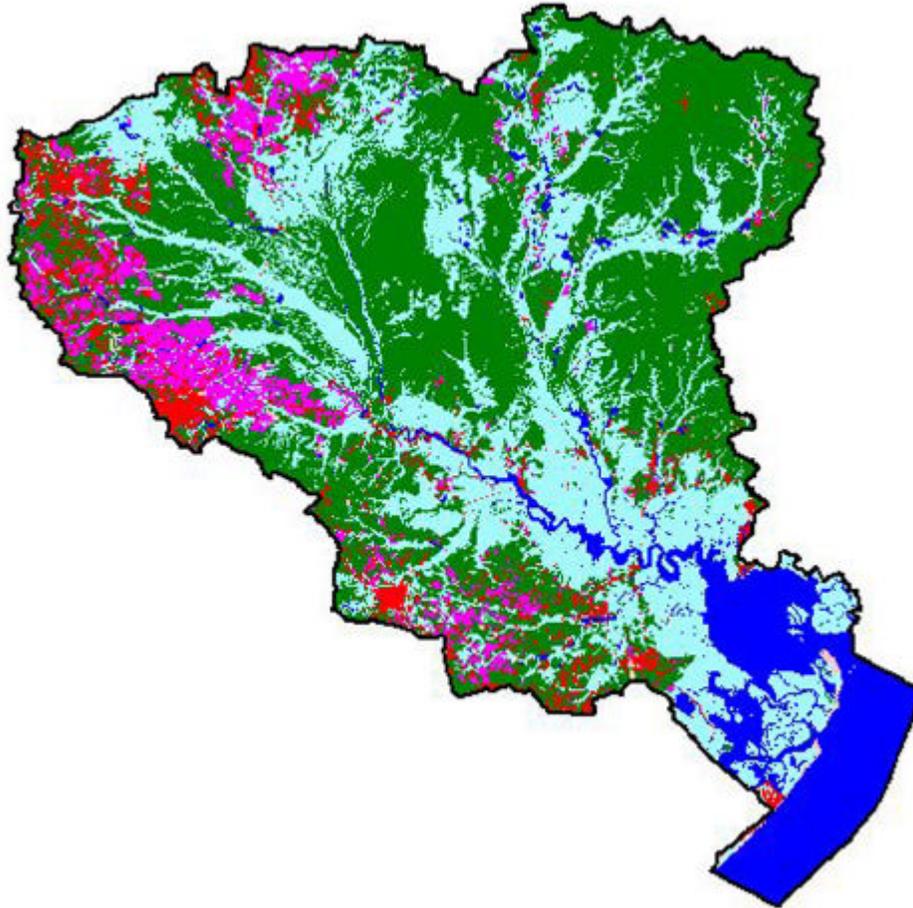


Changing Land Use in the Mullica River Watershed: Past and Future Trends.
1986 - 1995 - 2000 - Buildout



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ABSTRACT

The Mullica River Watershed is located in the Pinelands ecosystem and currently contains a high percentage of unaltered land. However, due to its close proximity to the Atlantic City, Philadelphia, and New York City metropolitan areas there is great potential for further development. We were interested in determining the potential impact of past and future development on water resources. The project has three parts: (1) identifying past land use; (2) determining the potential of future development; and (3) using indicators to assess the impacts of the past and potential future development on water demand and urban non-point source pollution. While there is currently little development in the watershed, our analysis indicates that a substantial portion of the land is available for future development. However, if growth is limited to the designated Pinelands' growth areas, the impacts to water resources will be minimized.

INTRODUCTION

The Mullica River Watershed, located in southeastern New Jersey (Figure 1), is part of the Pinelands ecosystem. The Pinelands are characterized by highly sandy acidic soils, a frequent fire regime, and a pine-oak dominated upland forest. Approximately 940,000 acres in size, the Pinelands stretch from the northern reaches of Ocean County to Cape May County. The Pinelands became the first National Reserve in 1978 and received international attention in 1983 when it was designated as an International Biosphere Reserve. Today, the Pinelands Commission regulates new development within the administrative boundaries of the New Jersey Pinelands Management Areas, approximately two-thirds of the Pinelands region. Eighty-two percent of the 420,000 acre Mullica River Watershed is within the Pinelands Management Areas. However, much of the watershed is potentially prime residential and commercial land due to the close proximity of Atlantic City, Philadelphia, and New York City.

Additional development would not only alter the terrestrial ecosystem, but also has the potential to negatively impact groundwater and the downstream estuary.

The goal of this project was to identify land use trends and determine the potential impact of past and future development on water resources. There were three parts to the analysis. First, past land use was identified from existing datasets and updates completed using satellite imagery. Second, future growth potential was determined through a build-out analysis, based on the location

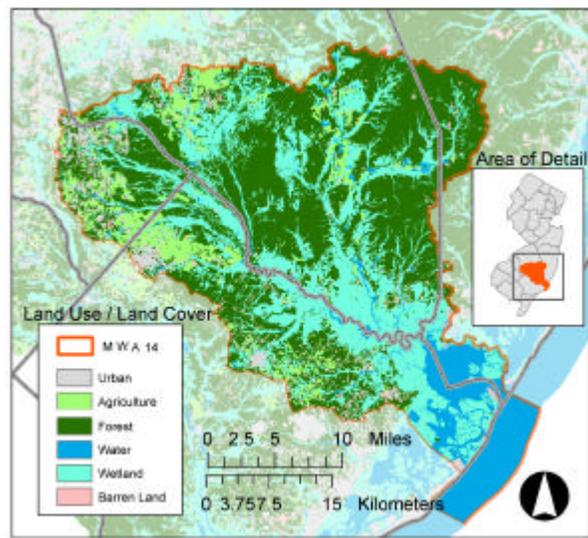


Figure 1. WMA 14 NJDEP Land Use / Land Cover 1995.

of existing development, permanently protected open space, and applicable regulations. Several different scenarios were examined, including low constraint and high constraint analyses. The third part of the project examined the potential impacts past and future urban development might have on water resources using the number of dwelling units and population as indicators of residential water demand and impervious surface as an indicator of urban non-point source pollution. By understanding potential changes in these indicators, we can better identify actions needed to protect the water resources of the Mullica River Watershed.

METHODS

To map land use and future developmental pressures in the Mullica River Watershed we used a Geographic Information System (GIS). GIS enables the creation, manipulation, and analysis of digital spatial data, allowing us to examine the location of past and future change. The Mullica River Watershed boundary used by the New Jersey Department of Environmental Protection (NJDEP) defined the spatial extent of the analysis.

Past Land Use

The NJDEP dataset of land use and land cover (LULC) was used to determine land use in 1986 and 1995 (Appendix 1). The LULC dataset is based on the interpretation of one meter color infrared photography, allowing a minimum mapping unit (MMU) of one acre and fine scale differentiations between LULC classes based on Anderson levels one through four. To update this dataset, we created a GIS data layer of land use in 2000, by comparing SPOT satellite panchromatic images (10 meter ground resolution cell) obtained in 2000 with the 1995 -1997 color infrared aerial photography flown by the United States Geological Service. Areas of change were on-screen digitized using ESRI GIS software. The large pixel size for the satellite sensor dictated a MMU of 1000 sq meters, approximately one quarter of an acre. A much simpler method was used to categorize altered or changed areas as compared to the NJDEP approach. Polygons were coded as urban, agriculture, or barren/ grassland. Urban areas identified included all new commercial and residential structures. Using only the satellite data, distinctions between multiple houses and single houses could be determined based on the relative size and shape of the development (Appendix 2), but differentiating between residential and commercial areas was not possible without ancillary data. New agriculture represents all new areas that are actively being farmed, determined by shape, size, and relative proximity to existing agriculture. Barren and managed grassland were grouped together because of the difficulty in differentiating between them using the satellite imagery (Appendix 2).

Build-out Analysis

Once we identified past land use, we were interested in examining the potential for future development. We used a build-out analysis to map potential future development across

the landscape under specific sets of constraints. The scope and location of future urban development is identified in this type of analysis, although timing of development is not predicted. The build-out was created using a grid environment, with a five-meter grid cell length, due to ease of computation. Appendix 1 lists the data layers used.

To locate developable land we excluded land already developed, wetlands, preserved open space, parcels with severed developmental rights, and buffer zones around water bodies and wetlands. The buffer zone width was determined based on our interpretation of NJDEP regulations and the Pinelands Management Plan. The buffer ranges from no buffer to 300 feet, depending on the size of the wetland, surrounding land uses, whether threatened or endangered species are present, and if the wetland is located within a Pinelands Management Area. The remaining land was assumed to be available for development in this analysis.

Four build-out scenarios were created:

1. Low constraint scenario (LC) representing current regulations. The current regulations included in this scenario were (1) limitation on development in wetlands or buffer zones around freshwater and tidal areas as specified under the NJDEP's Freshwater Wetlands and Coastal Programs, (2) municipal zoning regulations, and (3) Pinelands Area regulations.
2. High constraints scenario one (HC1) is the same as LC except that areas without sewer service are forced to have a minimum lot size of 3.2 acres. This lot size was chosen as the Pinelands Commission determined 3.2 acres was the smallest lot that could support a septic system without negative impacts in the region (Pinelands Commission 1982). This scenario does not take into account the Pinelands' pilot septic program that is testing new technologies that would make it possible to support septic systems on smaller lots. However, HC1 is similar to current activities guided by Executive Order 109 (Springer 2002), and the recently defeated Watershed Management Rules (NJDEP 2001a) meant to replace the temporary situation of the Executive Order.
3. High constraints scenario two (HC2) is the same HC1 with an additional constraint on the maximum impervious surface allowed based on the 2000 Coastal Zone Management Rules (NJDEP 2001b). These rules use the state planning designations to define limits on the maximum impervious surface in a given area (Table 2). Current centers and zone designations were included in the HC2 scenario. Only a small percentage of the watershed area (3%) is affected by the CAFRA rules because most of the watershed is in the Pinelands Management Area, which is not covered under these rules.
4. High constraints scenario three (HC3) is the same as the HC2 scenario except maximum impervious surface limits were applied using current and proposed town centers.

Table 2. Maximum impervious surface cover allowed in the CAFRA planning areas.

Planning Area	Maximum Impervious Surface Cover	Percent of Watershed in Each Planning Area
Metropolitan	80 %	0.02 %
Suburban, Sewer Service	30 %	0.87 %
Suburban, No Sewer Service	5 %	0.37 %
Rural	5 %	0.60 %
Environmentally Sensitive	3 %	2.18 %

*For the percent equation the total area of the Mullica River Watershed was 373,471 acres. Water areas were not included.

Indicator Analysis

To assess the impacts of future development on water resources, two indicators were used. The number of dwelling units and population were calculated as indicators of residential water demand, while impervious surface was used as an indicator of urban non-point source pollution. Indicator values for past conditions were calculated to compare with build-out estimates.

Dwelling Units and Population A growing population can negatively impact the region's water resources, as a larger population requires a larger supply of freshwater. We focused on residential water demand in this analysis because most land use conversions have been and are predicted to be from forest to residential uses. If the population continues to increase, the demand for potable freshwater could exceed the sustainable supply. Thus, it is important to understand the potential size of the population at build-out.

To determine the past population of the Mullica River Watershed census block data from 1990 and 2000 were used. The census block data were combined with the NJDEP LULC data for 1995. If the census block was completely within the Mullica River Watershed all of the population was counted. For census blocks that overlapped the watershed boundaries, a percentage of the population was added relative to the percentage of total residential area of the specific block that falls within the Watershed. For example, census block number 3879 has a 2000 population of 184 people. Eight-four percent of the residential areas of this census block in 1995 were located within the Watershed's boundaries, so 84.2 percent (155 people) of 182 people are considered within the watershed.

Build-out population estimates were based on the number of dwelling units. To estimate the number of dwelling units, areas that could be developed were combined with digital zoning density information supplied by the Pinelands Commission and the municipalities with land outside the Pinelands Management Areas (Appendix 1). We assumed that only 80 percent of the land in each polygon could be used for building lots to account for land needed for public infrastructure. While 80 percent is the value currently used by planners in the region (McKeon, 2001), it is likely that in areas with low density zoning a smaller

percentage of the land must be reserved for infrastructure. The building lot area was then divided by the maximum zoning density to determine the number of dwelling units per polygon. The number of dwelling units was then rounded down to reflect the impossibility of building a fraction of a dwelling unit. The number of predicted dwelling units was multiplied by the average number of people in a dwelling unit based on the 2000 census for the Watershed to determine the total predicted increase in population at build-out. Transfer of development rights, which could result in higher density development in certain areas, was not considered. However, the ability to transfer development rights does exist in the Pinelands Management Area, and may impact the density of future development.

In order to assess the validity of the build-out scenarios, the same methods used to calculate the number of dwelling units at build-out were applied to estimate dwelling units in 2000. The calculation was only completed for the census blocks that were completely within the Mullica River Watershed. The number of predicted dwelling units was then multiplied by average number of people per dwelling unit in 2000 (2.46 people per dwelling unit) to get an estimated population. This number was compared to the 2000 census numbers, and is discussed in the results section.

Impervious Surface When land is converted to urban uses, there are physical, chemical, and biological impacts on water quality (Zandbergen 1998). Impervious surface has been proposed as an accurate measure of non-point source pollution from urban run-off and a general indicator of watershed health (Soil Conservation Service 1975; Klein 1979; Arnolds and Gibbons 1996; Wang 2001). Impervious surface refers to streets, sidewalks, driveways, roofs, patios, and other impenetrable surfaces. Areas that are more intensely developed tend to have a larger percentage of impervious surface cover, contributing more non-point source pollution to the water in the watershed. Thus, impervious surface is an important environmental indicator of the intensity of human land use and closely correlates with water quality degradation and altered runoff patterns in urban and urbanizing areas (Novotny and Chesters 1981; Brown 1988; Driver and Troutman 1989; Ferguson and Suckling 1990; Arnold and Gibbons 1996; Charbeneau and Barrett 1998).

In compiling data from a number of watersheds, Arnold and Gibbons (1996) developed a set of impact thresholds: (1) less than 10 percent impervious surface cover can be considered non-impacted; (2) between 10 and 30 percent cover can be considered impacted; and (3) greater than 30 percent cover is generally considered degraded. While these thresholds should not be considered 'hard and fast' breakpoints, they do provide a useful guide in evaluating the comparative risk of water quality degradation at a watershed scale.

The NJDEP estimated impervious surface for 1986 and 1995 based on the LULC dataset. Build-out estimates were determined by calculating the average amount of land covered by impervious surface for each zone. There is an inverse relationship between lot size and the percent of the lot covered by impervious surface. However, large lot development creates more per capita impervious cover. For the largest lot size (70 acres) the impervious surface cover was estimated at one percent, while the smallest lot size

(0.08 acres) had an average impervious cover of 43 percent. The average amount of impervious surface by zoning density was applied to the build-out scenarios to determine the potential impervious surface at build-out.

RESULTS

Past Land Use

Table 3 shows land use in 1986, 1995, and 2000. A total of 370,571 acres, 88 percent of the watershed, was in a natural or unaltered state in 1986, making the Mullica River Watershed one of the most pristine watersheds in New Jersey. Since 1986, little change has occurred on the unaltered lands. Although 2,400 acres of forest and 300 acres of wetlands were lost between 1986 and 2000, this represents only 0.7 percent of the total watershed. Of this loss, most conversions from natural to altered land were from forest to urban land uses.

Table 3. Land use/ land cover in 1986, 1995, and 2000.

Land Cover	Acres 1986	Acres 1995	Acres 2000	Percent change 1986 to 2000
Agriculture	25,753	24,358	24,389	-5.3 %
Barren Land	2,666	2,459	2,799	+5.0 %
Forest	188,988	187,735	186,581	-1.3 %
Urban	20,926	23,824	24,736	+18.2 %
Water	46,311	46,444	46,441	-0.2 %
Wetlands	135,276	135,096	134,970	-0.3 %

Traditionally the Pinelands were thought of as a wasteland due the poor nutrient content and high acidity of the soil which hindered agricultural efforts. Today specialized agriculture exists mainly through the domestication and cultivation of indigenous plant species (cranberry and blueberry) that are adapted to these adverse conditions. In 1986, 25,753 acres of land in the Mullica River Watershed were actively being farmed, approximately six percent of the total watershed. Agriculture decreased by 1,395 acres between 1986 and 1995. Most of the land was converted to forest, with approximately 54 percent left fallow. Forty-three percent of the converted agriculture can be attributed to urban and commercial growth. It is difficult to accurately quantify the change in agricultural land between 1995 and 2000 due to the nature of satellite land use updates. Never the less, it appears that the loss of farmland may be slowing, with an increase of 30 acres of farmland between 1995 and 2000 identified.

In 1986, urban land comprised 5.84 percent of the watershed and by 1995 had increased to 6.6 percent of the watershed. Between 1995 and 2000, urban areas continued to increase to 6.9 percent. Most new development is occurring along the southwest edge of

the watershed, in the areas designated for growth. This trend indicates that Pinelands regulations are effectively keeping new development away from the core areas of the region.

Build-out Scenarios

The percent of urban land was compared to the amount of land available for development (Table 4). In general the sub-watershed areas that have the most development in 2000 (Figure 2; Upper and Lower Mullica River) have the greatest potential to increase in development. Sub-watersheds that are least developed in 2000 (Great Bay and Bass River) have less land available for development in the future. Bass River has so little land available for development because most of the land is protected open space (Wharton State Forest), while most of the Great Bay sub-watershed is open water and wetlands.



Figure 2. Sub-watersheds (USGS HUC 11) in the Watershed.

Table 4. Existing urban land and land available for future development, as a percent of entire watershed.

HUC-11	Urban 1986	Urban 1995	Urban 2000	Available for Development
Bass River	0.79	0.90	0.94	10.90
Basto River	4.40	5.46	5.68	11.85
Oswego River	0.86	0.97	1.02	17.77
Upper Mullica River	10.79	11.86	12.11	19.56
Mullica and Wading River	5.68	7.12	7.83	17.36
Lower Mullica River	6.84	7.52	7.76	18.20
Great Bay	5.54	6.05	6.21	4.71
Brigantine	38.35	39.84	39.84	13.68
Total Watershed	5.84	6.66	6.92	16.68

Indicator Results

The population was 76,383 and 83,501 in 1990 and 2000 respectively, representing a nine percent increase over the ten-year period. The build-out population was calculated as 110,363 to 124,334 (Table 5), an increase of 32 to 49 percent predicted. The LC scenario allowed the highest number of dwelling units, while the three high constraint models (H1, H2, H3) all allowed approximately the same number of dwelling units. However, all scenarios represent a substantial increase over the 2000 watershed population.

The quality check of the build-out methodology predicts a 2000 population of 55,300 for the census blocks completely within the Mullica River Watershed. The total census population for these blocks was 72,000 people, with the build-out analysis potentially underestimating predicted population by about 23 percent. The disparity is most likely due to differences in the existing zoning file and the density pre regulation development, primarily in areas of older development and the differences in the # of people per dwelling unit across the different residential development types. This may not be a problem for the model as new growth is expected to more consistently conform to the zoning information used in this analysis. But, if the model under predicts by 23 percent, however, the population and impervious surface could be significantly higher at build-out.

Table 6 shows impervious surface estimates for 1986, 1995, and the build-out scenarios. Impervious surface for the Mullica River Watershed in 1986 was 1.34 percent. Between 1986 and 1995 impervious surface increased by 741 acres to 1.53 percent. Both values are substantially less than the 10 percent threshold of Arnolds and Gibbons (1996). The build-out analysis aggregated across the entire Mullica River basin, predicted a range of impervious surface between 2.50 and 2.83 percent, with the low constraints scenario having the highest value. These values are also well below Arnold and Gibbons (1996) 10 percent threshold for impacted areas.

To highlight localized areas of potentially high impact from non-point source pollution, impervious surface was also analyzed using the USGS HUC 14 sub-watersheds. For 1986 and 1995, no sub-watersheds were over the 10 percent impervious surface threshold (Figure 3). The build-out scenarios predict anywhere from four to seven sub-watersheds over the 10 percent mark (Figure 4), with the potentially impacted sub-watersheds located in the Regional Growth Areas or outside the Pinelands Management Area. The LC scenario had the highest number of sub-watersheds over 10 percent. In addition, 19 sub-watersheds, approximately one-third of the total, are located downstream and are hydrologically connected to impacted areas in the LC scenario (Figure 5). The build-out scenarios based on the Coastal Zone Management Rules maximum impervious surface limits (HC2 and HC3) had the lowest levels of impervious surface predicted, indicating that enforcement of these rules could reduce the impact of future development on water quality.

Table 5. Estimated dwelling units and population.

	1990	2000	LC	HC1	HC2	HC3
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DU increase	30,587	33,916	50,249	45,306	44880	44984
Total Population	76,383	83,501	123,680	111,520	110,472	110,728

Table 6. Estimated impervious surface in 1986, 1995, and build-out.

	1986	1995	LC	HC1	HC2	HC3
Acres	5,005	5,746	10,556	9828	9,372	9,563
Percent*	1.34 %	1.53 %	2.83 %	2.63 %	2.50 %	2.56 %

*For the percent equation the total area of the Mullica River Watershed was 373,471 acres. Water areas were not included.

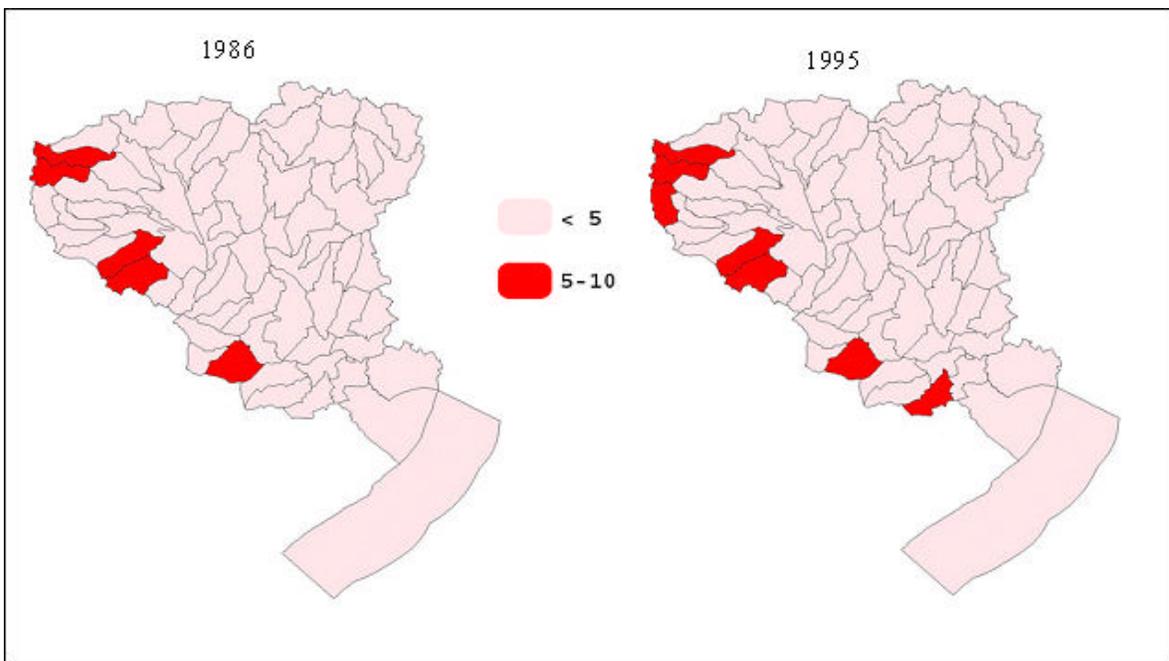


Figure 3. Impervious surface estimates by USGS HUC 14.

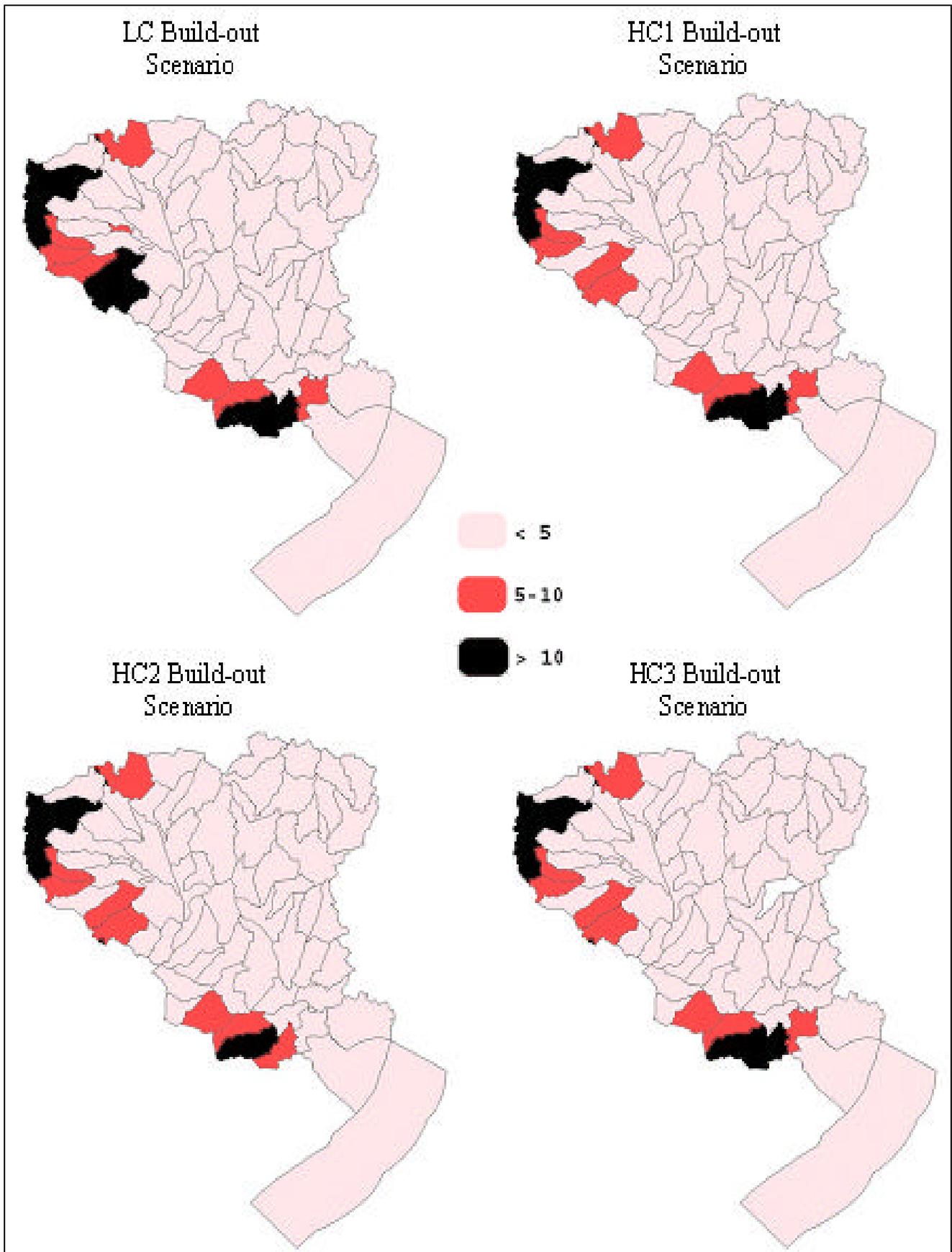


Figure 4. Build-out impervious surface estimates for USGS HUC 14.

CONCLUSIONS

Based on our analysis, there has been an 18 percent increase in urban land in the Mullica River Watershed between 1986 and 2000. Conversely this can be seen as a real loss of around 1% of the watershed to development between 1986 and 2000. These results highlight the strength of the Pinelands regulations in limiting overall growth and steering new development towards designated growth areas. Additionally, the slowing conversion rate of agricultural land indicates that another Pinelands management goal, preserving traditional agriculture, is being met.

While regulatory, social, and economic conditions are likely to change between now and build-out, there is the potential for a substantial increase in urban development to occur that could negatively impact the water supply and quality of the downstream estuary. Again, the Pinelands regulations should help limit the impacts, with most new development concentrated in a few sub-watersheds. By concentrating the areas of high impervious surface, mitigation of urban non-point source pollution can be made more feasible by the adoption of best management storm water runoff plans. However, if the Pinelands regulations are relaxed or not enforced, then there is the potential for more widespread development, greatly impacting water quality throughout the watershed and increasing the need for mitigation activities.

Of the build-out scenarios considered, the two high constraint models based on the Coastal Zone Management Rules (HC2 and HC3) are most effective at reducing the potential impacts of impervious surface. These rules take an approach similar to the Pinelands Management Area, trying to concentrate urban development in specific areas, while minimally impacting most of the land. Again, enforcement of these rules, or ones similar, will reduce overall impacts and increase the effectiveness of mitigation actions against non-point source pollution.

While the indicator analysis highlights the need for mitigation activity limiting impacts of impervious surface in the southwest portion of the watershed, the potential increase in population suggests that sufficient water supply is also a concern, particularly as many households rely on shallow wells. Future work should consider the location of the potential new growth and the supply of water to develop a water supply management plan to help ensure there is a sufficient supply of potable water to meet future demand.

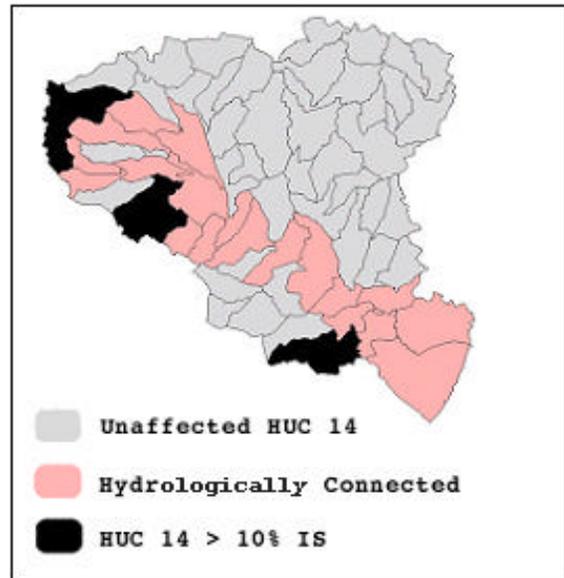


Figure 5. Hydrological connectivity for the LC build-out scenario.

ACKNOWLEDGEMENTS

The Pinelands Commission, Brigantine City, Galloway Township, and Port Republic Township provided essential zoning data for the project. Discussions with Chris Krupka (Pinelands Commission) in the early stages of the project provided necessary direction. John Bognar and Jim Trimble provided technical support.

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APPENDICES

Appendix 1. GIS datasets used in the analysis.

- NJDEP Watershed Management Areas

This coverage was used to delineate the Boundaries of the Mullica River Watershed. The Mullica River Watershed covers approximately 420,00 acres. This file was created by the NJDEP and can be downloaded from the following website <http://www.state.nj.us/dep/gis/>. Created 04/2000.

-NJDEP Pinelands Area Boundary

This coverage shows the boundaries of the Pineland Management area. This file was created by the NJDEP and can be downloaded at the following website <http://www.state.nj.us/dep/gis/>. Created 04/1994.

-NJDEP Land Use Land Cover data for Watershed Management Area 14

This data set was created by the NJDEP from 1995 – 1997 aerial photography and can also be downloaded from the <http://www.state.nj.us/dep/gis/>. Created 12/2000.

-Severed Developmental Rights

This data set show the boundaries of the properties in the Pinelands that have sold their development rights. This coverage was provided by the Pinelands Commission. Creation date unknown.

-State Open Space

This file shows the parts of the Mullica River Watershed that are owned by that state of NJ. The state opens space file was created by Green Acres and the NJDEP and can be found at the following website <http://www.state.nj.us/dep/gis/>. Created 1999.

-Federal Open Space

This file shows areas that are owned by the federal government. Created 1999.

-Streams (by county)

This dataset was used to determine the boundaries of the streams that run though the Watershed Management Area 14. d Management area. This file was created by the NJDEP and can be downloaded at the following website <http://www.state.nj.us/dep/gis/>. Created 11/1998.

- Roads (by county)

This data set was created by the New Jersey Department of Transportation. Created 1991.

-New Development (2000)

This dataset was created at the Center For Remote Sensing and Spatial Analysis. Created 2002.

-Pinelands Zoning File

This file was created by the Pinelands Commission. It was used to determine the zoning of the Pineland areas that could still be developed. Creation date unknown.

-Brigantine City Zoning File

This file was created by Brigantine City. It was used to determine the zoning of the pineland areas that could still be developed. Creation date unknown.

-Galloway Township Zoning File

This file was created by Galloway Township. It was used to determine the zoning of the pineland areas that could still be developed. Creation date unknown.

-Port Republic Township

This file was created by Port Republic Township. It was used to determine the zoning of the pineland areas that could still be developed. Creation date unknown.

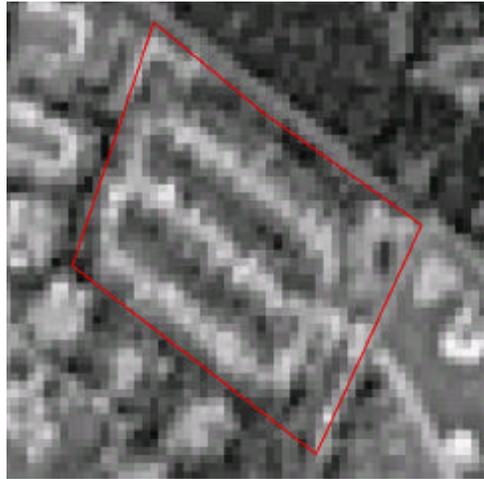
Appendix 2. Comparison of airphotos, satellite images, and ground photos used in 2000 updates.

A. Sapling Run Housing Complex in Waterford Twp. Camden County. New Jersey

Air photo taken in 1995



Satellite photo taken in 2000



Ground photo taken in June 2002

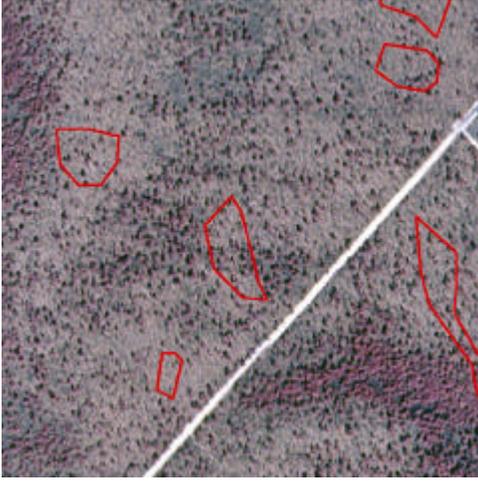


Ground photo taken in June 2002

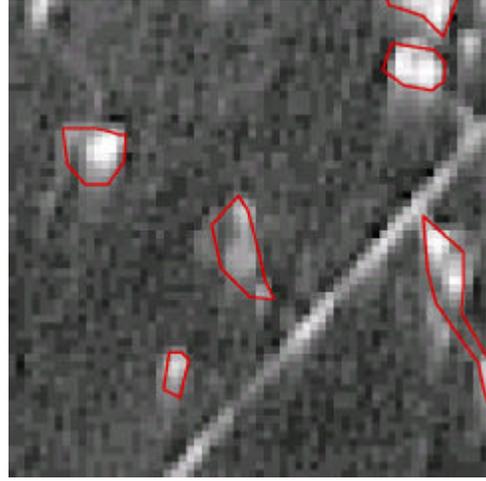


B . Single Family Home in Mullica Twp. Atlantic County New Jersey

Air photo taken in 1995



Satellite photo taken in 2000



Ground photo taken in June 2002

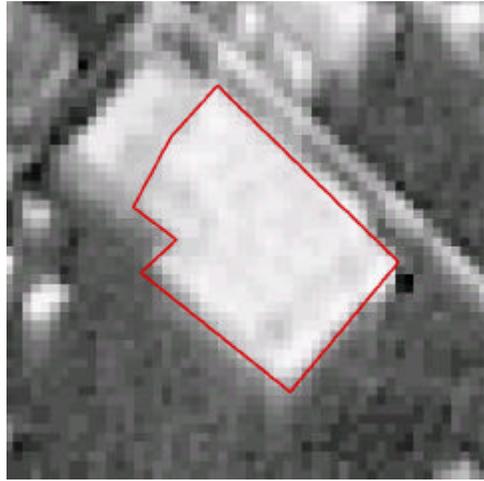


C. Commercial Building in Hamilton Town, Atlantic County New Jersey

Air photo taken in 1995



Satellite photo taken in 2000



Ground photo taken in June 2000



Ground photo taken in June 2002

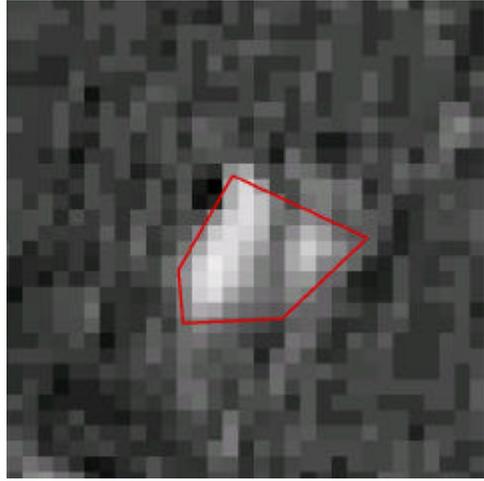


D. Managed Grassland in Mullica Twp. Atlantic County New Jersey

Air photo taken in 1995



Satellite photo taken in 2000



Ground photo taken in June 2002



Appendix 3. Field Check Methods for Land Use Update.

Field checks of the 2000 land use updates were accomplished using a Garmin Global Positioning Systems (GPS) unit attached to a laptop computer running Arcview 3.2x. The Minnesota Department of Natural Resources Garmin Extension was used to facilitate the interaction between the laptop and the GPS unit. This allowed real time mapping of the route being traveled by the field worker. Of the 107 polygons selected for field checks, nine could not be visited due to restricted access of private property, so 98 out of the 243 total polygons, or 40 percent, were actually field checked. The error matrix created to assess the accuracy of the 2000 land use updates (Table 1), shows an overall accuracy of 85 percent for the satellite land use update method. The urban land use updates show an accuracy of approximately 90 percent.

Table 1. Error matrix for 2000 land use updates*.

Field Check	Satellite Interpretation			
	Agriculture	Urban	Bare / Grass	Total
Agriculture	3	1	0	4
Urban	1	70	5	76
Bare / Grass	0	7	11	18
Total	4	78	16	98

*Overall Accuracy $84 / 98 = 85\%$