Final Report

Tracking New Jersey's Dynamic Landscape: Urban Growth and Open Space Loss 1986-1995-2002

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Introduction

At only five million acres in territory, New Jersey is the fourth smallest state in the United States of America. Yet, it is also the eleventh highest in total population. The result is that New Jersey, the Garden State, contains the highest population density of any state in the United States. New Jersey's 1,134 people per square mile place it at a higher overall population density than Europe, Japan, China or even India. New Jersey's population pressure stems from its geographic location, wedged between the nation's first and fifth largest cities, New York and Philadelphia. These factors have resulted in New Jersey maintaining its status as one of the most rapidly urbanizing states in the nation throughout the past several decades (Figure 1.1.1).

This study utilizes one of the most detailed digital land mapping databases in the nation to provide a highly accurate accounting of New Jersey's state of land use and development. The analysis provides a window into how the Garden State has developed over the past several decades and the subsequent consequences to its land base. It views land development patterns from many different angles providing a "report card" on urban growth and open space loss. Considering New Jersey's small size and continued pressure for growth, the Garden State is on-track to becoming the first state in the nation that will reach build-out within the next several decades. Build-out is a condition where all available land has been either preserved as open space or consumed for development. Far reaching implications of build-out include the integrity of ecosystems, the quality of settlement patterns and the amount of energy needed to function. These conditions will be set for years to come. The following assessment reveals how the landscape changes leading to build-out have been occurring over the sixteen year study period of 1986-2002.

Figure 1.1.1 New Jersey is one of the most rapidly urbanizing states in the United States of America, and at current development rates will reach build-out by the middle of this century. Photo: J. Hasse

1. Level I Land Use/Land Cover Change Analysis

1.1 Basic Level I Analysis

This study explores the 2002 New Jersey Land Use/Land Cover (LU/LC) digital dataset released by the New Jersey Department of Environmental Protection (NJDEP) in January of 2007 (NJDEP, 2007). A Level I analysis looks at the broadest categories of landscape change that have occurred by simplifying all land into six broad categories of land use/land cover: URBAN, AGRICULTURE, FOREST, WATER, WETLANDS, and BARREN. Since the digital LU/LC maps utilized in this study were produced for the years 1986, 1995 and 2002 the study is broken into three time periods, T0(pre-1986), T1(1986-1995) and T2(1995-2002). An accounting of the number of acres within each of the Level I categories reveals the changes over this sixteen year time period (Table 1.1.1). Annualizing the rates of change allows for more direct comparisons since the time-span between datasets are different.

Looking first at URBAN (i.e., developed) land, the analysis reveals that New Jersey continues to increase the amount of urban land at a remarkably rapid pace. Figure 1.1.2

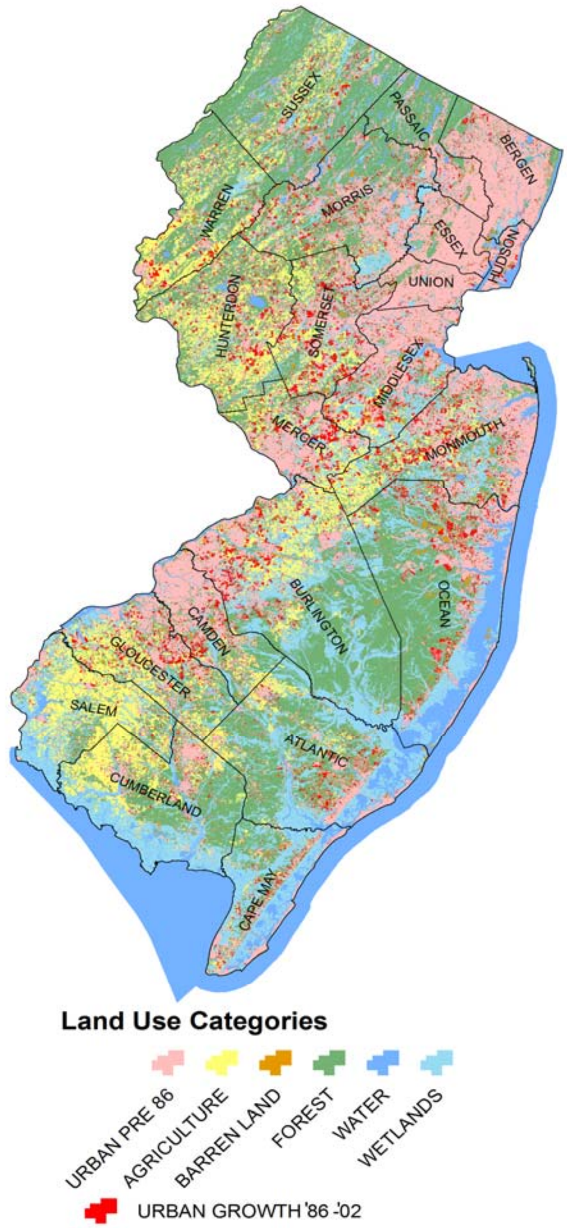

Figure 1.1.2 New Jersey land use as of 2002. Development that occurred from 1986-2002 is colored red.

Table 1.1.1 Level I Summary of Net Land Use/Land Cover Changes

Level I Land Use Type	1995 Total Acres	2002 Total Acres	Net Change T2(95-02')	Annualized Net Change T2(95'-02')	Annualized Net Change T1(86'-95')	% Change in Annualized Rates
Urban	1,334,476	1,440,464	105,988	15,141	14,886	+2%
Agriculture	652,334	596,804	-55,530	-7,932	-9,485	-16%
Forest	1,616,683	1,575,220	-41,463	-5,923	-4,300	+38%
Water	800,610	800,572	-38	-5	NA	NA
Wetlands	1,022,291	1,009,544	-12,747	-1,821	-1,755	+4%
Bare Land	57,562	61,352	3,789	541	NA	NA

depicts the urban growth within the state up through the year 2002. Land developed before the year 1986 is colored pink. Land developed between 1986 and 2002 is colored red. Between the years of 1995 and 2002 (T2) New Jersey expanded the amount of urban land by approximately 106,000 acres to a statewide total of 1,440,464 acres. The growth that occurred from 1986-1995 (T1) totaled 134,000 acres. The total combined growth of T1 and T2 summed is approximately 240,000 acres. This amount of land, nearly a quarter million acres that was converted from open space to development, is roughly equivalent to adding the entire developed land area in New Jersey's four most urbanized counties Bergen, Union, Essex and Hudson to the state every 16 years (Figure 1.1.3)

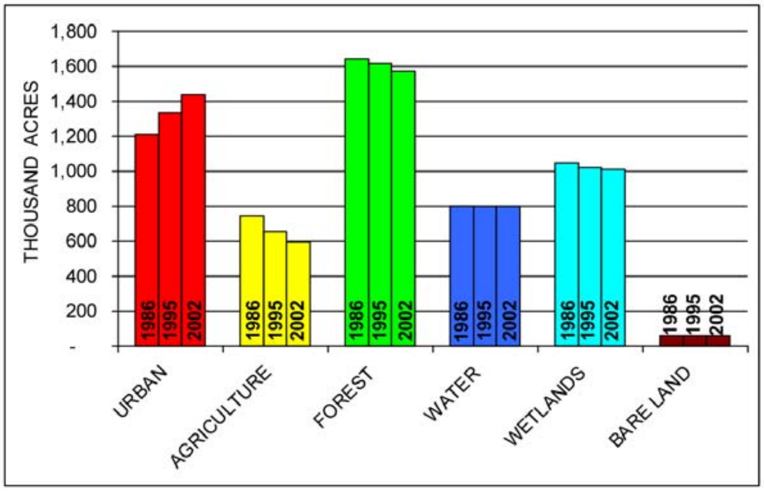

Figure 1.1.4 Land use change in New Jersey 1986-1995-2002.

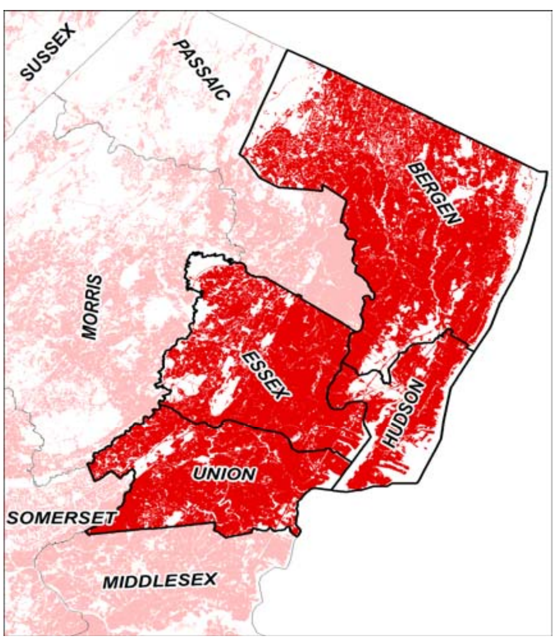

Figure 1.1.3 Land development in New Jersey between 1986-2002 added the equivalent acres of growth as the all the urban land in the states four most urbanized counties.

Given that the total territory of the state has not changed since colonial times, when development increases there must also be a corresponding decrease in other categories of land. The major losers are AGRICULTURE and FOREST lands. Figure 1.1.4 graphs the change in each Level I category over the 1986, 1995 and 2002 time period.

Normalizing the number of new acres of development by the seven year T2('95-'02) time period provides a rate of 15,140 acres of new development per year. This represents a slight increase in the rate of development from the previous land use mapping period of T1('86-'95) when urban development grew at a pace of 14,886 acres per year. Fifteen thousand acres of development per year is difficult for many to visualize. A more graspable measure of land is a football field (120 X 53 yards including end-zones or 1.3 acres). 15,000 acres of development is the equivalent of over 31 football fields of development occurring in New Jersey every day (Figure 1.1.5).

The land category to lose the greatest number of acres to urbanization was agriculture, which lost 55,530 net acres statewide during T2 ('95-'02). The pace of this loss is remarkable. Although when compared to the previous period, the rate of farmland loss actually slowed somewhat to an annualized rate of loss T2('95-'02) of 7,933 acres per year compared to a T1('86-'95) farmland loss rate of 9,485 acres per year.

In contrast, the rate of forest loss increased. The net amount of upland forest loss during T2 ('95-'02) was 41,463 acres. This represents an annualized rate of 5,923 acres per year. This is an increase in the rate of forest loss, up 38% when compared to the 4,300 acres of annualized loss experienced during the previous T1 time period. Upland forest has represented the largest single category of land in the state through 2002 when it measured over 1,575,000 acres. However, at the T2 rates of upland forest loss and simultaneous increase in developed land, the total amount of urban land in New Jersey is likely to surpass the total amount of upland forest land by the middle of 2008.

Wetlands also continued to lose ground to urban growth. Net acreage of wetlands lost totaled 12,747 acres statewide during T2('95-'02), increasing its annualized loss rate to 1,821 acres per year, a 4% increase over the 1,755 acres lost annually during T1('86-'95).

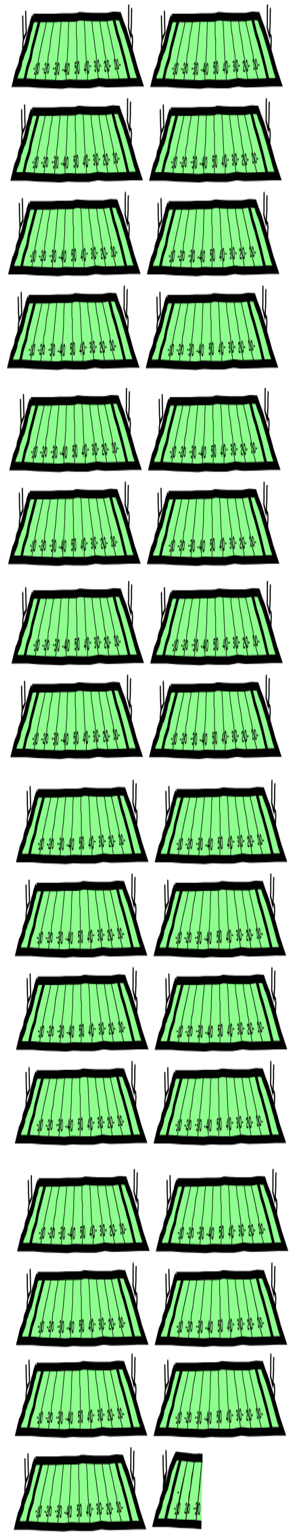

Figure 1.1.5 New Jersey develops land at the rate of over thirty one football fields per day.

The Level I net land use/land cover changes revealed in the T2('95-'02) dataset confirm that overall trends of urban development have remained robust, while open space and important land resources continue to be lost at an equally rapid pace. While the Level I analysis provides the basic outline as to the landscape changes that have been occurring in New Jersey, digging deeper into the data reveals more details of exactly how the changes have been taking place. This warrants first an explanation of the data.

1.2 H-L Class Analysis

The statewide mapping depicted in the NJ DEP LU/LC datasets contains two levels of land classification. The basic Level I system of classification discussed in the previous section is labeled as "TYPE" in the datasets and includes 6 categories; URBAN, AGRICULTURE, FOREST, WATER, WETLANDS and BARREN. The second level of land classification is much more detailed containing over 90 categories of land based on the Anderson classification system (Anderson et. al. 1976).

Summarizing land changes by the Level I TYPE classification provides broad indications of landscape patterns and the changes that have occurred during the T1 and T2 periods depicted. However, the Level I TYPE classification label has some limitations that mask a number of important trends and transitions in the landscape. The major complicating factor in the

Level I TYPE classification is the delineation of wetlands which are both a land use/land cover as well as a legally defined hydrologic condition of a given land parcel. Since the wetlands delineation in the datasets was derived from the original fresh water wetlands mapping analysis conducted by the state for regulatory purposes, the TYPE label WETLANDS includes all land types that satisfy the legal definition of wetlands regardless of their specific wetlands class. This results in a number of different wetlands categories that also function simultaneously as other land use categories.

The following example illustrates the problem. *Agricultural wetlands* are legally considered wetlands due to the hydric nature of the soil but they also function as agriculture in terms of land use. Measuring the amount of agriculture depicted in the dataset utilizing the AGRICULTURE category excludes *agricultural wetlands* which are an important component of agriculture in New Jersey. Other wetlands classes have similar simultaneous overlap with URBAN and BARREN land uses. Furthermore, the FOREST category only contains upland (non-wetlands) forest even though many forest areas in the state usually contain a combination of both upland forest as well as forested wetlands. The Level I TYPE classification makes it impossible to evaluate the total forest lands because forested wetlands are indistinguishable from the non-forested wetlands in the Level I TYPE category.

In order to address the complications posed by the wetlands labeling issue, the authors created an alternate Level I classification system. The Hasse-Lathrop (H-L) system utilizes the same labels as the DEP for: URBAN, AGRICULTURE, FOREST, WATER and BARREN. However, the WETLANDS category is re-grouped into different wetlands classes depending on their Level III Anderson land use codes (Table 1.2.1).

Table 1.2.1 H-L wetlands categories.

H-L wetlands name	Anderson Codes
Coastal Wetlands WETCOAST	6110, 6111, 6112, 6120, 6130, 6141
Emergent Wetlands WETEMERG	6230, 6231, 6232, 6233, 6234, 6240, 6241
Forested Wetlands WETFOREST	6210, 6220, 6221, 6250, 6251, 6252
Urban Wetlands WETURB	1461, 1711, 1750, 1850
Agricultural Wetlands WETAGR	2140, 2150,
Disturbed Wetlands WETDIST	7430, 8000

The H-L classification scheme allows the user to differentiate the wetlands that are simultaneously associated with other land uses/land covers. This makes it possible for alternate evaluation by combining the wetlands categories with associated non-wetlands land uses (Figure 1.2.1). For example an inventory of total forest land can be calculated by adding the FOREST acreage (upland forest) to the WETFOREST (wetlands forest) acreage. Similarly an inventory of total agricultural land can be achieved by adding AGRICULTURE to WETAGR (Agricultural Wetlands). The transition between natural wetlands and altered wetlands classes can also be more readily analyzed with the H-L class system. Tables 1.2.2 depict the summary of the H-L classes for time periods covered in the analysis.

Results H-L Class

Analyzing land use/land cover change, utilizing the H-L classing method, allows for a better understanding of the subtle dynamics in land use changes that have occurred, which are concealed in the standard Level I net change values alone. For example, while the net loss of Agriculture (upland) lands slowed

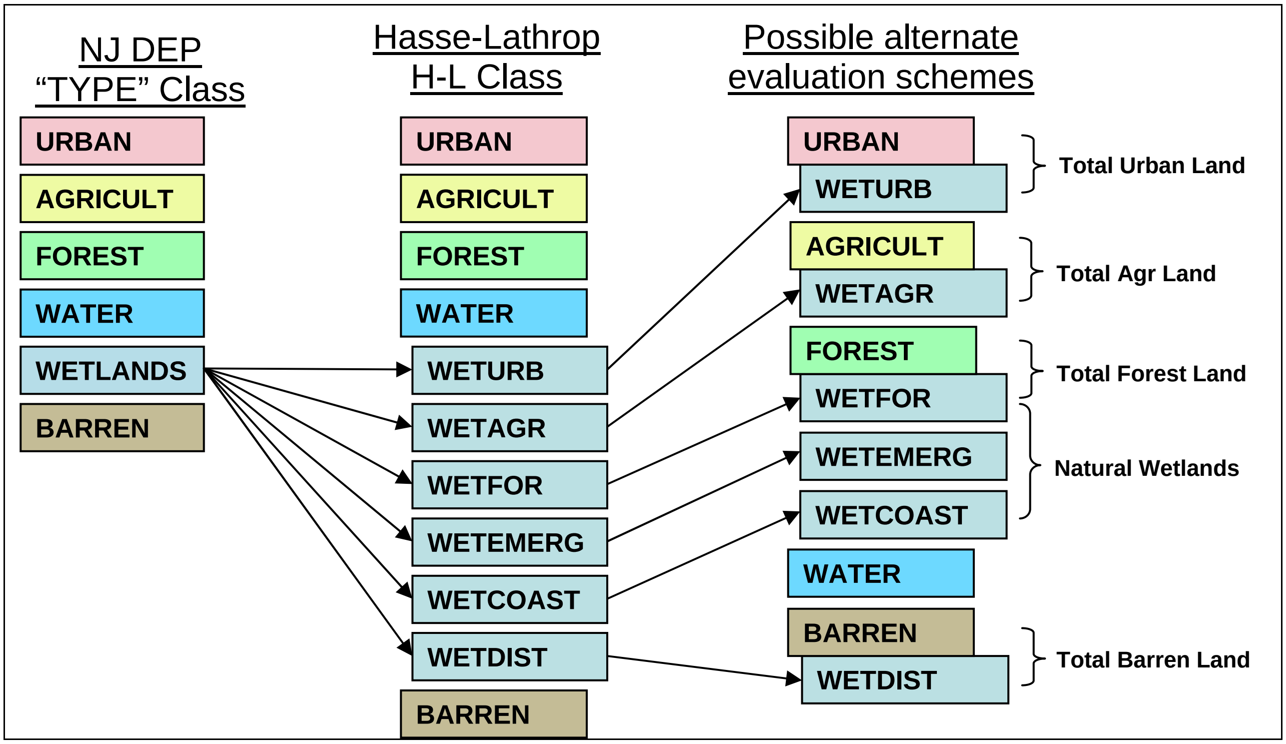

Figure 1.2.1 Diagram of Hasse-Lathrop (H-L) reclassification demonstrating differentiation of wetlands classes to allow alternate evaluation schemes.

from 9,485 acres per year during T1(1986-1995) to 7,933 acres per year during T2(1995-2002) (Table 1.2.2a,b) the rate of Agricultural-Wetlands loss climbed from 91 to 1,117 acres per year during the same respective time periods. Combining Agriculture with Agricultural Wetlands (Total Agriculture) reveals that the slowdown in total agricultural land loss was less significant (i.e., from 9,576 in T1('86-'95) to 9,050 acres/yr in T2('95-'02)) representing a 5.5% change vs. a 16.4% net Level I change (as indicated in Table 1.1.1) which excludes wetlands agriculture.

Whether Urban land includes or excludes Urban Wetlands, there appears to be a slight increase in the annual rate of new urban land (Tables 1.2.2 a,b). The Barren land category includes naturally occurring barren features such as rock outcrops and beaches, human-created barren areas such as gravel pits and rock quarries, as well as temporarily barren areas such as areas cleared for development and are thus considered Transitional. The annual change of Barren land (excluding Disturbed Wetlands) shows an increase from T1 (83 acres/yr) to T2 (541 acres/yr) (Table 1.2.2a,b). If Disturbed Wetlands are included, the amount of Total Barren land actually decreases in T2. Some of this difference is due to the approximately 6,400 acres of Disturbed Wetlands in 1995 that were reclassified as Emergent Wetlands in 2002 (see discussion below).

Tables 1.2.3a,b and 1.2.4a,b depict the landscape change matrix under the H-L classification system. These tables allow for the examination of all possible transitions between different land classes. Not only can the total acreage of a particular class be read at the final column and bottom row of the tables, the number of acres of change for each possible transition can also be traced. For example, closer examination shows that upland FOREST which had an overall net loss of 41,463 during T2 ('95-'02) (Table 1.2.2b) actually experienced a much greater area change with 58,495 acres converted to urbanization. The net change conceals the relatively large amount of FOREST that became urbanized because other land uses simultaneously changed into FOREST (namely, AGRICULTURE, URBAN and BARREN).

Since the time span covered by T1 and T2 are different (nine and seven years respectively) Tables 1.2.3b and 1.2.4b provide annualized change so that the rates of change can be directly compared.

Table 1.2.2a H-L class change T1('86-'95).

	1986	1995	DIF86_95	PCT_CHG	ANN_CH
AGRICULTUR	744,382	659,017	-85,365	-11.5%	-9,485
BARREN	57,223	57,971	748	1.3%	83
FOREST	1,641,279	1,602,578	-38,701	-2.4%	-4,300
URBAN	1,208,553	1,342,525	133,972	11.1%	14,886
WATER	783,260	788,405	5,145	0.7%	572
WETAGR	84,519	83,698	-821	-1.0%	-91
WETCOAST	210,168	208,847	-1,321	-0.6%	-147
WETDIST	12,627	19,636	7,009	55.5%	779
WETEMERG	180,158	167,773	-12,385	-6.9%	-1,376
WETFOR	550,037	540,294	-9,743	-1.8%	-1,083
WETURB	11,286	12,749	1,463	13.0%	163

Table 1.2.2b H-L class change T2('95-'02).

	1995	2002	DIF95_02	PCT_CHG	AN_CH
AGRICULTUR	652,334	596,804	-55,530	-8.5%	-7,933
BARREN	57,562	61,352	3,789	6.6%	541
FOREST	1,616,683	1,575,220	-41,463	-2.6%	-5,923
URBAN	1,334,476	1,440,464	105,988	7.9%	15,14
WATER	800,610	800,572	-38	0.0%	-5
WETAGR	86,774	78,958	-7,816	-9.0%	-1,117
WETCOAST	201,515	198,760	-2,755	-1.4%	-3934
WETDIST	17,069	11,129	-5,941	-34.8%	-849
WETEMERG	169,336	112,486	-56,850	-33.6%	-8,121
WETFOR	533,811	593,539	59,728	11.2%	8,533
WETURB	13,786	14,672	886	6.4%	127

Table 1.2.3a,b H-L class land use/land cover total and annual acres change matrix for T1('86-'95). These tables allow for the examination of all possible transitions between different land classes. Not only can the total acreage of a particular class be read at the final columns and bottom rows of the tables, the number of acres of change for each possible transition can also be traced.

Table 1.2.3a T1('86-'95) total acres transition matrix.

1986					1995							
	AGRICULTUR	**BARREN**	**FOREST**	**URBAN**	**WATER**	**WETAGR**	**WETCOAST**	**WETDIST**	**WETEMERG**	**WETFOR**	**WETURB**	**total 1986**
AGRICULTUR	649,021	8,562	31,255	55,029	398	59	16	34	2	0	7	**744,382**
BARREN	519	33,500	8,129	12,558	2,021	5	457	25	7	0	3	**57,223**
FOREST	7,604	10,463	1,553,996	67,322	1,537	61	154	82	28	25	7	**1,641,279**
URBAN	1,664	3,148	9,053	1,194,447	197	8	22	12	0	1	1	**1,208,553**
WATER	5	1,525	33	149	779,815	79	744	687	202	3	18	**783,260**
WETAGR	120	20	2	2,029	129	81,119	3	1,046	25	26	1	**84,519**
WETCOAST	1	383	94	183	2,004	10	207,408	74	5	4	3	**210,168**
WETDIST	17	141	10	1,635	303	203	0	9,764	251	19	285	**12,627**
WETEMERG	17	117	1	2,445	1,073	1,406	37	2,589	167,179	4,836	458	**180,158**
WETFOR	50	112	6	6,711	928	745	5	5,318	73	535,379	710	**550,037**
WETURB	0	0	0	20	2	2	0	5	1	0	11,257	**11,286**
total 1995	**659,017**	**57,971**	**1,602,578**	**1,342,525**	**788,405**	**83,698**	**208,847**	**19,636**	**167,773**	**540,294**	**12,749**	**5,483,492**
Net Change '86-'95	**-85,365**	**748**	**-38,701**	**133,972**	**5,145**	**-821**	**-1,321**	**7,009**	**-12,385**	**-9,743**	**1,462**	**-15,798**

Table 1.2.3b T1('86-'95) annualized acres transition matrix.

1986					1995							
	AGRICULTUR	**BARREN**	**FOREST**	**URBAN**	**WATER**	**WETAGR**	**WETCOAST**	**WETDIST**	**WETEMERG**	**WETFOR**	**WETURB**	**total 1986**
AGRICULTUR	-	951	3,473	6,114	44	7	2	4	0	0	1	**10,596**
BARREN	58	-	903	1,395	225	1	51	3	1	0	0	**2,636**
FOREST	845	1,163	-	7,480	171	7	17	9	3	3	1	**9,698**
URBAN	185	350	1,006	-	22	1	2	1	0	0	0	**1,567**
WATER	1	169	4	17	-	9	83	76	22	0	2	**383**
WETAGR	13	2	0	225	14	-	0	116	3	3	0	**378**
WETCOAST	0	43	10	20	223	1	-	8	1	0	0	**307**
WETDIST	2	16	1	182	34	23	0	-	28	2	32	**318**
WETEMERG	2	13	0	272	119	156	4	288	-	537	51	**1,442**
WETFOR	6	12	1	746	103	83	1	591	8	-	79	**1,629**
WETURB	0	0	0	2	0	0	0	1	0	0	-	**3**
total 1995	**1,111**	**2,719**	**5,398**	**16,453**	**954**	**287**	**160**	**1,097**	**66**	**546**	**166**	**-**
Net Change '86-'95	**-9,485**	**83**	**-4,300**	**14,886**	**572**	**-91**	**-147**	**779**	**-1,376**	**-1,083**	**162**	**0**

Table 1.2.4a,b H-L class land use/land cover total and annual acres change matrix for T2('95-'02). This table allows for the examination of all possible transitions between different land classes. Not only can the total acreage of a particular class be read at the final column and bottom rows of the tables, the number of acres of change for each possible transition can also be traced.

Table 1.2.4a T2('95-'02) total acres transition matrix.

1995					2002							
	AGRICULTUR	BARREN	FOREST	URBAN	WATER	WETAGR	WETCOAST	WETDIST	WETEMERG	WETFOR	WETURB	total 1995
AGRICULTUR	585,349	8,641	21,633	36,044	249	254	10	22	78	41	12	**652,334**
BARREN	722	30,649	6,618	17,216	1,347	0	813	34	145	13	6	**57,562**
FOREST	7,592	12,200	1,536,980	58,495	568	62	118	84	184	388	12	**1,616,683**
URBAN	2,602	4,965	9,177	1,317,273	261	16	20	29	59	46	28	**1,334,476**
WATER	6	2,543	104	230	793,368	98	1,414	270	2,397	156	24	**800,610**
WETAGR	262	457	117	2,185	80	76,152	5	899	4,963	1,036	619	**86,774**
WETCOAST	10	316	24	140	3,305	14	196,024	1,436	208	32	7	**201,515**
WETDIST	35	648	162	2,605	252	475	120	4,705	6,407	904	758	**17,069**
WETEMERG	83	320	155	1,369	898	1,406	179	1,149	96,091	67,248	438	**169,336**
WETFOR	131	559	227	4,518	229	349	57	2,382	1,495	523,538	327	**533,811**
WETURB	13	52	24	390	16	132	0	120	458	138	12,442	**13,786**
total 2002	**596,804**	**61,352**	**1,575,220**	**1,440,464**	**800,572**	**78,958**	**198,760**	**11,129**	**112,486**	**593,539**	**14,672**	**5,483,955**
Net Change 95'-02'	**-55,530**	**3,789**	**-41,463**	**105,988**	**-38**	**-7,816**	**-2,755**	**-5,941**	**-56,850**	**59,728**	**886**	**-12,747**

Table 1.2.4b T2('95-'02) annualized acres transition matrix.

1995					2002							
	AGRICULTUR	BARREN	FOREST	URBAN	WATER	WETAGR	WETCOAST	WETDIST	WETEMERG	WETFOR	WETURB	total 1995
AGRICULTUR	-	1,234	3,090	5,149	36	36	1	3	11	6	2	**9,569**
BARREN	103	-	945	2,459	192	0	116	5	21	2	1	**3,845**
FOREST	1,085	1,743	-	8,356	81	9	17	12	26	55	2	**11,386**
URBAN	372	709	1,311	-	37	2	3	4	8	7	4	**2,458**
WATER	1	363	15	33	-	14	202	39	342	22	3	**1,035**
WETAGR	37	65	17	312	11	-	1	128	709	148	88	**1,517**
WETCOAST	1	45	3	20	472	2	-	205	30	5	1	**784**
WETDIST	5	93	23	372	36	68	17	-	915	129	108	**1,766**
WETEMERG	12	46	22	196	128	201	26	164	-	9,607	63	**10,463**
WETFOR	19	80	32	645	33	50	8	340	214	-	47	**1,468**
WETURB	2	7	3	56	2	19	0	17	65	20	-	**192**
total 2002	**1,636**	**4,386**	**5,463**	**17,599**	**1,029**	**401**	**391**	**918**	**2,342**	**10,000**	**319**	**-**
Net Change 95'-02'	**-7,933**	**541**	**-5,923**	**15,141**	**-5**	**-1,117**	**-394**	**-849**	**-8,121**	**8,533**	**127**	**-0**

2 Detailed Urban Growth Analysis

2.1 Level III Analysis of Urbanization

When the T1('86-'95) land use/land cover dataset was released by the NJDEP it indicated a net urban growth rate of 14,883 acres per year (Table 1.1.1). It was not known at the time if this rate represented an on-going trend or a short-term spike in development rate. With the release of the T2('95-'02) dataset, a better assessment of the long-term trends in development can be conducted. What stands out is that the development rate of T2 is nearly identical to T1, with a slight increase to 15,141 acres per year. New Jersey's pace of development appears to have been surprisingly steady over the past two decades.

The net acres of urban growth is an important measure to track given that development comes at the loss of open space in a state with a limited amount of land. However, equally important to the question of 'how much' urban growth has occurred are the questions of 'where' and 'what kind' of development has occurred. Level III analysis of the data facilitates a detailed look at the specific types of development that occurred and from what types of land they changed from.

Urbanization is primarily a uni-directional landscape change. When land is developed, it tends to stay in a developed land use. In other words farms become subdivisions far more often then subdivisions become farms. Yet the analysis reveals that a substantial amount of land (about 10%-14% of net urbanized land) actually transitions out of the URBAN category and back into non-URBAN categories. Table 2.1.1 portrays that during the earlier T1('86-'95) time period 148,079 acres changed from non-URBAN to URBAN land classes, while at the same time 14,131 acres change from URBAN to non-URBAN land uses. The majority of the land that became "unurbanized" converted to FOREST or BARREN categories. This is a logical transition since urban land that is abandoned may eventually have structures demolished (i.e., conversion to barren) and ultimately become re-vegetated (i.e., conversion to 'brownfields' to scrub/shrub, then forest). The T2('95-'02) dataset shows a similar transition into and out of urban land with 123,191 acres of land transitioning into URBAN while 17,203 acres transitioning out of urban for a net urban growth of 105,988

Table 2.1.1 Transition into and out of URBAN land classes 1986-1995-2002 in acres.

	T1('86-'95)	T1('86-'95)	T1('86-'95)	T1('86-'95)	T2('95-'02)	T2('95-'02)	T2('95-'02)	T2('95-'02)
HL Class	**Acres Urbanized**	**Acres out of Urban**	**Net Acres Urban Change**	**Annual Urban Change**	**Acres Urbanized**	**Acres out of Urban**	**Net Acres Urban Change**	**Annual Urban Change**
AGRICULTUR	55,029	1,664	53,365	5,929	36,044	2,602	33,442	4,777
BARREN	12,558	3,148	9,409	1,045	17,216	4,965	12,250	1,750
FOREST	67,322	9,053	58,269	6,474	58,495	9,177	49,319	7,046
URBAN	0	0	0	0	0	0	0	0
WATER	149	197	-48	-5	230	261	-31	-4
WETAGR	2,029	8	2,020	224	2,185	16	2,169	310
WETCOAST	183	22	161	18	140	20	120	17
WETDIST	1,635	12	1,623	180	2,605	29	2,576	368
WETEMERG	2,445	0	2,445	272	1,369	59	1,310	187
WETFOR	6,711	1	6,710	743	4,518	46	4,472	639
WETURB	20	1	19	2	390	28	362	52
Total	**148,079**	**14,131**	**133,972**	**14,883**	**123,191**	**17,203**	**105,988**	**15,141**

acres. Since the T1('86-'95) dataset depicts changes over a nine year period whereas the T2('95-'02) dataset covers only seven years, the total change must be normalized by the number of years covered in order to be directly compared. Annualized change is also provided in Table 2.1.1

An even more in-depth urban analysis can be conducted by utilizing the Level III Anderson land use codes that are contained within the datasets. By analyzing the polygons within each dataset that changed from a non-URBAN to URBAN land, significant details of this change can be revealed. Table 2.1.2 provides a statistical breakdown of all twenty-eight Level III urban classes included in the datasets[1]

Table 2.1.2 Summary of total acres within urban Level III land use category for T0(pre '86), T1('86-'95) and T2('95-'02).

Land Use Code	Land Use LABEL	T0(pre '86) Total Urban Acres	T0(pre '86) % of Total Urban	T1('86-'95) Acres of Urban Growth	T1('86-'95) % of total Urban Growth	T2('95-'02) Acres of Urban Growth	T2('95-'02) % of total Urban Growth
1110	RESIDENTIAL, HIGH-DENSITY OR MULTIPLE DWELLING	115,032	9.4%	11,170	7.4%	7,018	5.6%
1120	RESIDENTIAL, SINGLE UNIT, MEDIUM-DENSITY	330,489	27.1%	20,258	13.5%	18,556	14.8%
1130	RESIDENTIAL, SINGLE UNIT, LOW-DENSITY	143,095	11.7%	21,440	14.3%	16,550	13.2%
1140	RESIDENTIAL, RURAL, SINGLE UNIT	183,297	15.0%	45,415	30.3%	35,675	28.5%
1150	MIXED RESIDENTIAL	884	0.1%	125	0.1%	11	0.0%
1200	COMMERCIAL/SERVICES	110,288	9.0%	9,179	6.1%	7,173	5.7%
1211	MILITARY INSTALLATIONS	8,125	0.7%	429	0.3%	197	0.2%
1214	FORMER MILITARY, INDETERMINATE USE	33	0.0%	9	0.0%	2	0.0%
1300	INDUSTRIAL	63,525	5.2%	5,384	3.6%	4,943	4.0%
1400	TRANSPORTATION/COMMUNICATION/ UTILITIES	65,606	5.4%	5,030	3.4%	1,553	1.2%
1410	MAJOR ROADWAY	NA	NA	NA	NA	475	0.4%
1419	BRIDGE OVER WATER	NA	NA	NA	NA	10	0.0%
1440	AIRPORT FACILITIES	NA	NA	NA	NA	150	0.1%
1461	WETLAND RIGHTS-OF-WAY	4,150	0.3%	197	0.1%	108	0.1%
1462	UPLAND RIGHTS-OF-WAY DEVELOPED	NA	NA	NA	NA	109	0.1%
1463	UPLAND RIGHTS-OF-WAY UNDEVELOPED	NA	NA	NA	NA	297	0.2%
1499	STORMWATER BASIN	NA	NA	NA	NA	4,148	3.3%
1500	INDUSTRIAL/COMMERCIAL COMPLEXES	378	0.0%	118	0.1%	50	0.0%
1600	MIXED URBAN OR BUILT-UP LAND	1,444	0.1%	4	0.0%	3	0.0%
1700	OTHER URBAN OR BUILT-UP LAND	103,542	8.5%	22,617	15.1%	14,468	11.6%
1710	CEMETERY	NA	NA	NA	NA	220	0.2%
1711	CEMETERY ON WETLAND	NA	NA	NA	NA	34	0.0%
1741	PHRAGMITES DOMINATE URBAN AREA	NA	NA	NA	NA	87	0.1%
1750	MANAGED WETLAND IN MAINTAINED LAWN GREENSPACE	4,727	0.4%	999	0.7%	1,464	1.2%
1800	RECREATIONAL LAND	60,877	5.0%	6,127	4.1%	10,115	8.1%
1804	ATHLETIC FIELDS (SCHOOLS)	14,252	1.2%	754	0.5%	845	0.7%
1810	STADIUM THEATERS CULTURAL CENTERS AND ZOOS	NA	NA	NA	NA	155	0.1%
1850	MANAGED WETLAND IN BUILT-UP MAINTAINED REC AREA	2,409	0.2%	770	0.5%	595	0.5%

[1] The 1986-1995 dataset has fewer urban categories than the 1995-2002 dataset. Classes that do not exist in the earlier dataset are indicated with a NA. The acreage for these land uses would have been included in other more generalized categories of the dataset. For example, *LU type 1499* (Stormwater basins) were often included in *LU type 1700* (Other Urban or Built-up Land) in the earlier dataset.

The majority of land developed during these time periods was attributable to residential housing development (Figure 2.1.1). Combined categories of residential growth represented 62.2% of the total amount of land developed during the T2('95-'02)time period. Other significant categories of development include *other urban or built-up land* (15.4%), *commercial services* (5.7%), *industrial* (4.0%), *transportation/ communication/utility* (about 1.2%) and *recreational land* (8.1%).

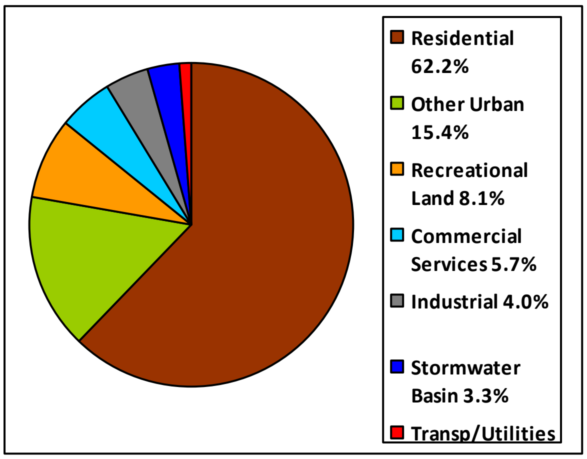

Figure 2.1.1 Types of urban growth T2('95-'02).

Residential land represents 63.3%, 65.5% and 62.2% of the total development in T0, T1 and T2 respectively. Breaking residential land down further into the different categories of residential land reveals that the largest consumers of land were the large-lot units that have become prevalent during the last two decades. *Land Use* (*LU*) *type 1130 Residential (Single-Unit, Low-Density)* represents approximately fourteen percent of the land that was developed during both the T1 and T2 time periods and consists of single-unit residential neighborhoods with areas greater than 1/2 acre up to and including one acre lots. *LU type 1140 Residential (Rural, Single-Unit)* represents approximately 30% of the land developed and consists of single-unit residential neighborhoods with areas between one acre and up to and including two acre lots.

2.2 Identifying Sprawl Versus Smart Growth

Analysis of the datasets can provide insight not only into the rate at which land is being developed but also for characterizing the patterns of development. In recent decades, it has become increasingly common for urban development to be more spread out, scattered and inadequately coordinated. This type of poorly planned and dispersed growth is often labeled *urban* or *suburban sprawl*. While the suburban/exurban lifestyle that large-lot residential development affords has an obvious appeal to a significant percentage of the population, as demonstrated by continued popularity of homes in large-lot residential developments, the sprawl that results from this type of housing has also been associated with many negative environmental, social and quality of life impacts. Sprawl is being increasingly linked to health-related consequences such as obesity, diabetes and depression (Ewing, et al 2006). Recent efforts to rein-in sprawl development are often grouped under the broad policy label of "Smart Growth". The state of New Jersey has embraced the goals of Smart Growth at multiple levels including the state Office of Smart Growth.

Analysis of the NJ land use/land cover data sets provides a window into how the Garden State is faring in its efforts to channel development toward Smart Growth and away from sprawl. While sprawl is a complex phenomenon, some of the most significant characteristics can be modeled and measured within a Geographic Information System

(Hasse 2007; Hasse and Lathrop, 2003a, 2003b). The sprawl characteristics investigated in this study include: *density, fragmentation, Smart Growth location, leapfrog* and *land use inefficiency.* The analysis evaluated residential growth only.

<u>Density:</u> Low-density is perhaps the most commonly cited characteristic of sprawl as an indicator of comparatively inefficient use of residential land (i.e., large amount of land consumed per capita housed). The low-density residential (e.g., >1/2 acre per housing unit) categories combined accounted for approximately sixty-seven percent of the total residential land consumed even though they only housed twenty-four percent of the people buying new houses. The data suggests that this trend toward low-density large-lot residential units increased substantially after 1986 (T0). In the pre-1986 urban inventory, the two low-density categories combined comprised only 26.7% of the total T0(pre ’86) urban land. In other words, the growth that occurred after 1986 had a significantly greater proportion of land dedicated to large-lot residential than previous to 1986.

Conversely, the highest-density residential (i.e., <1/8 acre per housing unit) land category (*LU type 1110)* became an increasingly smaller proportion of total new residential development going from 10.1% of T0(pre ’86) urban land to 7.4% during T1(’86-’95) and dropping further to 5.8% of urbanized land during T2(’95-’02). When looking at density, the study reveals that since 1986, the proportion of developed land consumed by large-lot, low-density housing has substantially increased while the proportion of land that went into higher-density housing associated with Smart Growth dropped (Figure 2.2.1).

Figure 2.2.1a High-density residential *(LU type 1110).*

Figure 2.2.1b Medium-density residential (*LU type 1120*).

Figure 2.2.1c Low-density residential (*LU type 1130*).

Figure 2.2.1d Low-density growth (*LU type 1140*).

Figure 2.2.1a,b,c,d During the study, high-density residential became a smaller proportion of total acres developed, while low-density residential increased. Photos: J. Hasse

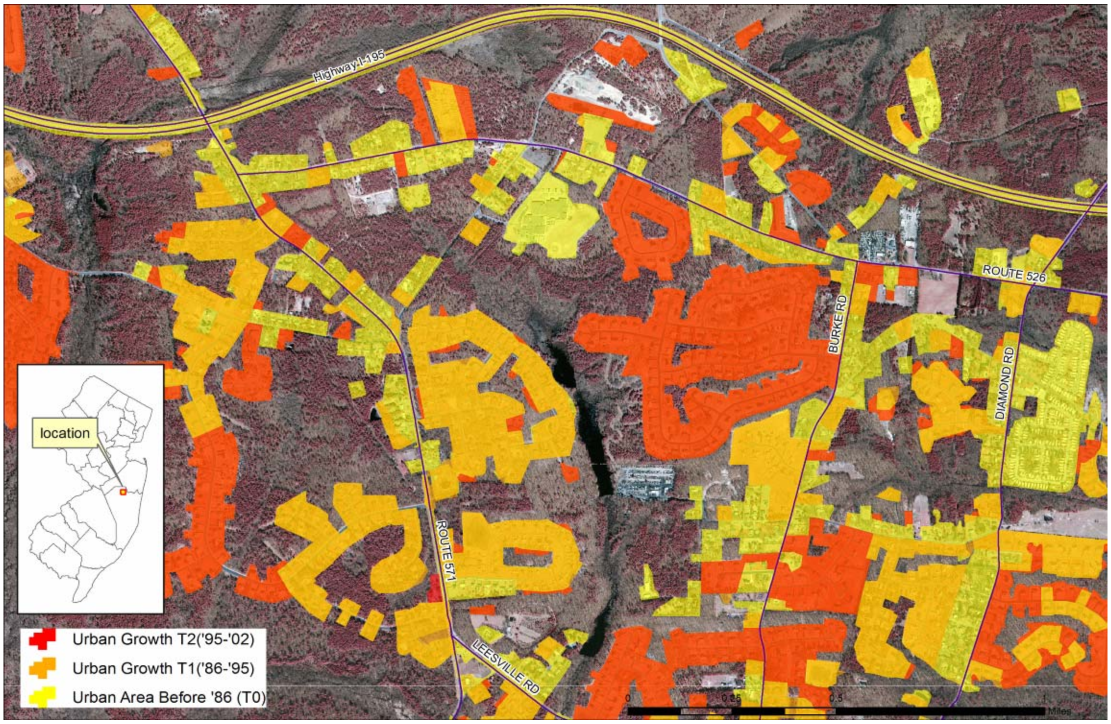

Figure 2.2.2 The above image, near Freehold, New Jersey, demonstrates the increased fragmentation of urban growth over time. Polygons of growth during T1('86-'95) (depicted in orange) become more scattered, numerous and smaller during T2('95-'02) (depicted in red). T0(pre-'86) development is depicted in yellow.

Fragmentation: Table 2.2.1 provides other sprawl statistics. Not only is the amount of land developed trending toward low-density residential, the individual development tracts are also becoming more numerous and fragmented. The average size of newly urbanized areas (represented by polygons in the GIS data) became substantially smaller from T1('86-'95) to T2('95-'02). The individual development tracts are on average becoming smaller and more numerous[2] (Figure 2.2.2). This fragmentation of development has implications for traffic generation, carbon emissions, fragmentation of habitat, and farmland nuisance, among other concerns.

Smart Growth Location: The NJ Office of Smart Growth (OSG) has delineated "Smart Growth areas" within the New Jersey State Plan and the Pineland Comprehensive Management Plan. The number of acres and percentage of new development for each category of urban land that occurred within the Smart Growth areas is provided in Table 2.2.1. More acres of growth actually occurred outside of Smart Growth designated areas than within during T2('95-'02). Most dramatically, 83.7% of the low-density *Rural Residential Single-Unit* development occurred outside of Smart Growth zones, whereas all other residential categories fell largely within Smart Growth zones. Figure 2.2.3 graphs the proportion of residential growth during T2('95-'02) that occurred inside and outside Smart Growth areas. Again, revealing that the large-lot single-unit residential *LU type 1140* exhibits the greatest sprawl footprint.

[2] The decrease in average size and increase in number of polygons could also be attributed to the increased resolution of the 1995-2002 dataset compared with the previous dataset. Further study is necessary to differentiate the degree to which these values indicate fragmentation versus data differences.

Table 2.2.1 Sprawl metrics by urban land category

		T1('86-'95) Growth	T2('95-'02) Growth	T1('86-'95) Growth	T2('95-'02) Growth	T1('86-'95) Growth	T2('95-'02) Growth	T1('86-'95) Growth	T2('95-'02) Growth
LU Code	LABEL	Acres Develop per Year	Acres Develop per Year	Average size Acres	Average size Acres	Average dist to Smart Growth	Average dist to Smart Growth	% Outside Smart Growth	% Outside Smart Growth
1110	RESIDENTIAL, HIGH-DENSITY OR MULTIPLE DWELLING	1,241.0	1,003.0	3.4	2.3	261.5	175.3	14.7	12.4
1120	RESIDENTIAL, SINGLE UNIT, MEDIUM-DENSITY	2,251.0	2,651.0	2.8	1.6	235.5	292.8	9.5	13.8
1130	RESIDENTIAL, SINGLE UNIT, LOW-DENSITY	2,382.0	2,364.0	2.3	1.2	1,642.9	1,749.1	41.8	41.8
1140	RESIDENTIAL, RURAL, SINGLE UNIT	5,046.0	5,096.0	2.1	1.3	4,467.5	4,425.5	85.3	83.7
1150	MIXED RESIDENTIAL	14.0	2.0	8.9	1.9	6.1	1,899.9	0	27.3
1200	COMMERCIAL/SERVICES	1,020.0	1,025.0	1.6	1.1	634.6	703.5	18.7	21.4
1300	INDUSTRIAL	598.0	706.0	1.8	1.3	652.7	604.6	20.2	20.1
1700	OTHER URBAN OR BUILT-UP LAND	2,513.0	2,067.0	2.4	1.3	2,012.5	1,859.3	45.7	42.7

Leapfrog: Another characteristic of sprawl is the leapfrogging of development deeper into rural areas where often there is no infrastructure (i.e. water/sewer/ roads/etc.). Leapfrogging was measured for this analysis by calculating the distance that new polygons of development occurred from the Smart Growth zones as described in the previous section. In Table 2.2.1 the column "Average distance to Smart Growth" provides the average number of feet that a given polygon of new growth was from the OSG Smart Growth areas for selected land types. If a polygon is within a Smart Growth area then it would have a value of zero. The further a polygon is away from Smart Growth areas the more leapfrogging the polygon can be considered. What stands out when differentiating between the different residential categories is that *LU type 1140 Residential Rural Single-Units* are being developed substantially farther away from designated Smart Growth areas than other categories of residential growth. On average a *LU type 1140 Residential Rural Single-Unit* development is over 4,400 linear feet (4/5ths of a mile) from a Smart Growth area. This contrasts with the other residential types including *LU types 1110*, *1120* and *1130*

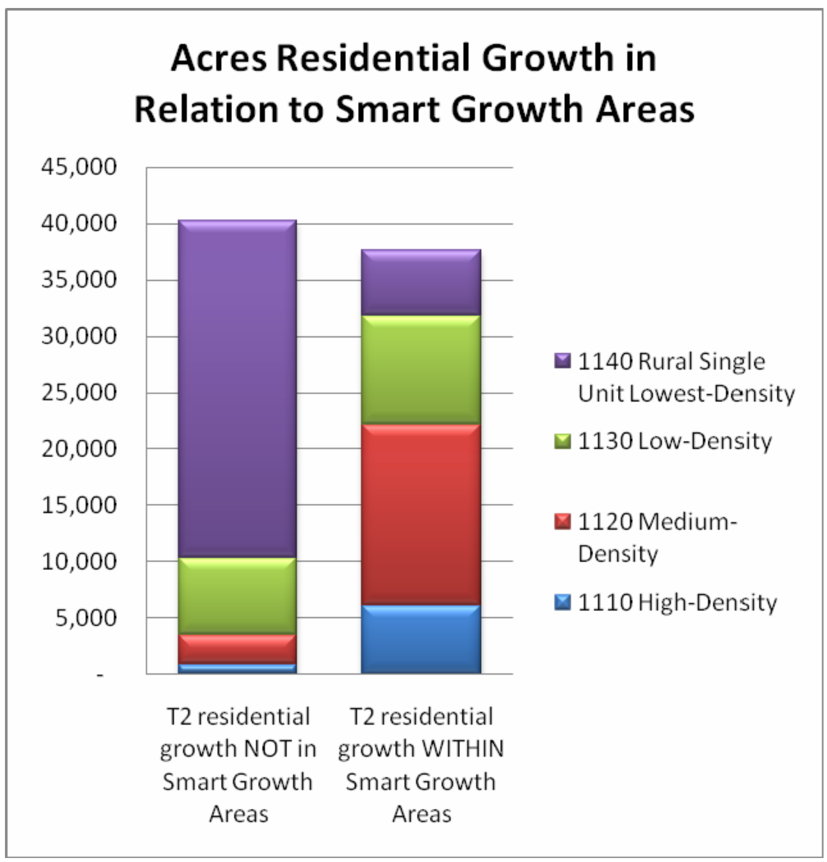

Figure 2.2.3 During T2('95-'02) more acres of residential development occurred outside of Smart Growth designated areas than within. The majority of this growth is attributable to rural, single unit residential.

which are on average 179, 243, and 1,749 feet distance from Smart Growth areas respectively. The large-lot residential housing not only consumes more land per capita housed, it has also leapfrogged outside of Smart Growth designated areas substantially more than any other category of housing.

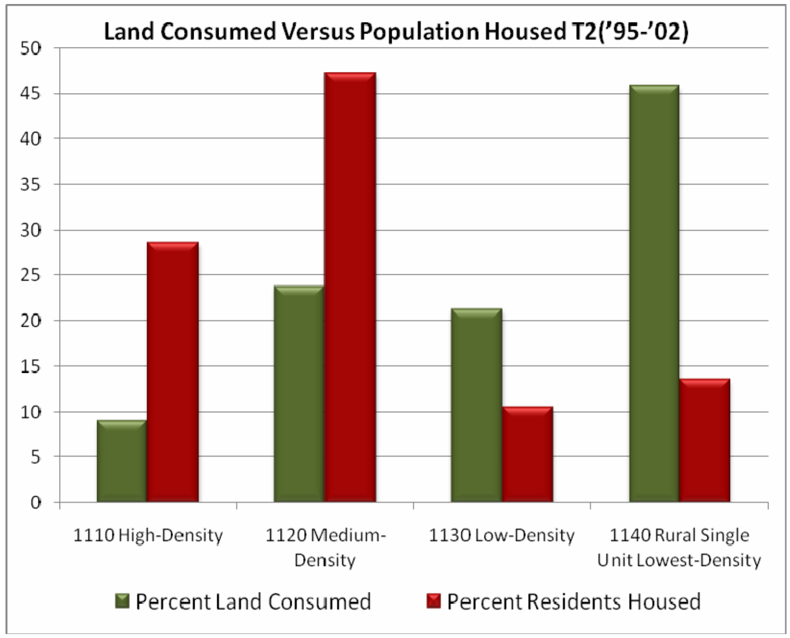

Figure 2.2.4 The land consumed by each residential LU type, versus the population that each type houses, demonstrates that low-density housing consumes a much greater proportion of open space while housing relatively few residents.

Land Use Inefficiency: Another indicator of sprawl is poor land use efficiency. This is measured by the number of people housed vs. the land consumed doing so. Sprawling development wastes land. By estimating the average population density of each residential land use category[3] an approximation of the per-capita land use consumption can be made for each residential type. Statistical comparisons between residential types make evident the sprawling characteristics of the *LU type 1130* and *LU type 1140* low-density residential. Figure 2.2.4 graphs land consumption versus population housed for T2(95'-02). The two low-density residential categories combined occupied over 66% of the land consumed for housing during T2('95-'02) but they only housed twenty-four percent of the population growth. Conversely the two higher-density residential categories combined housed seventy-six percent of the population growth but only consumed thirty-four percent of the land that went into residential.

The sprawl indicators examined indicate that throughout the sixteen year study period, the proportion of development that can be characterized as sprawl increased substantially while the proportion of development that is characteristically Smart Growth decreased in terms of Greenfield acres developed.[4] A total of 77,800 acres of land were developed into residential housing during T2('95-'02). Of that amount, 52,225 acres (67% of the total residential land) was consumed by the two low-density residential categories (*LU type 1130* & *LU type 1140*) even though they only housed twenty-four percent of the people occupying new houses. If those same number of people were housed in *LU type 1120 Residential, Single-Unit,*

[3] Estimates of population density for each residential category were generated by utilizing the category description and US CENSUS population data.

[4] The analysis only examined development that occurred on previously undeveloped land. It should be noted that Smart Growth often entails redevelopment of land that was already developed. Therefore the results do not account for the amount of Smart Growth that could have occurred as redevelopment.

Medium Density (representing 1/8 – 1/2 acre lots), they would have consumed only 9,451 acres which is only eighteen percent of the 52,225 acres actually consumed. Shifting the low-density residential growth to medium density residential would have saved 42,774 acres (fifty-six percent of the total residential land developed during T2) from development.

The findings indicate that two thirds of the acres developed during the past two decades occurred outside of the OSG's Smart Growth areas. At the same time development trends became less dense, more fragmented, leapfrogged further and utilized land less efficiently than development patterns pre 1986. These patterns are classic indications of sprawl. As of 2002, New Jersey is falling substantially short of its goal to channel new development that occurs on green fields (e.g., previously undeveloped land) into Smart Growth.

Photo A. Knee

3 Landscape Impacts of Urbanization

The process of urban growth entails the loss of open space. However, urbanization in and of itself is not inherently problematic when done in a sustainable manner. Urban development provides needed housing for a growing population as well as new business locations for various sectors of a growing economy. When urban growth occurs in a manner that is well designed and sensitive to the environment it often results in built communities with high quality of life while also maintaining the integrity of ecological systems. Conversely, unchecked and sprawling urban growth, such as much of the growth that has occurred in New Jersey over the past several decades, has a number of hidden economic costs and has had significant adverse impacts on the environment and important land resources. The cost of these losses in open space and natural resource lands in both environmental impact and economic consequences are substantial but not often tallied.

By focusing specifically on impacts of urbanization to some of the most valuable and sensitive land resources, one can identify patterns of development that are well planned and lower impact versus development that has a costly footprint. Several indicators of important landscape impacts attributable to urban sprawl were identified utilizing the NJ Land Use/Land Cover dataset and include impacts to farmland, forest, wetlands, wildlife habitat, and impervious surface (Hasse and Lathrop, 2003a). The following section explores these key landscape impact indicators of urban growth in New Jersey.

3.1 Impacts to Farmland

Agriculture is a major activity in the Garden State. Cash sales of agriculture during 2005 were estimated at $857.6 million. When all farming and food related activity is considered, agriculture is remarkably the third largest segment of the New Jersey economy contributing $82 billion (NJDA 2007).

The impact of sprawling urban growth on agriculture is complex. On one hand New Jersey farmers benefit from being close to a large and wealthy population to which to market their harvest resulting in elevated revenue potentials. On the other hand, soaring land values coupled with the conflicts caused by encroaching urban development make it very difficult to continue farming successfully in New Jersey over the long term (Adelaja and Schilling 1999). The result has been that many farms have gone under in the past several decades with land owners discontinuing farming activities in lieu of eventual urban development.

The analysis examined the location and amount of farmland lost over the study period. The results are depicted in Table 3.1.1. During T2('95-'02) 55,530 acres of farmland were lost overall statewide and 36,044 acres were lost specifically to urban development (Figure 3.1.1). To put this amount of farmland loss into perspective, the net loss of agricultural land statewide during the seven year T2 time period was a greater amount of land than the total remaining farmland in Gloucester County as of 2002. In other words, New Jersey is losing statewide one Gloucester County's worth of agricultural land every seven years.

Table 3.1.1 Agricultural land loss statistics

	T1('86-'95)	T2('95-'02)
Ag land loss	85,365	55,530
Annual Ag loss	9,485	7,933
Ag loss to Urban	55,029	36,044
Annual Ag loss to Urban	6,114	5,149
Prime Ag loss to Urban	31,602	22,196
Annual prime Ag loss	3,511	3,171
Annual WETAG loss	91	1,117
WETAG loss to Urban	225	312

Perhaps more significant is the loss of prime farmland. New Jersey benefits from a comparatively large proportion of high-quality agricultural soils. Prime farmland accounted for 57.6% of all farmland under the plow in 1995. During T2 it accounted for 61.6% of the development that occurred on farmland (22,196 acres). Prime farmland is often the easiest to develop since it is relatively flat and often has soil properties amenable to septic systems. Prime farmland loss to development occurred on 3,170 acres per year during T2('95-'02). This suggests that prime farmland is more vulnerable to urbanization than non-prime farmland. The loss of New Jersey's prime farmland undermines agricultural viability in the garden state.

Another impediment that sprawling development places on agriculture is fragmentation. A farmer may choose to stay in farming and even place his or her farm in preservation, but if there are fewer neighboring farms to continue a critical mass of local farm suppliers and other aspects of a local farm culture may diminish. New housing developments that leapfrog into farming areas often create new difficulties for farmers with nuisance complaints about smell

Figure 3.1.1 Farmland is being lost in New Jersey at the rate of 22 acres per day. Photo: J. Hasse

and noise, trespassing, vandalism and increased traffic conflicting with farm equipment (Adelaja and Schilling 1999, Greene and Harlin 1995).

In recent decades, a substantial amount of residential housing (as detailed in the previous section), has leapfrogged into agricultural areas resulting in significant farmland fragmentation (Figure 3.1.2). Table 3.1.2 summarizes the fragmentation characteristics for patches of agricultural land throughout the study period. Not only is farmland shrinking in acreage, but the average size of farmland patches are shrinking. Along with shrinking sizes, the number of farmland patches are increasing as farmland becomes disconnected from other farmland into separate patches. The ratio of edge to area of farmland is also increasing suggesting that there is an increase in non-farming activities adjacent to farmland, thereby increasing the possibility of land use conflicts.

Table 3.1.2 Agricultural land fragmentation analysis

	1986	1995	2002
Total Acres Agricultural Land	829,422	738,994	675,657
Number Agriculture patches	20,071	22,957	23,472
Miles of Agricultural edge	28,391	27,835	26,404
Average Agricultural patch acre	41.3	32.2	28.7
Edge miles per sq mile	21.9	24.1	25.0

Farmland fragmentation is of particular concern to New Jersey's farmland preservation program. Considerable state, county and local public funds have been spent on permanently preserving farmland. The program is voluntary and while the preserved parcel is prevented from development in perpetuity, surrounding

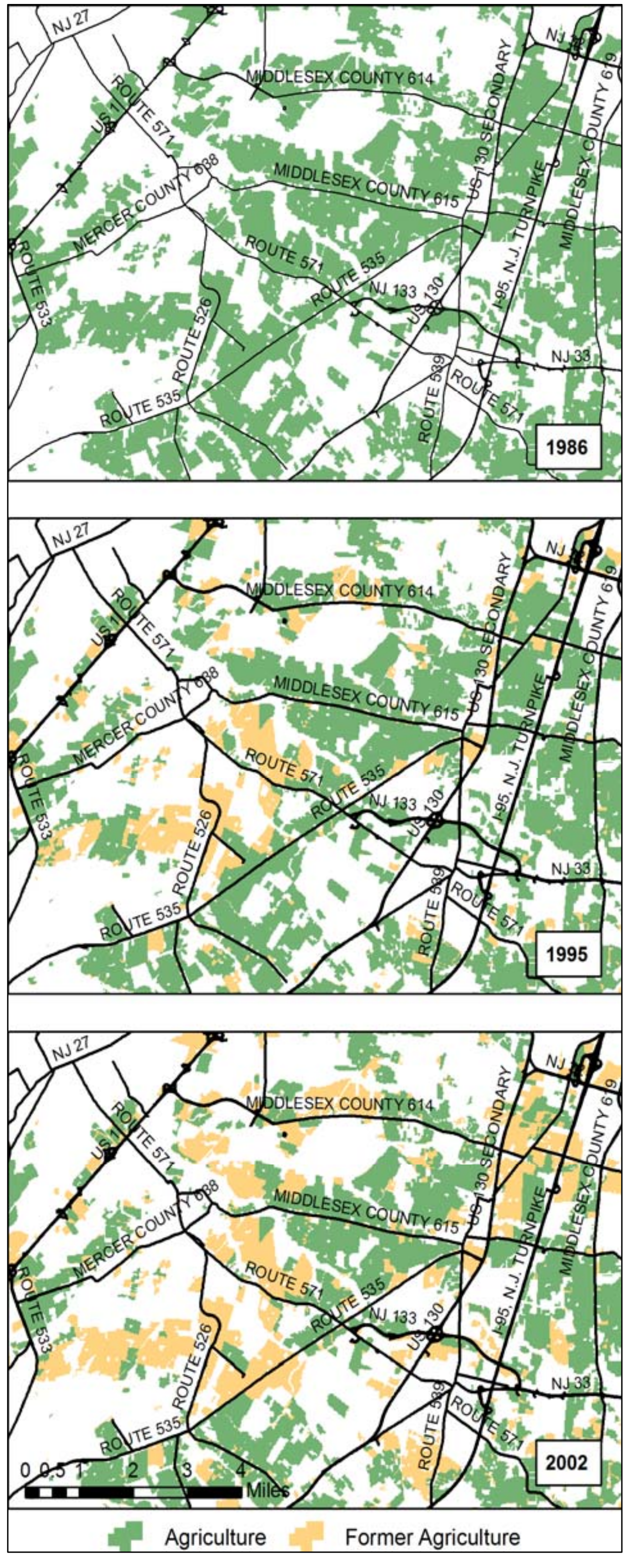

Figure 3.1.2 Farmland fragmentation in central New Jersey near Hightstown, Mercer County. During the sixteen year period of the study, farmland became fragmented into smaller, more numerous and more isolated patches. Farmland fragmentation diminishes agricultural viability.

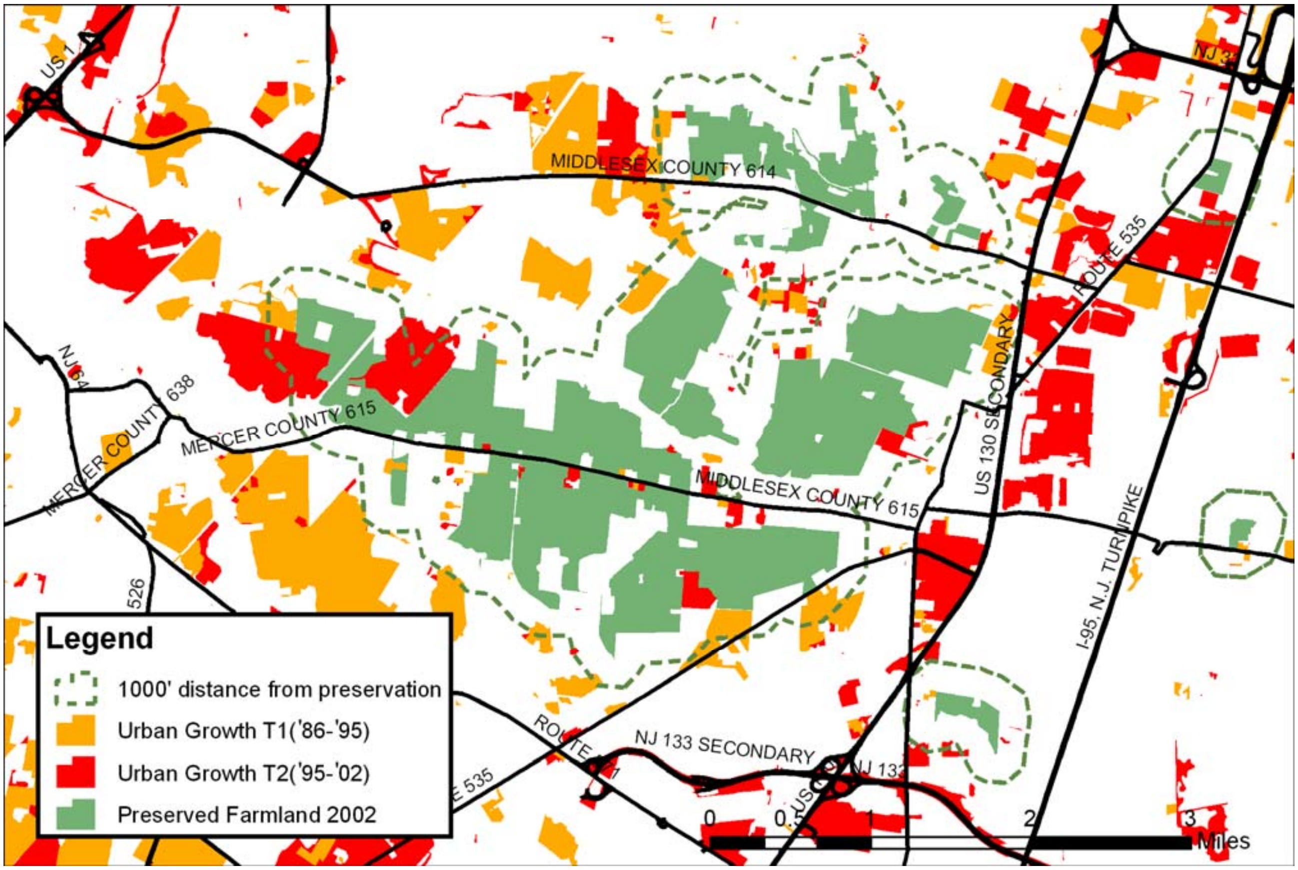

Figure 3.1.3 This map depicts an area of Middlesex County that contains a number of farms in the state's preservation program (green). Significant urban encroachment during T1(orange) and T2(red) has occurred.

farmland may still be developed. This may become a windfall for development of adjacent parcels which benefit from the bordering farmland being preserved while the preserved farms suffer the consequences of urban encroachment (Figure 3.1.3). During the T2 time period 8,380 acres of new development occurred within 1,000 feet of land in farmland preservation.

The state of urbanization and loss of farmland bodes poorly for New Jersey's goal to maintain a vibrant agricultural economy over the long term. However, there are some promising changes revealed in the data that may be an indication of a shift toward more effective agricultural land management. The net annualized rate of total agricultural land loss to all other land use categories dropped to some extent from 9,485 acres per year T1('86-'95) to 7,933 acres per year during T2('95-'02) (Table 3.1.1). The annualized rate of agriculture land that became "urbanized" decreased from 6,114 acres per year T1('86-'95) to 5,149 acres per year during T2('95-'02).

This slowdown in farmland conversion may be at least partly attributable to New Jersey's very active farmland preservation program which has currently preserved over 165,000 acres of land (NJDA SADC 2008). Since any given farm that is in preservation usually contains some land areas that are not under cultivation (woodland, wetlands, etc) the amount of actual acres under the plow that have been preserved will be less than the total preserved acres and was calculated at

92,995 acres. The farmland preservation program has preserved 15.6% percent of New Jersey's remaining active agricultural lands, arguably one of the more successful programs in the country. This is a noteworthy step in reaching the state's goal of preserving 600,000 acres of active agricultural land. Although at the current rate of loss 7,933 acres per year the pace of preservation would need to increase considerably if the Garden State Trust intends to reach its goal of preserving 450,000 additional acres of farmland.

3.2 Impacts to Forestland

The New Jersey landscape has been dominated by forest since the last ice age ended over 10,000 years ago. Forests play a vital role in the landscape due to all the attendant ecosystem services that forests provide such as watershed protection, carbon sequestration, wildlife habitat, and recreation, to name just a few (Costanza, et al., 1997, 2007; Millenium Ecosystem Assessment, 2005a). For many decades, forest land has been the most prevalent landscape category in the state occupying more acres than any other land use category. Recent decades, however, have seen deforestation in New Jersey accelerate largely due to sprawling residential development (Figure 3.2.1). What is more, urban growth is consuming forest at such a pace that at current trends the amount of developed land statewide will surpass upland forest in total acres by midyear 2008.

Table 3.2.1 Upland forest loss

	T1('86-'95)	T2('95-'02)
Net upland forest loss	38,701	41,463
Net annual forest loss	4,300	5,923
Forest loss to Urban	67,322	58,495
Net annual forest to Urban	7,480	8,356

The NJ DEP land use/land cover dataset facilitated the assessment of several factors of forest impact, including: rate of deforestation, forest fragmentation and reduction of interior forest core. The results demonstrate that during the seven year T2 time period, the state lost a net amount of upland forest land of 41,463 acres (Table 3.2.1). The actual amount of forest lost to development is greater than these net results suggest because the net accounts for an increase in forest from the conversion of farmland to forest. (see Table 3.2.2 for transitions into and out of upland forest). Urban growth during T2 actually consumed 58,495 acres of upland forest land or 8,356 acres per year. This amount of forest conversion is equivalent to about ten Central Parks worth of forest being lost to development every year (Figure 3.2.2).

Figure 3.2.1 The annual rate of forest loss, T1('86-'95) to T2('95-'02), increased by 38% during the study period. Forest lost to urban growth rose to 8,356 acres per year. Photo: J. Hasse

In contrast to farmland loss, which slowed slightly during T2 ('95-'02), the rate of forest loss in New Jersey increased. The annual rate of forest conversion for the state's upland forest increased substantially from 4,300 acres per year T1 to 5,923 acres per year T2 (Table 3.2.1), which is an increase of 37.7%. The annual rate of forest land lost specifically to urbanization also increased from 7,480 acres per year T1 to 8,356 acres per year T2.

Table 3.2.2 Acres into and out of upland forest T2.

	Acres converted into *Upland Forest* T2	Acres converted out of *Upland Forest* T2	Net Change of *Upland Forest T2*
Urban	9,177	58,495	49,318
Agriculture	21,633	7,592	-14,041
Natural Wetlands	406	690	284
Altered Wetlands	303	158	-145
Barren	6,618	12,200	5,582
Water	104	568	464
TOTAL	**38,241**	**79,703**	**41,462**

Much of the conversion of forested lands was the result of low-density single unit detached residential development as forested lots draw a premium price from new homebuyers. This type of development not only consumes significant amounts of forest land due to clearing, it also results in forest fragmentation and loss of core forest habitat.

Fragmentation occurs when large patches of forest land are perforated and broken into smaller separate segments (Zipperer, 1993) (Figure 3.2.3). Edge forest adjacent to development and agriculture is impacted by a change in microclimate, disturbance regimes and species composition versus interior or core forest habitat. Fragmentation also results in the ratio of forest edge to area increasing as interior holes and border incursions of deforestation decrease the forest area while adding to the length of forest edge (Heilman et al., 2002; Riitters et al., 2002).

Fragmentation and forest core loss have significant ecological implications (Franklin 1993; Robinson et al., 1995). Habitat areas and movement corridors are diminished and disrupted when forest stands are broken into smaller and non-connecting sections. Many species that rely on large blocks of uninterrupted forest core for habitat may be adversely affected. Other species that prefer forest edge may actually benefit for a time period with increased edge caused by fragmentation. Ultimately, however, continued forest loss and fragmentation reaches a point where the edge begins to shrink once again.

Forest fragmentation worsened in recent decades as indicated by the average size of a forest patch shrinking from 14.6 acres in 1986 to 9.6 acres by 2002 while the total miles of forest perimeter increased from 67,807 in 1986 to 76,874 miles by 2002 (Table 3.2.3).

Figure 3.2.2 Central park is approximately 843 acres in size. New Jersey converted the equivalent of ten Central Parks worth of upland forest to urban development every year between 1995 and 2002. (This photo is a file from the Wikimedia Commons, author: Summ, taken August 2005. This file is licensed under the Creative Commons Attribution ShareAlike 2.5 License.)

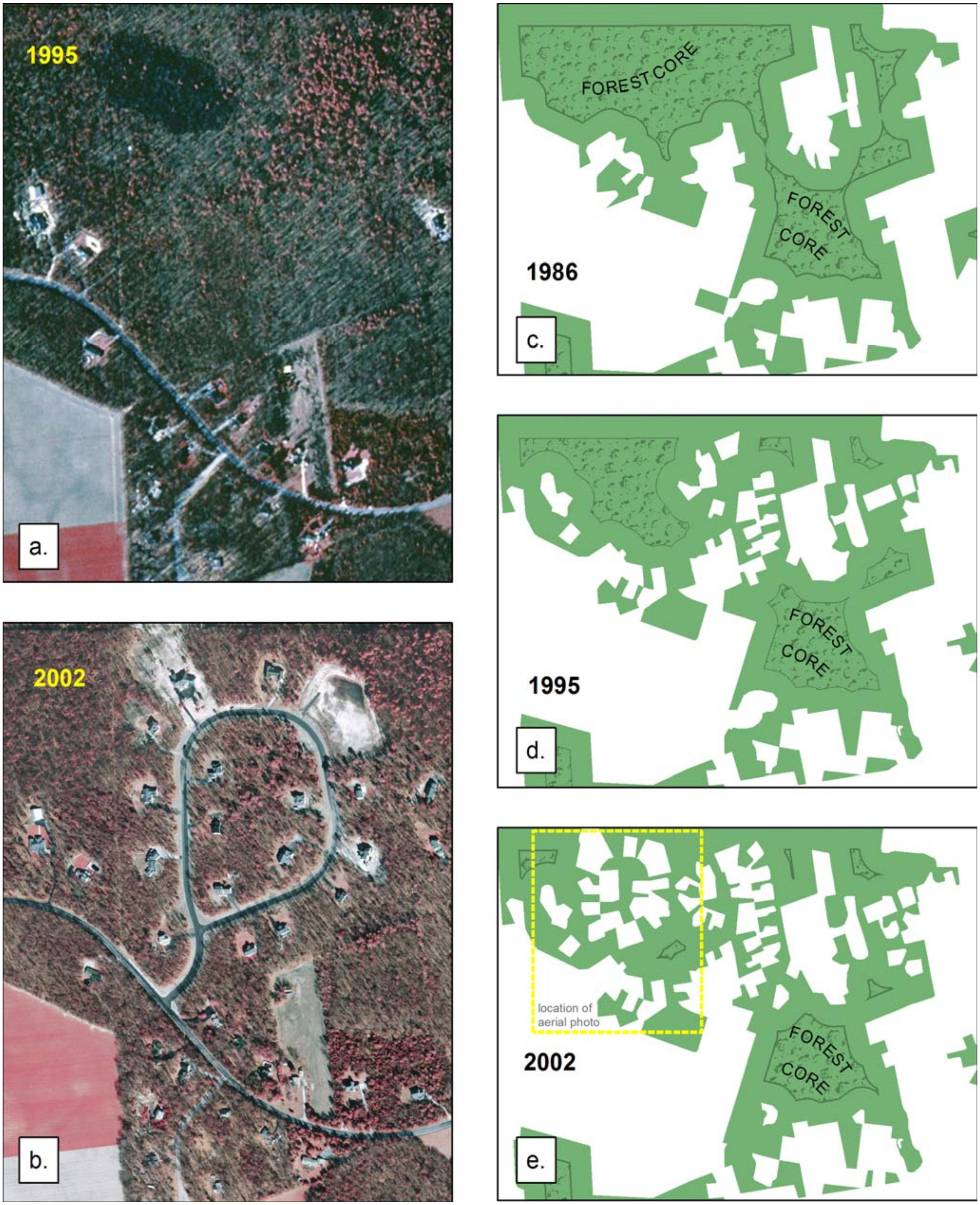

Figure 3.2.3 Forest Fragmentation Orthophotos (a. and b.) show a patch of forest being fragmented by residential development between 1995 and 2002. The maps on the right show fragmentation of forest between 1986 (c.), 1995 (d.) and 2002 (e.). Fragmentation results in smaller forest patches, larger forest edge and diminishing forest core each of which has significant ecological implications. Note: yellow inset box in e. shows location of aerial photos in a. and b.

Forest loss is one of the more critical land management issues facing New Jersey. Unlike farmland which has measurable economic value, the intrinsic value of forest land is less easy to quantify though the New Jersey Department of Environmental Protection recently attempted to do just that (NJDEP, 2007). Healthy forests play a fundamental role in maintaining air quality, ground water aquifer recharge, flood control, micro and macro climate change, carbon sequestration and abatement of soil erosion among many others.

Table 3.2.3 Upland forest fragmentation analysis

	1986	1995	2002
Acres upland forest	1,641,297	1,616,683	1,575,220
Number forest patches	114,622	151,462	164,616
Miles of forest edge	67,807	74,760	76,874
Average forest patch acre	14.3	10.7	9.6
Forest core acres	662,651	608,770	580,631

The effect of urbanization on New Jersey's forest land is worse in some areas than others. The New Jersey Pine Barrens which occupies 1/5th of the state's land territory acts to buffer the statewide magnitude of forest loss since it is relatively well protected. The Pine Barrens contains thirty-four percent of the state's upland forest but it experienced only 11.6% of the total amount of forest loss attributable to urban growth. Conversely, the forested lands outside of the Pinelands are less protected and more vulnerable to deforestation. As a result the sixty-six percent of the state's forest land that exists outside of the Pinelands incurred 88.4% of the deforestation attributable to urbanization.

The findings indicate that New Jersey's forest lands are experiencing significant losses to urbanization and the rate of impact is increasing. If this trend is to be changed, land management policies need to focus on measures that protect the integrity of New Jersey's remaining forest lands.

3.3 Impacts to Wetlands

Wetlands are a vital land resource (Figure 3.3.1). They provide a multitude of both ecological and human functions including wildlife habitat, flood mitigation, and water purification (Costanza, et al., 1997, 2007; Millenium Ecosystem Assessment, 2005b). The value and vulnerability of wetlands led to a number of federal and state measures to safeguard them over the past several decades. Coastal wetlands have been protected since 1970. Fresh water wetlands have been regulated since the 1987 New Jersey Freshwater Wetlands Protection Act. The 2002 LU/LC update provides a means of

Figure 3.3.1 Wetlands represent nearly twenty percent of New Jersey's land territory and provide vital functions for habitat, water quality and flood control. Photo: J. Hasse

Table 3.3.1 Wetlands analysis (all values represent NET change in acres)

	T1('86-'95)	T2('95-'02)
Total Wetlands loss	15,795	12,747
Wetlands loss per yr	1,755	1,821
Wetlands loss to Urban per year	1,442	1,573
Coastal Wetlands change	-1,321	-2,755
Coastal Wetlands loss to Urban	161	120
Coastal Wetlands loss to Urban per year	18	17
Non Coastal Wetlands loss	14,477	9,992
Non Coastal Wetlands loss to urban	12,817	10,889
Non Coastal Wetlands loss to urban per year	1,424	1,556
Natural Wetlands (Non Coastal) change	-22,128	+2,878
Natural Wetlands (Non Coastal) loss to Urban	9,155	5,782
Natural Wetlands (Non Coastal) loss to Urban per year	1,017	826

assessing the effectiveness of these laws in managing wetlands loss in recent decades as compared to pre-regulatory days when wetlands were commonly referred to as "swamps" and often indiscriminately filled.

During the seven year T2('95-'02) a net total of 12,747 acres of mapped wetlands were lost representing an annualized rate of 1,821 acres per year (see Table 3.3.1). This rate held relatively consistent from the T1 net loss of 1,755 acres per year. Total net wetlands loss represents transitions of all land classes into and out of all mapped wetland types.

Looking specifically at wetlands lost to urban development, the net rate increased by about 9% from 1,442 acres per year T1('86-'95) to 1,573 acres per year being urbanized by T2('95-'02) (Figure 3.3.2). To put this rate of

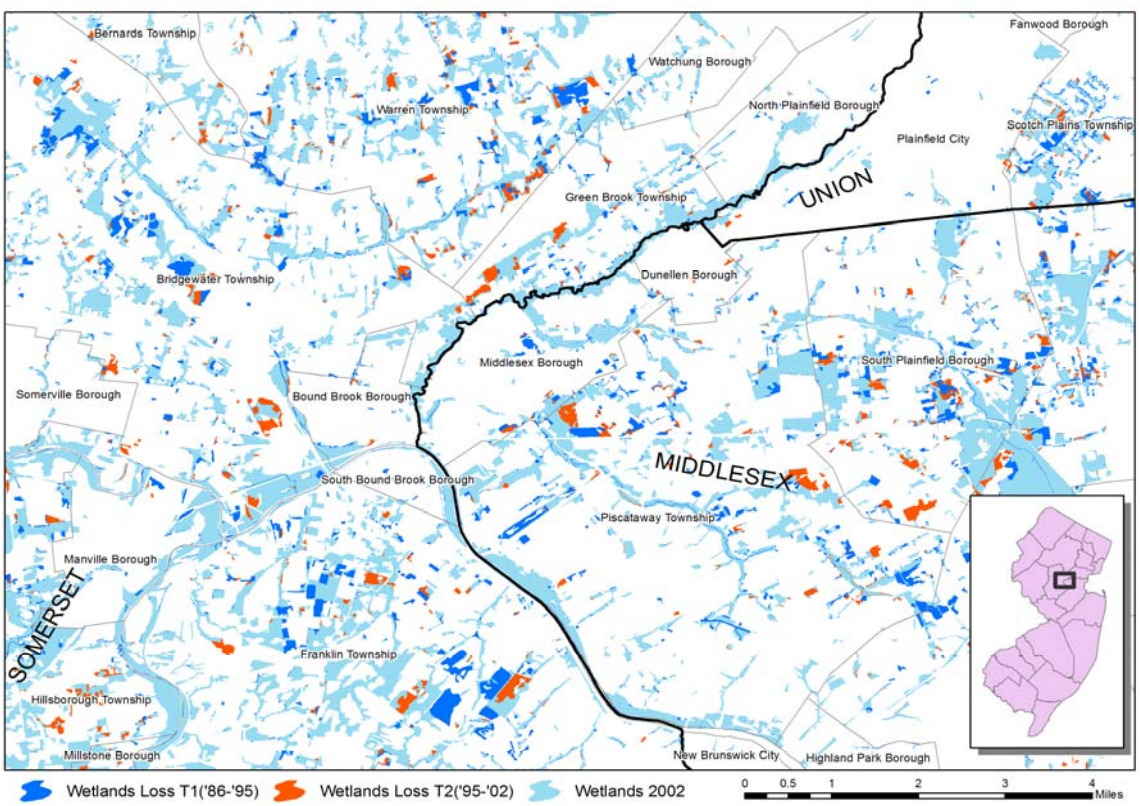

Figure 3.3.2 Wetlands loss attributable to urban growth 1986-1995-2002. The area depicted is between Somerset and Middlesex Counties centered near Bound Brook Borough. Over 28,000 acres of mapped wetlands were lost in the sixteen year study period.

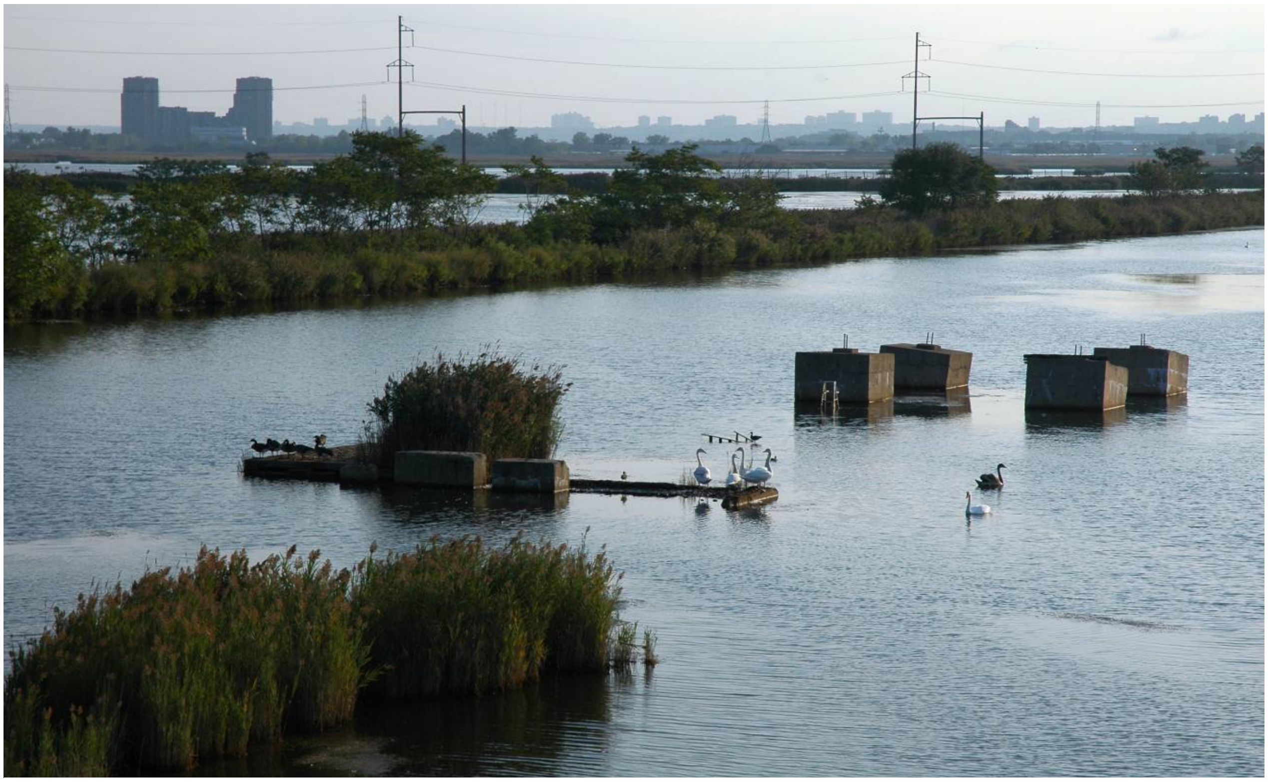

Figure 3.3.3 This is a photo of the New Jersey Meadowlands from Route 7 near South Arlington. New Jersey loses one Hackensack Meadowlands worth of wetlands every 5.3 years. (This photo is a file from the Wikimedia Commons, author: Leif Knutsen, taken September 2006. This file is licensed under the Creative Commons Attribution ShareAlike 2.5 License.)

wetlands loss into perspective, the Hackensack Meadowlands located in northeastern part of the state between Newark and Jersey City, contains over 8,400 acres of wetlands. At the net annual rate of 1,573 acres per year conversion to urbanization during T2('95-'02), every 5.3 years New Jersey loses an amount of wetlands equivalent to the total amount of wetlands remaining in the Hackensack Meadowlands (Figure 3.3.3).

Of particular interest is the examination of "natural" and "altered" wetland classes. Using the H-L classification scheme, Natural Wetlands include the Wetland Forest, Coastal and Emergent Wetland categories while the Altered Wetlands are those heavily modified by some human action and include Urban, Agricultural and Disturbed/Barren Wetlands.

Coastal wetlands comprise 20% of NJ's total delineated wetlands. The net Coastal Wetlands loss attributable directly to urbanization was only about 120 acres during T2('95-'02) and 161 acres during T1('86-95) (Table 3.3.1). The relatively small amount of urbanization of coastal wetlands suggests that New Jersey's Coastal Wetlands Act of 1970 is succeeding in slowing the loss of tidal salt marshes due to human development. Prior to the 1970's, the Barnegat Bay area alone lost more than 10,000 acres of coastal salt marsh (Lathrop and Bognar, 2001).

While the Non Coastal Natural Wetlands (i.e. Wetland Forest and Emergent wetland) category shows significant loss in T1 ('86-'95), there appears to be a gain in wetland area in the T2 ('95-'02) time period (Table 3.3.1). However, examining the wetland class changes in the land use/land cover change matrix (see tables 1.2.3a,b and 1.2.4a,b) reveals a more complex story. While net Natural Wetlands appears to have increased in size during T2, approximately 1,369 acres of Emergent Wetland and 4,518 acres of Forest Wetland transitioned to Urban in 2002. The non-coastal natural wetlands have clearly not fared as well as coastal wetlands as far as the impact of urban development.

These findings indicate that although New Jersey's Freshwater Wetlands Act of 1987 has substantially stemmed pre-regulatory rates of wetlands loss, there nonetheless has been continued loss of freshwater wetlands attributable to urbanization. It must be noted that New Jersey's Freshwater Wetlands Act is not a strict prohibition on development in wetlands and that the data also show some positive trends. For example, the urbanization of "Natural" wetlands appears to have declined between T1 and T2 (from 1,017 to 826 acres per year, Table 3.3.1). Emergent and forested wetlands accounted for 70% of the wetlands that transitioned to Urban during T1('86-'95); this percentage declined to 53% during T2 .

The apparent gain in overall amount of Natural Wetlands in 2002 (Table 3.3.2b) is the result of other LU/LC categories reclassified as Natural Wetlands. The transition matrix (Table 1.2.4b) reveals that a significant area of approximately 4,960 acres of Agricultural Wetlands and 6,400 acres of Disturbed Wetlands were re-classified to Emergent Wetlands in T2. Likewise, a large area of Emergent Wetland of approximately 67,000 acres was reclassified as Wetland Forests in T2. As stated in the background section above, some of the LU/LC change is attributable to "real" conversions or transitions (i.e., natural succession of emergent to forested wetland) and some may be an artifact of the differences in the T1 vs. T2 mapping.

The data indicates that the wetlands component of land use change throughout the study period is complex. Nonetheless, the results suggest that the impact of urbanization on wetlands continues to be an important land management issue.

Table 3.3.2a,b Wetlands aggregation into "natural" and "altered"

Table 3.3.2a Natural versus disturbed wetlands T1(´86-´95)

	1986 Total Acres	1995 Total Acres	Net Change T1(´86-´95)	PCT Change T1(´86-´95)	Annualized Net Change T1(´86-´95)
"Natural Wetlands" Including WETCOAST, WETEMERG, WETFOREST	940,363	916,914	-23,449	-2.50%	-2,605
"Altered Wetlands" Including WETURB, WETAGR, WETDIST	108,432	116,083	7,651	7.00%	850

Table 3.3.2b Natural versus disturbed wetlands T2(´95-´02)

	1995 Total Acres	2002 Total Acres	Net Change T2(´95-´02)	PCT Change T2(´95-´02)	Annualized Net Change T2(´95-´02)
"Natural Wetlands" Including WETCOAST, WETEMERG, WETFOREST	904,662	904,785	123	0	18
"Altered Wetlands" Including WETURB, WETAGR, WETDIST	117,629	104,759	-12,870	-11	-1,838

3.4 Impacts of Urbanization to Threatened and Endangered Species

The previous categories of landscape resource impact that we have explored (farmland, forest and wetlands) all share a common function as habitat for wildlife. Therefore, impacts to these resources in general will result in impacts to the habitat that they provide for all New Jersey's wildlife. Threatened and Endangered (T&E) species of wildlife, however, are more vulnerable to habitat destruction than others (Figure 3.4.1). Endangered Species are those whose prospects for survival in New Jersey are in immediate danger because of a loss or change in habitat, over-exploitation, predation, competition, disease, disturbance or contamination. Assistance is needed to prevent future extinction in New Jersey. Threatened Species are those who may become endangered if conditions surrounding them begin to or continue to deteriorate (NJDEP FGW, 2008). Species that fall under these circumstances are officially "listed". There are both state and federal T&E lists.

The New Jersey Division of Fish and Wildlife maintains the official New Jersey list for

Figure 3.4.1 Endangered species are those that are in immediate danger of becoming extinct or extirpated (locally extinct). The Bog Turtle pictured here is one such animal. Photo: NJ FGW

Threatened and Endangered species. Currently there are over seventy species listed. The Division of Fish and Wildlife have also developed detailed digital maps of New Jersey's critical wildlife areas under a program called the Landscape Project. The Landscape Project began in 1994 by the division's Endangered and Nongame Species Program (ENSP) (NJDEP, 2002). The Landscape Project focuses on large land areas called "landscape regions" that are ecologically similar with regard to their plant and animal communities. Using an extensive database that combines imperiled and priority species location information with land-use/land-cover data, the Endangered and Nongame Species Program has identified and mapped areas that potentially serve as habitat for imperiled species within each landscape region.

Landscape Project habitat maps (Figure 3.4.2) were developed to provide users with peer-reviewed, scientifically-sound information regarding Threatened and Endangered wildlife habitat. The mapping has a number of different landscape types including: emergent wetlands, forested wetlands, forest, grasslands and beach as well as other specialty types including wood turtle habitat and bald eagle foraging areas. Each landscape type is mapped in "patches" of contiguous land area. The patches are then ranked from one to five based on their suitability for Threatened and Endangered species. A rank of one indicates that the habitat is suitable for listed species but that no cases or sightings have been documented. A rank of two indicates that the habitat has occurrences of priority species that are at some risk although not yet listed. A rank of three indicates that a polygon contains occurrences of a threatened species from the NJ list. A rank of four indicates that the

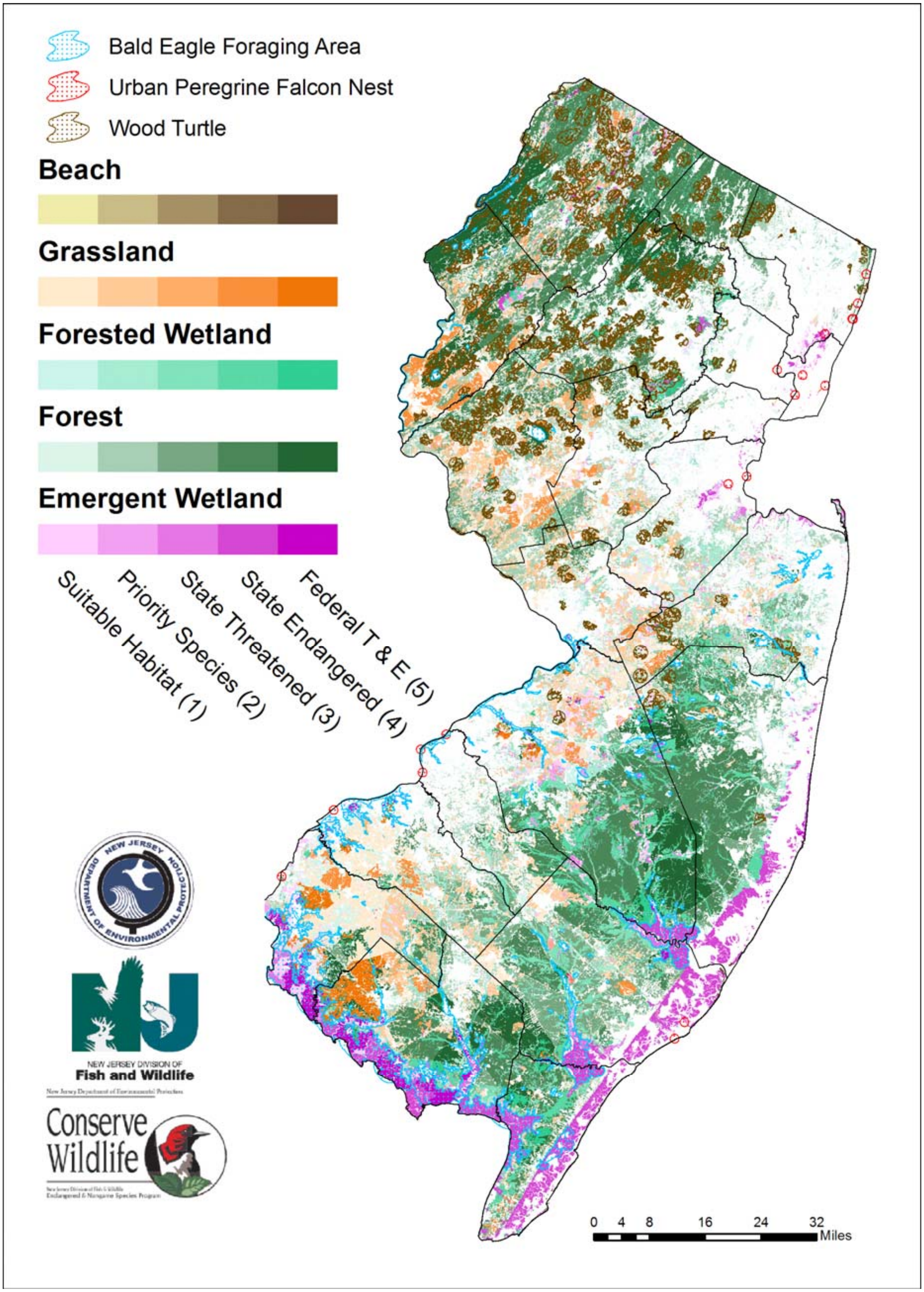

Figure 3.4.2 This map from New Jersey's Landscape Project, produced for the NJ Division of Fish & Wildlife, maps critical remaining habitat of Threatened and Endangered species.

habitat has occurrences of endangered species from the NJ list. A rank of five indicates that federally listed species have been documented within the patch.

By overlaying the Landscape Project database with newly urbanized polygons from the T2('95-'02) NJ Land Use/Land Cover database, an inventory of lost habitat was performed. Table 3.4.1 portrays the number of acres lost for each Landscape Project habitat type and ranking for the seven year T2('95-'02) time period.

The findings indicate that habitat loss attributable to urbanization was substantial although varied by habitat type. New Jersey Grasslands experienced the greatest impact with 28,505 acres (4.9% of total acreage) lost during T2. The New Jersey Grasslands also had the greatest percentage of Rank 5 habitat loss (federally listed endangered species) due to losing 1,146 Rank 5 acres (about 2.6% of total mapped grasslands). Forest habitat (including wetlands and uplands forest) also lost a substantial amount of 49,200 acres (approximately 2.4% of total forest habitat acres).

Table 3.4.1 Land lost by rank.

Emergent Wetlands

rank	total area	pct total	acres lost T2	pct loss of rank
1	99,258	28%	2,539	2.6%
2	42,747	12%	825	1.9%
3	25,526	7%	176	0.7%
4	144,490	41%	180	0.1%
5	44,072	12%	95	0.2%
total	**356,093**	**100%**	**3,815**	**1.1%**

Forested Wetlands

rank	total area	pct total	acres loss T2	pct loss of rank
1	168,844	26%	3,316	2.0%
2	130,056	20%	1,388	1.1%
3	139,876	22%	551	0.4%
4	172,215	27%	445	0.3%
5	37,606	6%	83	0.2%
total	**648,598**	**100%**	**5,783**	**0.9%**

Forest

rank	total area	pct total	acres loss T2	pct loss of rank
1	68,483	3%	2,600	3.8%
2	335,786	16%	16,575	4.9%
3	359,779	17%	10,281	2.9%
4	923,386	45%	16,904	1.8%
5	369,758	18%	2,840	0.8%
total	**2,057,193**	**100%**	**49,200**	**2.4%**

Grasslands

rank	total area	pct total	acres loss T2	pct loss of rank
1	192,888	33%	10,712	5.6%
2	223,992	38%	12,578	5.6%
3	59,883	10%	2,029	3.4%
4	63,912	11%	2,040	3.2%
5	44,661	8%	1,146	2.6%
total	**585,335**	**100%**	**28,505**	**4.9%**

Beach

rank	total area	pct total	acres loss T2	pct loss of rank
1	2,296	42%	34	1.5%
3	87	2%	3	3.1%
4	1,027	19%	6	0.6%
5	2,068	38%	7	0.3%
total	**5,479**	**100%**	**49**	**0.9%**

Sum of all habitat type loss by rank.

Total Rank 1	Suitable Habitat	19,201
Total Rank 2	Priority Species	31,369
Total Rank 3	State Threatened	13,043
Total Rank 4	State Endangered	19,576
Total Rank 5	Federal T & E	4,213
sum	**total habitat loss all ranks**	**87,401**

Wood Turtle

total area	loss	pct loss
268,469	7,204	2.7%

Bald Eagle Forage

total area	loss	pct loss
241,524	692	0.3%

3.5 Impervious Surface Increase

One of the more significant landscape impacts attributable to urbanization is the construction of impervious surface. In nature water is continually moving between the atmosphere, ground water aquifers, lakes and rivers. When land becomes developed, a portion of the parcel is necessarily covered with impervious surface such as asphalt and concrete (Figure 3.5.1). The creation of impervious surface changes the natural hydrologic cycle by impeding precipitation infiltration to groundwater while increasing the amount of surface runoff. Storm peaks are amplified in velocity and magnitude changing the load carrying and erosion characteristics of stream channels. These changes have significant environmental consequences including impacts to ground water recharge, frequency and magnitude of flooding, elevated non-point source pollutant levels and degraded biological activity (Kennen, 1998; Brabec et al., 2002).

Research has shown that the water quality and environmental condition of a watershed is demonstrably related to the amount of

Figure 3.5.1 Impervious surface is created with new urban growth. Impervious surface has significant implications for water quality and flooding as runoff and non-point source pollution is channeled rapidly into stream systems. Photo: J. Hasse

impervious surface within the watershed. A landmark paper by Arnold & Gibbons (1996) described the relationship. Watersheds with less than ten percent impervious surface cover are generally considered unimpacted. At levels greater than ten percent impervious surface watersheds show signs of impact. As impervious surface reaches thirty percent and beyond, water quality has typically become seriously degraded.

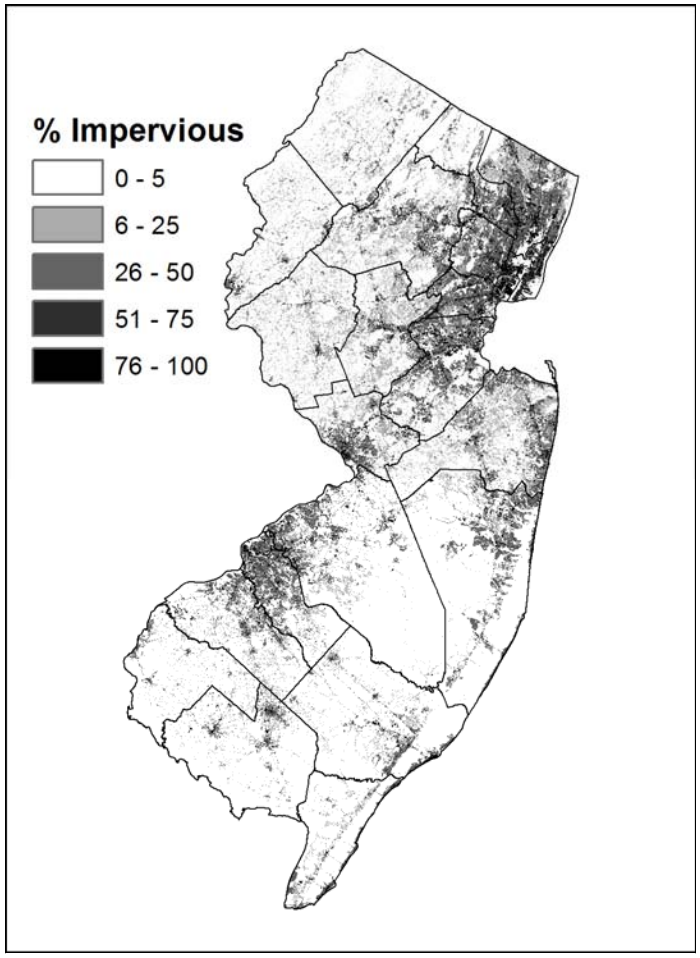

Figure 3.5.2 Impervious surface. This map depicts the pattern of impervious surface in NJ. Darker shades of gray represent higher percentage of impervious cover.

As of 2002, New Jersey's landscape was estimated to be covered with nearly 490,000 acres of impervious surface or about ten percent of the state's total land area (Figure 3.5.2). To put this vast amount of impervious surface into perspective, it is the equivalent of a wall to wall slab of concrete the size of Ocean County. During T2('95-'02) 35,809 acres of impervious surface were added to New Jersey's landscape representing an annual rate of 5,116 acres of impervious surface increase per year. This rate of impervious surface formation is roughly equivalent to paving 1,742 new parking spaces every day (Figure 3.5.3). Growth trends of the 1980s and 90s added one acre of impervious surface for every 4.2 acres of development. In other words, newly developed land is, on average, 23.8% impervious surface.

Figure 3.5.4 illustrates the impervious surface conditions for New Jersey's watersheds. Ten watersheds, representing 315,351 acres or 6.4% of watershed lands in New Jersey are currently thirty percent or greater impervious surface. This indicates that the stream has a high likelihood of being in a degraded condition. These watersheds are located in the highly urban areas of the state adjacent to the cities of New York and Philadelphia. Forty watersheds representing 1,372,189 acres of New Jersey's watershed lands are between 10% and 29.9% impervious surface indicating a high likelihood of impacted water quality. Twenty-nine watersheds representing 1,006,060 acres of New Jersey's watershed lands are between 5% and 9.9% impervious suggesting impending water quality impacts. The remaining seventy-three watersheds representing 3,015,159 acres of New Jersey's watershed lands are less than five percent impervious surface indicating relatively non-impacted water quality (however, this does not include possible agricultural impacts).

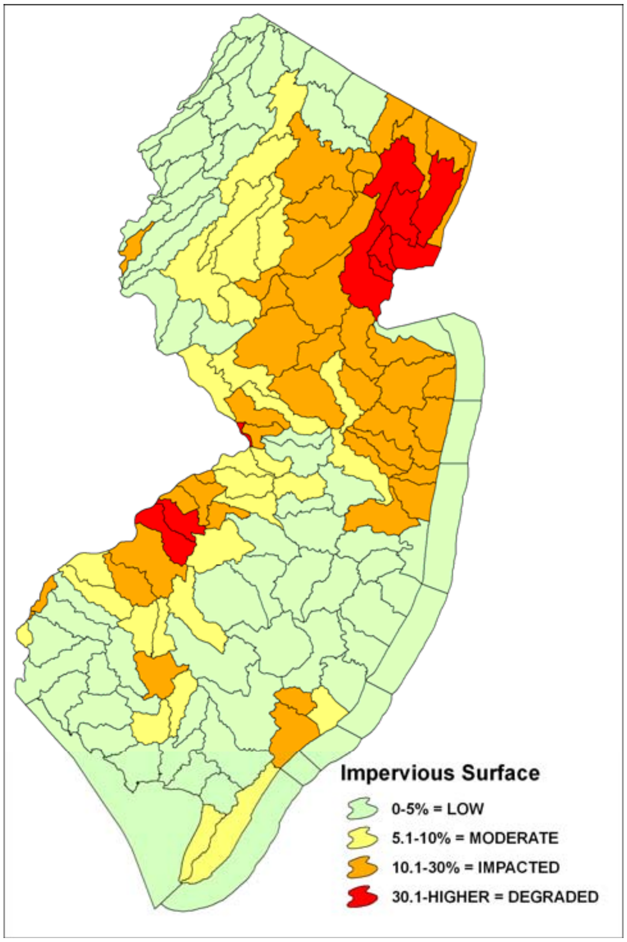

Figure 3.5.4 Impacted and degraded watersheds as indicated by impervious surface cover. Watersheds with over thirty percent impervious surface coverage (colored red) are considered degraded. Watersheds with between ten and thirty percent impervious surface coverage (orange) can be considered impacted. Watersheds with five to ten percent impervious surface (yellow) have impending water quality issues.

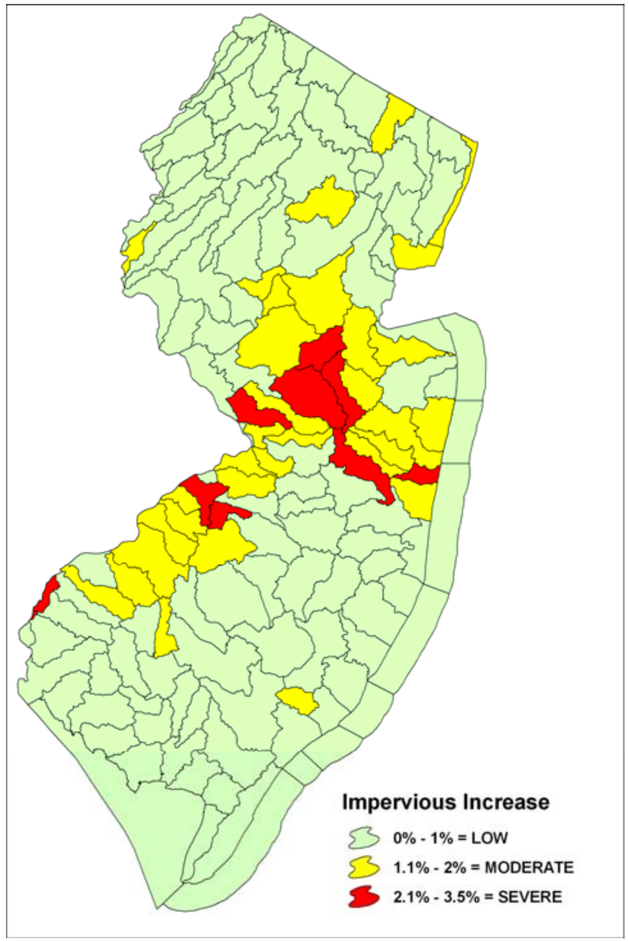

Figure 3.5.5 Impervious surface increase. Many watersheds experienced a significant increase in impervious surface from 1995 to 2002. Watersheds that increased their total impervious surface coverage by one to two percent are colored yellow. Watersheds that have experienced greater than two percent increase in total impervious surface coverage are colored red.

The amount of impervious surface has been increasing in-step with urban growth. During the T2 study period, thirty-two watersheds increased their total impervious surface coverage by one to two percent and nine watersheds increased their total impervious surface coverage by more than two percent (Figure 3.5.5). These rapidly growing watersheds are at the greatest risk for experiencing degradation of water quality. Impervious surface management has the potential to play an important role in sound land management practice. While the ten and thirty percent thresholds have become generally accepted rules of thumb for correlating water quality with impervious surface, further research is needed to clarify the unique relationship of impervious surface to water quality particular to the various physiographic regions of New Jersey. For example, recent research in the New Jersey Pinelands confirms the extreme vulnerability of stream water quality to human altered land use (Zampella et al., 2007). In the

Pinelands, even at impervious surface covers of below five percent, significant water quality impacts have been observed (Conway, 2007).

By focusing on the impacts of urbanization to important land resources such as farmland, forest, wetlands, Threatened and Endangered Species and impervious surface, the least sustainable and most sustainable development types can be identified. By integrating these data with the information provided by the New Jersey Department of Environmental Protection, an economic lens is provided through which to view landscape impacts of urbanization (NJDEP 2007). Utilizing the information provided in the natural capital valuation analysis in conjunction with the landscape change information in this study can potentially provide a means of quantifying the monetary costs of these landscape impacts.

Figure 3.5.3 impervious surface is being created in New Jersey at the rate of 1,742 parking spaces per day, three times the area of the parking lot pictured above. Photo: J. Hasse

4 Evaluation of New Jersey's Land Management Systems

New Jersey has experienced urban development pressure for many decades. By the 1970s it was becoming evident that explosive growth in urbanization brought with it many problematic consequences including: traffic, urban flight, environmental impacts and loss of open space. Under New Jersey's home rule system of local land management, development decisions were largely determined by local municipal governments in competition with rather than in coordination with one another.

In an effort to address the negative consequences of inadequately planned development and poorly coordinated planning between municipalities, the state has taken several large scale regional planning initiatives including: 1) the New Jersey State Development and Redevelopment Plan; 2) the Pinelands Comprehensive Management Plan; and 3) more recently, in 2004, the state passed the Highlands Water Protection and Planning Act, and the New Jersey Highlands Council was formed. By examining urban growth in each of the planning areas for the various management plans, the NJ LULC datasets provide a mechanism for evaluating the effect that these plans have had on shaping patterns of urbanization and guiding development into growth zones while steering development away from sensitive lands. Due to the formation of the Highlands Preservation and Planning Area after the study's 2002 time period, the Highlands were not evaluated separately.

4.1 Urban Growth and The New Jersey State Development and Redevelopment Plan

The New Jersey State Development and Redevelopment Plan (NJSDRP) had its beginnings in the 1980s. In order to make the plan inclusive to local interest and to provide flexibility, the plan was designed to evolve through an interactive process called cross-acceptance. The plan delineates seven zones of land use (Figure 4.1.1); 1) *PA1 Metropolitan Planning Area,* 2) *PA2 Suburban Planning Area,* 3) *PA3 Fringe Planning Area,* 4) *PA4 Rural Planning Area,* 5) *PA4B Rural/Environmentally Sensitive Planning Areas,* 6) *PA5 Environmentally Sensitive Planning Area,* and 7) *PA5B Environmentally Sensitive Barrier Island*. The planning areas prescribe the type of urban development and land preservation that is most appropriate for each zone. PA1 (Metro) & PA2 (Suburban) are areas where development growth and redevelopment is encouraged. PA3 is a fringe area intended to receive some growth balanced with land conservation measures. Planning areas PA4, PA4B and PA5 are "rural" and/or "environmentally sensitive" zones in which the intention is to minimize large scale development and concentrate land preservation. The plan also designates centers which are focused areas of development and redevelopment that can occur in any of the planning areas.

The objective of the State Plan is to provide the regional coordination long lacking in New Jersey's home rule municipal land use system. The State Plan does not have regulatory power but is instead a "statement of state policy" that is intended to guide local agencies in the exercise of their statutory authority. If municipalities coordinate their

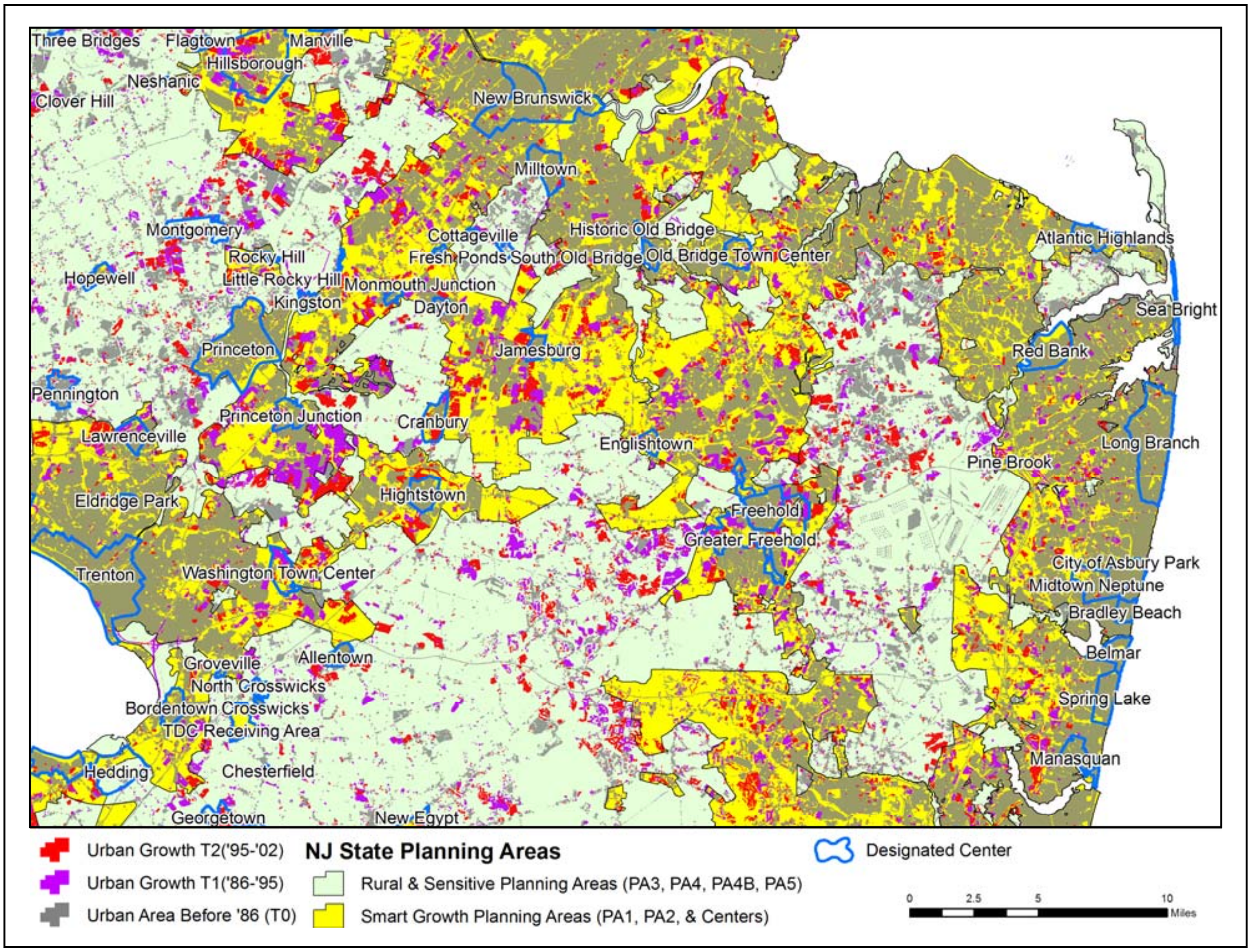

Figure 4.1.1 This map portrays development in relationship to the NJ State Planning Areas for central New Jersey. Urban growth that occurred during T1('86-'95) is purple and growth during T2('95-'02) is red. Yellow areas represent the Smart Growth zones consisting of PA1, PA2 and Centers. Light green areas represent the sensitive planning areas of PA3, PA4, PA4b and PA5. The map reveals the scattered pattern of development throughout the state. Nearly half of all acres developed did not occur in the states Smart Growth zones.

own land use planning initiatives with the state plan through cross-acceptance then the local plans are considered "endorsed." Endorsement provides some benefits such as financial and technical assistance from the state. It also accelerates the coordination between state agencies regarding planning and development review.

Table 4.1.1 provides a breakdown of the acres of growth T2('95-'02) in the various planning areas by detailed urban land use type. What stands out is the substantial amount of development that occurred in the planning areas intended to receive minimal growth. During T2('95-'02), about 40% of all the development (45,830 acres) that occurred in areas of the state covered by the state plan took place in the PA4 Rural, PA4B Rural/Environmentally Sensitive or PA5 Environmentally Sensitive planning areas.

The preponderance of the growth in these planning areas was attributable to a single land use category, *LU type 1140 Residential Rural Single-Unit low-density* housing. Large-lot single-unit housing is responsible for consuming the majority of state's most sensitive lands.

Urban growth in both PA1(Metro) and PA2(Suburban) had the majority of development occur as *LU type 1120 Residential, Single-Unit, Medium Density*. This is housing on 1/8 to 1/2 acre lots. PA2 had a larger proportion (17.3%) of development occur as *LU type 1130 Residential Single-Unit, Low-density* on 1/2 to one acre lots. Commercial and industrial land uses were most likely to be developed in PA1(Metro) followed by PA2(Suburban). PA3(Fringe) experienced the smallest total amount of growth among all the major planning areas receiving only 8,417 acres (7.3%) of the growth. This makes sense since PA3 covers the smallest amount of territory. The majority of growth in PA3 was attributable to low-density and rural single-unit housing.

The two right-most columns of Table 4.1.1 portray the development patterns within the designated and planned centers as they existed in the summer of 2007. The urban growth that occurred within the centers demonstrates strong characteristics of Smart Growth with a high proportion of the development occurring as high-density and medium-density housing as well as a substantial amount of commercial services. The centers overlay the state planning areas so the amount of acreage of growth occurring within them (13,115 acres) is not an additional amount of development but a subset of growth in other planning areas. While the centers development characteristics are consistent with Smart Growth, it only represents 11.4% of total growth in acres, meaning that 88.6% of development did not occur in a designated center. However, the designation of a center is approved by a local municipality through cross-acceptance and there are many other locations that have been identified that are yet to be sanctioned which may eventually become future designated centers.

The State Plan analysis demonstrates that there is substantial differentiation in the development patterns occurring in the various planning areas. A significant amount of development did occur where it was intended in the PA2(Suburban) followed by PA1(Metro). However, the plan is not regulatory and its power to substantially effect development is secondary to the forces that drive development at the local level. The plan's secondary status is evident by looking at the fact that 40% of development that occurred throughout the state was in areas where the State Plan recommended avoiding development. The development patterns indicate that the State Plan has not effectively mitigated sprawl in New Jersey's sensitive planning areas.

Table 4.1.1 Urban growth T2('95-'02) tabulated by the New Jersey State Planning areas

		PA1 Metro		PA2 Suburban		PA3 Fringe		PA4 Rural		PA4B Rur Env Sens		PA5 Env Sens		Centers	
LU Code	LABEL	acres devel	% total	acres devel	% total	acres devel	% total	acres devel	% total	acres devel	% total	acres devel	% total	acres devel	% total
1110	RES, HIGH DENSITY	1,835	9.0%	4,021	10.5%	138	1.6%	293	1.9%	42	0.3%	280	1.6%	1,980	15.1%
1120	RES, SIN UNIT, MED DENS	5,138	25.1%	8,879	23.2%	601	7.1%	537	3.5%	342	2.6%	1,116	6.5%	2,474	18.9%
1130	RES, SIN UNIT, LOW DENS	2,110	10.3%	6,612	17.3%	1,763	20.9%	1,554	10.1%	906	6.8%	2,315	13.5%	902	6.9%
1140	RES, RUR, SIN UNIT	1,298	6.3%	3,510	9.2%	3,155	37.5%	8,509	55.4%	7,888	59.2%	8,501	49.6%	998	7.6%
1150	MIXED RESIDENTIAL	-	0.0%	7	0.0%	-	0.0%	-	0.0%	2	0.0%	-	0.0%	2	0.0%
1200	COMMERCIAL/SERVICES	2,483	12.1%	2,573	6.7%	312	3.7%	322	2.1%	327	2.5%	547	3.2%	1,425	10.9%
1211	MILITARY INSTALLATION	4	0.0%	3	0.0%	-	0.0%	-	0.0%	4	0.0%	24	0.1%	1	0.0%
1214	FORMER MILITARY	2	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
1300	INDUSTRIAL	1,704	8.3%	1,917	5.0%	119	1.4%	214	1.4%	123	0.9%	409	2.4%	856	6.5%
1400	TRANS/COMM/UTIL	524	2.6%	463	1.2%	57	0.7%	79	0.5%	47	0.4%	94	0.5%	433	3.3%
1410	MAJOR ROADWAY	142	0.7%	205	0.5%	20	0.2%	8	0.1%	5	0.0%	73	0.4%	84	0.6%
1419	BRIDGE OVER WATER	1	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	1	0.0%
1440	AIRPORT FACILITY	46	0.2%	37	0.1%	2	0.0%	24	0.2%	3	0.0%	5	0.0%	31	0.2%
1461	WETLAND RIGHTS-OF-WAY	19	0.1%	24	0.1%	5	0.1%	8	0.1%	21	0.2%	16	0.1%	1	0.0%
1462	UPLAND R-O-W DEVELOP	9	0.0%	43	0.1%	5	0.1%	22	0.1%	17	0.1%	6	0.0%	16	0.1%
1463	UPLAND R-O-W UNDEVEL	35	0.2%	89	0.2%	14	0.2%	33	0.2%	71	0.5%	29	0.2%	29	0.2%
1499	STORMWATER BASIN	695	3.4%	1,919	5.0%	269	3.2%	249	1.6%	283	2.1%	357	2.1%	425	3.2%
1500	INDUST/COMMERC CMPLX	31	0.2%	18	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	15	0.1%
1600	MIXED URBAN OR BUILT UP	1	0.0%	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	3	0.0%
1700	OTHER URBAN OR BUILT	2,722	13.3%	4,860	12.7%	782	9.3%	1,616	10.5%	1,495	11.2%	1,653	9.6%	1,846	14.1%
1710	CEMETERY	57	0.3%	23	0.1%	36	0.4%	48	0.3%	12	0.1%	43	0.3%	20	0.2%
1711	CEMETERY ON WETLAND	18	0.1%	1	0.0%	1	0.0%	2	0.0%	-	0.0%	11	0.1%	1	0.0%
1741	PHRAGMITES DOM URBAN	17	0.1%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	15	0.1%	1	0.0%
1750	MANAGED WETLAND LAWN	344	1.7%	451	1.2%	97	1.1%	137	0.9%	150	1.1%	181	1.1%	152	1.2%
1800	RECREATIONAL LAND	917	4.5%	2,212	5.8%	876	10.4%	1,490	9.7%	1,378	10.3%	1,347	7.9%	1,081	8.2%
1804	ATHLETIC FIELDS (SCHLS)	130	0.6%	237	0.6%	53	0.6%	148	1.0%	162	1.2%	58	0.3%	233	1.8%
1810	STADIUM / CULTURAL CENT	36	0.2%	44	0.1%	67	0.8%	1	0.0%	-	0.0%	-	0.0%	47	0.4%
1850	MANAGED WETLAND REC	133	0.7%	151	0.4%	45	0.5%	61	0.4%	55	0.4%	58	0.3%	58	0.4%
	Total Acres Developed	**20,452**		**38,301**		**8,417**		**15,357**		**13,333**		**17,140**		**13,115**	
	% of Total Acres Developed	**18.1%**		**33.9%**		**7.4%**		**13.6%**		**11.8%**		**15.2%**		**11.6%**	

4.2 Urban Growth and the Pinelands Comprehensive Management Plan

The New Jersey Pine Barrens is a unique pine and oak forest located in the sandy soils of southern New Jersey's Outer Coastal Plain. Occupying approximately 1.1 million acres of relatively undeveloped forest land, the Pine Barrens is internationally recognized as an exceptional and unique ecosystem. The Pine Barrens is also located above the Kirkwood-Cohansey aquifer, one of the most significant and pristine ground water aquifers in the northeast.

The Pinelands Comprehensive Management Plan (CMP) is a regional plan that designates several different planning zones. While local municipal planning and zoning still exists

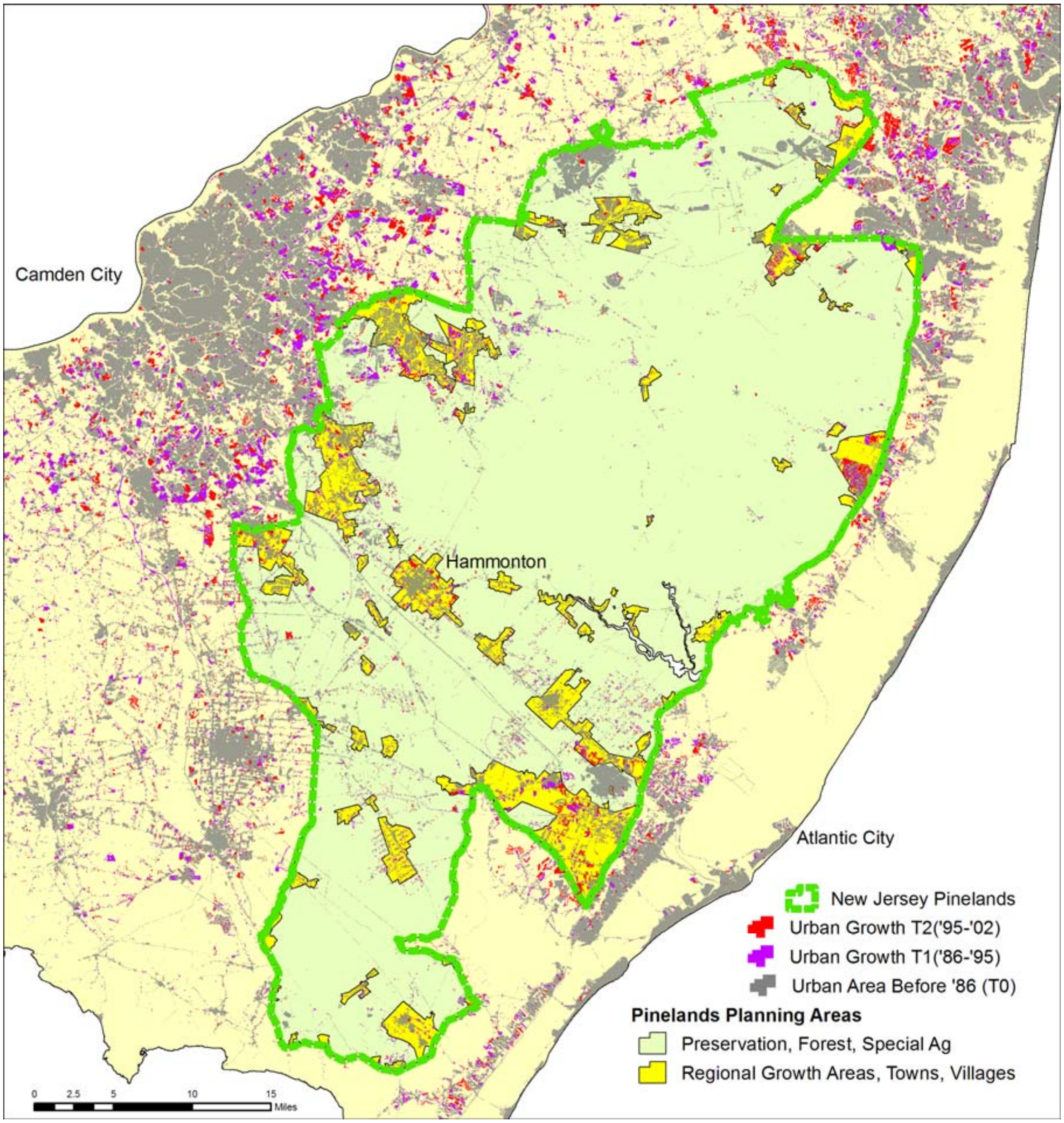

Figure 4.2.1 This map portrays development within the area governed by the Pinelands Comprehensive Management Plan. Urban growth that occurred during T1('86-'95) is purple and growth during T2('95-'02) is red. Yellow areas within the Pinelands represent the Smart Growth zones consisting of Regional Growth, Towns and Villages. Light green areas represent the Preservation, Forest and Specialty Ag planning zones. The map reveals the minimal growth that occurred overall within the Pinelands compared to the rest of the state as well as the success of the plan to channel growth into the Growth zones.

within the area, local plans are required by statute to be consistent with the goals of the regional plan. Planning areas have specific goals ranging from preservation in the "core" area to higher density development consistent with the principles of Smart Growth in designated growth areas. Each management area allows a different level of development and housing densities, ranging from almost no new development to areas where development is encouraged (NJAPA, 2004).

The Pinelands CMP's purpose is to "promote orderly development of the Pinelands so as to preserve and protect the significant and unique natural, ecological, agricultural, archaeological, historical, scenic, cultural and recreational resources of the Pinelands" (Pinelands Commission 2007). The Pinelands CMP (Figure 4.2.1) is similar to the New Jersey State Plan in that there are various planning areas that are intended to preserve and conserve sensitive areas, while steering development toward growth areas. However, the Pinelands CMP is very different from the State Plan in that it does have statutory control.

When comparing urban growth inside the Pinelands CMP to growth in the rest of the state covered by the State Plan the greater effectiveness of the Pinelands plan is unmistakable. Table 4.2.1 compares development of available land inside and outside the regulatory area of the Pinelands. In 1995, the Pinelands contained 25.8% of the land available for development in the state. However, during T2('95-'02) it experienced only 7.5% of the state's development growth. In contrast, areas outside the Pinelands Zone developed 92.5% of the state's growth T2('95-'02) even though it contained only 74.2% of the state's available land. The overall pace of urbanization gauged against the proportion of available land demonstrates that the magnitude of development was considerably slower inside than outside of the Pinelands. The Pinelands Comprehensive Management Plan has slowed development growth relative to the rest of the state, as well as effectively steered development to planned areas.

Factors other than regulatory control such as geographical location and context could also account for this lower propensity of development within the Pinelands. Most significantly, the lack of development in the Pinelands could simply be an effect of the distance that the Pinelands is located away from urban centers. However, New Jersey's small size and the fact that the Pinelands is surrounded by metropolitan New York, Philadelphia and Atlantic City put the entire Pinelands area well within acceptable commuting distance for a high concentration of people. Furthermore, when one views the location of the urban growth that occurred statewide 1995 to 2002, significant tracts of

Table 4.2.1 Urban growth T2('95-'02) inside and outside the Pinelands Comprehensive Management Plan

	Total Acres	% Total Acres	Available Land (1995)	% Total Available (1995)	Urban Growth T2('95-'02)	% Total Urban Growth T2('95-'02)
Pinelands	938,175	18.8%	315,319	25.8%	9,359	7.5%
Outside Pinelands	4,046,000	81.2%	906,482	74.2%	115,546	92.5%
New Jersey	**4,984,175**		**1,221,801**		**124,905**	

new development can be identified around the entire perimeter of the Pinelands with the exception of the extreme southern portion.

It should be recognized that there is also substantial local, county and state land management controls outside of the Pinelands including the Coastal Area Facility Review Act on the ocean-side of the Pinelands boundary. Nonetheless, the effectiveness of the Pinelands management control seems to be significantly stronger as indicated by land development patterns. The ring of development outside of the Pinelands boundary is a compelling indication that regulation is having a different effect on alternate sides of the regulatory line. The findings clearly demonstrate that overall rates of urban growth are substantially slower within the Pinelands compared to the rest of New Jersey.

More significant than controlling the magnitude of urbanization in the Pinelands, the findings demonstrate that the Pinelands CMP has functioned well at channeling the development into the designated growth areas. Table 4.2.2.displays the development rates for each planning area and the proportion of development for both T1('86-'95) and T2 ('95-'02).

The effect of the management plan can be seen by looking at the acreage of new urban development within each of the nine management areas. A substantially higher proportion of development occurred in the designated areas, which include the Regional Growth, Towns, Villages, and Rural Development areas, when compared to the more protected Preservation, Special Agricultural and Forest areas which receive far less development. It's important to note that the amount of available land for each management area is significantly different between zones and that the amount of available land in each management area is substantially less than its total area of land.

Equally important as where the development is occurring is what type of development is occurring. Low-density development will consume substantially more land per person than high-density growth. If areas intended to receive little growth have a significant total number of acres developed, and the development is low-density, then the total population growth will be less than if those same numbers of developed acres were occupied by high-density growth. The findings indicate that the majority of residential development in the Preservation area, Rural, Single-Unit and Single-Unit, Low-Density are consistent with the permitted housing densities for the area at one half to one acre lots. A low-density of one housing unit to ten to forty acres is allowed in the Agricultural Production areas, which was 70.7% Rural, Single-Unit. This type of residential development has the lowest housing density.

Conversely, when looking at the zones intended to receive growth, the types of development that occurred are substantially higher density. This indicates that a higher population will be housed for each acre developed. The results demonstrate that the types of development that occurred in the sensitive zones are consistent with the goals of the management plan. The bottom line is that the Pinelands Comprehensive Management Plan is functioning quite successfully as evident in the pattern of development that has occurred.

Table 4.2.2 Urban growth T2('95-'02) tabulated by the Pinelands Comprehensive Management Planning zones.

		Preservation		Forest		Agricultural Production		Rural Development		Regional Growth		Town		Federal		Village		Special Agr Production	
	Size of Planning Area	294,609 ac		305,570 ac		66,081 ac		110,005 ac		77,174 ac		21,813 ac		47,519 ac		24,002 ac		33,987 ac	
	Available land 1995	42,069 ac		94,976 ac		33,066 ac		56,855 ac		31,266 ac		8,732 ac		23,530 ac		13,295 ac		11,510 ac	
LU code	**LABEL**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**
1110	RES, HIGH DENSITY	0	0.1	30	3.6	0	0.0	28	1.5	198	4.8	57	6.4	0	0.0	0	0.0	0	0.0
1120	RES, SIN UNIT, MED DENSI	5	3.0	15	1.7	1	0.2	44	2.3	1,645	40.1	90	10.1	0	0.0	58	8.3	0	0.0
1130	RES, SIN UNIT, LOW DENS	13	7.4	58	6.8	13	3.2	347	18.4	487	11.9	184	20.7	0	0.1	143	20.6	0	0.0
1140	RES, RUR, SIN UNIT	40	22.1	581	68.5	299	70.7	827	43.7	375	9.1	109	12.2	3	0.9	319	46.0	2	30.3
1200	COMMERCIAL/SERVICES	15	8.5	15	1.8	7	1.6	52	2.8	347	8.4	84	9.4	0	0.0	21	3.1	1	15.2
1211	MILITARY INSTALLATION	0	0.0	4	0.5	0	0.0	7	0.4	3	0.1	0	0.0	3	0.8	0	0.0	0	0.0
1300	INDUSTRIAL	1	0.4	18	2.2	18	4.2	69	3.6	32	0.8	34	3.8	0	0.0	25	3.6	4	45.5
1400	TRANS/COMM/UTIL	8	4.3	16	1.8	2	0.5	26	1.4	46	1.1	44	4.9	15	4.5	7	1.0	1	9.1
1410	MAJOR ROADWAY	0	0.0	0	0.0	0	0.0	0	0.0	6	0.2	0	0.0	0	0.0	0	0.0	0	0.0
1461	WETLAND RIGHTS-OF-W	3	1.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	141	41.9	0	0.0	0	0.0
1462	UPLAND RIGHTS-OF	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	1	0.2	0	0.0	0	0.0
1463	UPLAND RIGHTS-OF-W	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1499	STORMWATER BASIN	4	2.3	19	2.3	19	4.5	27	1.4	214	5.2	39	4.4	0	0.0	18	2.7	0	0.0
1700	OTHER URBAN OR BLT	74	41.2	53	6.3	27	6.5	131	6.9	268	6.5	138	15.4	150	44.9	50	7.2	0	0.0
1710	CEMETERY	0	0.1	0	0.0	0	0.0	1	0.1	11	0.3	1	0.1	6	1.9	0	0.0	0	0.0
1750	MANAGED WETLAND	0	0.3	0	0.0	3	0.7	8	0.4	3	0.1	3	0.3	16	4.7	0	0.0	0	0.0
1750	MANAGED WETLAND	0	0.0	1	0.1	0	0.0	7	0.4	46	1.1	0	0.0	0	0.0	0	0.0	0	0.0
1800	RECREATIONAL LAND	15	8.5	37	4.4	34	7.9	319	16.9	414	10.1	75	8.4	0	0.0	43	6.3	0	0.0
1804	ATHLETIC FIELDS	0	0.0	0	0.0	0	0.0	0	0.0	12	0.3	32	3.6	0	0.0	8	1.2	0	0.0
	Total Acres Develop:	**181**		**848**		**424**		**1,892**		**4,108**		**892**		**335**		**693**		**8**	
	% of total Acres Developed	**1.9%**		**9.0%**		**4.5%**		**20.2%**		**43.8%**		**9.5%**		**3.6%**		**7.4%**		**0.1%**	

5 Regional Urban Growth Analyses

For a breakdown of urban growth on a regional basis, we return to a Level I analysis in order to explore the geographic distribution of development during the 1986-1995-2002 time period. Though substantial amounts of development occurred in total, the spatial pattern was uneven with some areas that were hotspots of growth as well as other areas in which growth was relatively slower than the rest of the state. Regional divisions follow political boundaries as well as environmental boundaries. We examine growth at the watershed management area, county and municipal level. Tables of Level I land use/land cover change are provided on the NJ DEP GIS website for county and watershed management area divisions. Municipal level change tables are available on the companion website to this report (see below).

5.1 Watershed Management Area

Hydrological and ecological processes often cross political boundaries. In order to better represent environmental processes, the New Jersey Department of Environmental Protection (NJDEP) has shifted management for some of its jurisdictional responsibilities away from politically defined regions into twenty watershed management areas (WMA). Each of the twenty WMAs have unique natural and cultural characteristics as well as different land use patterns. Evaluating urban growth by WMA provides an indication of which regional ecosystems have been most impacted by recent development.

Urban growth was analyzed within New Jersey's twenty Watershed Management Areas (WMA's). Figure 5.1.1a depicts the

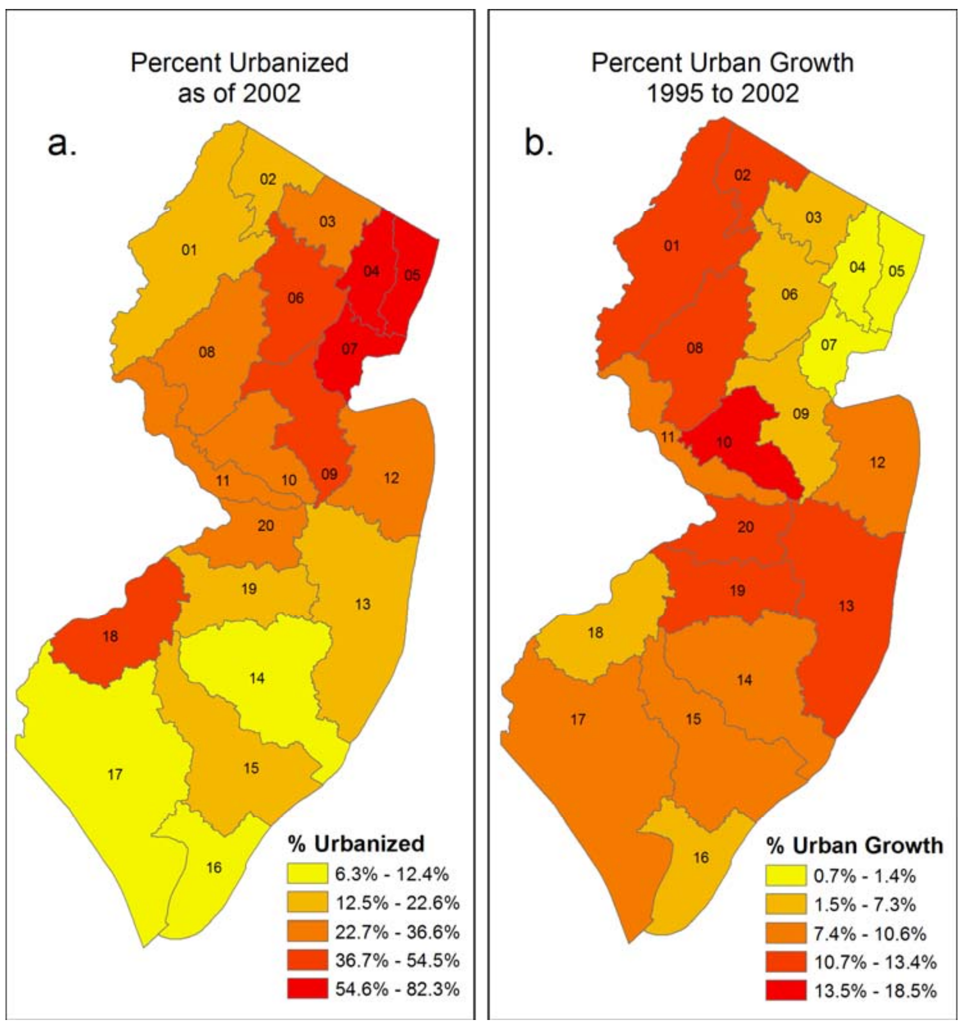

Figure 5.1.1a,b These maps depict the percent urbanized and percent urban growth in each WMA. The lowest growth WMAs have already been largely developed whereas some of the more rural WMAs such as WMA-1 and WMA-2 have, until recently, been sparsely developed and are now growing more rapidly in relative terms. The moderate growth WMAs are largely in southern New Jersey.

percentage that has been urbanized as of 2002 and 5.1.1b depicts the rate of growth during T2('95-'02).

In Figure 5.1.1a the WMA's are classed into five categories depending on the amount of developed land within each watershed. The map categories range from rural (less than 15% urbanized) to highly urbanized (greater than 50% urbanized). Each class will likely have different priorities of land management as they are in different stages of build-out and have grown at different densities.

Figure 5.1.1b maps urban growth as a percentage of previously existing urban area. Both maps are complementary to each other since it is important when viewing growth rates to look at the amount of previously existing urban area, as well as, the overall size of the watershed (Table 5.1.1).

The most rapidly urbanizing watershed is WMA-10 (Millstone) followed by WMA-02, WMA-08, and WMA-13. Some of the watersheds that are less urbanized, and experienced lower growth include the southern New Jersey watersheds WMA-16, WMA-17, and WMA-15.

Table 5.1.1 Urban growth statistics in New Jersey's Watershed Management Areas (WMA).

WMA	WMA NAME	WMA Acres	URBAN Acres 2002	Percent Urbanized 2002	Acres URBAN Growth '95-'02	Percent URBAN Growth '95-'02
01	Upper Delaware	477,250	72,149	15.1	8,186	12.8
02	Wallkill	133,377	21,950	16.5	2,586	13.4
03	Pompton, Pequannock, Wanaque, Ramapo	152,229	37,751	24.8	1,932	5.4
04	Lower Passaic and Saddle	120,647	99,242	82.3	1,366	1.4
06	Upper Passaic, Whippany, and Rockaway	231,359	102,495	44.3	4,815	4.9
05	Hackensack, Hudson, and Pascack	105,629	72,689	68.8	720	1.0
08	North and South Branch Raritan	299,702	89,197	29.8	10,448	13.3
07	Arthur Kill	114,910	88,722	77.2	614	0.7
09	Lower Raritan, South River, and Lawrence	225,041	122,757	54.5	8,119	7.1
10	Millstone	182,146	66,641	36.6	10,411	18.5
11	Central Delaware	174,022	49,725	28.6	4,779	10.6
12	Monmouth	297,612	106,975	35.9	7,738	7.8
13	Barnegat Bay	508,242	99,394	19.6	11,548	13.1
14	Mullica	420,156	26,586	6.3	2,420	10.0
15	Great Egg Harbor	401,377	66,533	16.6	5,705	9.4
16	Cape May	214,098	26,511	12.4	1,795	7.3
17	Maurice, Salem, and Cohansey	789,279	77,421	9.8	5,798	8.1
18	Lower Delaware	250,459	122,939	49.1	7,649	6.6
19	Rancocas	224,500	50,715	22.6	5,051	11.1
20	Assiscunk, Crosswicks, and Doctors	161,915	40,073	24.7	4,219	11.8

Watershed-level statistics for land use/land cover change are available on the NJDEP website: **http://www.state.nj.us/dep/gis/lulc02statisticstables.htm**

5.2 County

At the county level, the geographic distribution of urban growth has remained consistent throughout the state with most counties experiencing 1995 to 2002 (T2) development rates (acres of growth per year) on-par with their 1986 to 1995 rates (T1). However, the rate of growth can be viewed from a number of different angles. In order to best understand the geography and demography of development during the study period, we view growth in urban land at the county level through a number of different lenses. Figure 5.2.1 a through h depicts each of the different treatments.

Net acres of growth: Figure 5.2.1a depicts the net change in urban land by county. Net growth reflects which counties increased the greatest number of urban acres. This number is important since the magnitude of growth by county shows which regions of the state are experiencing the most development pressures. The metric only considers total acres of growth and does not take into account the density of development nor the size of the county. The greatest magnitude of acres developed is occurring in central New Jersey.

Change in growth rate from T1 ('86-'95) to T2 ('95-'02): This metric compared the annual development rate during T1('86-'95) with the development rate of T2('95-'02). It is an indicator of which counties are speeding up (or slowing down) their rate of development. The result portrayed in Figure 5.2.1b indicates the counties that had the most significant increase in development rates from the early part of study period to the later part of the study period.

Counties standing out as growth hotspots with significant up-ticks in development rates include coastal counties (Atlantic, Monmouth and Ocean with +24%, +22%, +37% increase in annual rate, respectively) and central New Jersey counties (Middlesex and Somerset with +18% and +19% increase in annual rate, respectively).

Several counties including Salem, Cumberland and Hunterdon saw their development rates decrease with annualized development rates dropping -24%, -23% and -19% respectively.

Growth as a percentage of previously urbanized land: Figure 5.2.1c depicts the growth in urban acres as a percentage of previously developed land within a county. This value indicates the counties that are most rapidly increasing their total urban land. This view is important since at the beginning of T2(1995) counties in New Jersey have very different states of development from highly urbanized to mostly rural. Rural counties that are rapidly expanding their urban lands include Warren, Hunterdon, Somerset, Ocean, and Gloucester. The older urban counties including Bergen, Hudson, Union, Essex and Camden have large areas of previous development, therefore, their percentage of urban growth is lower than some of the lesser developed counties.

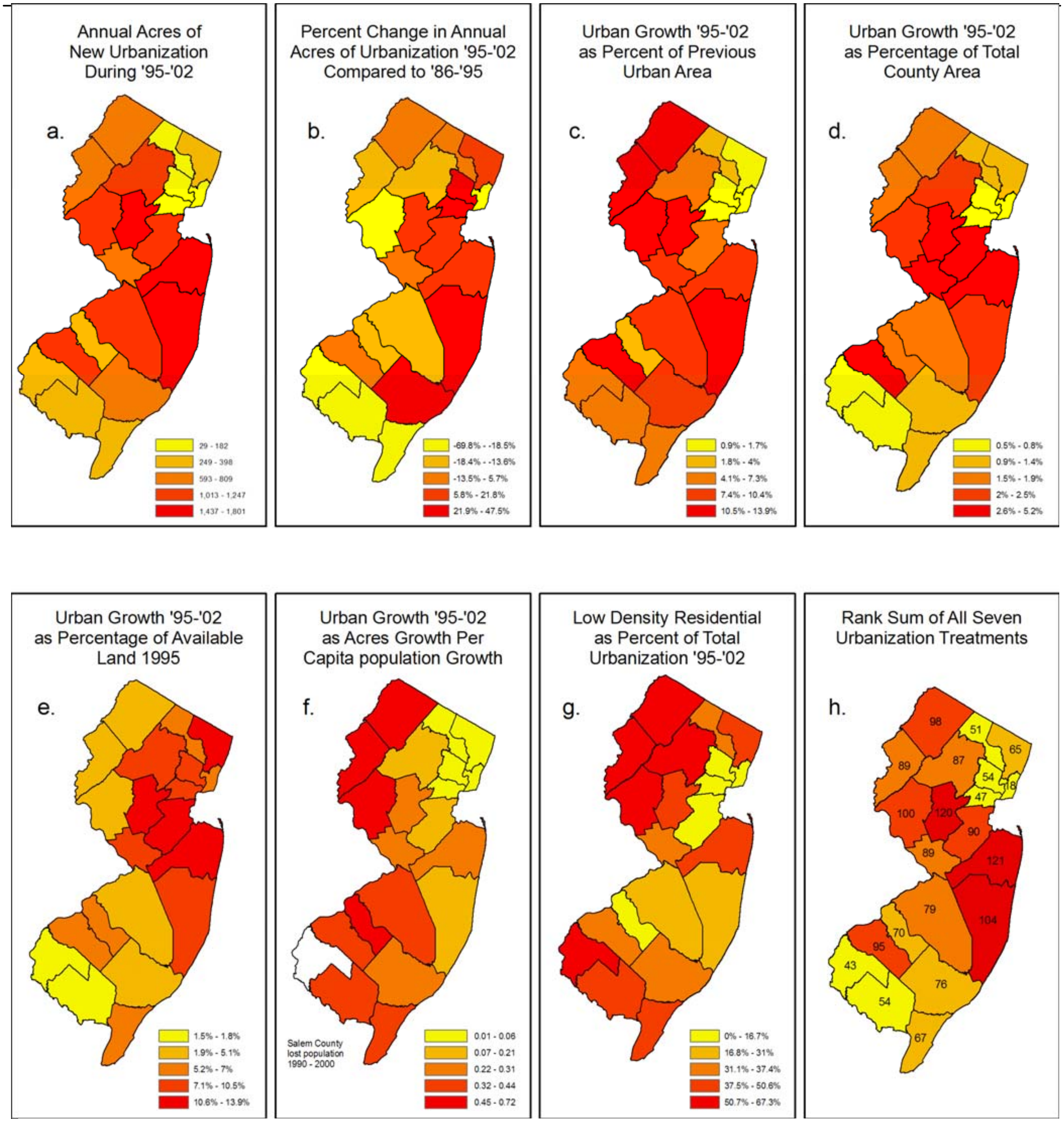

Figure 5.2.1 County level urban growth analysis viewing from various treatments. Map h represents a rank sum of maps a through g demonstrating that central Jersey and New Jersey's coastal counties have experienced the most significant combined effects of urban growth during the study period.

<u>Growth as a percentage of the county size:</u> Figure 5.2.1d depicts the growth in urban acres as a percentage of the gross size of a county. Counties in New Jersey range in size from sixty-two square miles to over 820 square miles. Figure 5.2.1d presents urban growth normalized by the size of each county. Counties that had the greatest percentage of their land developed include Somerset, Monmouth, Mercer, Middlesex and Gloucester.

Growth as a percentage of the available land remaining: Another view of urban growth for a county is to consider the county's growth in relationship to the remaining land available for development. Regardless of the total size a county may have varying amounts of land able to receive new growth due to restricted lands such as wetlands, lands already preserved from development or lands that have already been urbanized. This metric normalizes the number of acres of growth for each county by an estimate of how much land was available for development in 1995. The resulting map (Figure 5.2.1e) demonstrates that the northern counties adjacent to New York City, including Monmouth, Middlesex, Somerset, Bergen and Union, all utilized over ten percent of the remaining available land during T2('95-'02).

Acres of growth per person added to population: Another interesting way to look at development growth is to compare it to population growth. By normalizing the acres of growth for a county by the estimated change in population during the study period one can gage which counties had the largest development footprint for each new person added to their population (Figure 5.2.1f). This provides an indication of efficiency in land development. The northern rural counties of Hunterdon, Sussex and Warren have experienced low-density development patterns that consume significant quantities of land while housing relatively few people. Camden County performs poorly in this per capita growth treatment since development that occurred in its less developed southern region was counterbalanced by the loss of population in a number of its smaller and older towns. Salem County lost population, and therefore, was left out of the calculation.

Proportion of growth that is low-density large-lot: A significant portion of this study focused on the low density residential growth associated with sprawl. At the county level Figure 5.2.1g depicts the proportion of total residential urban growth that was the lowest density type. More than half of all of the residential growth that occurred in the rural counties of Hunterdon, Sussex, Morris, Warren and Salem was the lowest-density residential growth.

Combined Sprawl Calculation: Each of the previous seven metrics portrays a different nuance of urban growth and open space loss at the county level. In the eighth map (Figure 5.2.1h) we combine each of the metrics by placing them in rank order, normalizing their percentile rank and then adding the rank totals to provide a cumulative meta growth index. This final map indicates the counties most impacted by growth during the T2('95-'02) time period. A number of patterns can be identified including the growth pressures in coastal New Jersey, the continued growth in central New Jersey and growth in counties that are on the suburban fringe of metropolitan New York City and Philadelphia, including Hunterdon and Gloucester Counties. Another pattern that emerges is the relative low growth occurring in New Jersey's older urbanized counties, as well as, rural southern New Jersey.

Other statistics, not represented in the maps, also vary depending on their location. The major hotspots of upland forest loss at the county level (>500 acres/year) include the coastal counties of Atlantic, Monmouth and Ocean, where the annual rates (acres/year) of forest loss have all significantly increased (+58%, +82%, and +59% respectively) and Morris county, (north central Jersey) which lost approximately 741 acres/year (though this is a slower rate than the 1986 to 1995 time period).

Major hotspots of agricultural land loss (> 500 acres/year) are Burlington, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Somerset, Sussex and Warren counties. While most counties have shown a decline in the annual rate of farmland loss, T1('86-'95) to T2('95-'02), Monmouth County experienced an increase from 898 acres/year to 1038 acres/year (an increase of approximately 15%).

County-level statistics for land use/land cover change are available on the NJDEP website: http://www.state.nj.us/dep/gis/lulc2002stattablescounty.htm

5.3 Municipal

The majority of land use management occurs at the municipal level in New Jersey. Evaluating urban growth by municipality provides a window into which municipalities are experiencing the greatest growth pressures. As in the county analysis, we treat growth in urban land at the municipal level with a number of different lenses. Figure 5.3.1 a through h depicts each of the different treatments. This section is, in essence, our municipal report card on urban growth.

Net acres of growth: Figure 5.3.1a depicts the net change in urban land by municipality. Net growth reflects which municipalities grew the greatest number of urban acres. This number is important since the magnitude of growth in any municipality has implications for the impacts, costs and services that will be generated by the amount of development. The metric only considers total acres of growth and does not take into account the density of development or the size of the municipality. Eighty-seven municipalities experienced no growth in urban land, or they lost urban land, during T2('95-'02). They are depicted in black in the map series. The top twenty municipalities to receive the greatest number of acres of new development during T2('95-'02) are depicted in column a of Table 5.3.1.

Change in growth rate from T1 ('86-'95) to T2 ('95-'02): This metric compared the annual development rate during T1('86-'95) with the development rate of T2('95-'02). It is an indicator of which municipalities are speeding up (or slowing down) their rate of development. The result portrayed in Figure 5.3.1b indicates the municipalities that had the most significant increase in development rates (color yellow through red), from the early part of study period to the later part of the study period, as compared to those municipalities that slowed their rates of growth (colored green). The map and the corresponding list of the top twenty municipalities to increase their development rate is depicted in Table 5.3.1 column b.

Growth as a percentage of previously urbanized land: Figure 5.3.1c depicts the growth in urban acres as a percentage of previously developed land within a municipality. This value indicates the municipalities that are most rapidly increasing their total urban land. This view is important since at the beginning of T2(1995) New Jersey's municipalities existed with a wide range of degrees of development. Municipalities that have a relatively small amount of previously existing urbanized land that received a large amount of new development relative to the existing urban land would come out high on this list

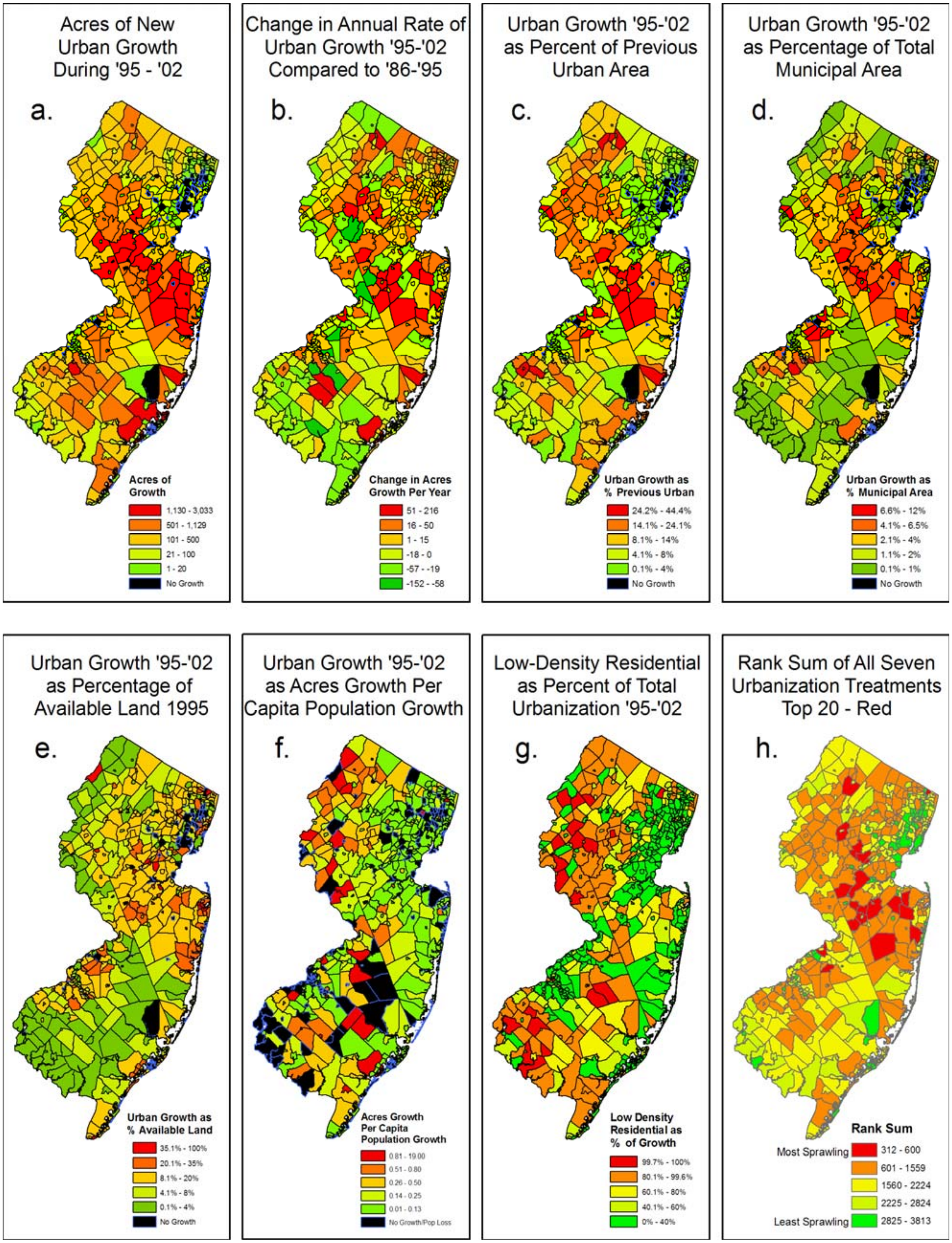

Figure 5.3.1 Urban growth at the municipal level viewing from various treatments. Map h depicts a combination of maps a through g utilizing rank sum. The municipalities in map h that are dark red represent those that have experienced the most significant combined effects of urban growth.

The top twenty municipalities to receive the greatest proportion of new development relative to previous development during T2('95-'02) are depicted in column c of Table 5.3.1.

Growth as a percentage of the municipal size: Figure 5.3.1d depicts the growth in urban acres as a percentage of the gross size of a municipality. Municipalities in New Jersey range in size from sixty-two acres to over 72,000 acres. Clearly the same number of acres of growth in a small town has a greater relative impact than an equal size of development in a much larger town. This value portrayed by Figure 5.3.1d and Table 5.3.1 column d normalizes the acres of urban growth by the size of the municipal territory. This provides an indication of the magnitude of development for a given size of a municipality. The top twenty municipalities are depicted in column d of Table 5.3.1.

Growth as a percentage of the available land remaining: Another view of urban growth for a municipality is to consider the municipality's growth in relationship to the remaining land available for development. Regardless of the total size of the municipality, a municipality may have varying amounts of land actually able to receive new growth due to restricted lands such as wetlands, lands already preserved from development or lands that have already been urbanized. This metric normalizes the number of acres of growth for each town by an estimate of how much land was available for development in 1995. The resulting map (Figure 5.3.1e) provides an indication of which towns have moved fastest toward build-out during the study period. There are several patterns that emerge, including older towns that have reached build-out, by urbanizing most of their land, and rural municipalities, that have large quantities of preserved land. Both of these have experienced low percentages of urban growth because of the limited amount of land available for urbanization. The top twenty municipalities to receive the greatest proportion of new development relative to their available land are depicted in column e of Table 5.3.1.

Acres of growth per person added to population: Another interesting way to look at development growth is to compare it to population growth. By normalizing the acres of growth for a municipality by the estimated change in population during the study period one can gage which municipalities had the largest development footprint for each new person added to their population (Figure 5.3.1f). Population growth was not as strongly linked to growth in urban land as one might think. This is evident in the map where rural municipalities increased development while growing sparsely in population. Some 145 municipalities lost population between the years 1990 to 2000 (colored black on the map). Many of these are older inner-ring suburbs. Others were rural communities in remote areas of the Pinelands and deep Delaware Bay areas. This provides an indication of efficiency in land development. The top twenty municipalities in acres of growth per capita of urban land increase are depicted in column f of Table 5.3.1.

Proportion of growth that is low-density large-lot: A significant portion of this study has focused on the low-density residential growth associated with sprawl. At the municipal level Figure 5.3.1g depicts the proportion of total residential urban growth that was the lowest-density type.

Table 5.3.1 Top twenty municipalities for various treatments of urban growth.

Rank	a. Acres of New Urban Growth During '95-'02	b. Change in Annual Rate of Urban Growth '95-'02 Compared to '86-'95	c. Urban Growth '95-'02 as Percent of Previous Urban Area	d. Urban Growth '95-'02 as Percentage of Total Municipal Area
1	Jackson Twp, Ocean	Jackson Twp, Ocean	Cranberry Twp, Middlesex	Burlington Twp, Burlington
2	Egg Harbor Twp, Atlantic	Egg Harbor Twp, Atlantic	Millstone Twp, Monmouth	Englishtown Boro, Monmouth
3	Montgomery Twp, Somerset	Marlboro Twp, Monmouth	Woolwich Twp, Gloucester	Lumberton Twp, Burlington
4	Marlboro Twp, Monmouth	Lakewood Twp, Ocean	Lumberton Twp, Burlington	Plainsboro Twp, Middlesex
5	Millstone Twp, Monmouth	Bernards Twp, Somerset	Hardyston Twp, Sussex	Montgomery Twp, Somerset
6	Franklin Twp, Somerset	Monroe Twp, Gloucester	Mansfield Twp, Burlington	Marlboro Twp, Monmouth
7	Monroe Twp, Middlesex	Upper Freehold Twp, Monmouth	Upper Freehold Twp, Monmouth	Green Brook Twp, Somerset
8	Hillsborough Twp, Somerset	Monroe Twp, Middlesex	Upper Freehold Twp, Monmouth	Bernards Twp, Somerset
9	Toms River Twp, Ocean	Stafford Twp, Ocean	Robbinsville Twp, Mercer	South River Boro, Middlesex
10	Raritan Twp, Hunterdon	Colts Neck Twp, Monmouth	Greenwich Twp, Warren	Cranberry Twp, Middlesex
11	Hopewell Twp, Mercer	Cranberry Twp, Middlesex	Burlington Twp, Burlington	Lakewood Twp, Ocean
12	Howell Twp, Monmouth	East Windsor Twp, Mercer	Stafford Twp, Ocean	Washington Twp, Gloucester
13	Bernards Twp, Somerset	Millstone Twp, Monmouth	Lafayette Twp, Sussex	Lopatcong Twp, Warren
14	Lakewood Twp, Ocean	Upper Freehold Twp, Monmouth Co	Jackson Twp, Ocean	Mount Laurel Twp, Burlington
15	Colts Neck Twp, Monmouth	Wall Twp, Monmouth	Plumsted Twp, Ocean	Millstone Twp, Monmouth
16	Freehold Twp, Monmouth	Hardyston Twp, Sussex	Lopatcong Twp, Warren	Berlin Boro, Camden
17	South Brunswick Twp, Middlesex	Chester Twp, Morris	Harrison Twp, Gloucester	Morrestown Twp, Burlington
18	Galloway Twp, Atlantic	Franklin Twp, Gloucester	Far Hills Boro, Somerset	East Windsor Twp, Mercer
19	Stafford Twp, Ocean	Burlington Twp, Burlington	Oxford Twp, Warren	High Bridge Boro, Hunterdon
20	Washington Twp, Gloucester	Tewksbury Twp, Hunterdon	Plainsboro Twp, Middlesex	Greenwich Twp, Warren

Rank	e. Urban Growth '95-'02 as Percentage of Available Land 1995	f. Urban Growth '95-'02 as Acres Growth Per Capita Population Growth	g. Low-Density Residential as Percent of total Urbanization '95-'02	h. Rank Sum of all Seven Urbanization Treatments
1	Interlaken Boro, Monmouth	Pine Valley Boro, Camden	West Amwell Twp, Hunterdon	Marlboro Twp, Monmouth
2	Walpack Twp, Sussex	Mullica Twp, Atlantic	Lebanon Twp, Hunterdon	Cranberry Twp, Middlesex
3	East Newark Boro, Hudson	Cinnaminson Twp, Burlington	Alexandria Twp, Hunterdon	Montgomery Twp, Somerset
4	Manville Boro, Somerset	Stillwater Twp, Sussex	Kingwood Twp, Hunterdon	Colts Neck Twp, Monmouth
5	Victory Gardens Boro, Morris	West Paterson Boro, Passaic	Green Twp, Sussex	Plainsboro Twp, Middlesex
6	Oceanport Boro, Monmouth	Lebanon Twp, Hunterdon	Mansfield Twp, Warren	Bernards Twp, Somerset
7	Cape May City, Cape May	Franklin Twp, Hunterdon	Franklin Twp, Warren	Lumberton Twp, Burlington
8	Moonachie, Bergen	Fredon Twp, Sussex	Blairstown, Twp, Warren	Robinsville Twp, Mercer
9	South River Boro, Middlesex	West Amwell Twp, Hunterdon	Hopewell Twp, Cumberland	Green Brook Twp, Somerset
10	Englishtown Boro, Monmouth	Southampton Twp, Burlington	Audubon Boro, Camden	Wall Twp, Monmouth
11	Dunellen Boro, Middlesex	East Amwell Twp, Hunterdon	Frelinghuysen Twp, Warren	East Windsor Twp, Mercer
12	Windfield Twp, Union	East Greenwich Twp, Gloucester	Tabernacle Twp, Burlington	Warren Twp, Somerset
13	Green Brook Twp, Somerset	Haworth Boro, Bergen	Shamong Twp, Burlington	Sparta Twp, Sussex
14	Shrewsbury Boro, Monmouth	Egg Harbor Twp, Atlantic	Deerfield Twp, Cumberland	Monroe Twp, Middlesex
15	Little Silver Boro, Monmouth	Woodbine Boro, Cape May	Franklin Lakes Boro, Bergen	Franklin Twp, Somerset
16	Old Tappan Boro, Bergen	Newfield Boro, Gloucester	Upper Pittsgrove Twp, Salem	Chester Twp, Morris
17	Netcong Boro, Morris	Springfield Twp, Burlington	South Harrison Twp, Gloucester	Holmdel Twp, Monmouth
18	Neptune City Boro, Monmouth	Hammonton Town, Atlantic	Mannington Twp, Salem	Old Tappan Boro, Bergen
19	South Plainfield Boro, Middlesex	Harmony Twp, Warren	Fairfield Twp, Cumberland	Burlington Twp, Burlington
20	Red Bank Boro, Monmouth	Sadyston Twp, Sussex	Mendham Boro, Morris	Jackson Twp, Ocean

Rural municipalities clearly have the largest proportion of low-density growth (colored orange and red on the map). This is logical since there are no necessary services or infrastructure available in these areas for high-density urban growth. However, this pattern of low-density development is most rapidly consuming and impacting the rural quality of these municipalities. The top twenty municipalities in this indicator (Table 5.3.1 column g) had the greatest proportion of their development consist of low-density sprawl.

Combined Sprawl Calculation: Each of the previous seven metrics portrays a different nuance of urban growth and open space loss at the municipal level. In the eighth map (Figure 5.3.1h) we combine each of the metrics by placing them in rank order and then adding the rank totals to provide a cumulative meta growth index. Table 5.3.1 column h provides the rankings of the top twenty municipalities as scored by the combined meta growth index. This is our "report card" of the most sprawling municipalities. These municipalities are largely located in a band that runs through central New Jersey stretching to the coast. Municipalities in the northern ridge and valley, Pine Barrens, and Delaware Bay area have experienced relatively less impacts from sprawl.

This municipal-level analysis is where the rubber meets the road. We provided lists of which municipalities are experiencing the most significant impacts to urban growth and open space loss in terms of the number of acres developed, the context of that development in terms of increasing urban area, open space loss and the speed at which a municipality is approaching build-out. We have highlighted the top twenty municipalities for each category. Detailed land use/land cover change values for all municipalities are available on the companion website to this report.

www.crssa.rutgers.edu/projects/lc

Photo: A. Knee

6 Build-Out - Looking Forward at Development Trends

This report has detailed the remarkable pace of development and the subsequent loss of open space that has been occurring over the past few decades in New Jersey. However, as a counterbalance to the continuing development pressure, New Jersey has positioned itself as a leader in preserving open space through programs such as Green Acres and Farmland Preservation. Many of these activities have been coordinated under the Garden State Preservation Trust, a mechanism of funding dedicated toward preserving open space. Land trusts and transfer of development rights (TDR) are some of the other planning tools being employed for preserving open space and for fostering Smart Growth.

Open space preservation permanently removes land from availability for urbanization thus locking it away from potential development. With the entire state within 1 ½ hours drive to New York or Philadelphia, most, if not all, privately held land will eventually be developed to its "highest and best use" as a consequence of economics, unless the development rights are retired through deed restriction or easement.

New Jersey stands at an interesting juncture. Land has never been developed as rapidly as it is being developed today. At the same time open space preservation measures have been preserving many thousands of acres. These two forces are racing to claim the available undeveloped land still remaining. The speed of that race is striking. By projecting those rates forward, one can get an idea of how the Garden State will reach build-out, a condition where all land is either in a developed state or is protected open space.

In order to examine build-out, a statewide open space coverage was produced by combining available open space GIS datasets (Figure 6.1.1). The open space datasets included the NJDEP, federal and state preserved open space layers and additional open space data developed at CRSSA. The coverage also includes farmland preservation parcels as of March 2007 acquired from the NJ Department of Agriculture. The total land estimated as preserved in New Jersey as of 2007 was 1,233,967 acres. This is almost 1/4 of the state's territory in preservation of one type or another. The Garden State Preservation Trust estimates that 412,191 acres of preservation has occurred from 1999 to 2007 (NJ GSPT 2002).

The restricted lands coverage was created by overlaying all non-developable lands which were defined as preserved open space (as mentioned above), steep slopes above fifteen percent water, wetlands and already developed lands. All other lands not mapped as restricted based on the above criteria were considered available for future urban development. The total available land still remaining, as estimated by this method, was 1,347,487 acres. Since the land use data was from 2002, whereas the open space data was as of 2007, five years of urban growth at the 15,123 acres per year was subtracted to arrive at 1,271,872 acres of available land as of 2007. While this is a reasonable estimate of remaining available lands, it is likely that there is actually somewhat less land available due to incomplete open space inventories, privately held land trusts and other constraints on a given property's developability such as zoning, lot configuration and road access.

Figure 6.1.1. depicts the remaining lands available for development. There is a strong measure of land management in areas controlled by the Pinelands Comprehensive Management Area and the recently established Highlands Regional Management Plan. These planning areas are likely to have development occur in a more prudent manner than the rest of the state.

The areas with significant available unprotected land most at risk include the Ridge and Valley, lower Hunterdon County-Sour lands and the South Jersey Bayshore regions. These are the areas where there is still significant viable agricultural activity and where large tracts of rural lands are still intact. These are also areas that have begun to see an increase in development activity as other parts of the state run out of available land.

As the remaining available lands are consumed for development or preserved, ultimately New Jersey will run out of “raw” undeveloped land. Urban growth pressure is likely to make it the first state in the nation to reach build-out. Predicting the exact date of when build-out will occur is not precisely possible since variables will certainly change in the future. Urban growth is affected by multiple factors, not withstanding, economic conditions, political trends, cultural values and changes in technology. Nonetheless, a projection of current rates of growth helps to put the land management circumstances facing New Jersey into perspective. New Jersey’s growth trajectory, as of 2002, was 1,440,404 acres of developed land

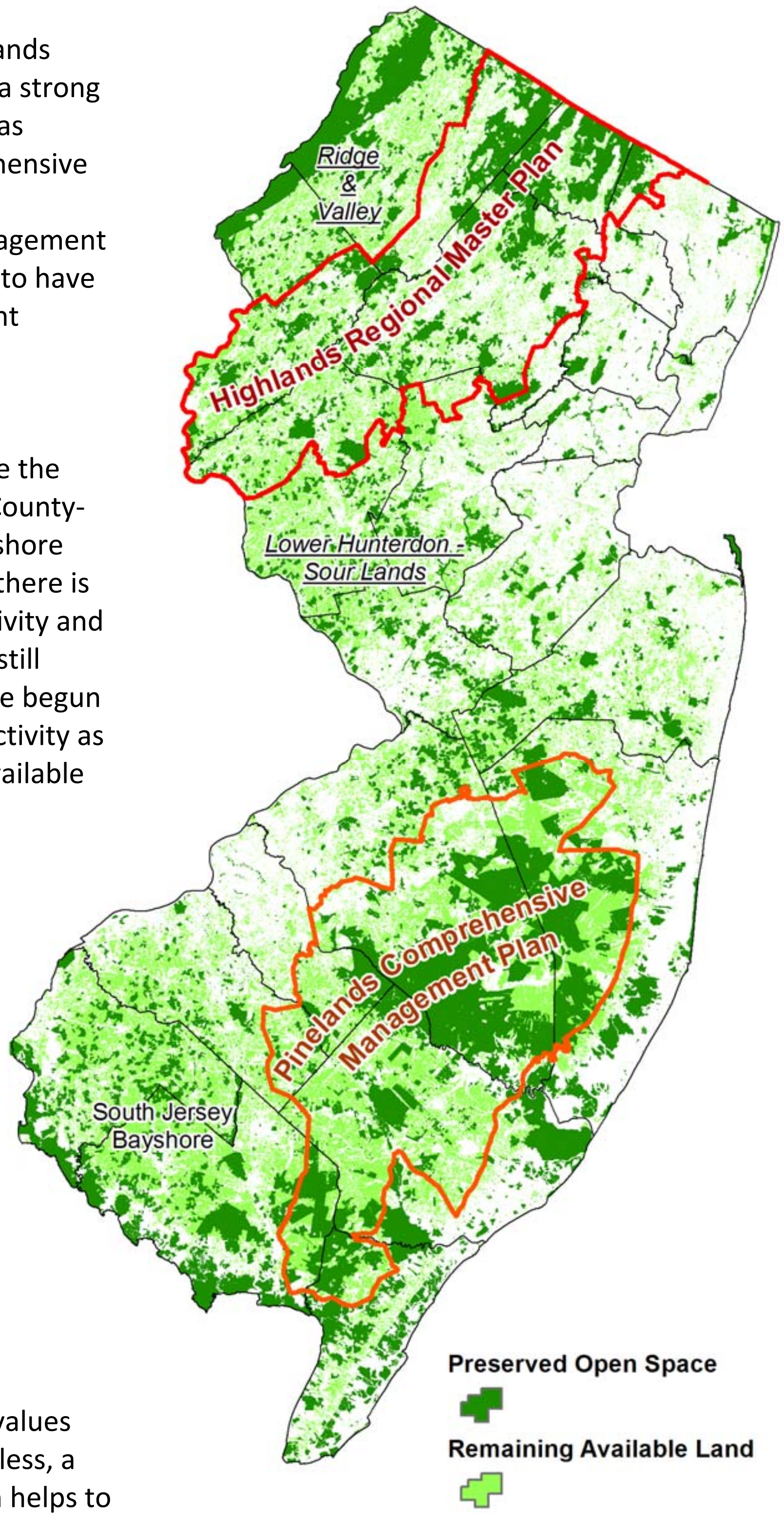

Figure 6.1.1 - Preserved open space and remaining available land. The remaining available lands (light green) will become either preserved or developed as New Jersey reaches build-out in the coming decades.

growing at a net rate of 15,123 acres per year. If the growth rate remained steady in the subsequent years, developed land would be 1,516,020 acres as of 2007. It is estimated that there are 1,271,872 acres of available undeveloped land in New Jersey as of 2007. Since the Garden State Preservation Trust began in 1999, it has preserved 412,191 acres (NJ GSPT 2007). If the GSPT is successful at reaching its 1 million acres goal, it will have to preserve an additional 587,809 acres reducing the available land to 684,063 acres. The land left available to be developed, at the current net rate of 15,123 acre per year, would reach build-out in forty-five years.

However, total urbanization of all available land is not a realistic scenario and many additional factors will also influence New Jersey's build out scenario. Some factors will have the effect of making build-out occur sooner and some will delay the date of build-out. Our previous report, (Hasse and Lathrop, 2001) explores some of the factors that should be considered when projecting build-out at greater length. Exploring the multiple factors that will likely play into NJ's build-out trajectory is not intended to be a prediction of the exact build-out scenario that will occur, but rather a conceptual exercise to help put the magnitude of New Jersey's current growth rate into perspective. The reader is left to decide which factors, and to what degree those factors, will affect the actual build-out date. Even if the exact date cannot be foreseen with certainty from this vantage point, it is efficacious to approach land management by keeping in mind that near total build-out will likely be approached in New Jersey sometime within the middle of this century.

At this point in time New Jersey's final landscape pattern is being set for centuries to come. This final landscape is being determined by the collective actions of all the development and land preservation stakeholders in the race for the remaining open space. The important questions to be asked are not about when build-out will be reached, but should focus on what New Jersey's built-out landscape will look like, after build out happens. How will it function for both New Jersey's human and nonhuman communities? Will we be able to maintain the value of the state's ecosystem services and natural capital? How viable will our agriculture, forests, watersheds, wetlands and wildlife habitat be in that final landscape? At current trends future generations will likely be disappointed by the result of how today's policies shaped their landscape.

What steps need to be taken now to ensure the healthiest possible landscape in the future? Planning from the perspective of impending build-out can help to guide prudent land management decisions in the present.

7 Conclusion

New Jersey is a national leader on many fronts. It has pioneered the nation on initiatives for land management, Smart Growth and open space preservation. This report brings to light that it is also leading the nation as the first state likely to reach build-out. The development patterns evaluated from 1986-2002 demonstrate that sprawling development continues to consume large quantities of open space. Large-lot rural single-unit residential development is the largest land consumer even though the number of people housed by such development is proportionately much lower. Farmland is being lost at a rapid pace although it has slowed slightly whereas upland forest loss has accelerated and forest lands are becoming increasing fragmented. Wetlands have also continued to be lost mostly to development and habitat for threatened and endangered species continues to lose ground. The development category that is most rapidly transforming New Jersey's landscape with wide-ranging impacts is large-lot rural housing development.

Recent reports have suggested that sprawl might be coming to an end in the New York City metropolitan region (Hughes and Seneca, 2004). Their evidence for the beginning of the end of sprawl was the relative shift of building permits from the suburbs to the urban core between 1994 and 2002. While the evidence cited may indicate a shift toward greater urban redevelopment, a goal of Smart Growth, the conclusion that this signifies the end of sprawl in New Jersey remains to be seen. Our study shows that the rapid conversion of open land into a dispersed, sprawling pattern of development continued unabated through 2002. The End of Sprawl? Not Yet! At least not as of 2002.

Photo J. Hasse

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Appendix

Background on the 2002 Land Use/Land Cover Data

The 2002 NJ Land Use/Land Cover (LULC) data set was produced by the visual interpretation of leaf off color infrared digital orthoimagery with a spatial resolution of approximately 1 foot. Detailed metadata is available from the NJ DEP which documents the creation of each dataset (NJDEP URL http://www.state.nj.us/dep/gis/). Using the 2002 imagery along with the polygonal boundaries of the 1995 NJ, LULC changes that took place between 1995 and 2002 were interpreted and polygonal boundaries digitized. In the process, some earlier (i.e., 1995 –era) interpretations and boundaries were refined with the higher resolution imagery and a slight change in interpretation/mapping protocols, leading to two sets of 1995 LULC boundaries, one from the T1 data set and one from the T2 data set. Thus there are discrepancies if one compares the area totals for the year 1995 from the T1 and T2 data sets. For example, the T1 1995 total for Agriculture = 659,017 acres (Table 2a) while the T2 1995 total is 652,334 acres, a difference of 6,683 acres or approximately 1%. Thus to help control for these discrepancies, for the T2 analysis we are only comparing the “new” 1995 LULC boundaries with the 2002 data and for the T1 analysis we are comparing the “old” 1995 boundaries with the 1986 data. While it can be assumed that the T2 (’95-’02) dataset is more accurate than the T1 (’86-’95) dataset, errors and inconsistencies are inherent in all datasets and must be properly understood by the user.

The 1995-2002 and 1986-1995 LULC data sets were analyzed using ArcInfo software in a vector polygonal format. For the purposes of this report, the area totals are reported in acres out to the ones place. We recognize that there are errors of both omission and commission in this data set (as with any photo-interpretation and LULC mapping exercise) and thus the reported acreages should be treated as estimates and not “absolute” amounts. As the metadata does not include a quantitative assessment of error, nor have we undertaken an independent assessment, it is difficult to determine what the error bars around any LULC acreage figure or change amount should be. To be conservative, only LULC changes more than 5% will be treated as significant.