making.
- Improved mapping, assessment and tracking of forested wetlands.
- Identification and mapping of forested areas critical to water resources and habitats – and incorporation into land use planning and regulation.
- Prioritization of areas for protection (see current work by The Nature Conservancy for the National Fish and Wildfe Foundation).
- Identification of areas where forest loss is occurring in each Region, and its cause.
- Public action to protect priority forested areas, especially headwaters, in the basin.
- Local ordinances to manage forested areas and protect and improve tree canopy.

3.6 Summary

Developed land increased in every watershed of the basin in the decade between 1996 and 2006; nearly 88 mi2 (227 km2) of land was converted in total. The greatest aggregate loss was in forest (nearly 50 mi2, 127 km2). The watersheds of the Upper and Lower Estuary, Schuylkill Valley, and Lower region watersheds experienced the greatest increases in developed land. Agricultural land also experienced a net loss in the basin, although the Upper region experienced an increased in cultivated and grasslands. While wetland loss has been calculated at nearly 19 mi2 (49 km2) this number is not particularly reliable due to the nature of satellite imagery, the failure to capture freshwater wetlands under tree canopy, and reflectance issues associated with coastal wetlands and water. The loss of forest area continues to be a concern, as land is cleared for agriculture or development. The arrival of natural gas extraction in the upper basin poses a potential threat to the basin's important forested headwaters.

4 – Impervious Cover

Data Sources and Processing

Impervious cover was calculated for each NOAA-CSC land cover classification based on conversion factors (percent impervious cover) provided by University of Delaware based on independent analysis from values modified from the published literature (Grieg, et al., Cloud). Assessment units were summed to watershed groups and to regions. The conversion factors are shown in Table 1.4.1. The factors that have been applied for this analysis are reasonable, but are general and may over or under estimate the amount of impervious surface in any given watershed. Imperviousness is based on land cover and is more accurately determined for developed landscapes, and more problematic when estimated for "undeveloped" land cover, such as farm field, grasslands, and forests. Several attributes other than land cover, soil health and compaction, type of vegetation, and underlying geology, for example—can affect the functional degree of imperviousness. The results of this evaluation are best used as relative differences of imperviousness across the watersheds of the basin, rather than as precise estimates of the aerial extent of impervious cover.

4.1 Description of Indicator

Impervious cover comprises features on the ground which prevent water from infiltrating into the ground, and cause that water to run off to adjacent areas. Imperviousness is a measure of the degree to which an area of the ground is covered by such features, which include rooftops, asphalt or concrete paving, and other hard, impermeable surfaces. Locations with a high degree, or percentage, of imperviousness disrupt the normal hydrologic cycle, in which a portion of water from precipitation percolates into the ground, eventually recharging the water table. Impervious cover hinders a landscape's ability to capture, filter, store, and infiltrate water, and results in an increase in the amount of pollutants which enter streams and other waterbodies. A measure of imperviousness is therefore an indication of the overall health of a watershed. A high percentage of impervious cover leads to more polluted waters, and streams which flood more during storms and flow less during dry times, relative to more natural areas, such as forests or meadows. An example of a high impervious factor is a paved roadway or a parking lot.

Table 1.4.1. Impervious Cover Factor by Land Cover Type

CSC code	CSC_class	I.C. factor
2	High Intensity Developed	0.85
3	Medium Intensity Developed	0.6
4	Low Intensity Developed	0.3
5	Open Spaces Developed	0.08
6	Cultivated Land	0.02
7	Pasture/Hay	0.02
8	Grassland	0.02
9	Deciduous Forest	0.02
10	Evergreen Forest	0.02
11	Mixed Forest	0.02
12	Scrub/Shrub	0.02
13	Palustrine Forested Wetland	0
14	Palustrine Scrub/Shrub Wetland	0
15	Palustrine Emergent Wetland	0
16	Estuarine Forested Wetland	0
17	Estuarine Scrub/Shrub Wetland	0
18	Estuarine Emergent Wetland	0
19	Unconsolidated Shore	0.1
20	Bare Land	0.1
21	Water	0
22	Palustrine Aquatic Bed	0

Source: University of Delaware

A survey of 225 publications compiled by the Center for Watershed Protection assessing the correlation of imperviousness to stream health and aquatic life condition links impervious cover to a variety of impacts, which become detrimental when the percentage becomes high enough (usually when imperviousness is between 3 and 10% of the total area). These impacts include, among others:

- Reduced macroinvertebrate and fish diversity
- Decline in biological function
- Increase in stream temperature
- Decline in channel stability and fish habitat
- Compromised wetlands water quality and water level fluctuation

Impervious cover can also exacerbate the "heat island" effect—the phenomenon in which urban regions experience warmer temperatures than their rural surroundings.

See http://www.epa.gov/heatisld/resources/pdf/BasicsCompendium.pdf for additional information on urban heat islands.

Important Caveat

"When evaluating the direct impact of urbanization on streams, researchers have emphasized hydrologic, physical and biological indicators to define urban stream quality. In recent years, impervious cover (IC) has emerged as a key paradigm to explain and sometimes predict how severely these stream quality indicators change in response to different levels of watershed development . . .

Quite simply, the influence of IC in the one to 10% range is relatively weak compared to other potential watershed factors, such as percent forest cover, riparian continuity, historical land use, soils, agriculture, acid mine drainage or a host of other stressors. Consequently, watershed managers should never rely on IC alone to classify and manage streams in watersheds with less than 10% IC. Rather, they should evaluate a range of supplemental watershed variables to measure or predict actual stream quality within these lightly developed watersheds."

(Center for Watershed Protection, 2003).

4.2 Present Status

Based on values for each land cover types (see Table 1.4.1), the total amount of impervious cover has been estimated for each watershed group, as shown in Table 1.4.2. The Upper Estuary shows the highest percentage of impervious cover (18%), nearly twice that of the second-highest value, which is not surprising since these watersheds are also the most highly developed. The impervious cover values for each watershed group are compared in Table 1.4.2. See the more detailed discussion on impervious cover related to water quality in Chapter 5C. Note that the values for rates of imperviousness treated here have been derived from different data sources than those in Chapter 5.

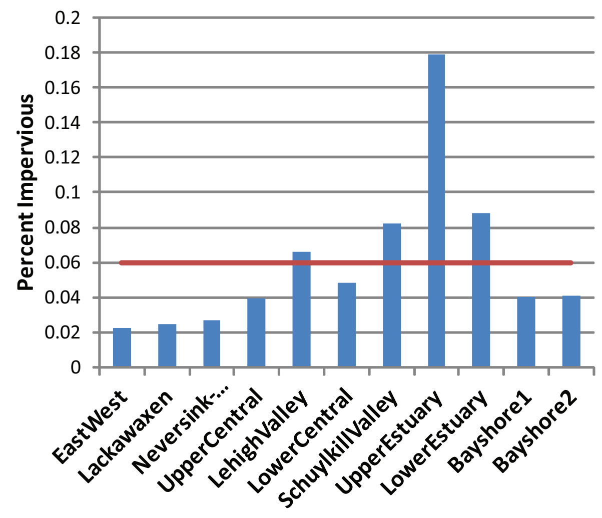


Fig. 1.4.1. Impervious Cover 2006 by Watershed

4.3 Past Trends

Impervious cover estimates were not calculated for past years. However, since developed land has steadily increased, impervious cover amounts could be expected to have increased proportionately.

4.4 Future Predictions

Since impervious cover is a direct result of development, impervious cover will continue to increase as developed land increases. This trend could be slowed through the increased use of permeable materials to replace impervious paving for roads and parking lots. In addition, the effects of impervious cover can be mitigated. Stormwater runoff from impervious surfaces can be intercepted for passive treatment, detention and/or infiltration. Increasing green areas—such as parks, and street trees—in urban areas can reduce the heat island effect of impervious cover.

Table 1.4.2. Impervious Cover by Watersheds and Regions, 2006.

	I.C. Km²	I.C. Mi²	% I.C.	Total Area Mi²	I.C. Hectares	I.C. Acres
Watershed Groups						
EastWest	116	45	2%	2,029	11,636	28,754
Lackawaxen	38	15	2%	597	3,801	9,394
Neversink-Mongaup	57	22	3%	816	5,727	14,151
Upper Central	157	61	4%	1,527	15,733	38,879
LehighValley	232	89	7%	1,360	23,165	57,244
Lower Central	57	22	5%	454	5,653	13,968
Schuylkill Valley	404	156	8%	1,891	40,418	99,880
Upper Estuary	809	312	18%	1,743	80,874	199,850
Lower Estuary	234	90	9%	1,021	23,354	57,710
Bayshore1(W)	66	26	4%	634	6,620	16,359
Bayshore2 (E)	83	32	4%	789	8,350	20,633
Regions						
UPPER	212	82	2.4%	3,443	21,164	52,299
CENTRAL	446	172	5.1%	3,341	44,551	110,092
LOWER	1446	558	12.0%	4,656	144,646	357,440
BAYSHORE	150	58	4.1%	1,424	14,970	36,992
ESTUARY	1596	616	10.1%	6,079	159,615	394,432
Basin						
	2253	870	6.8%	12,863	225,331	556,823

4.5 Actions and Needs

Calculations of impervious cover are most useful at scales smaller than those used for reporting here. The use of land use information with a finer resolution that satellite imagery would be a more robust source for useful impervious cover calculations at the community or catchment scale. Furthermore, since impervious cover is an indicator cause of several potential impacts, additional indicators should be developed to address the conditions most necessary to report.

- Impervious cover estimates at a finer resolution to be helpful at community-level planning & mitigation efforts.
- An indicator of urban "forest" and mitigation of the "heat island" effect, for example: ratio of tree canopy to impervious cover.

4.6 Summary

While impervious cover can be a useful indicator of both aquatic habitat condition and heat island issues in developed areas, reporting of the indicator should be at a scale suitable for informing planning, mitigation and remediation efforts.

5 – State and Federal Protected Land

5.1 Description of Indicator

Protected land is defined as federal, state, and local parks and conservation easements accessible to the public where urban and suburban development cannot occur. Watersheds with high amounts of protected land usually have healthier streams and habitat.

5.2 Present Status

According to data compiled by the Northeast Landscapes Initiatives Atlas and the Nature Conservancy, the Delaware Basin is covered by 2,160 mi^2 (5592 km^2) or 18% of the land area by federal, state, and local parks and conservation easements accessible to the public (Fig. 1.5.1).

Within the basin, protected land covers 15% of Delaware, 35% of Maryland, 36% of New Jersey, 30% of New York, and 15% of Pennsylvania (Table 1.5.1 and 1.5.2). The East/West Branch (NY), Christina Basin (DE/PA), and NJ Coastal Plain watersheds are covered by over 30% protected open space.

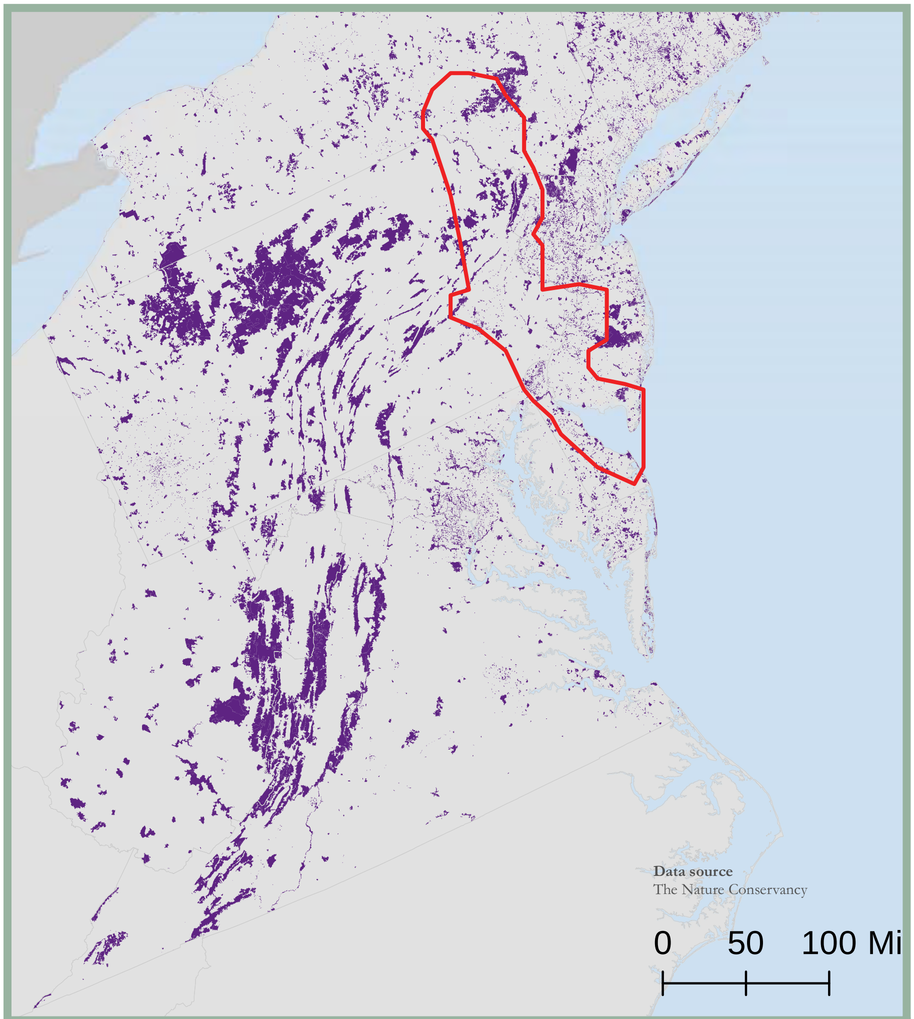


Figure 1.5.1 Location of local, state, and federal parks and conservation easements accessible to the public. Red outline shows the Delaware River Basin.

http://www.rpa.org/northeastlandscapes/images/openspace/834%20Open%20Space1.pdf

5.3 Past Trends

Protected open space data for is available only for 2010 and not for previous years. Therefore past trends are unavailable.

5.4 Future Predictions

Protected open space is projected to expand in the Delaware Basin as the federal, state, local, and nonprofit open space programs add to their inventories.

5.5 Actions and Needs

Each of the four basin states and the federal government should plan to achieve a goal of 20% protected land in the Delaware Basin by 2020 or a 2% increase from 2010. This increase would add 240 square miles (153,600 ac, 62160 ha) by 2020.

A strategic initiative should be established by the Delaware River Basin Commission and the Partnership for the Delaware Estuary to track open space inventory by GIS and recommend prioritized acquisition or conservation of land on a watershed basis.

5.6 Summary

According to data compiled by the Northeast Landscapes Initiatives Atlas and the Nature Conservancy, the Delaware Basin is covered by 2,160 mi^2 (5592 km^2) or 18% of the land area by federal, state, and local parks and conservation easements accessible to the public.

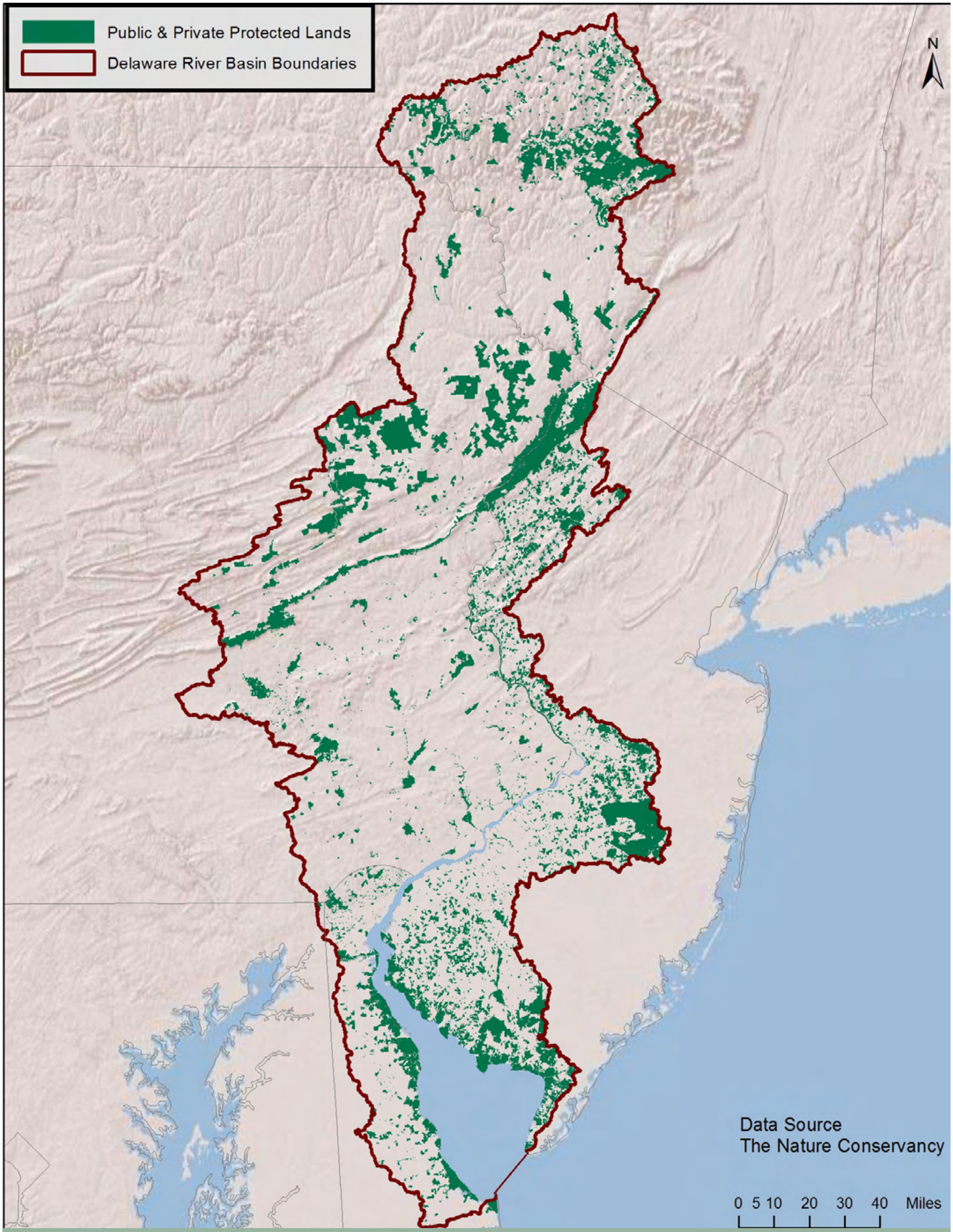


Fig. 1.5.2. Public and private lands in the Delaware River Basin

Table 1.5.1 Protected open space by county in the Delaware River Basin

State/county	Land Area[1] mi² (km²)
Kent	389 (1007)
New Castle	381 (986)
Sussex	195 (505)
Delaware	**965 (2498)**
Cecil	8 (21)
Maryland	**8 (21)**
Atlantic	
Burlington	495 (1282)
Camden	123 (318)
Cape May	104 (269)
Cumberland	490 (1269)
Gloucester	279 (722)
Hunterdon	215 (557)
Mercer	180 (466)
Monmouth	20 (52)
Morris	
Ocean	30 (78)
Salem	347 (898)
Sussex	320 (828)
Warren	358 (927)
New Jersey	**2,961 (7666)**
Broome	85 (220)
Chenango	
Delaware	1,295 (3353)
Greene	25 (65)
Orange	65 (168)
Schoharie	
Sullivan	940 (2434)
Ulster	145 (375)
New York	**2,555 (6615)**
Berks	777 (2012)
Bucks	607 (1572)
Carbon	381 (986)
Chester	616 (1595)
Delaware	184 (476)
Lackawanna	25 (65)
Lancaster	
Lebanon	20 (52)
Lehigh	347 (898)
Luzerne	50 (129)
Monroe	609 (1577)
Montgomery	483 (1250)
Northampton	374 (968)
Philadelphia	135 (350)
Pike	547 (1416)
Schuylkill	420 (1087)
Wayne	705 (1825)
Pennsylvania	**6,280 (16,259)**
Delaware Basin	**12,761 (33,038)**

1. NOAA CSC 2005. 2. The Nature Conservancy

Table 1.5.2. Protected open space by watershed in the Delaware River Basin

Watershed	Land Area[1] mi² (km²)
LE1 Brandywine/Christina	187 (484)
LE2 C&D Canal	152 (394)
DB1 Delaware Bay	626 (1621)
Delaware	**965 (2498)**
LE 1 Maryland	9 (23)
Maryland	**9 (23)**
UC2 NJ Highlands	745 (1929)
LC1 Del. R. above Trenton	159 (412)
UE2 New Jersey Coastal Plain	1,021 (2643)
LE3 Salem River	254 (658)
DB2 Delaware Bay	782 (2025)
New Jersey	**2,961 (7666)**
EW1 East Branch Del. R.	666 (1724)
EW2 West Branch Del. R.	841 (2177)
EW3 Del. R. above Pt. Jervis	314 (813)
NM1 Neversink R.	734 (1900)
New York	**2,555 (6615)**
EW3 Del. R. above Pt. Jervis	210 (544)
NM1 Neversink R.	82 (212)
LW1 Lackawaxen R.	598 (1548)
UC1 Pocono Mt.	779 (2017)
LV1 Lehigh River above Lehighton	451 (1168)
LV2 Lehigh River abv Jim Thorpe	430 (1113)
LV3 Lehigh River above Bethlehem	480 (1243)
LC1 Del. R. above Trenton	295 (764)
SV1 Schuylkill above Reading	338 (875)
SV2 Schuylkill above Valley Forge	649 (1680)
SV3 Schuylkill above Philadelphia	874 (2263)
UE1 Penna Fall Line	693 (1794)
LE1 Brandywine/Christina	401 (1038)
Pennsylvania	**6,280 (16259)**
Delaware Basin	**12,761 (33038)**

6 –Public Access Points

6.1 Description of Indicator

Public access points are publicly and privately owned land adjacent to the Delaware River and Bay that provide entrance for boaters, fishermen, and water-borne recreational activities.

6.2 Present Status

The States of Delaware, New Jersey, New York, and Pennsylvania; U.S. National Park Service; and private marinas own 150 public access points along 330 miles (531 km) of the Delaware River and Bay from Cape Henlopen, Delaware up to the Catskill Mountains of New York. This is a density of one access point for every 2 river miles (3.2 km).

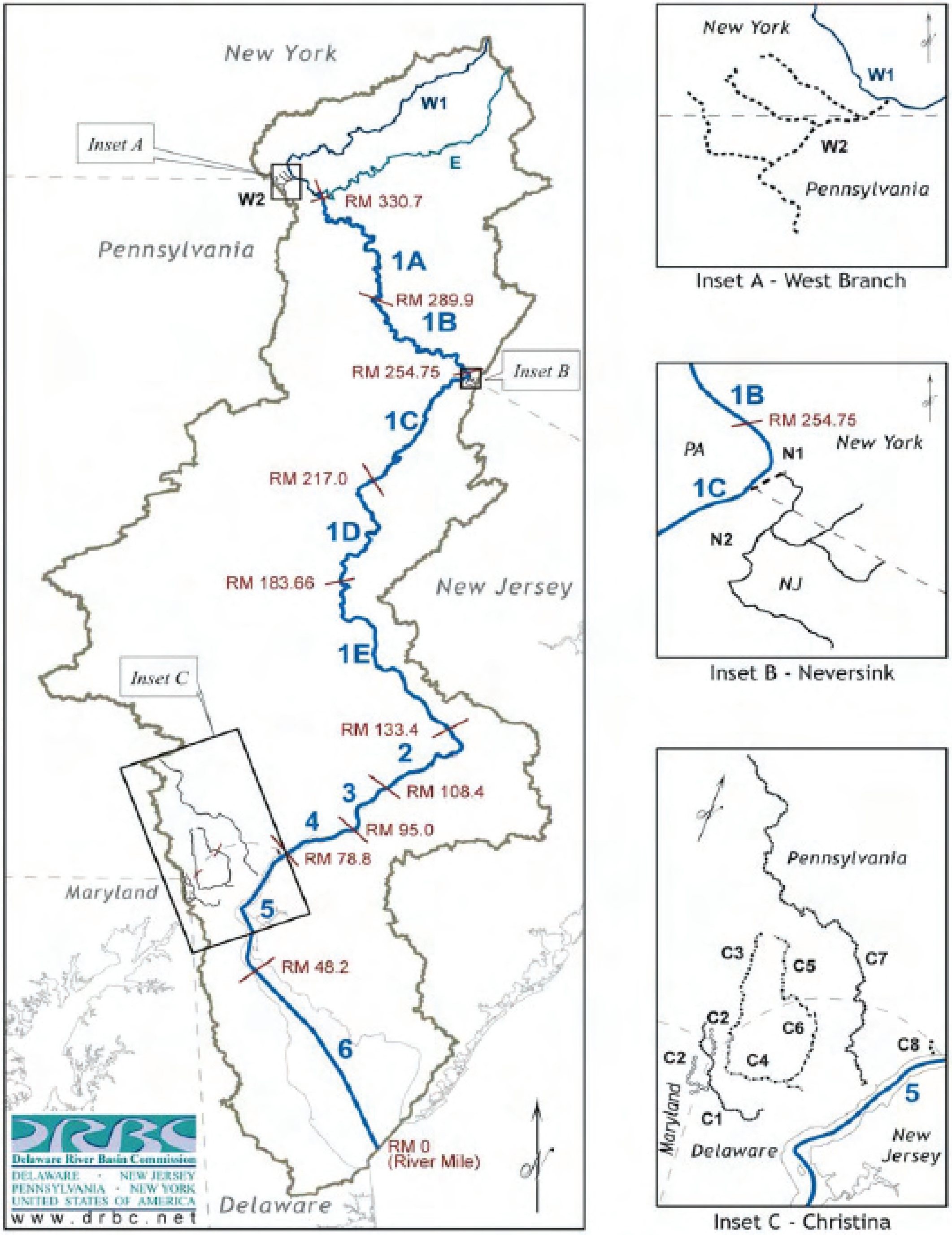


Fig. 1.6.1. Delaware River by river mile is used to locate public access sites (see Table 1.6.1).

Table 1.6.1. Delaware River and Bay Public Access Sites. (See map on previous page for locations)

River Mile	Location	State	County
1	Lewes Wildlife Mgmt. Area (DNREC DFW)	DE	Sussex
11	Cedar Creek Wildlife Mgmt. Area (DNREC DFW)	DE	Sussex
22	Bowers Beach Wildlife Mgmt. Area (DNREC DFW)	DE	Kent
29	Port Mahon Wildlife Mgmt. Area (DNREC DFW)	DE	Kent
41	Woodland Beach Wildlife Mgmt. Area (DNREC DFW)	DE	New Castle
44	Woodland Beach - Duck Creek Wildlife Mgmt. Area (DNREC DFW)	DE	New Castle
45	Collins Beach Wildlife Mgmt. Area (DNREC DFW)	DE	New Castle
49	NJDFW Mad Horse Creek WMA Stow Neck Rd. Canton	NJ	Cumberland
55	Augustine Beach Wildlife Mgmt. Area (DNREC DFW)	DE	New Castle
58	Fort DuPont Wildlife Mgmt. Area (DNREC DFW)	DE	New Castle
59	Penn Salem Marina Rte. 49 Salem	NJ	Salem
65	Pennsville Municipal Boat Ramp Riviera Dr.	NJ	Salem
81	Bridgeport Boat Yard (Raccoon Creek) 118 Ferry Lane	NJ	Gloucester
82	Chester Boat Ramp Commodore Barry Bridge	PA	Delaware
82	Chester City at Flower St	PA	Delaware
86	Anchorage Marina	NJ	Gloucester
86	Lagoon Marina	NJ	Gloucester
91	RiverWinds Point, West Deptford Township	NJ	Gloucester
93	West Deptford Mun. Boat Ramp Center St.	NJ	Gloucester
93	West Deptford Township	NJ	Gloucester
94	Fort Mifflin	PA	Philadelphia
95	William Hargrove Marina	PA	Philadelphia
95	West Creek Westville	NJ	Gloucester
99	Piers Marina	PA	Philadelphia
99	Penns Landing Corporation	PA	Philadelphia
99	Wiggins Park Camden	NJ	Camden
100	Pyne Point Marine Services 7th St. Camden	NJ	Camden
100	Philly Marine Center	PA	Philadelphia
104	NJDFW Pennsauken Boat Ramp Derousse Ave. Delair	NJ	Camden
105	Pennsauken	NJ	Camden
106	PFBC Frankford Arsenal Access 5600 Tacony St.	PA	Philadelphia
106	PFBC Frankford Arsenal	PA	Philadelphia
107	Palmyra Cove Nature Park	NJ	Burlington
108	PFBC Tacony Access Milner St.and Princeton Ave.	PA	Philadelphia
108	PFBC Tacony	PA	Philadelphia
110	Linden Ave at Pleasant Hill Park	PA	Philadelphia
110	Dredge Harbor Riverside	NJ	Burlington
110	Clarks Landing Marina	PA	Philadelphia
111	Lightening Jacks Marina 625 Harrison St. Riverside	NJ	Burlington
111	Philadelphia Boat Ramp Linden Ave.	PA	Philadelphia
111	Amico Island Riverside	NJ	Burlington
111	Lightning Jack's Marina	NJ	Burlington
111	Riverside Marina	NJ	Burlington
112	Hawks Island Marina 130 Rancocas Ave. Delanco	NJ	Burlington
112	Hawk Island Marina Delanco	NJ	Burlington
113	Station Avenue	PA	Philadelphia

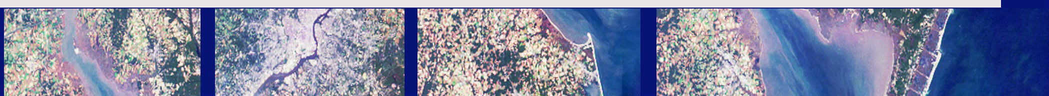


Table 1.6.1. Continued...

115	Neshaminy State Park Marina	PA	Bucks
115	Three Seasons marina	NJ	
116	Neshaminy State Park State Rd. and Cedar Ave. Bensalem	PA	Bucks
116	Neshaminy State Park	PA	Bucks
118	Curtin Marina E.Pearl Str. Burlington City	NJ	Burlington
118	Burlington City Boat Ramp Tathem Ave and Pearl St.	NJ	Burlington
118	Burlington	NJ	Burlington
118	Curtin Marina Burlington	NJ	Burlington
119	Bristol	PA	Bucks
122	D&S Boats and Marina Florence	NJ	Burlington
123	Florence	NJ	Burlington
128	Bordentown	NJ	Burlington
129	Bordentown Beach Park St.	NJ	Burlington
131	Trenton	NJ	Mercer
131	Ross Marina Trenton	NJ	Mercer
132	Trenton Waterfront Park	NJ	Mercer
133	Trenton Waterfront Park 1595 Lamberton Rd. off Rte. 29	NJ	Mercer
133	Welcome Park, Morrisville	PA	Bucks
133	W Mercer County's Roebling Park	NJ	Mercer
135	Ferry Road, Morrisville	PA	Bucks
138	PFBC Yardley Access Rte. 32, north end Yardley Boro.	PA	Bucks
147	Firemans Eddy Rte. 29, 1.8 mi. south Lambertville/New Hope Br.	NJ	Mercer
149	D&R Canal State Park Lambertville Bridge St.	NJ	Hunterdon
154	Virginia Forest Recreation Area Rte. 32	PA	Bucks
155	D&R Canal Park Byram Rte. 29, 3.4 mi. north of Stockton	NJ	Hunterdon
156	D&R Canal State Park Bulls Island Rec. Area	NJ	Hunterdon
163	Tinicim Park Rte. 32, Erwinna	PA	Bucks
164	NJDFW Ringwood Access Rte. 29, 1 mi. below Frenchtown	NJ	Hunterdon
168	PFBC Upper Black Eddy Access Rte. 32, below Milford Bridge	PA	Bucks
174	NJDFW Holland Church River Rd., 1 mi. south of Riegelsville bridge	NJ	Hunterdon
174	PFBC Reigelsville Access Rte. 611 north of Rte. 212	PA	Bucks
177	Frys Run Park Rte. 611, 6 mi. south of Easton	PA	Northampton
178	Theodore Roosevelt Recreation Area Rte. 611, 1 mi. south Raubsville	PA	Northampton
181	Wi-Hit-Tuk County Park Holmes Drive, 3 mi. south of Easton	PA	Northampton
183	Scott Park Boat Ramp Easton Rte. 611,mouth of Lehigh River	PA	Northampton
184	Phiilipsburg Boat Ramp Riverside Way, by free bridge	NJ	Warren
186	Northampton County Park Frost Hollow Rte. 611, 2.3 mi. north	PA	Northampton
189	Martins Creek PP&LRte. 611, 5.2 mi above Easton bridge	PA	Northampton
189	PFBC Sandts Eddy Access Rte.611, 5.2 mile above Easton bridge	PA	Northampton
197	NJDFW Belvidere Access Downstream from Belvidere bridge	NJ	Warren
198	Northampton Co. Park Doe Hollow River Rd. u.s. f Belvidere bridge	PA	Northampton
212	DWGNRA Kittatinny Beach Del. Water Gap below I-80 bridge	NJ	Warren

Table 1.6.1. Continued...

216	Worthington State Forest Old Mine Rd., 4 mi. north of I-80	NJ	Warren
218	DWGNRA Smithfield Beach River Rd.,3 mi.north of Shawnee	PA	Warren
220	DWGNRA Poxono Old Mine Rd., 8 mi. north of Del. Water Gap	NJ	Warren
222	DWGNRA Depew Old Mine Rd., 9.3 mi. north of Del. Water Gap	NJ	Warren
227	DWGNRA BushkillRte. 209, 1 mile north of Bushkill	PA	Pike
232	DWGNRA Eshback Rte. 209 mile markers 6 and 7	PA	Pike
239	DWGNRA Dingmans Ferry Toute 739 at Dingmans Bridge	PA	Pike
246	DWGNRA Milford Beach Rte. 209, 0.2 miles north of Rte. 206 bridge	PA	Pike
254	Tri-States Monument Pt. Jervis I-84 bridge	NY	Orange
255	West End Beach, Port Jervis	NY	Orange
258	Deerpark north of junction Routes 97 and 42. Sparrowbush	NY	Sullivan
258	UDSRRA DWGNRA Sparrowbush	NY	Sullivan
259	Sparrowbush	NY	Sullivan
260	Monguap	NY	Sullivan
261	UDSRRA DWGNRA Mongaup Access	NY	Sullivan
267	Buckhorn Natural Area	PA	Sullivan
272	UDSRRA NPS Barryville Office	NY	Sullivan
273	National Park Service Barryville Office	NY	Sullivan
274	Highland. Route 97 1.5 miles west of Barryville.	NY	Sullivan
274	UDSRRA Highland	NY	Sullivan
277	UDSRRA Lackawaxen	PA	Wayne
278	Lackawaxen	PA	Wayne
278	Lackawaxen	PA	Wayne
282	Ten Mile River	NY	Sullivan
282	Highland	NY	Sullivan
282	Highland	NY	Sullivan
283	UDSRRA Ten Mile River	NY	Sullivan
290	Narrowsburg Race Course Road (Co Rte 24) to DeMauro Lane	NY	Sullivan
290	UDSRRA Narrowsburg, NY	NY	Sullivan
290	UDSRRA Narrowsburg, PA	PA	Wayne
290	Narrowburg,NY	NY	Sullivan
290	Narrowburg, PA	PA	Wayne
295	UDSRRA Skinners Falls	NY	Sullivan
296	Skinners Falls	NY	Sullivan
297	Milanville, PA	PA	Wayne
298	UDSRRA Damascus	PA	Wayne
299	Cochecton off Route 97 on Skinners Falls Road	NY	Sullivan
299	Damascus, PA	PA	Sullivan
304	Off Route 97 Callicoon,	NY	Sullivan
304	UDSRRA Callicoon, NY	NY	Sullivan
304	UDSRRA Callicoon, PA	PA	Wayne
304	Callicoon, NY	NY	Sullivan
304	Callicoon,PA	PA	Wayne
305	Kellams, Little Equinunk Creek	NY	Sullivan

Table 1.6.1. Continued...

310	Hankins	NY	Sullivan
311	UDSRRA River Estaamground	NY	Sullivan
312	Basket Creek at Basket Creek	NY	Sullivan
315	UDSRRA Long Eddy Access	NY	Sullivan
315	Long Eddy	NY	Sullivan
322	UDSRRA Lordville Access	NY	Delaware
323	Lordville	NY	Delaware
325	UDSRRA Buckingham Boat Access	NY	Delaware
325	Buckingham	PA	Wayne
330	Hancock Bard Parker Rd, south edge of Village off Rte. 97	NY	Delaware
330	UDSRRA Hancock Access	NY	Delaware
330	Hancock	NY	Delaware
W. Br.	Airport Rd. south edge of Deposit, ½ mi from Rte. 17	NY	Delaware
W. Br.	Hale Eddy Rte. 58 off Rte. 17, 6 ½ mi. west of Hancock	NY	Delaware
E. Br.	UDSRRA Balls Eddy Access	NY	Delaware

New Jersey Division of Fish and Wildlife (NJDFW)
Pennsylvania Fish and Boat Commission (PFBC)
Delaware Water Gap National Recreation Area (DWGNRA)
Upper Delaware River Scenic and Recreational Area (UDSRRA)
Delaware Department of Natural Resources and Environmental Control (DNREC) Division of Fish and Wildlife (DFW)

6.3 Past Trends

Past data is not available to establish trends.

6.4 Future Predictions

Federal, state, local, and nonprofit agencies will continue to acquire public access points along the Delaware River and Bay.

6.5 Actions and Needs

Public access points should be acquired to achieve a density of one site per mile compared to the present 2 sites per mile along the Delaware River and Bay. Gaps where public river access sites should be acquired include:

* Between RM 1 and 11 (Lewes to Cedar Creek)
* Between RM 11 and 22 (Bowers Beach)
* Between RM 29 and 41Woodland Beach)
* Between RM 65 and 81 (Chester)
* Between RM 138 and 147 ((Lambertville)
* Between RM 198 and 212 (Delaware Water Gap)
* Between RM 315 and 322 (Long Eddy)

6.6 Summary

The States of Delaware, New Jersey, New York, and Pennsylvania; U.S. National Park Service; and private marinas own 150 public access points along 330 miles (531 km) of the Delaware River and Bay from Cape Henlopen, Delaware up to the Catskill Mountains of New York. This is a density of one access point for every 2 river miles (3.2km).

7 – Natural Capital Value

7.1 Description of Indicator

This section tabulates the economic value of the Delaware Estuary watershed as (1) market and nonmarket economic activity, (2) value of ecosystem goods and services, and (3) jobs and wages related to the watershed (Kauffman 2011).

7.2 Present Status

The natural resources of the Delaware Estuary watershed provide tremendous economic value such as:

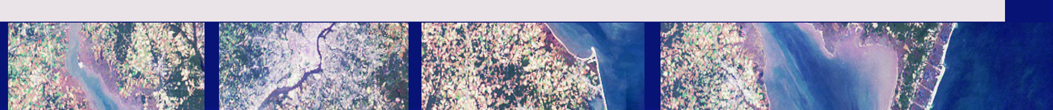
- **Through economic value directly related to the Delaware Estuary's water resources and habitats.** Using economic activity as a measure of value, we find that the Delaware Estuary contributes over **$10 billion** in annual economic activity from recreation, water quality and supply, hunting and fishing, forests, agriculture, and parks.

- **Through the value of the goods and services provided by the Delaware Estuary's ecosystems.** Using ecosystem goods and services as a measure of value, we find that the ecosystems of the Delaware Estuary provide **$12 billion** annually in goods and services in 2010 dollars ($2010), with a net present value (NPV) of **$392 billion** calculated over a 100-year period.

- **Through employment related to the Delaware Estuary's water resources and habitats.** Using employment as a measure of value, we find that the Delaware Estuary directly and indirectly supports over **500,000 jobs** with over **$10 billion** in wages annually. This does not include the thousands or even millions of jobs in companies and industries that rely on waters of the Delaware Estuary for their industrial and commercial processes.

Table 1.7.1. Ecosystem goods and services value of the Delaware Estuary

Economic Value	**$ million**
Market Value	**> 8 billion**
Water Quality	
Water Treatment by Forests ($62/mgd)	17
Wastewater Treatment ($4.00/1000 gal)	1,490
Increased Property Value (+8% over 20 years)	13
Water Supply	
Drinking Water Supply ($4.78/1000 gal)	1,333
Irrigation Water Supply ($300/ac-ft)	30
Thermoelectric Power Water Supply ($44/ac-ft)	298
Industrial Water Supply ($200/ac-ft)	140
Fish/Wildlife	
Commercial Fish Landings ($0.60/lb)	34
Fishing (11-18 trips/angler, $17-$53/trip)	334
Hunting (16 trips/hunter, $16-50/trip)	171
Wildlife/Bird-watching (8-13 trips/yr, $15-$27/trip)	306
Agriculture	
Crop, poultry, livestock value ($2,300/ac)	2,522
Maritime Transportation	
Navigation ($15/ac-ft)	221
Port Activity	2,400
Non-Market Value	**>2 billion**
Recreation (Boating, Fishing, Swimming)	
Swimming ($13.40/trip)	9
Boating ($30/trip)	47
Fishing ($62.79/trip)	52
Wildlife/bird watching ($77.73/trip)	104
Water Quality	
Willing to Pay for Clean Water ($38/nonuser-$121/user)	660
Forests	
Carbon Storage ($827/ac)	981
Carbon Sequestration ($29/ac)	34
Air Pollution Removal ($266/ac)	316
Building Energy Savings ($56/ac)	66
Avoided Carbon Emissions ($3/ac)	4
Public Parks	
Health Benefits ($9,734/ac)	1,057
Community Cohesion ($2,383/ac)	259
Stormwater Benefit ($921/ac)	100
Air Pollution Control ($88/ac)	9



Annual Economic Value

The Delaware Estuary watershed contributes over $10 billion in annual market and non-market value. Market value is determined by the sale/purchase of watershed goods such as drinking water, fish, or hunting supplies. Nonmarket value is provided by ecosystems such as pollution removal by forests, public willingness to pay for improved water quality, forest carbon storage benefits, and health benefits of parks. Note that totals are rounded down to avoid double counting (Table 1.7.1).

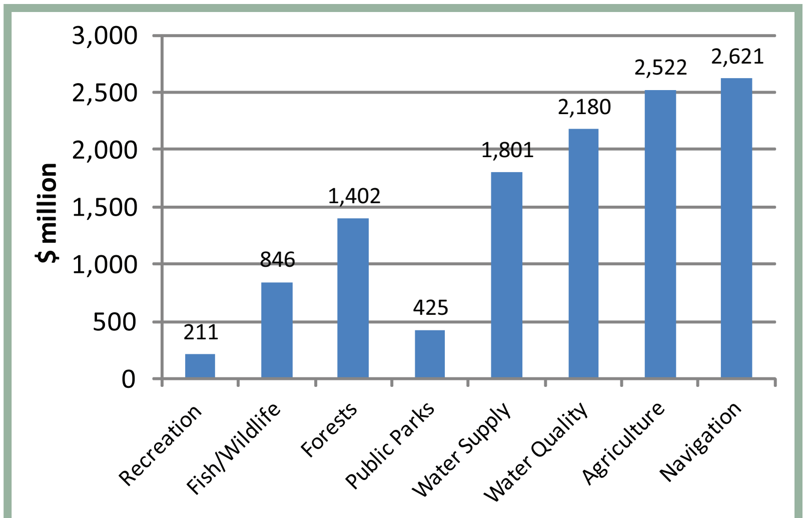


Fig. 1.7.1. Annual economic value of the Delaware Estuary watershed

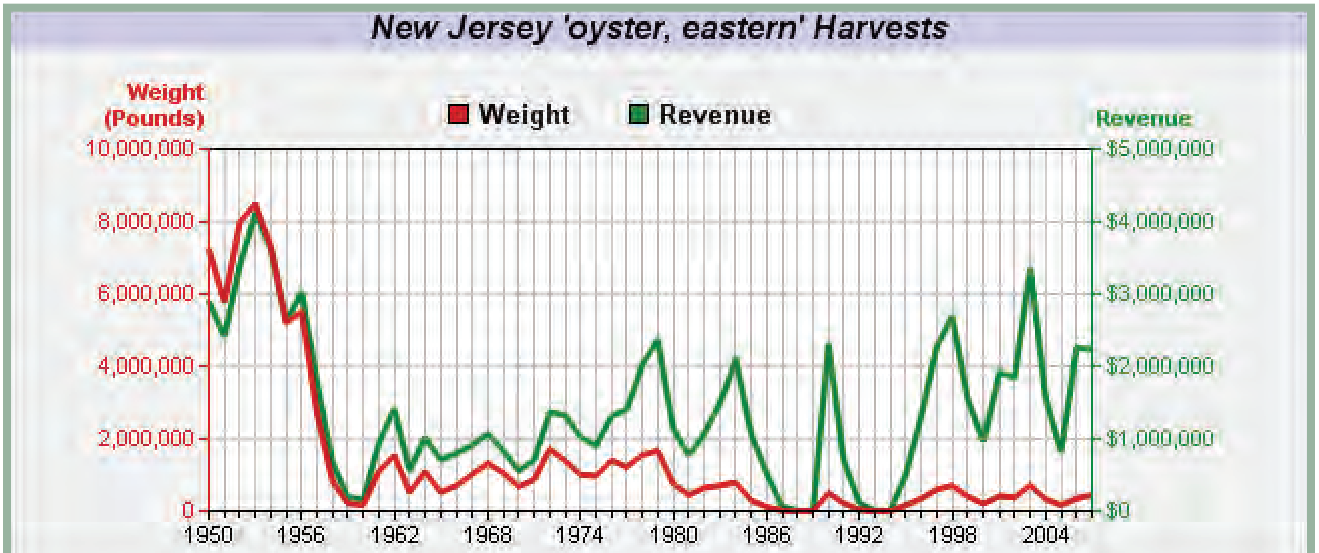


Fig. 1.7.2. New Jersey Eastern Oyster Harvests

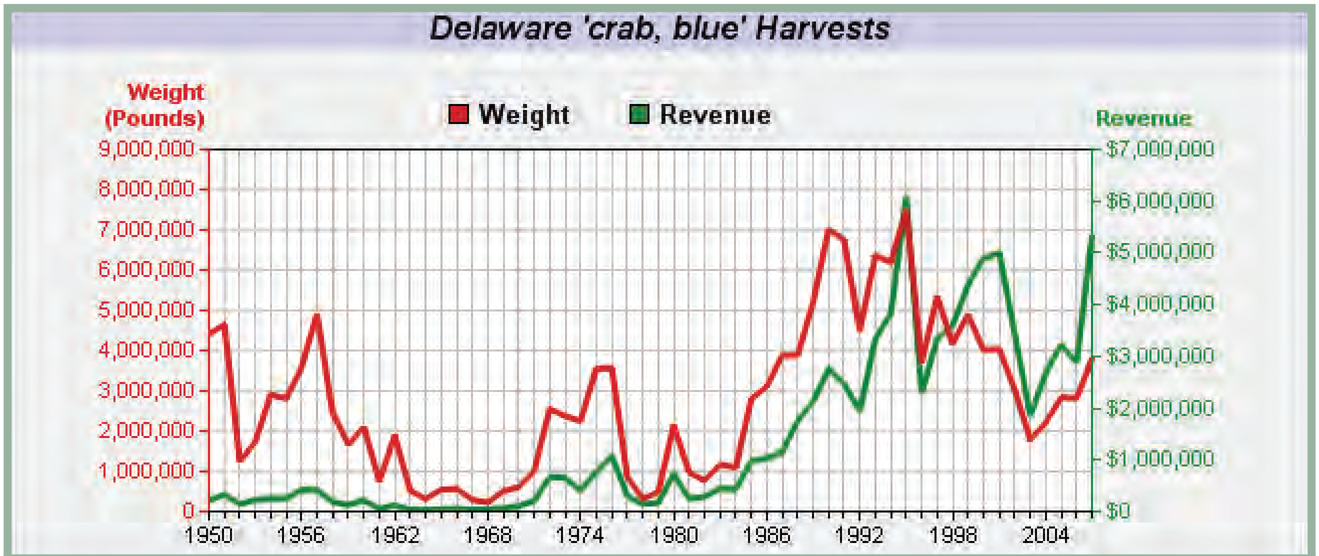


Fig. 1.7.3. Delaware Blue Crab Harvests

Ecosystem Services

The Delaware Estuary watershed is rich in natural resources and habitat as measured by the economic value of ecosystem goods and services. Ecosystem goods are benefits provided by sale of watershed products such as drinking water and fish. Ecosystem services are economic benefits provided to society by nature such as water filtration, flood reduction, and carbon storage. The value of natural goods and services from ecosystems in the Delaware Estuary watershed is $12 billion ($2010) with net present value (NPV) of $392 billion using a discount rate of 3% over in perpetuity (about 100 years) (Table 1.7.2). Ecosystem services by state include Delaware ($2.5 billion, NPV $81.9 billion), New Jersey ($5.3 billion, NPV 173.6 billion), and Pennsylvania ($4.1 billion, NPV $132.0 billion).

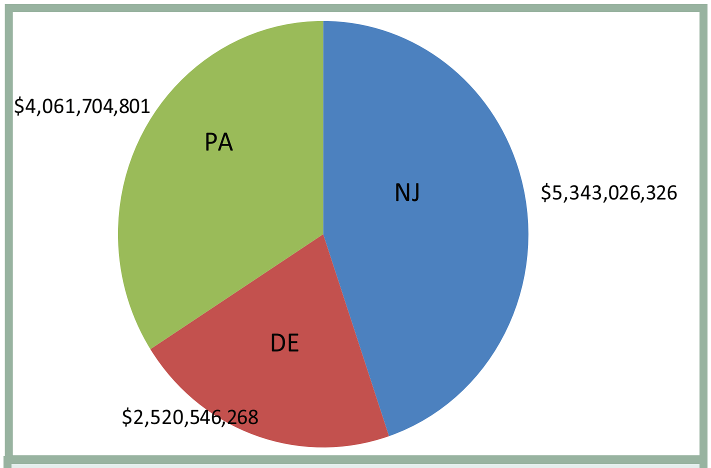


Fig. 1.7.4. Ecosystem services value in the Delaware Estuary watershed by state

The Delaware Estuary watershed is a jobs engine that supports over 500,000 direct and indirect jobs with $10 billion in annual wages in the coastal, farm, ecotourism, water/wastewater, recreation, and port industries. Note that total jobs and wages are rounded down to avoid double counting (Table 1.7.3).

Table 1.7.2. Ecosystem services value in the Delaware Estuary watershed

Ecosystem	Area ac	$/ac/yr 2010[1]	$/yr 2010	NPV million $
Freshwater wetlands	317,213 (128344)	13,621	4,320,647,087	140,421
Marine	16,588 (6712)	10,006	165,982,947	5,394
Farmland	1,112,580 (450,150)	3,215[2]	3,577,486,604	116,268
Forest land	1,186,784 (480,173)	1,978	2,347,605,465	76,297
Saltwater wetland	145,765 (58,977)	7,235	1,054,617,851	34,275
Barren land	18,630 (7538)	0	0	0
Urban	865,778 (350,294)	342	295,761,123	9,612
Beach/dune	900 (364)	48,644	43,758,633	1,422
Open water	131,388 (53,160)	1,946	255,655,983	8,308
Total	**3,795,626 (1,535,710)**		**12,061,000,000**	**391,999**

1. NJDEP 2004. 2. USDA 2009 Jobs and Wages

Table 1.7.3. Jobs and wages related to the Delaware Estuary watershed

Sector	Jobs	Wages ($ million)	Data Source
Direct Basin Related	192,785	4,280	U.S. Bureau of Labor Statistics (2009)
Indirect Basin Related	231,342	3,420	U.S. Census Bureau (2009)
Coastal	44,658	947	National Coastal Economics Program (20090
Farm	28,276	1,159	USDA Census of Agriculture (2007)
Fishing/Hunting/Birding	24,713	812	U.S. Fish and Wildlife Service (2008)
Water Supply Utilities	2,290	127	UDWRA and DRBC (2010)
Wastewater Utilities	1,021	51	UDWRA and DRBC (2010)
Watershed Organizations	150	8	UDWRA and DRBC (2010)
Port Jobs	12,121	772	Economy League of Greater Phila. (2008)
Delaware Estuary watershed	**> 500,000**	**>$10 billion**	

Jobs directly associated with the Delaware Estuary watershed (i.e. water/sewer construction, water utilities, fishing, recreation, tourism, and ports) employ 192,785 people with $4.3 billion in wages:

- Delaware (15,737 jobs, $340 million wages)
- New Jersey (52,007 jobs, $1.1 billion wages)
- Pennsylvania (125,041 jobs, $2.8 billion wages)

Jobs indirectly related to the waters of the Delaware Estuary watershed (based on multipliers of 2.2 for jobs and 1.8 for salaries) employ 231,342 people with $3.4 billion in wages in:

- Delaware (18,884 jobs, $270 million wages)
- New Jersey (62,408 jobs, $0.9 billion wages)
- Pennsylvania (150,049 jobs, $2.2 billion in wages)

The National Coastal Economy Program (2009) reports coastal employment in the Delaware Estuary watershed provides 44,658 jobs earning $947 million in wages in:

- Delaware (12,139 jobs, $214 million wages)
- New Jersey (4,423 jobs, $140 million wages)
- Pennsylvania (28,096 jobs, $593 wages).

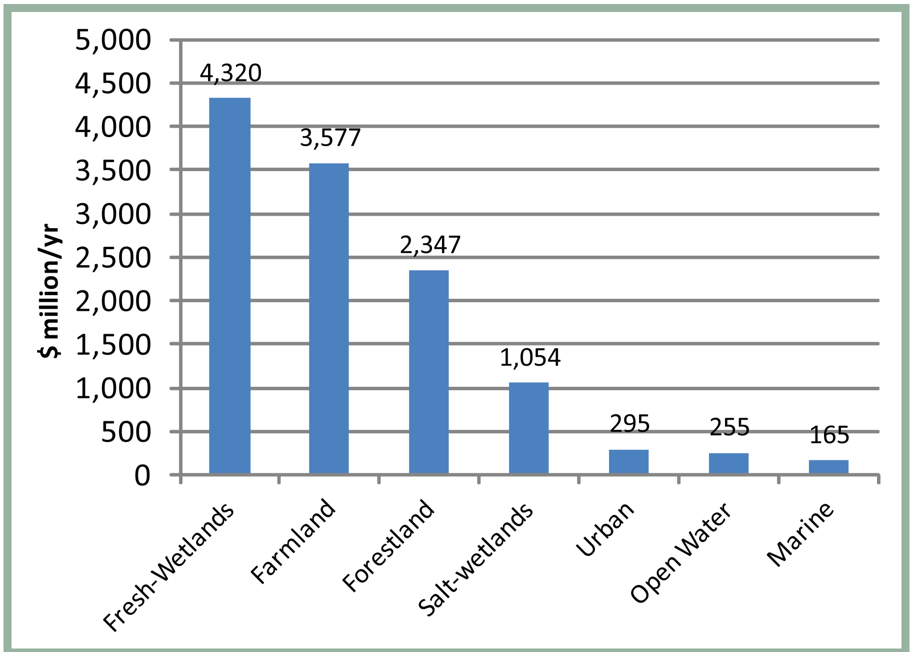


Fig. 1.7.6. Value of ecosystem services in the Delaware Estuary Watershed

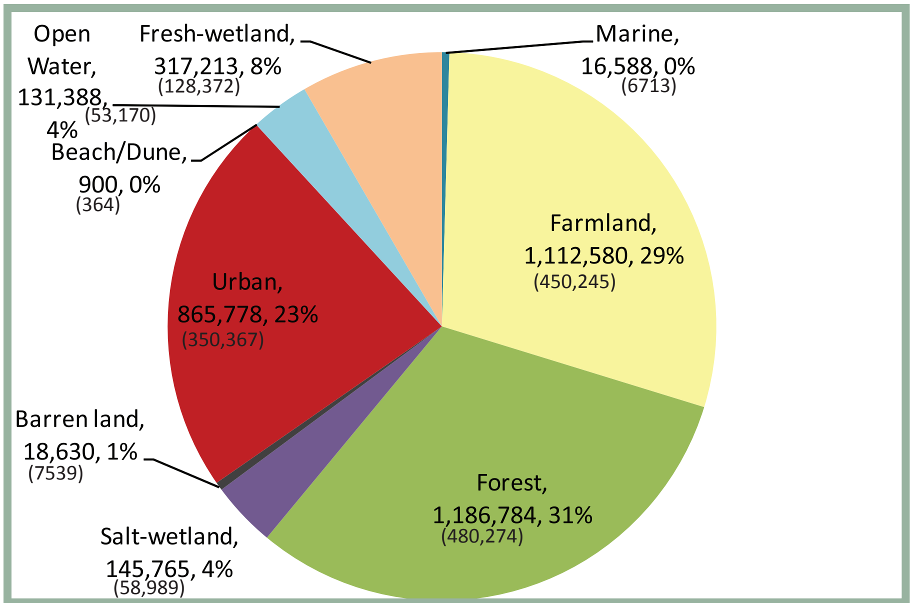


Fig. 1.7.7. Ecosystem acres (ha) in the Delaware Estuary Watershed, 2005

Table 1.7.4. Jobs and wages in the Delaware Estuary watershed by state.

Sector	DE Jobs	NJ Jobs	PA Jobs	DE Wages ($M)	NJ Wages ($M)	PA Wages ($M)
Direct Basin Related	15,737	52,007	125,041	340	1,100	2,800
Indirect Basin Related	18,884	62,408	150,049	270	900	2,200
Coastal	12,139	4,423	28,096	214	140	593
Farm	3,289	8,287	16,700	135	340	685
Fishing/Hunting/Birding	4,092	11,365	9,256	134	373	304
Water Supply Utilities	126	509	1,654	7	28	92
Wastewater Utilities	106	215	700	5	11	35
Delaware Estuary watershed	**54,373**	**139,214**	**331,496**	**1,105**	**2,892**	**6,709**

7.3 Past Trends

Based on recent forest loss estimates from section 3.3 of this chapter, if the basin lost 31,471 acres of forest from 1996-2006, then the loss in ecosystem services value is $62 million over 100 years at $1,978 per acre.

7.4 Future Predictions

The economic value of the Delaware Estuary and Basin may increase with improved water quality and habitat.

7.5 Actions and Needs

Continued investment is needed to support the multi-billion dollar economic value of the Delaware Estuary and Basin.

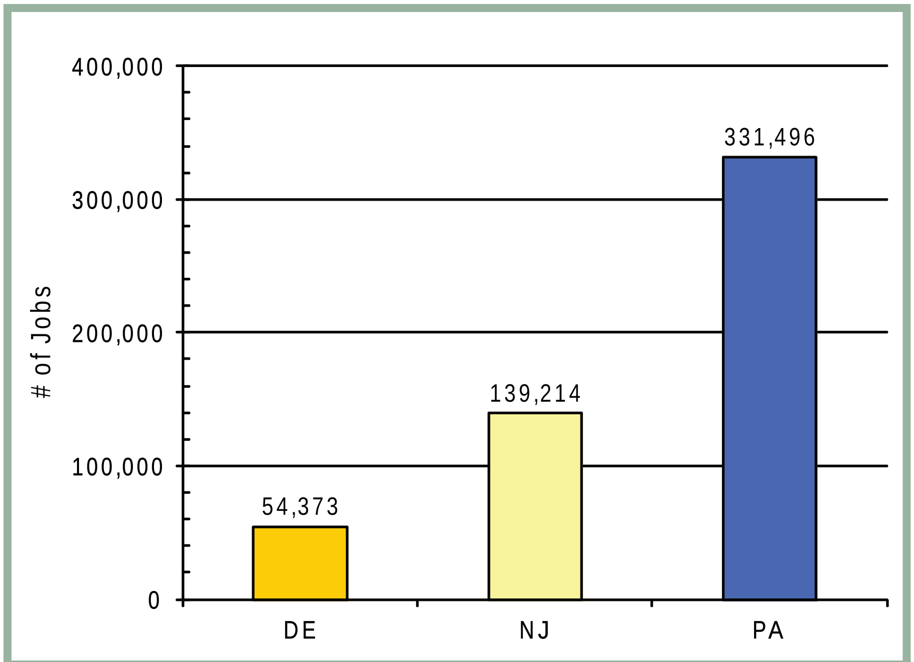


Fig. 1.7.8. Wages from jobs related to the Delaware Estuary watershed

7.6 Summary

The natural resources of the Delaware Estuary watershed provide tremendous economic value such as (a) $10 billion in annual economic activity from recreation, water quality and supply, hunting and fishing, forests, agriculture, and parks; (b) ecosystems goods and services value of $12 billion annually ($2010); and (c) direct and indirect support of over 500,000 jobs with over $10 billion in wages annually.

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