EARTHQUAKE LOSS ESTIMATION STUDY FOR MIDDLESEX COUNTY, NEW JERSEY:

GEOLOGIC COMPONENT

Prepared for the
New Jersey State Police
Office of Emergency Management

by the
New Jersey Geological Survey

September 2003

CONTENTS

FINAL REPORT

GEOLOGIC COMPONENT OF THE EARTHQUAKE LOSS ESTIMATION STUDY FOR MIDDLESEX COUNTY, NEW JERSEY

Prepared for the New Jersey State Police, Office of Emergency Management

by
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Summary: Geologic, topographic, and test-boring data were acquired and analyzed in order to map seismic soil class, liquefaction susceptibility, and landslide susceptibility for Middlesex County (maps folded in pocket). The soil class, liquefaction susceptibility, and landslide susceptibility data were entered into the HAZUS model for each census tract in the county (Appendix A). The HAZUS model was run with the full upgraded geologic data and with the default geologic data for earthquake magnitudes of 5.5 and 6. To assess the effect of liquefaction, runs were also made with full upgraded geology and with upgrade without liquefaction for magnitudes 5, 5.5, 6, 6.5, and 7. Selected outputs from these runs are attached in Appendices B through M. The upgraded geology changed both the spatial distribution of damage and the total damage estimates compared to default geology. The upgraded geology produced greater building damage in the lower Raritan River valley and Arthur Kill areas of the county (Figure 1), where salt-marsh soils are softer and more liquefiable than the default, and less building damage in most other areas, where till, weathered-bedrock soils, and Cretaceous clay and sand are stronger than the default. Because most soils in the county are stronger than the default, the total economic loss is between 10 and 20% less with the upgraded geologic data than with the default data at all magnitudes. Adding liquefaction increases building damage about 10% in susceptible census tracts, especially at magnitudes less than 7, but results in less than a 5% increase in total loss for the entire county. This is a minimum value because the model does not calculate damage to roads, railways, and underground utilities caused by liquefaction. Structures that are particularly susceptible to damage from permanent ground displacement, such as pipelines and bridges, show significantly increased breakage when liquefaction is added.

In addition to the HAZUS data upgrades and runs, shear-wave velocity was measured on four soil types (Cretaceous clay, Cretaceous sand, Pensauken Formation sand and gravel, and stream-terrace sand) at a total of 12 locations. These measurements were made to check the soil-class assignments, which use test-drilling data as a proxy for shear-wave velocity. The measured velocities generally confirmed the assignments. Weathering reduces velocities in the near-surface parts of Cretaceous sand and clay, an effect previously observed in till in glaciated terrain.

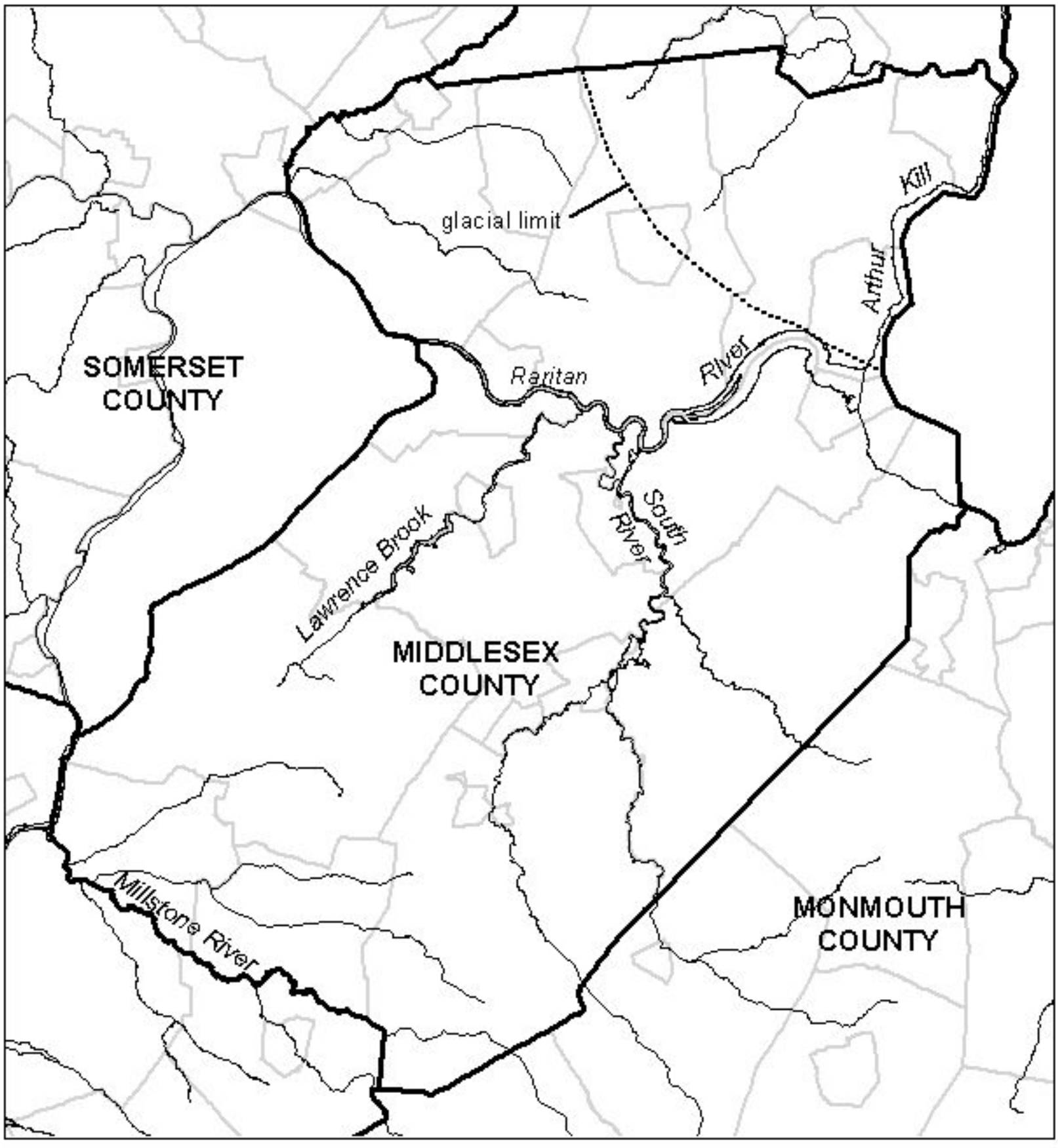


Figure 1. Middlesex County and vicinity. Gray lines are municipal boundaries.

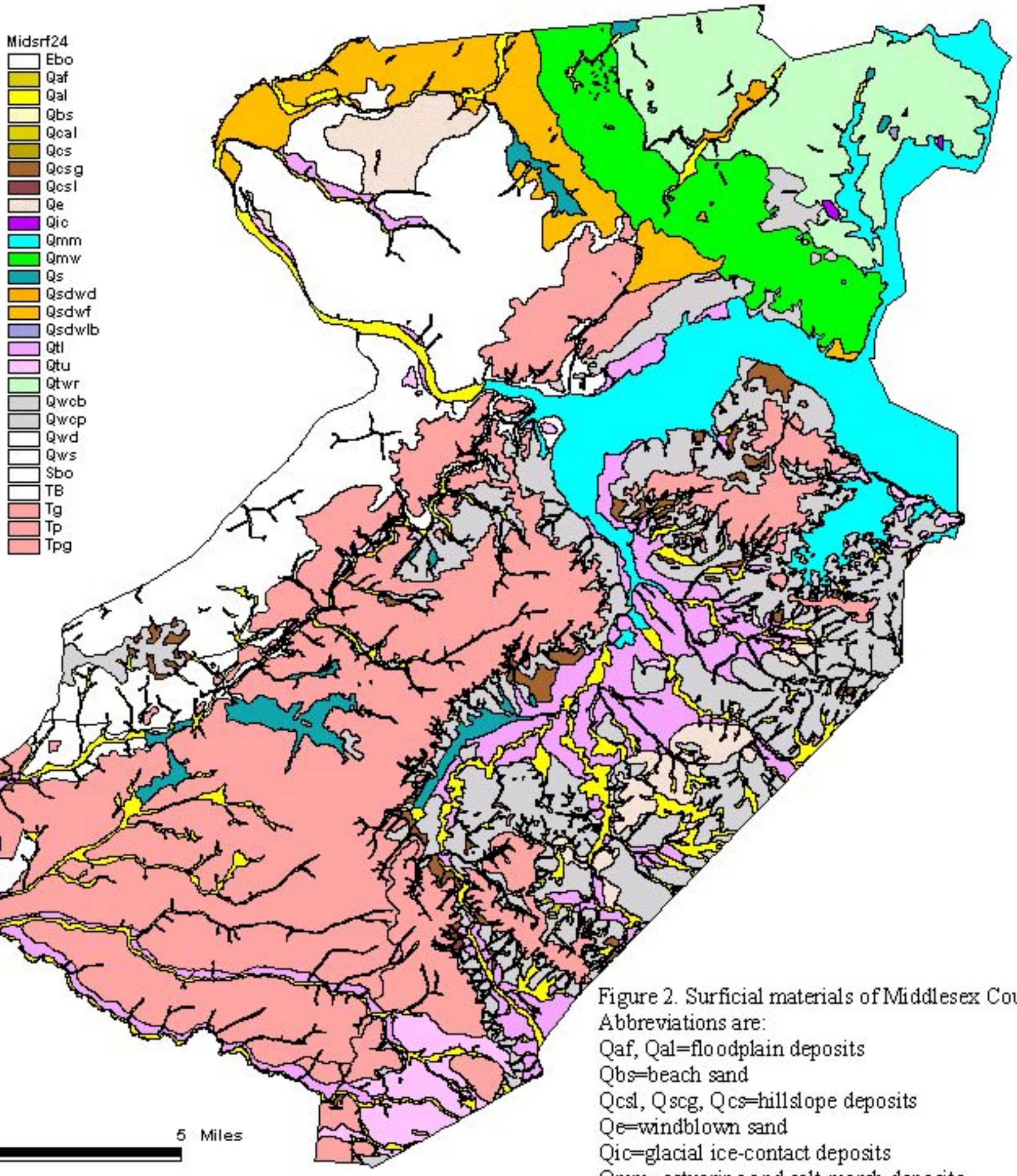


Figure 2. Surficial materials of Middlesex County.
Abbreviations are:
Qaf, Qal=floodplain deposits
Qbs=beach sand
Qcsl, Qscg, Qcs=hillslope deposits
Qe=windblown sand
Qic=glacial ice-contact deposits
Qmm=estuarine and salt-marsh deposits
Qmw=till of the terminal moraine
Qs=swamp deposits
Qsdwf, Qsdwd=glacial sand and gravel
Qsdwlb=glacial clay and silt
Qtl, Qtu=nonglacial stream-terrace sand and gravel
Qws, Qwd=weathered bedrock
Qwt=till
Qwcp, Qwcb=weathered Coastal Plain formations
sbo, ebo=bedrock outcrop
Tp, Tg, Tpg=Pensauken Formation

Geologic Data Acquired: Twelve surficial materials were identified and mapped in Middlesex County (figs. 1 and 2). These include till, glacial-lake and glacial-river sand and gravel deposits, glacial-lake silt and clay deposits, postglacial floodplain deposits, peat and organic silt and clay deposited in wetlands, nonglacial stream-terrace sand, windblown sand, a preglacial river-plain deposit (the Pensauken Formation), weathered shale and diabase bedrock, and sand and clay of Cretaceous age. The distribution and thickness of these materials were mapped at 1:24,000 scale using stereo-airphoto interpretation, field observations, archival geologic map data on file at the NJGS, and logs of about 1200 test borings (Stanford, 1999).

Till is a compact silty sand to sandy silt with gravel and a few boulders, deposited directly beneath glacial ice. It veneers the bedrock surface in the northeastern corner of the county, northeast of the glacial limit (fig. 1), and is as much as 130 feet thick. Glacial-lake deposits overlie the till in the lowlands along the Arthur Kill and its tributaries. The lake deposits include sand and gravel as much as 30 feet thick and silt and clay as much as 20 feet thick. Glacial-river sand and gravel forms plains in the north-central and northwestern parts of the county. The glacial-river deposits are as much as 100 feet thick. Alluvial sediment was deposited in floodplains along all the main streams in the county after the glacier retreated. It is as much as 20 feet thick. Along Raritan Bay, the Arthur Kill, and the lower reaches of the Raritan and South Rivers, salt-marsh and estuarine deposits were laid down during postglacial rise of sea level. These deposits are as much as 100 feet thick. The extent of these deposits is important because they are loose, saturated soils that are especially susceptible to seismic shaking. Archival maps at the NJGS dating back to 1880 were used to delineate the original limit of the marshes, which are now covered by fill over much of their former extent.

Most of the county is beyond the limit of glaciation (fig. 1). Geologic materials in the unglaciated area include nonglacial and preglacial river deposits, weathered bedrock, and Cretaceous sand and clay. Nonglacial stream-terrace deposits of sand and pebble gravel border the floodplains of larger creeks. Sheets of windblown sand veneer uplands adjacent to some of these terraces. The terrace and windblown sands are generally less than 20 feet thick. A preglacial river-plain deposit of sand and gravel, the Pensauken Formation, covers much of the county south of the Raritan River, and is as much as 140 feet thick. Shale and diabase bedrock outcrop along the western edge of the county. The weathered soil mantle on these rocks is generally less than 10 feet thick. Cretaceous sand and clay of the Coastal Plain underlies the Pensauken Formation and stream-terrace deposits in the southern and southeastern part of the county. The Cretaceous deposits thicken to the southeast, to about 600 feet at the Monmouth County line.

Data Analysis: Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. Soils can be classed into the HAZUS categories using Standard Penetration Test (SPT) data, which are acquired during the drilling of test borings. SPT tests report the number of blows of a 140-pound hammer falling 30 inches that are required to drive a sampling tube 12 inches into the test material. Glacial and postglacial alluvial and wetland soils in Middlesex County are similar to those in Hudson, Essex, and Union counties, so the SPT data collected for the previous HAZUS studies

of those counties are also applicable to Middlesex County. These earlier data include approximately 300 borings in the Hudson County-Newark area, with a total of 4,777 SPT tests; 60 borings, with a total of 688 SPT tests, collected for western Essex County; and 193 borings, with a total of 944 SPT tests, collected for Union County. An additional 448 borings, with a total of 3528 SPT tests, were collected for Middlesex County (table 1). These additional data include tests in nonglacial stream-terrace deposits, weathered diabase, Cretaceous clay, Cretaceous sand, and Pensauken Formation, which are soil types that have not been previously investigated.

Table 1.--Standard Penetration Test (SPT) data for surficial materials in Middlesex County.

Material	Number of Borings	Number of Tests	Range of SPT Values	Mean ± Standard Deviation	Percentage of Zero Values	Percentage of Refusals (SPT>200)
fill	92	245	2-200	18±24	0%	1%
salt-marsh deposits	173	656	0-33	3±5	48%	0%
alluvial silt, sand, and clay	20	53	0-69	13±14	24%	0%
nonglacial stream-terrace sand and gravel	125	471	2-200	32±29	0%	1%
glacial-river sand and gravel	41	170	2-200	20±17	0%	0.6%
till	75	342	2-200	41±41	0%	3%
glacial-lake silt and clay	4	14	5-26	16±5	0%	0%
weathered shale	100	179	2-200	70±51	0%	3%
weathered diabase	57	119	16-200	75±45	0%	2%
Cretaceous clay	90	608	4-240	51±45	0%	3%
Cretaceous sand	95	465	4-316	57±51	0%	4%
Pensauken Formation sand and gravel	49	206	4-51	20±9	0%	0%

SPT data from the additional Middlesex County borings yield means and ranges similar to those from the Hudson, Essex, and Union data for the same soil types. Till in Middlesex County yields a somewhat lower mean penetration value than tills farther north (40 vs. 60-70). This reduction is due in part to thinner glacial ice in Middlesex County, which was at the

southern edge of the glacier. Thinner ice exerts less compaction pressure on the underlying till. Also, till in Middlesex County is less bouldery and cobbly than that farther north, reducing the number of penetration tests with high counts from encountering these hard objects.

For each surficial unit, a mean SPT value, and standard deviation, were calculated. This mean value is then applied to the mapped extent of the surficial unit to prepare the soil class map. Where more than one surficial material is present overlying bedrock, the appropriate mean SPT value is applied to the thickness of each layer. Fill includes a variety of materials ranging from demolition debris and excavated bedrock to trash and dredged silt and sand. Because of the variable composition of fill it is inappropriate to apply a mean SPT value, and fill was not included in the soil classification determinations. The behavior of fill under seismic shaking should be assessed on a site-specific basis. HAZUS soil classes were assigned according to the procedures described in sections 4.1.2.1, 4.1.2.2, and 4.1.2.3 of the 1997 National Earthquake Hazards Reduction Program (NEHRP) Provisions. These procedures assign a soil class by using a weighting formula to sum the soil and rock layers to a depth of 100 feet.

Liquefaction susceptibility was assigned based on Table 9.1 of the HAZUS Users Manual, with some modifications to the classification scheme based on local penetration-test data and field observations. For example, low compaction and penetration resistance of some saturated glacial-lake, glacial-river, and stream-terrace deposits of Pleistocene age indicate a moderate-to-high liquefaction susceptibility, rather than the low susceptibility for Pleistocene lake and river deposits provided in Table 9.1.

Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Slope angles for Middlesex County were calculated from 1:24,000 topographic maps with 10- or 20-foot contour interval and slope materials were determined in the field. In places, particularly in the lower Raritan River valley, clay and sand mining operations and road construction have significantly changed the topography from that shown on the topographic maps. In these places, slope angles were estimated from aerial photography and field observations. Landslide susceptibility was assigned according to the classification in Table 9.2 of the HAZUS User's Manual (refer to map folded in pocket). Areas of potential landsliding include steep slopes on shale along the Raritan River and Lawrence Brook in the New Brunswick area, steep natural slopes in Cretaceous sand and clay, chiefly in the Cheesequake area along the southern shore of Raritan Bay, and faces of former sand and clay pits in the lower Raritan and South River valleys.

Shear-wave Velocity Measurements: To test the accuracy of using SPT data as a proxy for shear-wave velocity, and to collect data for soils lacking SPT tests, seismic data were collected at twelve sites in Middlesex County. The tested soil types include Cretaceous clay (3 sites), Cretaceous sand (3 sites), Pensauken Formation sand and gravel (3 sites), and stream-terrace sand (3 sites) (Table 2). The measurements were made at sites where the natural deposit was undisturbed and not covered or mixed with man-made fill. At each site, hand-auger holes were drilled to a depth of 5 feet to test for soil disturbance and fill. The seismic data were collected using a Bison 9000 digital engineering seismograph. Both shear wave (horizontal component) and compression (P) wave data were acquired (Appendix N). P-waves are much faster than shear waves and help in isolating the shear-wave signal in the seismic record. P-wave data generally show two velocity layers. The uppermost layer is unsaturated sediment and the lower

layer is saturated sediment. The boundary between the two layers is the water table. The water table is not detectable in shear wave data because liquids do not transmit shear waves.

Twelve shear geophones were used with a 6-foot spacing. The source was located 6 feet from the first geophone. Each geophone was oriented with its axis of movement parallel to the generating source. The source is a 6-inch channel steel beam that is 5 feet long and has triangular teeth welded to the bottom. A 10-pound sledgehammer is used to impact either side of the source. Two people stand on the source while it is being hit to improve ground coupling.

Compressional (P-wave) data were collected using the standard seismic refraction line type setup. Twelve 8-hertz geophones were used in-line at 6-foot spacing. A 10-pound sledgehammer and a strike plate are used as a source.

Table 2. Shear-wave velocity measurements. Complete data provided in Appendix N.

Site	Location (latitude; longitude)	Material	Measured shear-wave velocity (feet/second)	Shear-wave velocity range predicted from SPT data (feet/second)	Comments
New Road	40E21'46"; 74E33'02"	Pensauken Formation	1507	600-1200	faster than predicted due to clay hardening
Thompson Park	40E19'49"; 74E25'54"	Pensauken Formation	1998	600-1200	faster than predicted due to clay hardening
Pigeon Swamp	40E23'14"; 74E28'20"	Pensauken Formation	974	600-1200	agrees
Helmetta Boulevard	40E23'05"; 74E25'42"	Cretaceous sand	723 (layer 1) 2087 (layer 2)	1200-2500	agrees (layer 2)
Crescent Ave.	40E23'47"; 74E24'20"	Cretaceous sand	674 (layer 1) 1172 (layer 2)	1200-2500	slightly lower than predicted (layer 2)
Marlboro Road	40E21'51"; 74E19'19"	Cretaceous sand	638 (layer 1) 1799 (layer 2)	1200-2500	agrees (layer 2)
Texas Road	40E21'22"; 74E21'04"	Cretaceous clay	1252	1200-2500	agrees
Pension Road	40E20'10"; 74E21'22"	Cretaceous clay	768 (layer 1) 2122 (layer 2)	1200-2500	agrees (layer 2)
Old Bridge Golf Course	40E25'06"; 74E16'06"	Cretaceous clay	838 (layer 1) 1315 (layer 2)	1200-2500	agrees (layer 2)
Phillips Park	40E23'10"; 74E21'15"	stream-terrace sand	778 (layer 1) 1179 (layer 2)	600-1200	agrees

Jernee Mill Road	40E26'07"; 74E21'01"	stream-terrace sand	448 (layer 1) 632 (layer 2)	600-1200	agrees (layer 2)
River Road	40E32'12"; 74E29'59"	stream-terrace sand	771 (layer 1) 2857 (layer 2)	600-1200	agrees (layer 1; layer 2 is shale bedrock)

The first seismic break on the raw records from both the shear and compressional data is picked on the records much like picking first breaks for seismic refraction data. The regression velocity is calculated using the inverse slope on the time-distance curves. The data are also presented numerically as the interval velocity between consecutive geophones along each line and as an average of the interval velocities (Appendix N). This is done to check for lateral velocity variation along each seismic line. A large difference between the average velocity and the regression velocity is indicative of lateral hetereogeneities within the soil. The regression velocity is statistically more accurate as a bulk soil property.

Table 2 shows that 9 of the 12 tests yield velocities that fall within the range predicted from the county-wide SPT data for the layer in question. Seven of the nine measurements in Cretaceous sand, Cretaceous clay, and stream-terrace sand show an upper slow layer (layer 1). This layer, which is less than 5-10 feet thick, is material that has been decompacted by weathering, soil processes, and biologic activity such as root growth and animal burrowing. The faster velocities beneath this soil zone (layer 2) are better indicators of the compaction properties of the geologic material. The layer 2 velocities generally agree with the velocity range predicted from SPT data, which are acquired below the soil zone in most cases. At the River Road site, the stream-terrace deposit is about 10-15 feet thick over shale bedrock. Here, layer 1 is the velocity of the stream-terrace sand and layer 2 is the velocity of the shale bedrock.

Two of the three velocities measured in the Pensauken Formation are significantly faster than predicted from the SPT data. The Pensauken Formation is a feldspathic sand that weathers to form a clayey sand or sandy clay soil. When dry, the clay in the soil layer acts as a hardening agent and forms an upper layer of faster velocity than the formation itself. This fast layer masks the seismic signal from the slower material below. The Pigeon Swamp site is more poorly drained than the other two sites, and has a less-developed soil, so it does not have a dry, clay-hardened upper layer. The velocity measured here is likely more representative of the formation as a whole and falls within the range predicted from the SPT data.

HAZUS Simulations: To evaluate the effect of upgraded geology and liquefaction, a total of twelve simulations were run. Earthquake magnitudes of 5.5 and 6, with an epicenter at the county centroid (Appendix A) and a focal depth of 10 km, were simulated for both the default and the upgraded geology. Earthquake magnitudes of 5, 5.5, 6, 6.5, and 7, with the same epicenter and focal depth, were simulated for full upgraded geology and for upgraded geology without liquefaction. The selected magnitudes span the range of potential damaging earthquakes in the region. The largest local earthquake in historic records was an estimated magnitude 5.2 event in 1884 with an epicenter offshore from Brooklyn, and earthquakes with magnitudes between 6 and 7 have been recorded or estimated from historical accounts in South Carolina, the Boston area, southern Quebec, and the St. Lawrence Valley.

The geologic data were upgraded by modifying soil type, liquefaction susceptibility, and landslide susceptibility for each census tract using the seismic soil class, liquefaction susceptibility, and landslide susceptibility maps (folded in pocket). Many census tracts spanned two or more soil types. In these cases, the dominant soil under the most densely built part of the census tract was selected. Also, areas subject to landsliding cover only a small part of the census tracts that were assigned a landslide hazard. In these census tracts, however, highways and local roads, and some buildings, adjoin slopes that are landslide-prone, so the landslide hazard was judged significant. The default geology assigned a uniform soil type (class D), and no liquefaction or landslide susceptibility, for the entire county. Maps of the upgraded and default geology, by census tract, are provided in Appendix A.

Building damage best illustrates the effect of geology on the simulations, because it does not directly incorporate economic and demographic patterns. Appendices B through M provide tables showing the number of the buildings (classed by use) in various states of damage, and the probability of a given damage state for a given use class. The appendices also provide maps showing the percent moderate or greater building damage by census tract for the various simulations. The moderate-or-greater cutoff was used because buildings with moderate damage must be evacuated and inspected prior to reoccupancy. Thus, moderate damage requires significant population disruption and emergency response. A loss estimation sheet summarizing damage, economic loss, casualties, and population displacement for each HAZUS run is also provided. The total economic loss includes repair and replacement costs, contents damage, business inventory damage, relocation costs, capital-related income costs, wage loss, and rental loss. In order to assess the effect of liquefaction, tables showing damage to transportation and utility systems were also generated for each run.

Evaluation of Simulations: The upgraded geologic data produced increased damage estimates for census tracts on vulnerable soils in the lower Raritan River valley and Arthur Kill areas, and generally decreased damage estimates elsewhere, compared to the default data. This pattern reflects the softer salt-marsh soils along the lower Raritan and Arthur Kill, which are of less stable soil class and are more liquefiable than the default conditions, and the compact till, weathered rock, and Cretaceous clay and sand under much of the rest of the county. These soils are of stronger soil class than the default. Census tracts underlain by the vulnerable soils (classes D and E, with medium and high liquefaction susceptibility) show as much as 30% more buildings damaged to a moderate or greater state than the default (class D with no liquefaction susceptibility) damage. Census tracts underlain by compact soil (class C) show as much as 20% fewer buildings damaged than the default.

Because the area of the county underlain by compact soil is more extensive than the area underlain by vulnerable soils, the total number of buildings with moderate or greater damage is 30-40% less with the upgraded geologic data than with the default data, and the total economic and property loss is between 10 and 20% less with the upgraded geologic data (table 3). Note, however, that important transportation, waste-disposal, and industrial facilities are located in the vulnerable salt-marsh area, including segments of the Garden State Parkway and the New Jersey Turnpike, a powerplant, and several landfills, sewage treatment plants, refineries and oil terminals.

Table 3. Comparison of total economic loss (TEL, in billions of dollars), major building damage (MBD, in thousands of buildings), and displaced households (DH, actual number of households requiring shelter) for the HAZUS runs. Total economic loss includes building damage plus loss of building contents plus loss due to business interruption. Major building damage includes buildings of any type damaged to the "extensive" and "complete" state.

Magnitude	default			full upgrade			upgrade without liquefaction		
	TEL	MBD	DH	TEL	MBD	DH	TEL	MBD	DH
5.0	-	-	-	0.5-1.9	<1	140-500	0.4-1.7	<1	40-150
5.5	1.5-6.2	2-8	1500-6000	1.3-5.2	1-6	1200-5000	1.2-4.9	1-5	1000-4000
6.0	3.2-13	6-30	6000-22,000	2.9-11.5	5-20	5000-19,000	2.8-11.2	5-20	4000-18,000
6.5	-	-	-	5.1-20.3	11-50	10,000-40,000	5-19.8	11-50	10,000-38,000
7.0	-	-	-	7.7-30.6	20-80	17,000-68,000	7.5-29.9	19-80	16,000-65,000

Liquefaction accounts for less than 5% of countywide economic loss. However, census tracts with a moderate and high liquefaction susceptibility show as much as a 10% increase in the percentage of buildings damaged to a moderate or greater state, compared to no-liquefaction runs. More specific indicators of the effect of liquefaction are the performance of structures that are susceptible to damage from permanent ground displacement. Liquefaction, landsliding, and fault rupture (which is not a potential hazard in this area) cause permanent ground displacements, which are the principal cause of damage to gas, water, and sewer mains and other underground utilities, as well as damage to roads, railroads, and runways. Table 4 shows damage to bridges and table 5 shows damage to water and oil pipelines for each run. Note that water-line damage is proxied by households without water at day 1 following the earthquake, because HAZUS calculates loss of water service based on population, not from actual breaks and leaks in pipes. Outputs for road, railway, runway, and underground utility damage, other than the population proxy for water service, are not available, either because there is no default data (in the case of underground utilities) or because the software is not yet able to calculate the effect (in the case of road, railway, and runway damage).

Table 4. Comparison of bridge damage for HAZUS runs. Numbers indicate bridge segments (out of 936 total segments) damaged to the indicated state.

Magnitude	default		full upgrade		upgrade without liquefaction	
	moderate	complete	moderate	complete	moderate	complete
5.0	-	-	3	0	0	0
5.5	36	2	38	3	26	1
6.0	207	38	192	41	174	30
6.5	-	-	392	136	375	116
7.0	-	-	555	268	543	245

Table 5. Comparison of water-main and oil-pipeline damage for HAZUS runs. “Households without water” is the number of households without water at day 1 after the earthquake, out of 238,974 total households in county. Number in parentheses is percentage of total households. Number of leaks or breaks for oil pipelines is out of 112 km of pipeline length.

Magnitude	default			full upgrade			upgrade without liquefaction		
	households without water	oil pipeline leaks	oil pipeline breaks	households without water	oil pipeline leaks	oil pipeline breaks	households without water	oil pipeline leaks	oil pipeline breaks
5.0	-	-	-	0	0	0	0	0	0
5.5	0	2	0	24,234 (10%)	2	1	0	2	0
6.0	30,424 (13%)	10	2	129,570 (54%)	12	4	15,498 (6%)	10	2
6.5	-	-	-	196,616 (82%)	29	15	89,916 (38%)	28	10
7.0	-	-	-	226,245 (95%)	73	36	177,113 (74%)	62	16

Tables 4 and 5 show increases in damage to bridges and oil pipelines with the addition of liquefaction. There are 5 to 15% more pipeline breaks, 30 to 50% more pipeline leaks, and a 10 to 25% increase in completely damaged bridge segments, when liquefaction is added. The greatest impact is on water mains. Adding liquefaction increases the percentage of households without water from 0 to 10% at M 5.5, from 6 to 54% at M 6, from 38 to 82% at M 6.5, and from 74 to 95% at M 7. Similar results would be expected for gas mains. The combination of loss of water and rupture of gas mains creates increased fire hazard for structures on liquefiable soils.

The true impact of liquefaction is greater than indicated in these runs. As noted above, HAZUS did not calculate direct damage to underground utilities because there is no default data

for utility system lifelines. Upgrading the utility data would provide a more complete picture. Updated software that incorporates the effect of permanent ground displacements on roads, railways, and runways would also provide a more complete accounting.

Reference Cited (additional citations provided on map sheets)

Stanford, S. D., 1999, Environmental geology of Middlesex County, New Jersey: surficial geology: N. J. Geological Survey Open-File Map OFM 27, 1:48,000 scale.

APPENDIX A

Maps of Middlesex County, with census tracts, showing:

Epicenter location
Default soil type
Default liquefaction susceptibility
Default landslide susceptibility
Upgraded soil type
Upgraded liquefaction susceptibility
Upgraded landslide susceptibility

4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

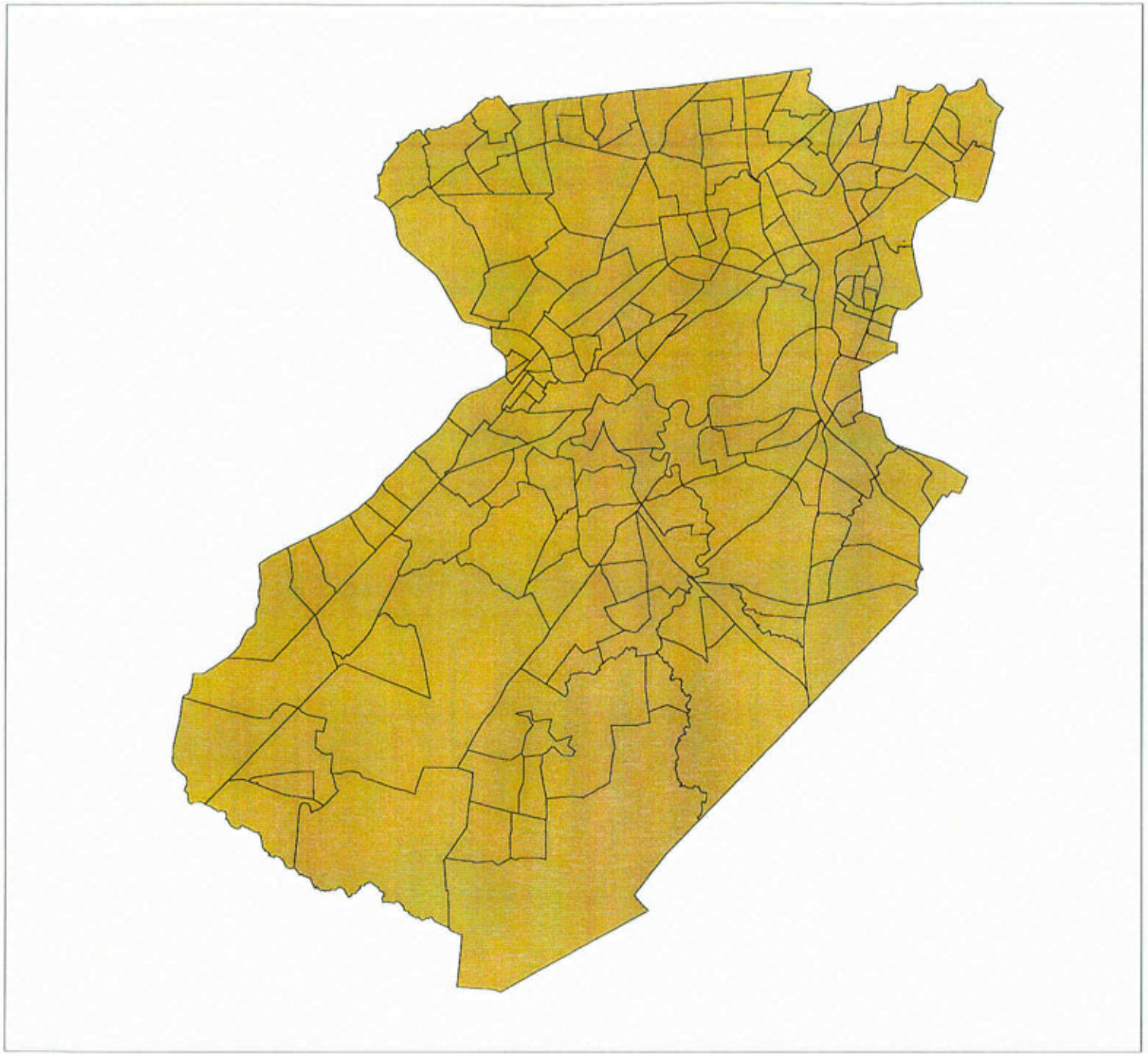
Table Description:

Study Region Epicenter

★ Epicenter (Arbitrary)
74 .428 degrees longitude
40.436 degrees latitude

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software.
July 15, 2003



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Table Description:

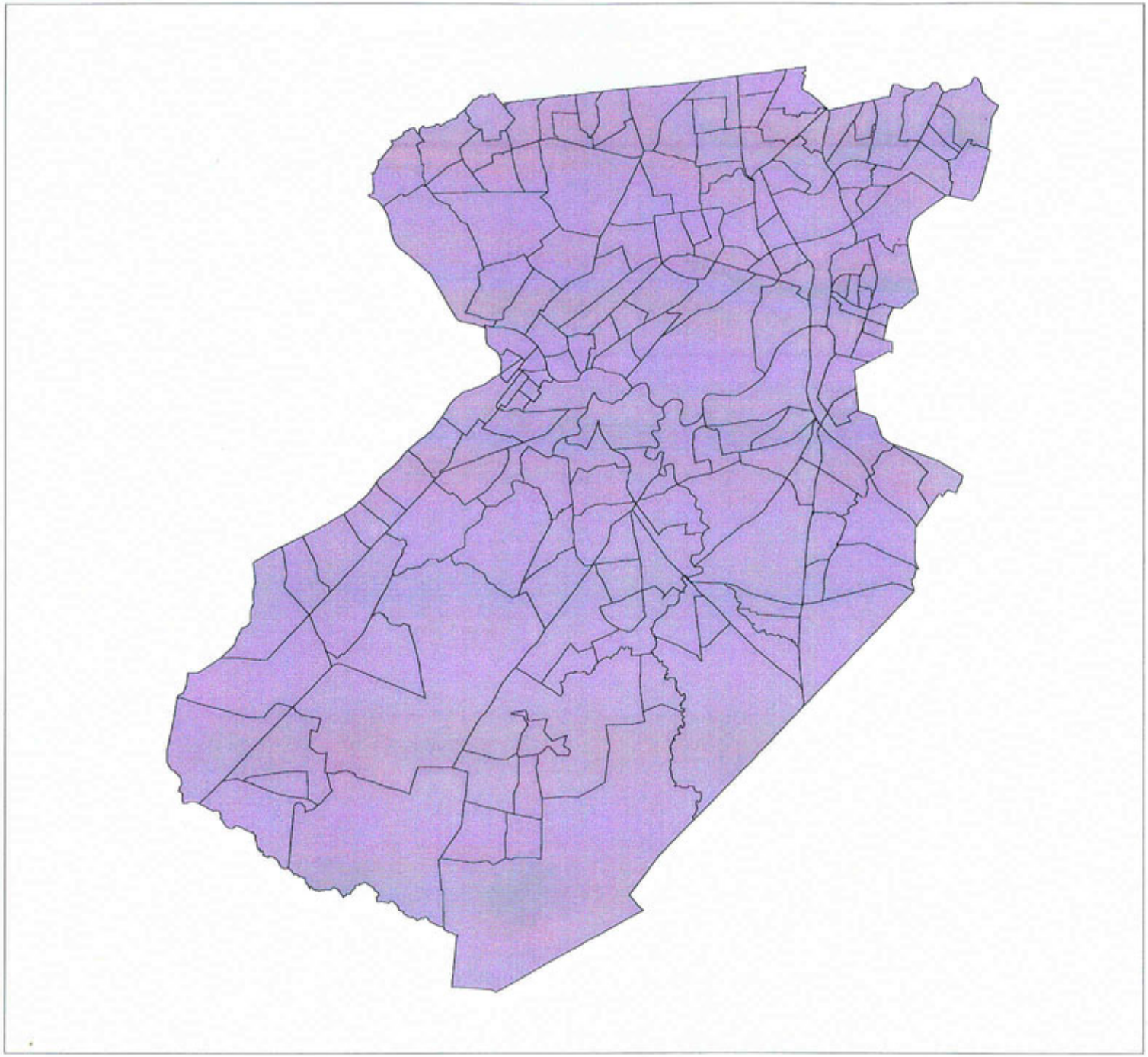
Default Soil Map

Soil Type

Class D

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software.
July 22, 2003



4 0 4 8 12 16 20 Miles

Study Region:
Middlesex County

Table Description:
Default Liquefaction Map

Liquefaction Susceptibility

None

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software.
July 23, 2003

4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Table Description:

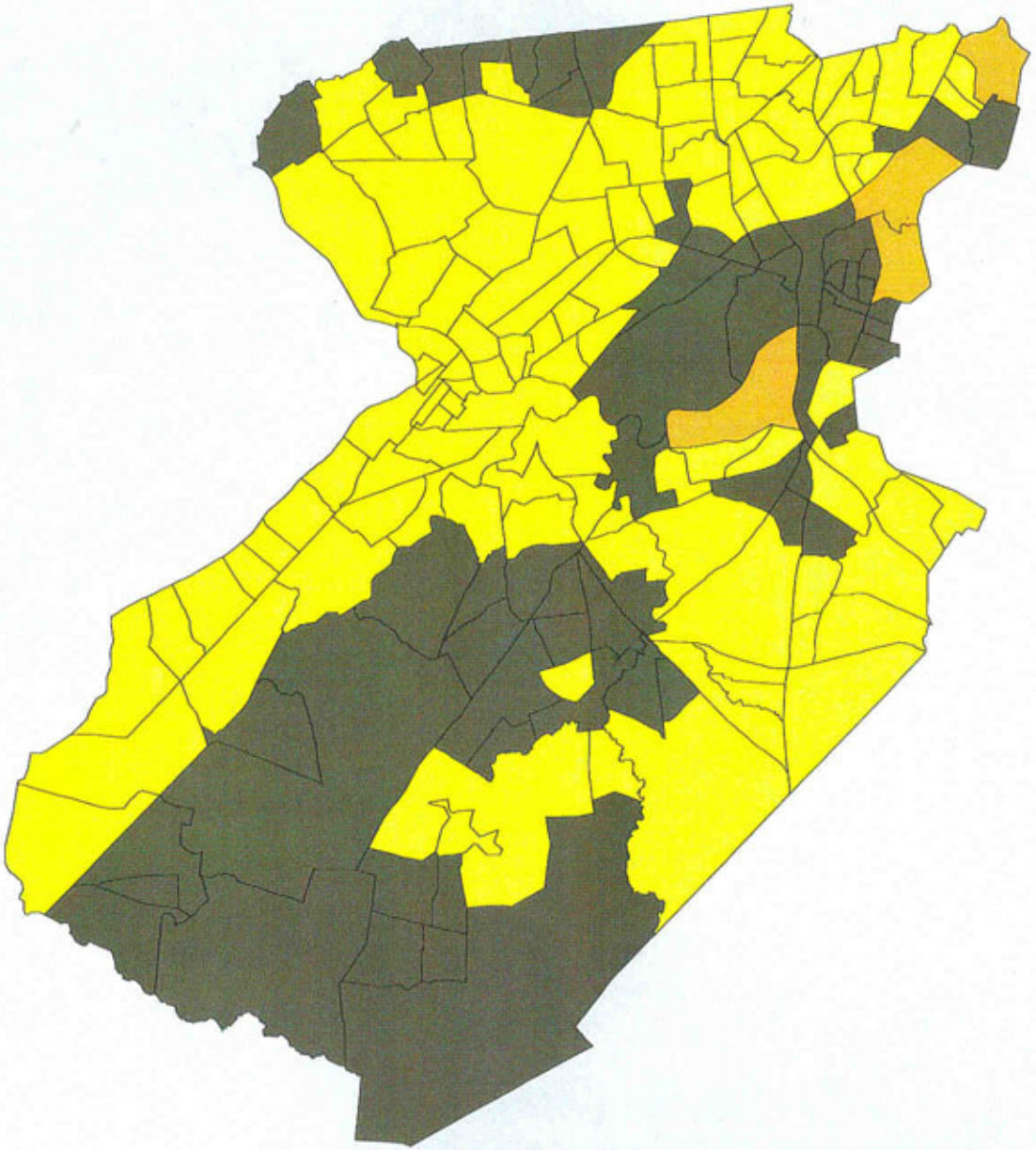
Default Landslide Map

Landslide Susceptibility

None

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS softwa
July 23, 2003



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Table Description:

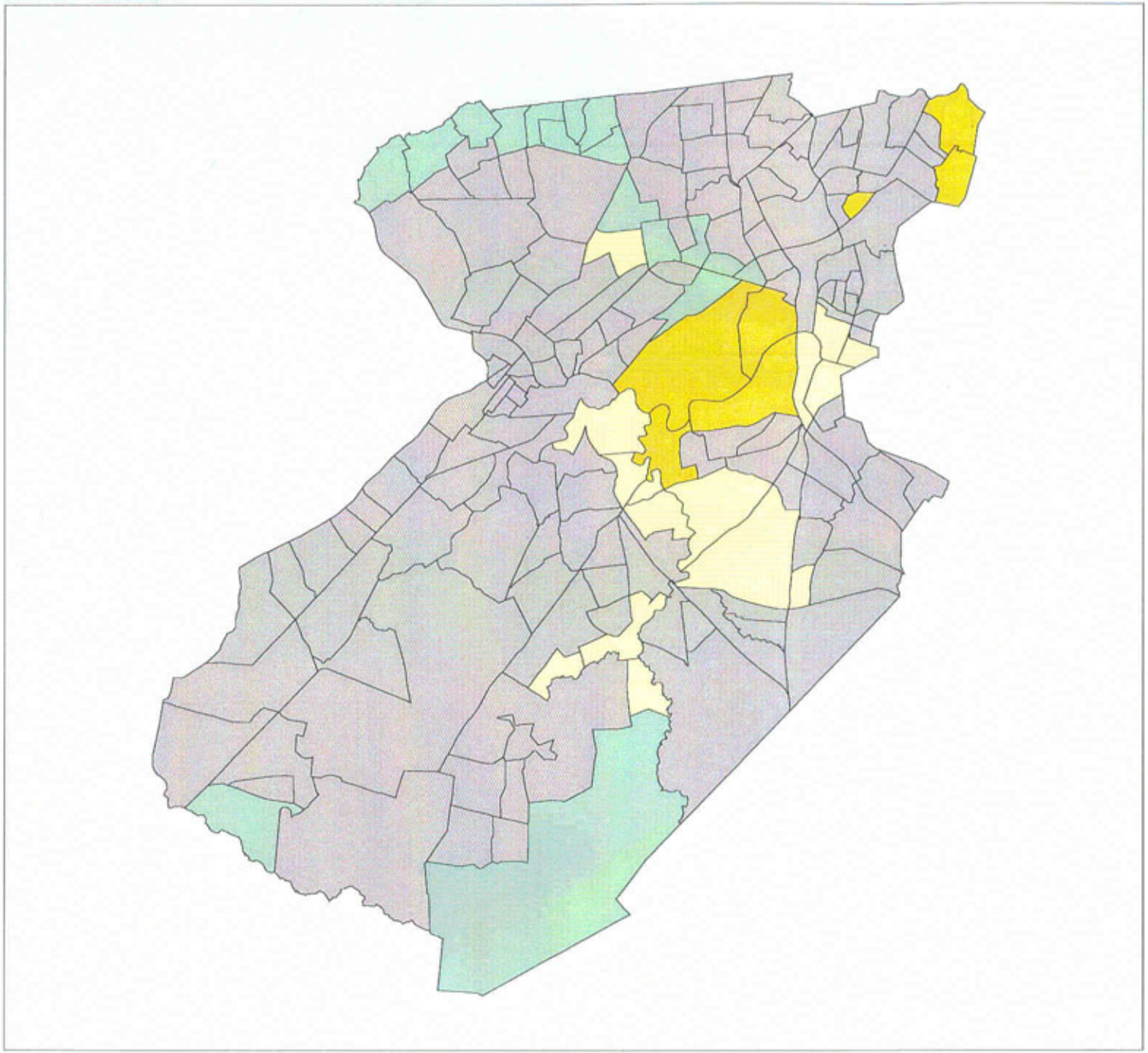
New Jersey Geological Survey Soils Map

Soil Type

- Class C
- Class D
- Class E

NEW JERSEY GEOLOGICAL SURVEY 1835

Data generated by the New Jersey Geological Survey.
July 23, 2003



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Table Description:

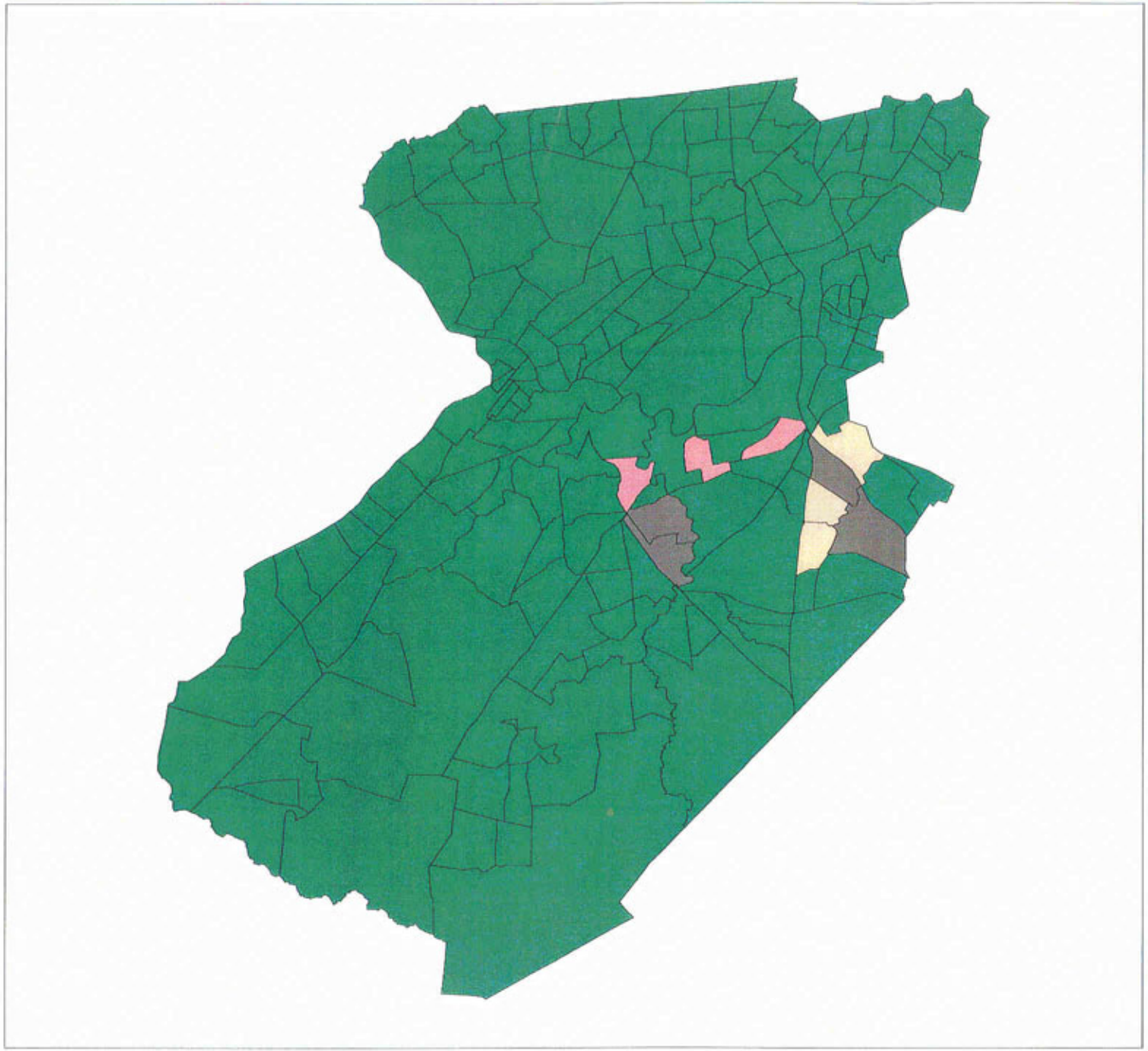
New Jersey Geological Survey Liquefaction Map

Liquefaction Susceptibility

- Very low
- Low
- Medium
- High

NEW JERSEY GEOLOGICAL SURVEY 1835

Data generated by the New Jersey Geological Survey
July 23, 2003



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Table Description:

New Jersey Geological Survey Landslide Map

Landslide Susceptibility

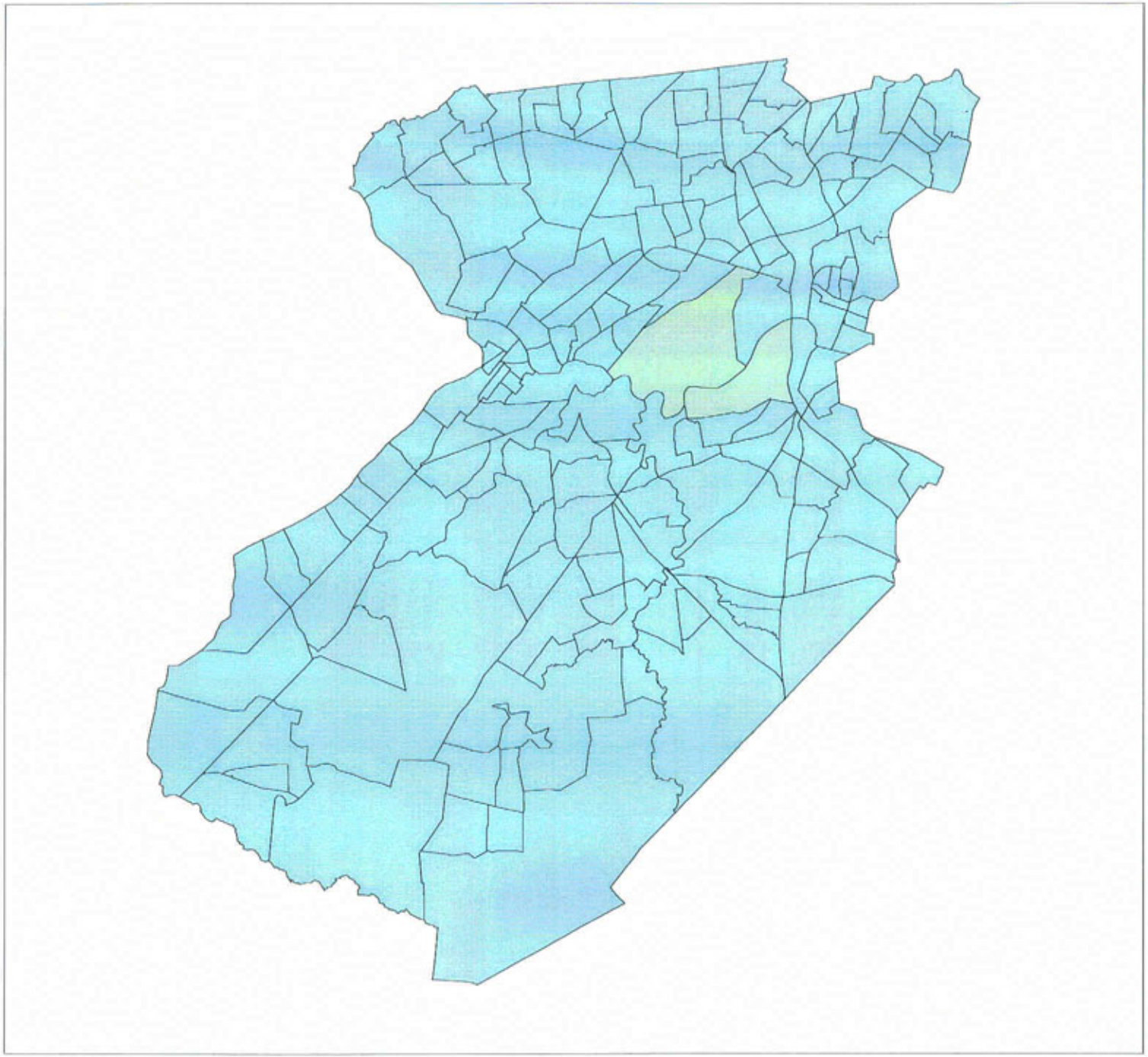
- None
- Susceptibility III
- Susceptibility IV
- Susceptibility VIII

NEW JERSEY GEOLOGICAL SURVEY 1835

Data generated by the New Jersey Geological Survey.
July 23 , 2003

APPENDIX B

Magnitude 5 with full upgrade geology



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

5.0 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	0.30 - 1.00
	Building Contents	0.20 - 0.70
	Business Interruption	0.00 - 0.10
Infrastructure	Lifelines Damage	
	Total	0.50 - 1.90

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	5 - 20	< 1.0	< 1.0	5 - 20
Major	0 - 1	< 1.0	< 1.0	0 - 1
Total	5 - 20	< 1.0	< 1.0	5 - 20

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	90 - 400
Level 2	Hospital Care	10 - 50
Level 3	Life-threatening	< 20
Level 4	Fatalities	< 20

Estimated Shelter Needs

Type	Households	People
Displaced Households	140 - 500	
Public Shelter		80 - 300

Comments :

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Earthquake Information

Location :

Origin Time:

Magnitude : 5.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.37

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

upg 5.0

Time of report: July 16, 2003 1:35 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Roads	70			70	70
	Bridges	936	3	0	936	936
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	0	0	2	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	8	0	28	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 % After Day 1	with Functionality > 50 % After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	1	0	1	3
Natural Gas	0	1	0	0	0
Oil Systems	8	5	0	1	8
Electrical Power	4	3	0	1	4
Communication	28	11	0	28	28
Total	43	19	1	31	43

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	0	0
Total	112	0	0

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	0	0	0	0	0
Electric Power	238,974	123,521	44,854	8,419	258	0

upg 5.0

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	58.88	4.68	1.64	0.23	0.01
Commercial	112,426	88.16	6.88	2.93	0.54	0.03
Education	5,402	68.46	5.08	2.13	0.40	0.02
Government	1,424	89.53	6.43	2.75	0.44	0.03
Industrial	45,607	88.14	6.47	2.83	0.46	0.03
Religion	3,212	69.44	5.47	2.38	0.46	0.02
Residential	345,636	92.18	5.54	1.20	0.21	0.03
State Average	515,207	79.26	5.79	2.27	0.39	0.03
Study Region Average	515,207	79.26	5.79	2.27	0.39	0.03

Study Region : midd
Scenario : upg5

Building Damage by Count by General Occupancy

July 29, 2003

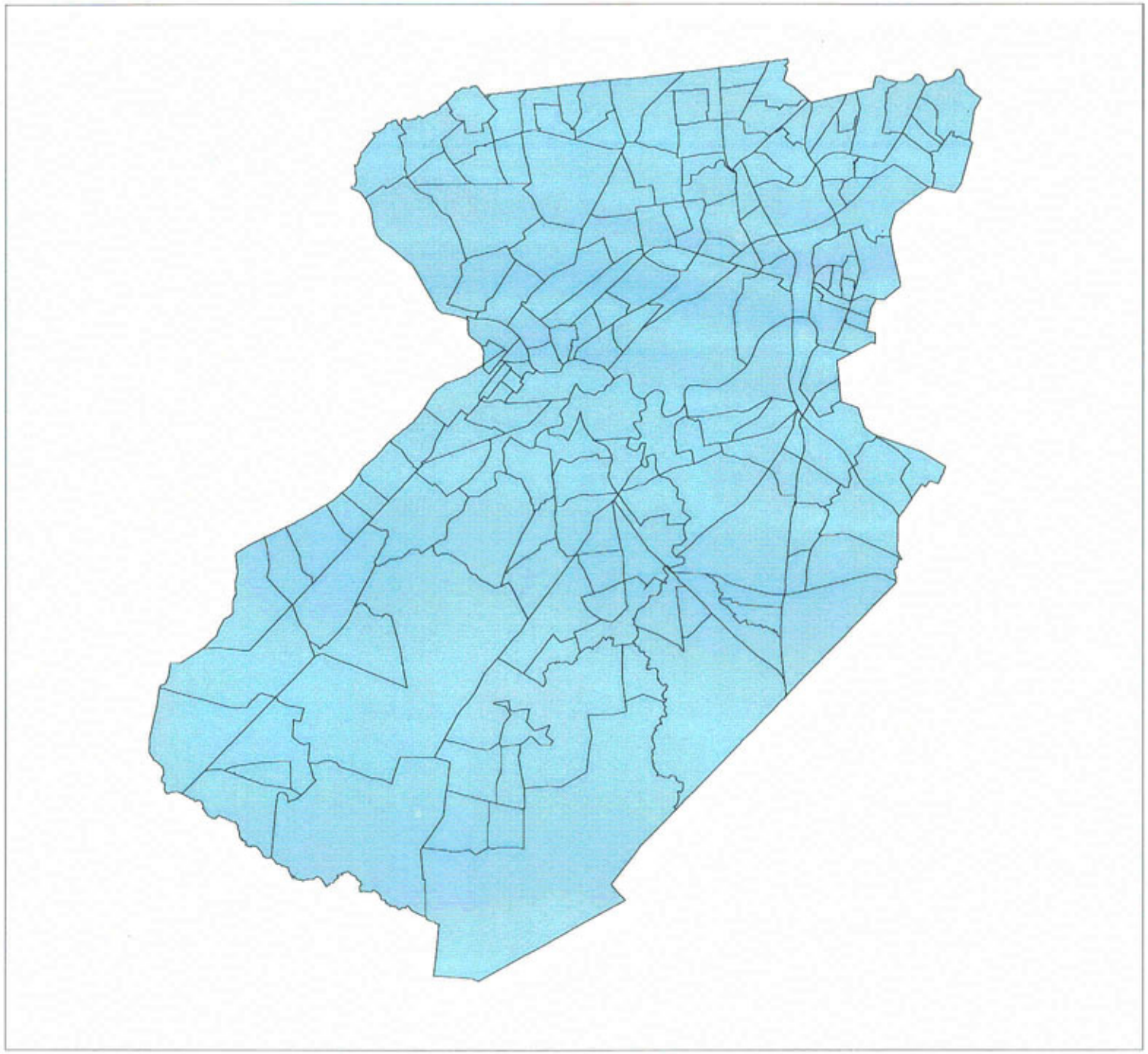
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	90	3	0	0	0	93
Commercial	4,410	227	62	23	5	4,727
Education	247	8	2	0	0	257
Government	19	0	0	0	0	19
Industrial	1,755	78	20	5	0	1,858
Religion	202	2	0	0	0	204
Residential	156,381	8,533	1,789	447	49	167,199
Total State	163,104	8,851	1,873	475	54	174,357
Study region	163,104	8,851	1,873	475	54	174,357

Study Region : midd

Scenario : upg5

APPENDIX C

Magnitude 5 with upgraded geology, no liquefaction



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

5.0 Upgrade Scenario With Default Liquefaction

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	0.20 - 0.90
	Building Contents	0.20 - 0.70
	Business Interruption	0.00 - 0.10
Infrastructure	Lifelines Damage	
	Total	0.40 - 1.70

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	5 - 20	< 1.0	< 1.0	5 - 20
Major	< 1.0	< 1.0	< 1.0	< 1.0
Total	5 - 20	< 1.0	< 1.0	5 - 20

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	60 - 300
Level 2	Hospital Care	10 - 30
Level 3	Life-threatening	< 20
Level 4	Fatalities	< 20

Estimated Shelter Needs

Type	Households	People
Displaced Households	40 - 150	
Public Shelter		20 - 80

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.37

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

4pg15

Time of report: July 16, 2003 3:24 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Roads	70			70	70
	Bridges	936	0	0	936	936
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	0	0	2	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	8	0	28	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	1	0	1	3
Natural Gas	0	1	0	0	0
Oil Systems	8	5	0	1	8
Electrical Power	4	3	0	1	4
Communication	28	11	0	28	28
Total	43	19	1	31	43

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	0	0
Total	112	0	0

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	0	0	0	0	0
Electric Power	238,974	123,521	44,854	8,419	258	0

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	58.94	4.69	1.64	0.15	0.00
Commercial	112,426	88.33	6.89	2.94	0.37	0.00
Education	5,402	68.59	5.08	2.14	0.27	0.00
Government	1,424	89.72	6.44	2.77	0.21	0.00
Industrial	45,607	88.33	6.49	2.84	0.27	0.00
Religion	3,212	69.59	5.48	2.38	0.32	0.00
Residential	345,636	92.41	5.55	1.20	0.02	0.00
State Average	515,207	79.42	5.80	2.27	0.23	0.00
Study Region Average	515,207	79.42	5.80	2.27	0.23	0.00

Study Region : midd
Scenario : upgl5

Building Damage by Count by General Occupancy

July 29, 2003

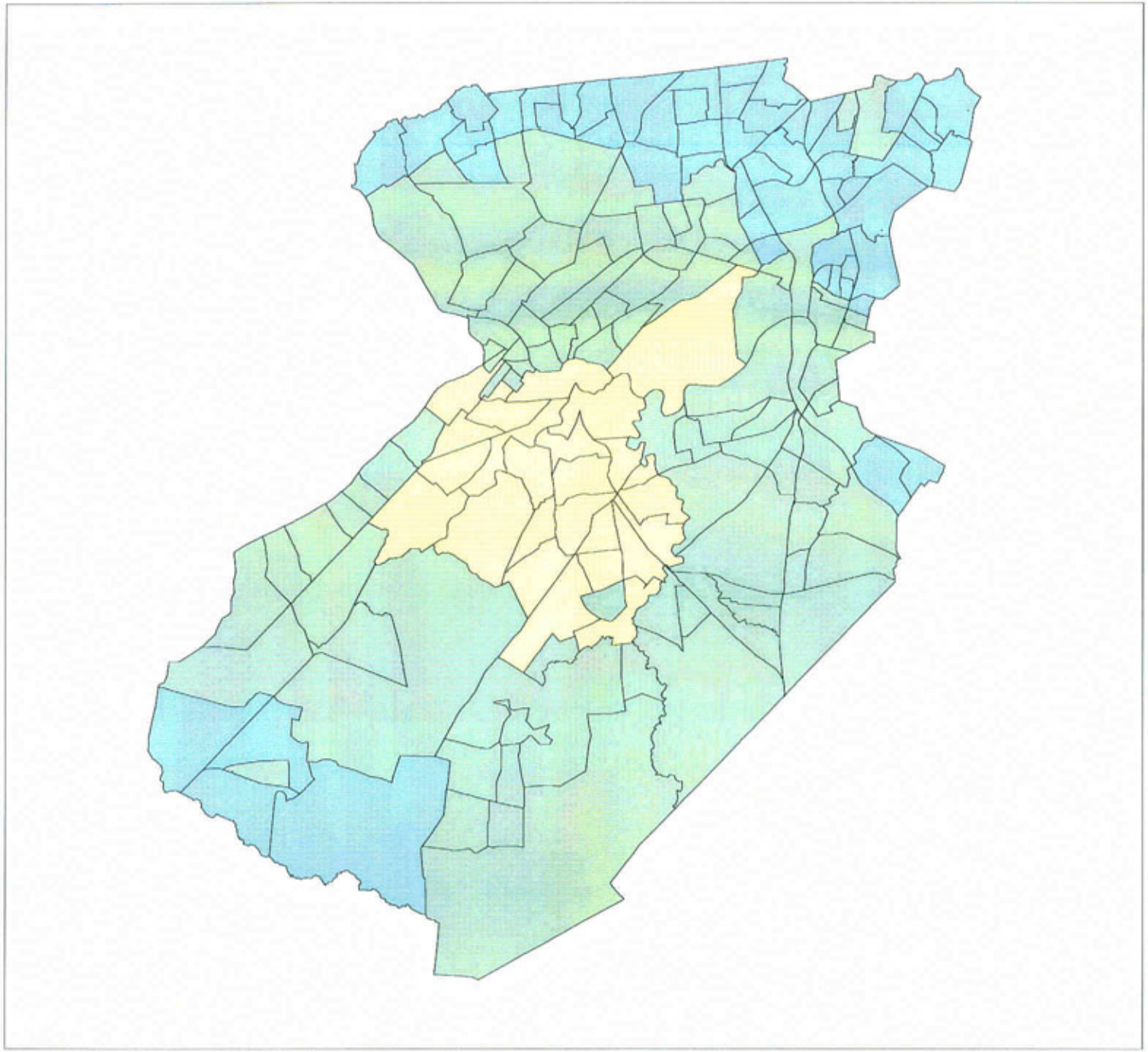
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	90	3	0	0	0	93
Commercial	4,432	229	62	5	0	4,728
Education	248	8	2	0	0	258
Government	19	0	0	0	0	19
Industrial	1,760	78	20	0	0	1,858
Religion	202	2	0	0	0	204
Residential	156,625	8,553	1,803	231	16	167,228
Total State	163,376	8,873	1,887	236	16	174,388
Study region	163,376	8,873	1,887	236	16	174,388

Study Region : midd

Scenario : upgl5

APPENDIX D

Magnitude 5.5 with default geology



Study Region:

Middlesex County

Scenario Description:

5.5 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

4 0 4 8 12 16 20 Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	0.90 - 3.50
	Building Contents	0.50 - 1.80
	Business Interruption	0.20 - 0.90
Infrastructure	Lifelines Damage	
	Total	1.50 - 6.20

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	30 - 120	0 - 2	< 1.0	30 - 130
Major	1 - 7	< 1.0	< 1.0	2 - 8
Total	30 - 130	0 - 3	< 1.0	30 - 140

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	600 - 2,000
Level 2	Hospital Care	120 - 500
Level 3	Life-threatening	10 - 60
Level 4	Fatalities	30 - 110

Estimated Shelter Needs

Type	Households	People
Displaced Households	1,500 - 6,000	
Public Shelter		1,000 - 4,000

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 5.5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.49

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

Time of report: July 16, 2003 9:24 am

Def CC

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	36	2	936	936
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	1	0	2	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	14	1	28	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Def 5.5

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	1	0	2	3
Natural Gas	0	1	0	0	0
Oil Systems	8	5	0	1	8
Electrical Power	4	3	0	0	4
Communication	28	17	1	28	28
Total	44	27	2	31	43

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	2	0
Total	112	2	0

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	0	0	0	0	0
Electric Power	238,974	182,455	114,092	42,890	3,139	0

Def 5.5

Building Damage By General Occupancy

July 16, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	39.36	14.41	9.14	2.29	0.26
Commercial	112,426	59.50	19.33	14.93	4.26	0.52
Education	5,402	46.65	14.41	11.41	3.19	0.50
Government	1,424	62.03	18.11	14.79	3.87	0.41
Industrial	45,607	60.17	18.01	15.08	4.20	0.40
Religion	3,212	44.13	17.25	12.05	3.76	0.88
Residential	345,636	60.18	24.92	11.60	2.45	0.15
State Average	515,207	53.15	18.06	12.71	3.43	0.45
Study Region Average	515,207	53.15	18.06	12.71	3.43	0.45

Study Region : midd
Scenario : def55

Building Damage by Count by General Occupancy

July 16, 2003

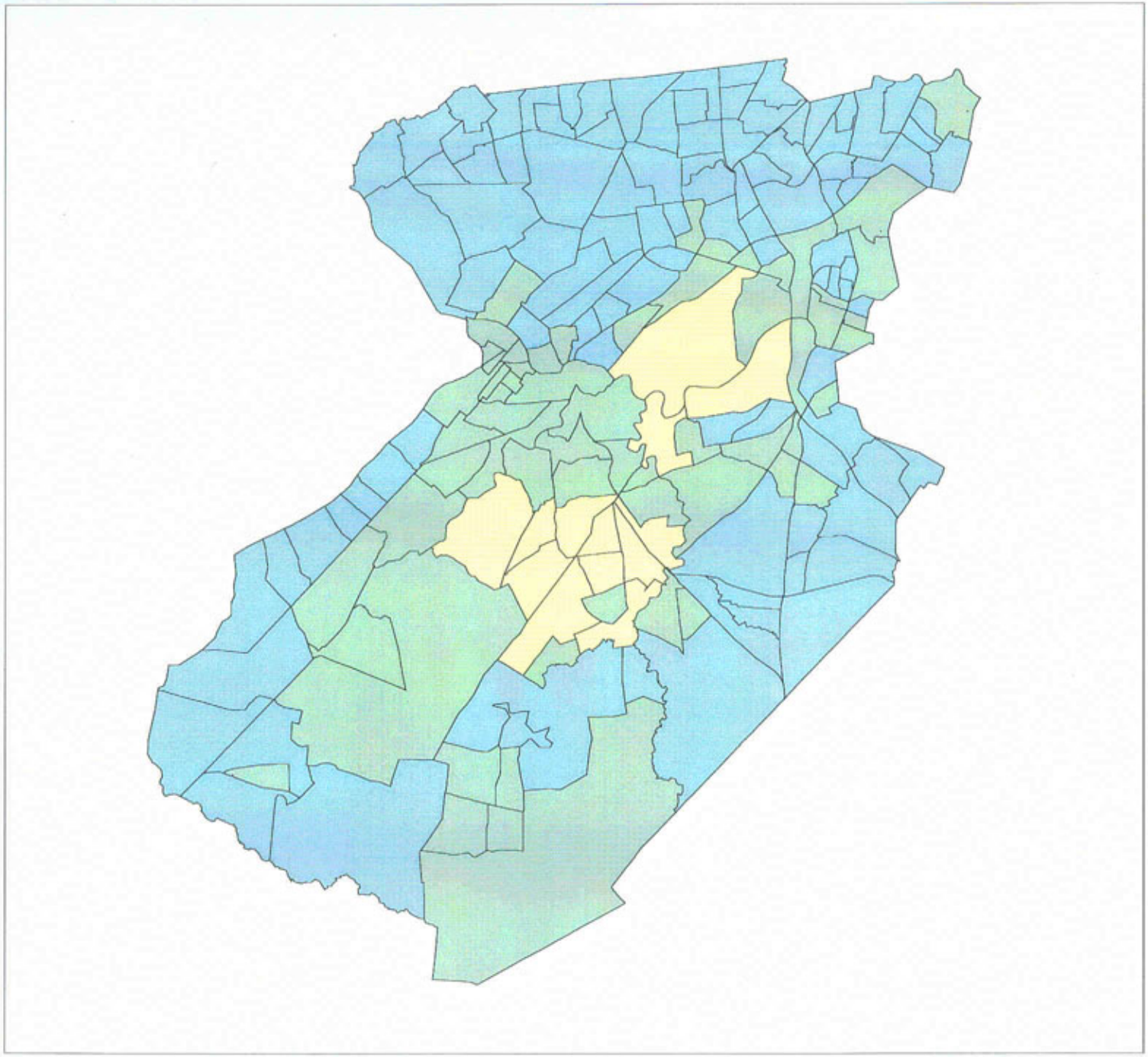
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	60	15	6	1	0	82
Commercial	2,976	838	636	108	9	4,567
Education	174	29	23	4	0	230
Government	14	0	0	0	0	14
Industrial	1,187	294	241	50	1	1,773
Religion	118	33	20	0	0	171
Residential	102,303	43,130	18,399	3,432	421	167,685
Total State	106,832	44,339	19,325	3,595	431	174,522
Study region	106,832	44,339	19,325	3,595	431	174,522

Study Region : midd

Scenario : def55

APPENDIX E

Magnitude 5.5 with full upgrade geology



Study Region:

Middlesex County

Scenario Description:

5.5 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	0.70 - 2.80
	Building Contents	0.40 - 1.60
	Business Interruption	0.20 - 0.70
Infrastructure	Lifelines Damage	
	Total	1.30 - 5.20

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	20 - 100	0 - 2	< 1.0	20 - 100
Major	1 - 5	< 1.0	< 1.0	1 - 6
Total	30 - 100	0 - 2	< 1.0	30 - 110

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	500 - 1,900
Level 2	Hospital Care	90 - 400
Level 3	Life-threatening	10 - 40
Level 4	Fatalities	20 - 80

Estimated Shelter Needs

Type	Households	People
Displaced Households	1,200 - 5,000	
Public Shelter		800 - 3,000

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 5.5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.49

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

4pg 5,5

Time of report: July 16, 2003 1:28 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	38	3	936	936
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	1	0	2	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	13	1	28	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	1	0	0	3
Natural Gas	0	1	0	0	0
Oil Systems	8	6	1	0	7
Electrical Power	4	3	0	0	4
Communication	28	16	1	28	28
Total	44	28	2	28	42

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	2	1
Total	112	2	1

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	24,234	4,058	0	0	0
Electric Power	238,974	174,178	101,809	35,246	2,333	0

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	44.54	12.20	6.84	1.70	0.11
Commercial	112,426	66.47	16.88	11.63	3.24	0.33
Education	5,402	52.18	12.48	8.72	2.38	0.29
Government	1,424	68.83	15.73	11.36	2.95	0.24
Industrial	45,607	67.13	15.72	11.66	3.14	0.23
Religion	3,212	50.19	14.85	9.41	2.92	0.66
Residential	345,636	68.16	20.60	8.44	1.82	0.14
State Average	515,207	59.64	15.50	9.72	2.59	0.29
Study Region Average	515,207	59.64	15.50	9.72	2.59	0.29

Building Damage by Count by General Occupancy

July 29, 2003

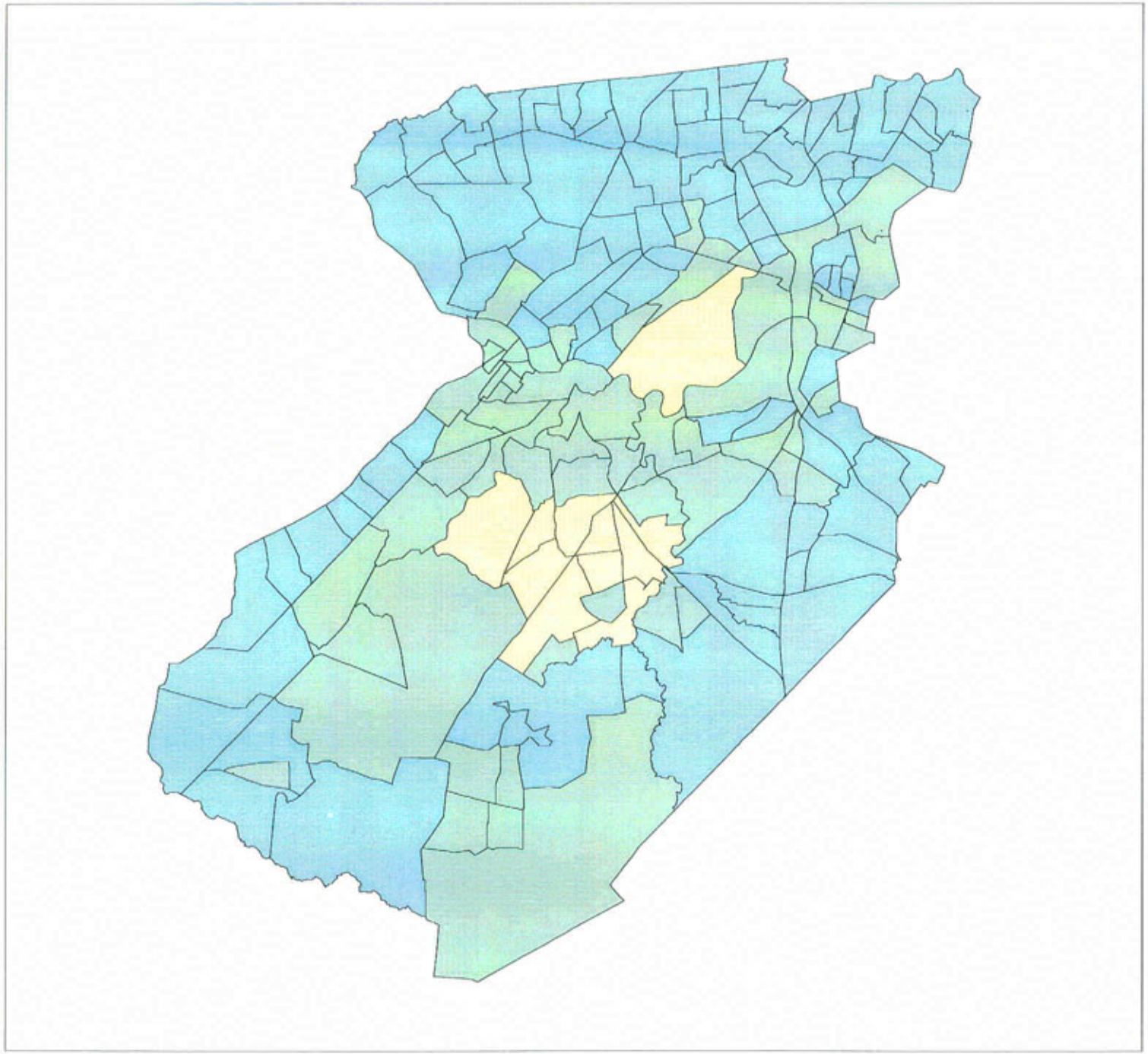
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	67	10	4	1	0	82
Commercial	3,308	723	449	86	8	4,574
Education	191	24	16	3	0	234
Government	17	0	0	0	0	17
Industrial	1,333	243	170	28	2	1,776
Religion	138	27	10	0	0	175
Residential	116,956	34,824	12,964	2,511	402	167,657
Total State	122,010	35,851	13,613	2,629	412	174,515
Study region	122,010	35,851	13,613	2,629	412	174,515

Study Region : midd

Scenario : upg55

APPENDIX F

Magnitude 5.5 with upgraded geology, no liquefaction



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

5.5 Upgrade Scenario With Default Liquefaction

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	0.70 - 2.70
	Building Contents	0.40 - 1.60
	Business Interruption	0.20 - 0.70
Infrastructure	Lifelines Damage	
	Total	1.20 - 4.90

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	20 - 100	0 - 2	< 1.0	20 - 100
Major	1 - 5	< 1.0	< 1.0	1 - 5
Total	30 - 100	0 - 2	< 1.0	30 - 100

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	400 - 1,700
Level 2	Hospital Care	80 - 300
Level 3	Life-threatening	10 - 40
Level 4	Fatalities	20 - 80

Estimated Shelter Needs

Type	Households	People
Displaced Households	1,000 - 4,000	
Public Shelter		700 - 3,000

Comments :

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Earthquake Information

Location :

Origin Time:

Magnitude : 5.5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.49

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

upg 155

Time of report: July 17, 2003 10:38 am

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	26	1	936	936
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	1	0	2	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	13	1	28	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	1	0	0	3
Natural Gas	0	1	0	0	0
Oil Systems	8	6	1	0	7
Electrical Power	4	3	0	0	4
Communication	28	16	1	28	28
Total	44	28	2	28	42

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	2	0
Total	112	2	0

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	0	0	0	0	0
Electric Power	238,974	174,178	101,809	35,246	2,333	0

Building Damage By General Occupancy

July 17, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	44.61	12.24	6.88	1.59	0.09
Commercial	112,426	66.66	16.94	11.68	3.02	0.26
Education	5,402	52.35	12.53	8.77	2.19	0.24
Government	1,424	69.05	15.81	11.41	2.67	0.15
Industrial	45,607	67.35	15.77	11.71	2.89	0.15
Religion	3,212	50.33	14.90	9.46	2.73	0.62
Residential	345,636	68.36	20.67	8.48	1.56	0.07
State Average	515,207	59.81	15.55	9.77	2.38	0.23
Study Region Average	515,207	59.81	15.55	9.77	2.38	0.23

Building Damage by Count by General Occupancy

July 17, 2003

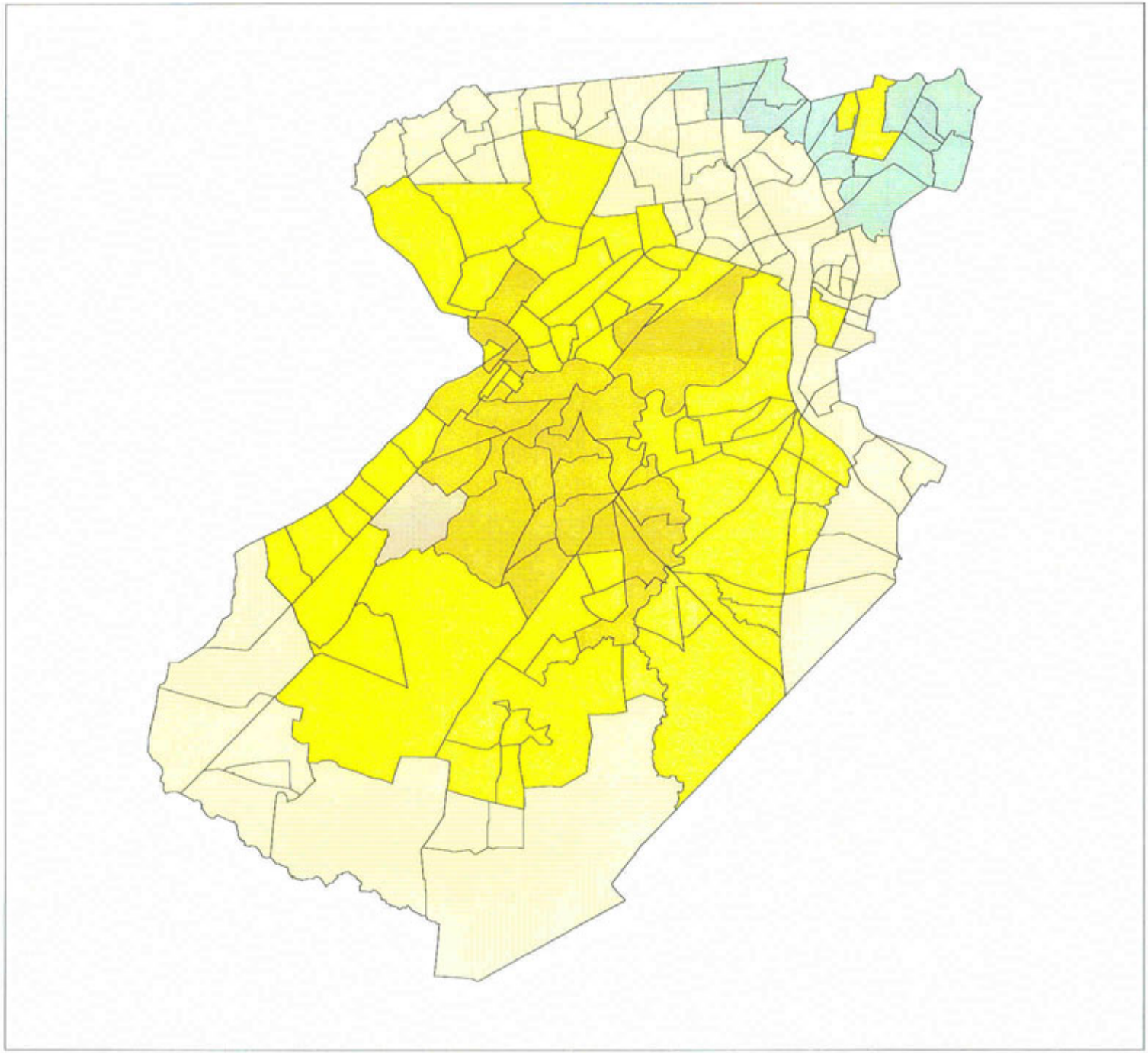
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	67	10	4	1	0	82
Commercial	3,330	726	451	66	5	4,578
Education	191	25	16	2	0	234
Government	17	0	0	0	0	17
Industrial	1,338	244	171	23	0	1,776
Religion	138	27	10	0	0	175
Residential	117,168	34,901	13,005	2,234	351	167,659
Total State	122,249	35,933	13,657	2,326	356	174,521
Study region	122,249	35,933	13,657	2,326	356	174,521

Study Region : midd

Scenario : upgl55

APPENDIX G

Magnitude 6 with default geology



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

6.0 Default Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	1.90 - 7.40
	Building Contents	0.80 - 3.10
	Business Interruption	0.60 - 2.40
Infrastructure	Lifelines Damage	
	Total	3.20 - 13.00

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	50 - 190	1 - 4	< 1.0	50 - 200
Major	6 - 20	0 - 1	< 1.0	6 - 30
Total	50 - 200	1 - 5	< 1.0	60 - 200

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	2,000 - 8,000
Level 2	Hospital Care	500 - 2,000
Level 3	Life-threatening	70 - 300
Level 4	Fatalities	130 - 500

Estimated Shelter Needs

Type	Households	People
Displaced Households	6,000 - 22,000	
Public Shelter		4,000 - 14,000

Comments :

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Earthquake Information

Location :

Origin Time:

Magnitude : 6.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.68

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure
(1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

def 6

Time of report: July 16, 2003 2:38 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	207	38	881	935
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	2	0	0	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	19	3	14	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 % After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	2	0	0	3
Natural Gas	0	2	0	0	0
Oil Systems	8	6	1	0	3
Electrical Power	4	4	1	0	2
Communication	28	22	2	13	28
Total	45	35	5	13	36

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	10	2
Total	112	10	2

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	30,424	17,056	933	0	0
Electric Power	238,974	205,971	162,141	90,766	12,409	0

def 6

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	20.61	17.14	18.65	7.19	1.98
Commercial	112,426	31.52	22.07	28.44	12.89	3.83
Education	5,402	25.28	16.63	21.69	9.71	2.99
Government	1,424	33.25	20.85	28.84	13.01	3.59
Industrial	45,607	31.95	20.42	28.58	13.59	3.72
Religion	3,212	24.34	19.86	20.77	9.74	3.30
Residential	345,636	35.11	32.34	23.34	6.79	1.74
State Average	515,207	28.87	21.33	24.33	10.42	3.02
Study Region Average	515,207	28.87	21.33	24.33	10.42	3.02

Study Region : midd
Scenario : def6

Building Damage by Count by General Occupancy

July 29, 2003

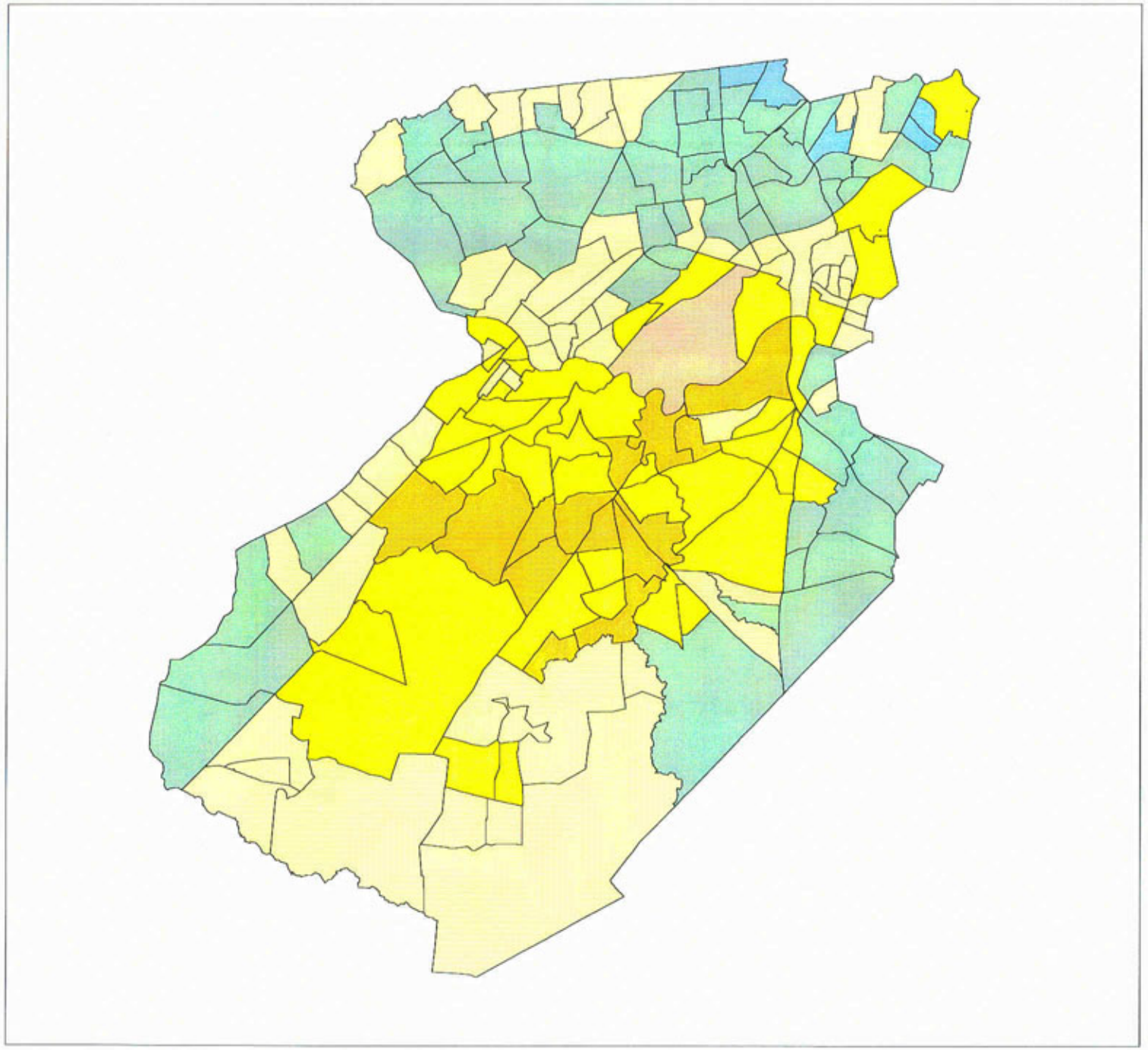
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	23	21	20	5	1	70
Commercial	1,455	953	1,364	539	94	4,405
Education	63	33	60	20	3	179
Government	1	0	1	0	0	2
Industrial	561	341	535	218	42	1,697
Religion	55	53	55	10	0	173
Residential	60,691	56,734	38,376	10,093	2,227	168,121
Total State	62,849	58,135	40,411	10,885	2,367	174,647
Study region	62,849	58,135	40,411	10,885	2,367	174,647

Study Region : midd

Scenario : def6

APPENDIX H

Magnitude 6 with full upgrade geology



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

6.0 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	1.60 - 6.50
	Building Contents	0.80 - 3.00
	Business Interruption	0.50 - 2.00
Infrastructure	Lifelines Damage	
	Total	2.90 - 11.50

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	40 - 160	1 - 4	< 1.0	40 - 170
Major	5 - 19	0 - 1	< 1.0	5 - 20
Total	50 - 180	1 - 5	< 1.0	50 - 190

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	1,600 - 7,000
Level 2	Hospital Care	400 - 1,500
Level 3	Life-threatening	50 - 200
Level 4	Fatalities	100 - 400

Estimated Shelter Needs

Type	Households	People
Displaced Households	5,000 - 19,000	
Public Shelter		3,000 - 12,000

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 6.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.68

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

ypg 6.0

Time of report: July 16, 2003 1:44 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	192	41	896	927
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	1	0	0	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	18	3	14	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

4pg 6.0

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	2	0	0	3
Natural Gas	0	2	0	0	0
Oil Systems	8	6	1	0	1
Electrical Power	4	4	1	0	2
Communication	28	21	2	13	28
Total	45	35	5	13	34

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	12	4
Total	112	12	4

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	129,570	112,056	68,409	0	0
Electric Power	238,974	202,840	155,514	83,955	11,027	0

upg 6.0

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	25.59	16.93	15.81	5.74	1.51
Commercial	112,426	38.34	21.91	24.82	10.56	3.06
Education	5,402	30.72	16.54	18.89	7.84	2.31
Government	1,424	40.14	20.72	25.19	10.49	2.90
Industrial	45,607	38.86	20.40	25.04	10.89	2.93
Religion	3,212	30.09	19.14	17.94	8.10	2.67
Residential	345,636	43.79	29.59	18.81	5.63	1.53
State Average	515,207	35.36	20.75	20.93	8.46	2.41
Study Region Average	515,207	35.36	20.75	20.93	8.46	2.41

Building Damage by Count by General Occupancy

July 29, 2003

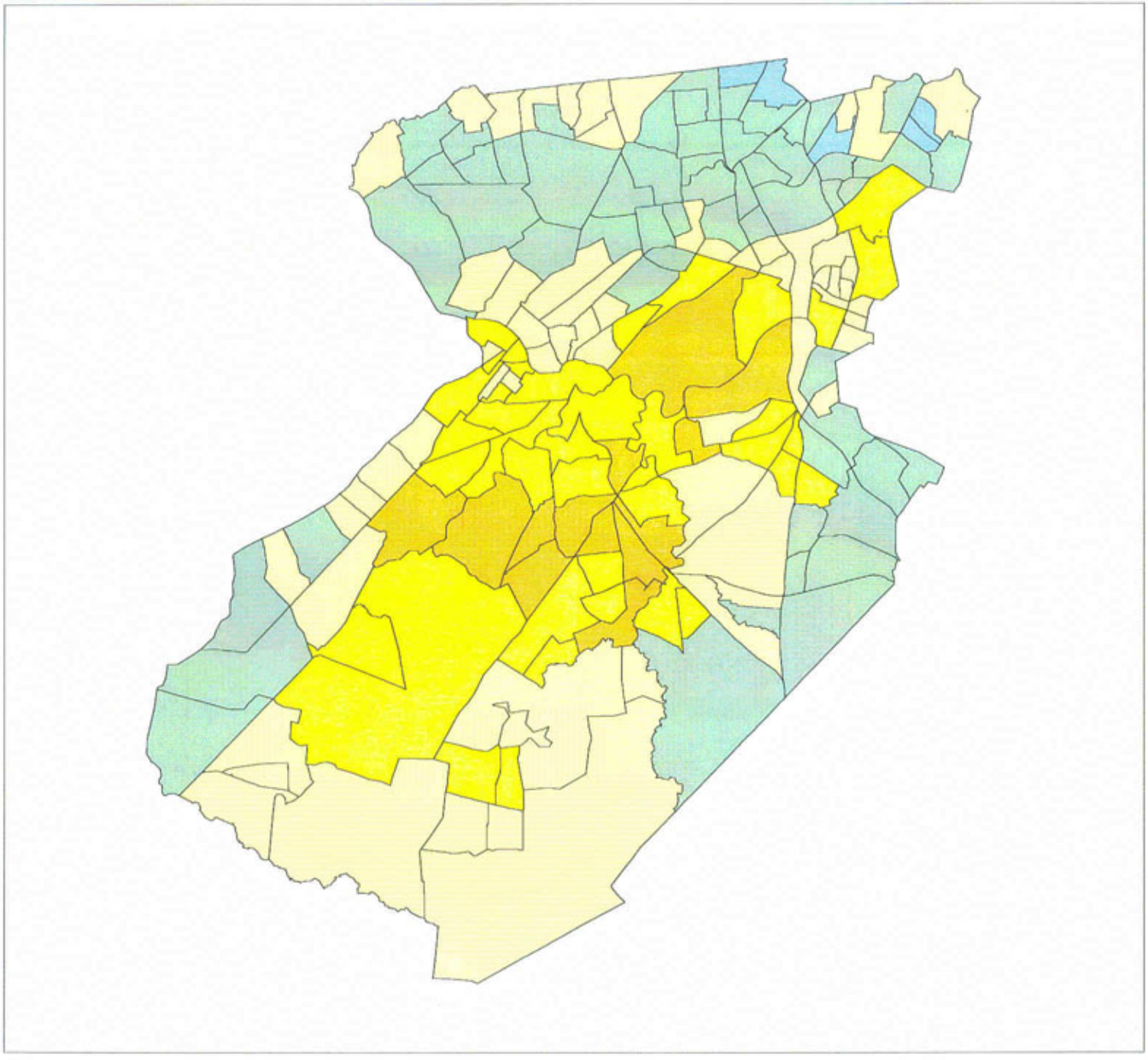
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	38	22	16	3	0	79
Commercial	1,845	953	1,167	431	73	4,469
Education	92	33	47	14	2	188
Government	4	0	0	0	0	4
Industrial	739	338	456	166	20	1,719
Religion	77	45	40	7	0	169
Residential	76,936	51,208	29,787	7,807	2,135	167,873
Total State	79,731	52,599	31,513	8,428	2,230	174,501
Study region	79,731	52,599	31,513	8,428	2,230	174,501

Study Region : midd

Scenario : upg6

APPENDIX I

Magnitude 6 with upgraded geology, no liquefaction



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

6.0 Upgrade Scenario With Default Liquefaction

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	1.60 - 6.40
	Building Contents	0.70 - 2.90
	Business Interruption	0.50 - 1.90
Infrastructure	Lifelines Damage	
	Total	2.80 - 11.20

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	40 - 160	1 - 4	< 1.0	40 - 170
Major	4 - 18	0 - 1	< 1.0	5 - 20
Total	50 - 180	1 - 5	< 1.0	50 - 190

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	1,600 - 6,000
Level 2	Hospital Care	400 - 1,500
Level 3	Life-threatening	50 - 200
Level 4	Fatalities	100 - 400

Estimated Shelter Needs

Type	Households	People
Displaced Households	4,000 - 18,000	
Public Shelter		3,000 - 11,000

Comments :

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Earthquake Information

Location :

Origin Time:

Magnitude : 6.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.68

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

4pg 16

Time of report: July 17, 2003 10:56 am

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Roads	70			70	70
	Bridges	936	174	30	912	934
	Tunnels	2	0	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	0	0	1	1
	Tunnels	0	0	0	0	0
	Facilities	2	1	0	0	2
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	18	3	14	28
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	2	0	0	3
Natural Gas	0	2	0	0	0
Oil Systems	8	6	1	0	1
Electrical Power	4	4	1	0	2
Communication	28	21	2	13	28
Total	45	35	5	13	34

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	10	2
Total	112	10	2

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	15,498	5,449	0	0	0
Electric Power	238,974	202,840	155,514	83,955	11,027	0

Building Damage By General Occupancy

July 17, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	25.71	16.99	15.89	5.54	1.46
Commercial	112,426	38.49	22.04	24.96	10.23	2.97
Education	5,402	30.89	16.66	18.99	7.54	2.25
Government	1,424	40.34	20.86	25.39	10.14	2.77
Industrial	45,607	39.02	20.50	25.22	10.56	2.84
Religion	3,212	30.25	19.23	18.06	7.80	2.58
Residential	345,636	44.00	29.80	18.95	5.24	1.41
State Average	515,207	35.53	20.87	21.07	8.15	2.33
Study Region Average	515,207	35.53	20.87	21.07	8.15	2.33

Building Damage by Count by General Occupancy

July 17, 2003

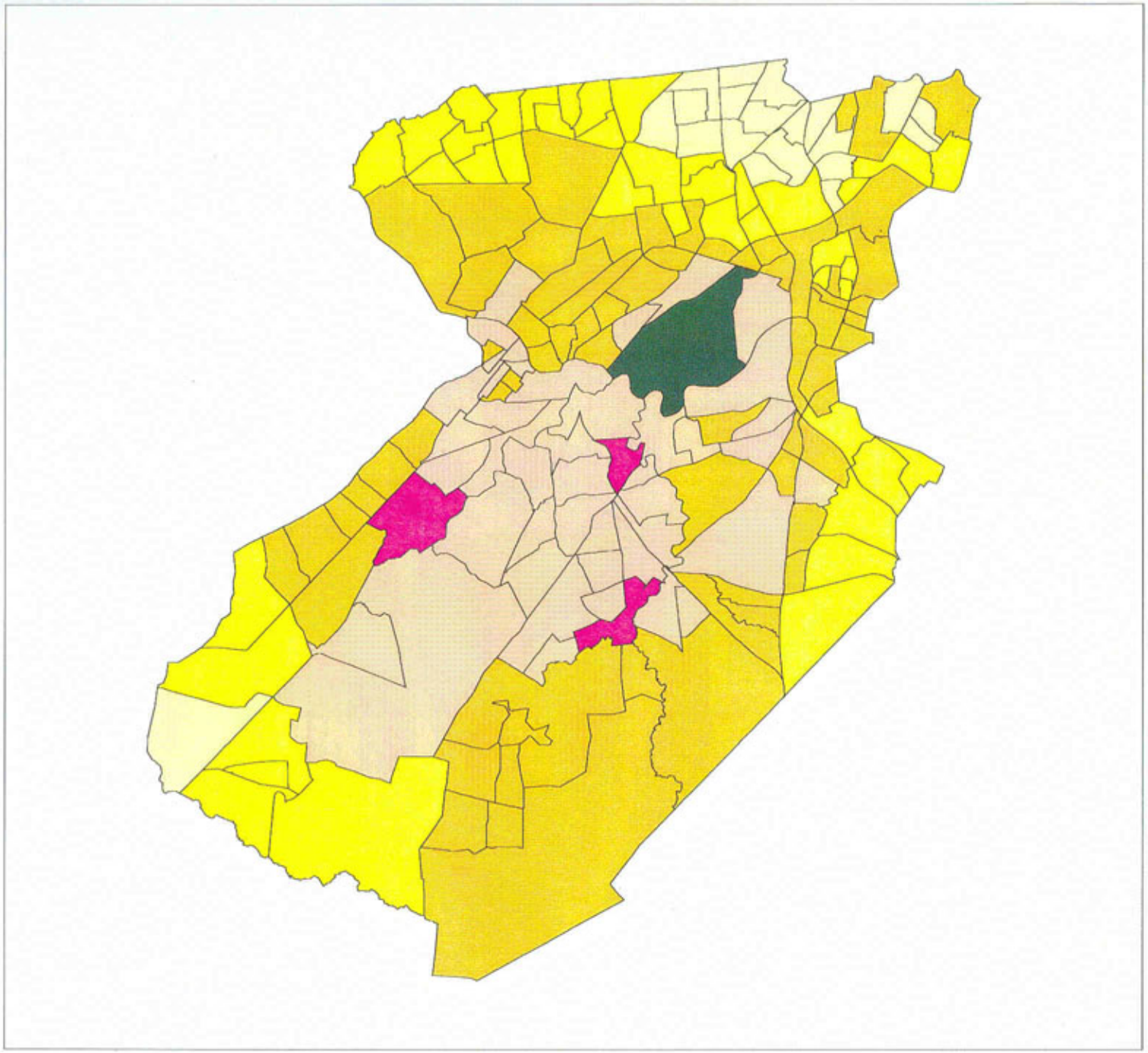
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	38	22	16	3	0	79
Commercial	1,859	960	1,177	407	68	4,471
Education	92	34	48	13	2	189
Government	4	0	0	0	0	4
Industrial	740	338	458	159	19	1,714
Religion	77	45	41	6	0	169
Residential	77,170	51,460	29,956	7,322	2,004	167,912
Total State	79,980	52,859	31,696	7,910	2,093	174,538
Study region	79,980	52,859	31,696	7,910	2,093	174,538

Study Region : midd

Scenario : upgl6

APPENDIX J

Magnitude 6.5 with full upgrade geology



Study Region:

Middlesex County

Scenario Description:

6.5 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

4 0 4 8 12 16 20 Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	3.00 - 11.80
	Building Contents	1.20 - 4.80
	Business Interruption	0.90 - 3.70
Infrastructure	Lifelines Damage	
	Total	5.10 - 20.30

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	50 - 200	1 - 4	< 1.0	50 - 200
Major	11 - 40	0 - 2	< 1.0	11 - 50
Total	60 - 300	1 - 7	< 1.0	70 - 300

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	4,000 - 15,000
Level 2	Hospital Care	1,000 - 4,000
Level 3	Life-threatening	150 - 600
Level 4	Fatalities	300 - 1,100

Estimated Shelter Needs

Type	Households	People
Displaced Households	10,000 - 40,000	
Public Shelter		6,000 - 26,000

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 6.5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.96

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

Upg 65

Time of report: July 16, 2003 2:01 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	392	136	467	768
	Tunnels	2	1	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	1	0	0	1
	Tunnels	0	0	0	0	0
	Facilities	2	2	1	0	0
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	23	6	5	22
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	2	0	0	2
Natural Gas	0	2	0	0	0
Oil Systems	8	7	2	0	1
Electrical Power	4	4	1	0	1
Communication	28	25	5	6	28
Total	48	40	9	6	32

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	29	15
Total	112	29	15

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	196,616	191,611	179,274	3,561	0
Electric Power	238,974	217,934	194,030	140,887	28,229	0

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	13.10	15.06	21.71	11.10	4.60
Commercial	112,426	19.75	18.82	31.60	19.88	8.92
Education	5,402	16.01	14.23	24.22	15.16	6.76
Government	1,424	20.58	17.46	31.92	20.83	8.86
Industrial	45,607	19.94	17.14	31.38	21.01	8.95
Religion	3,212	15.86	18.03	23.24	14.21	6.67
Residential	345,636	23.80	31.15	29.06	11.23	4.02
State Average	515,207	18.44	18.84	27.59	16.20	6.97
Study Region Average	515,207	18.44	18.84	27.59	16.20	6.97

Building Damage by Count by General Occupancy

July 29, 2003

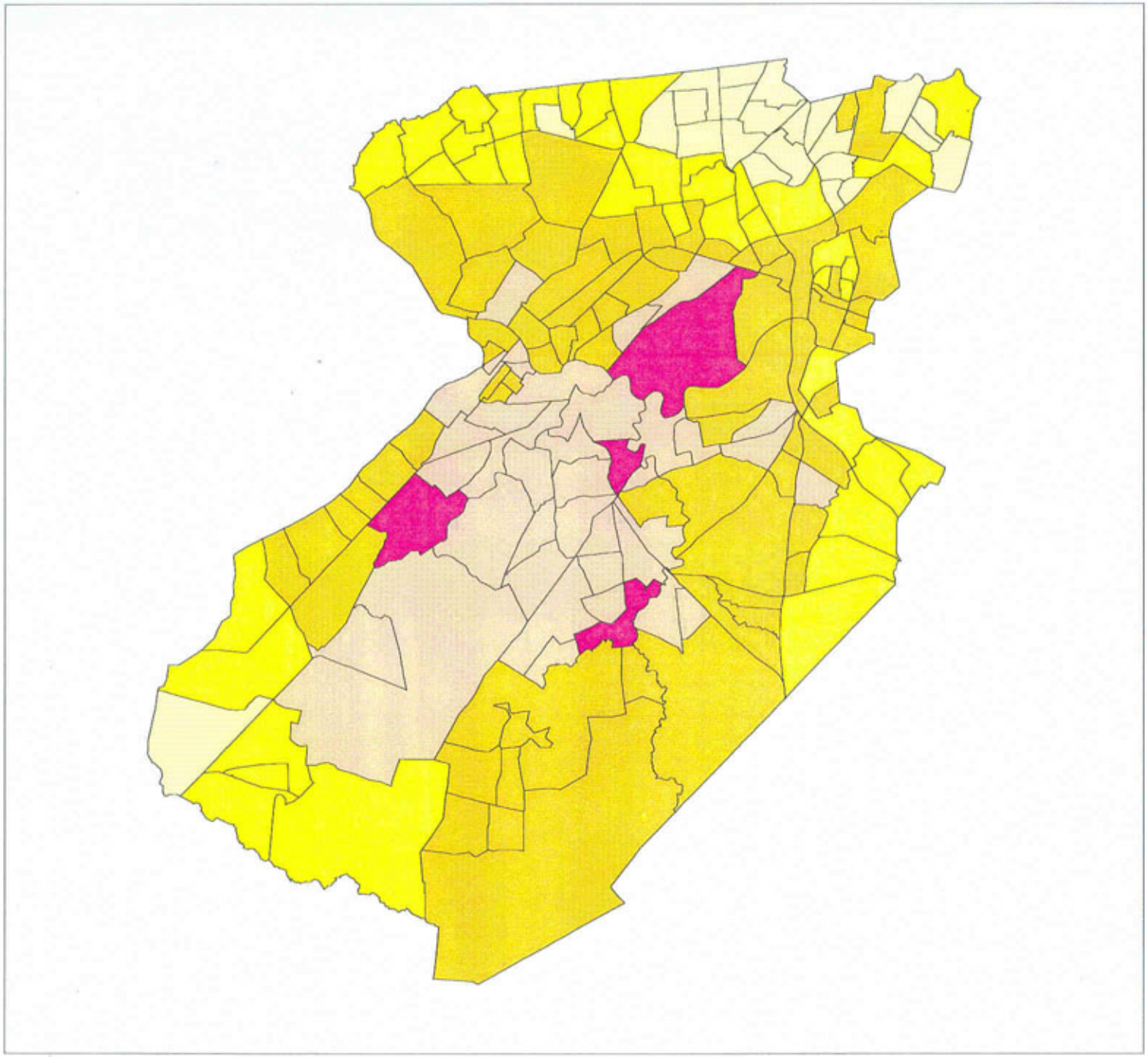
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	15	15	25	8	3	66
Commercial	879	822	1,502	897	336	4,436
Education	31	28	68	35	11	173
Government	1	0	1	0	0	2
Industrial	343	284	578	364	121	1,690
Religion	20	36	57	27	4	144
Residential	42,140	55,556	48,429	16,610	5,420	168,155
Total State	43,429	56,741	50,660	17,941	5,895	174,666
Study region	43,429	56,741	50,660	17,941	5,895	174,666

Study Region : midd

Scenario : upg65

APPENDIX K

Magnitude 6.5 with upgraded geology, no liquefaction



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

6.5 Upgrade Scenario With Default Liquefaction

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	2.90 - 11.50
	Building Contents	1.20 - 4.70
	Business Interruption	0.90 - 3.70
Infrastructure	Lifelines Damage	
	Total	5.00 - 19.80

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	50 - 200	1 - 4	< 1.0	50 - 200
Major	10 - 40	0 - 2	< 1.0	11 - 50
Total	60 - 300	1 - 7	< 1.0	70 - 300

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	4,000 - 15,000
Level 2	Hospital Care	1,000 - 4,000
Level 3	Life-threatening	140 - 600
Level 4	Fatalities	300 - 1,100

Estimated Shelter Needs

Type	Households	People
Displaced Households	10,000 - 38,000	
Public Shelter		6,000 - 24,000

Comments :

Disclaimer:
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Earthquake Information

Location : .

Origin Time:

Magnitude : 6.5

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 0.96

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

upg/65

Time of report: July 17, 2003 11:10 am

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	375	116	488	812
	Tunnels	2	1	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	1	0	0	1
	Tunnels	0	0	0	0	0
	Facilities	2	2	1	0	0
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	23	6	5	22
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	2	0	0	2
Natural Gas	0	2	0	0	0
Oil Systems	8	7	1	0	1
Electrical Power	4	4	1	0	1
Communication	28	25	5	6	28
Total	48	39	9	6	32

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	28	10
Total	112	28	10

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	89,916	77,468	50,551	0	0
Electric Power	238,974	217,934	194,030	140,887	28,229	0

Building Damage By General Occupancy

July 17, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	13.21	15.17	21.93	10.75	4.52
Commercial	112,426	19.90	19.01	31.90	19.43	8.73
Education	5,402	16.14	14.34	24.51	14.74	6.60
Government	1,424	20.73	17.62	32.23	20.34	8.68
Industrial	45,607	20.11	17.29	31.71	20.57	8.77
Religion	3,212	15.99	18.21	23.49	13.77	6.52
Residential	345,636	24.02	31.46	29.38	10.60	3.83
State Average	515,207	18.59	19.01	27.88	15.74	6.81
Study Region Average	515,207	18.59	19.01	27.88	15.74	6.81

Building Damage by Count by General Occupancy

July 17, 2003

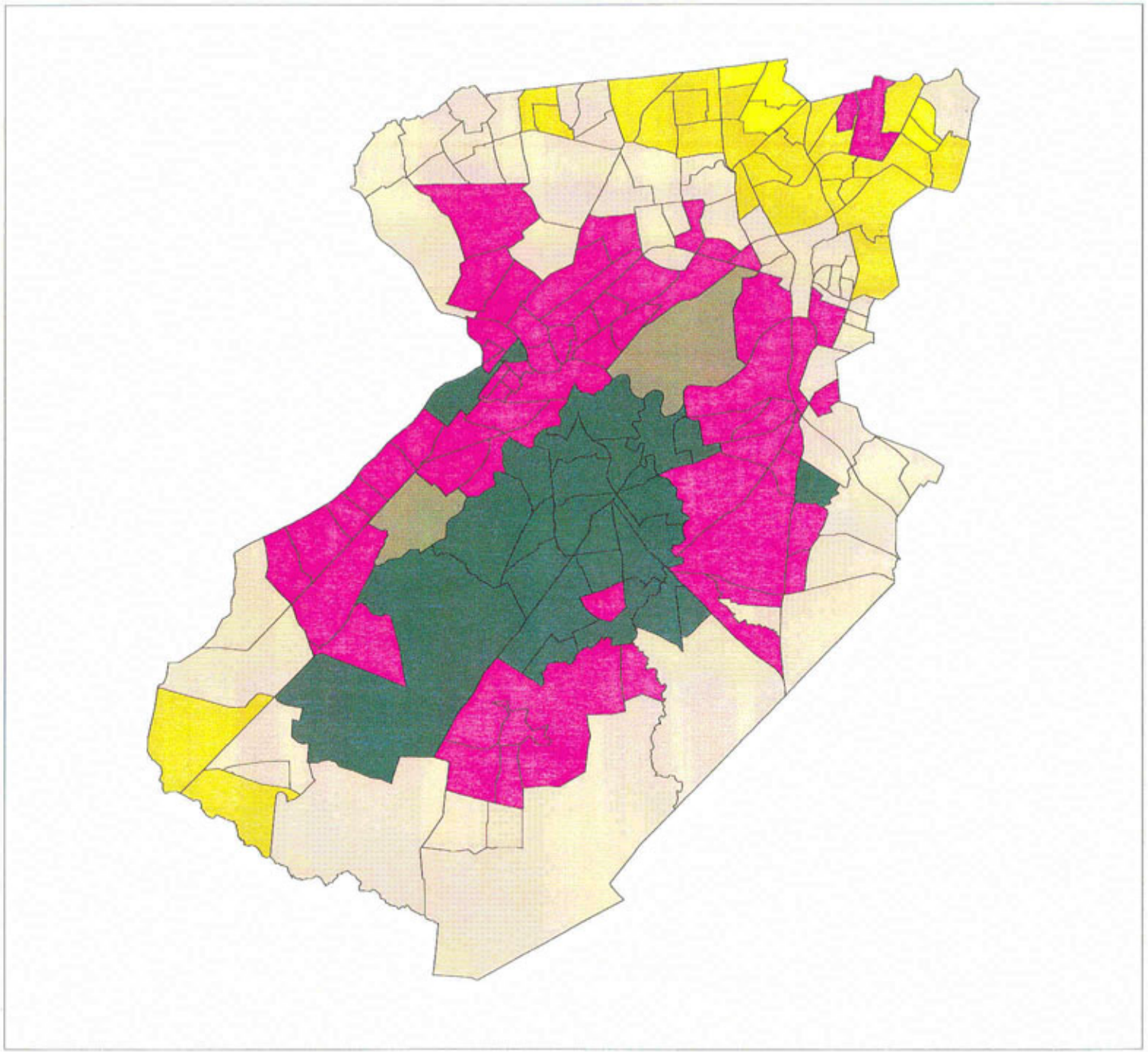
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	15	15	25	8	3	66
Commercial	888	828	1,517	865	325	4,423
Education	31	28	69	35	11	174
Government	1	0	1	0	0	2
Industrial	344	286	581	354	116	1,681
Religion	20	37	58	25	4	144
Residential	42,447	55,988	48,859	15,727	5,157	168,178
Total State	43,746	57,182	51,110	17,014	5,616	174,668
Study region	43,746	57,182	51,110	17,014	5,616	174,668

Study Region : midd

Scenario : upgl65

APPENDIX L

Magnitude 7 with full upgrade geology



Study Region:

Middlesex County

Scenario Description:

7.0 Upgrade Scenario

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

4 0 4 8 12 16 20 Miles

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	4.50 - 18.20
	Building Contents	1.70 - 6.60
	Business Interruption	1.50 - 5.80
Infrastructure	Lifelines Damage	
	Total	7.70 - 30.60

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	50 - 200	1 - 3	< 1.0	60 - 200
Major	19 - 80	1 - 4	< 1.0	20 - 80
Total	70 - 300	2 - 8	< 1.0	80 - 300

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	7,000 - 28,000
Level 2	Hospital Care	2,000 - 8,000
Level 3	Life-threatening	300 - 1,200
Level 4	Fatalities	600 - 2,000

Estimated Shelter Needs

Type	Households	People
Displaced Households	17,000 - 68,000	
Public Shelter		11,000 - 43,000

Comments :

Disclaimer:
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Earthquake Information

Location :

Origin Time:

Magnitude : 7.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 1.20

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

up 7

Time of report: July 16, 2003 2:16 pm

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	555	268	325	394
	Tunnels	2	1	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	1	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	2	2	1	0	0
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	25	10	0	13
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations			
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %
				After Day 1 / After Day 7
Potable Water	0	0	0	0 / 0
Waste Water	3	3	1	0 / 0
Natural Gas	0	3	1	0 / 0
Oil Systems	8	7	2	0 / 0
Electrical Power	4	4	2	0 / 1
Communication	28	26	8	0 / 14
Total	51	43	15	0 / 15

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	73	36
Total	112	73	36

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	226,245	225,224	222,868	193,790	0
Electric Power	238,974	223,704	212,056	179,207	44,066	0

upg 7

Building Damage By General Occupancy

July 29, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	6.15	10.50	22.06	16.10	10.73
Commercial	112,426	9.04	12.62	29.73	27.62	19.82
Education	5,402	7.37	9.53	22.80	21.53	15.03
Government	1,424	9.07	11.14	28.85	29.51	20.91
Industrial	45,607	8.84	11.06	28.42	29.11	20.81
Religion	3,212	8.02	14.00	23.82	19.11	13.15
Residential	345,636	12.67	26.31	34.58	17.73	8.01
State Average	515,207	8.74	13.59	27.18	22.96	15.50
Study Region Average	515,207	8.74	13.59	27.18	22.96	15.50

Building Damage by Count by General Occupancy

July 29, 2003

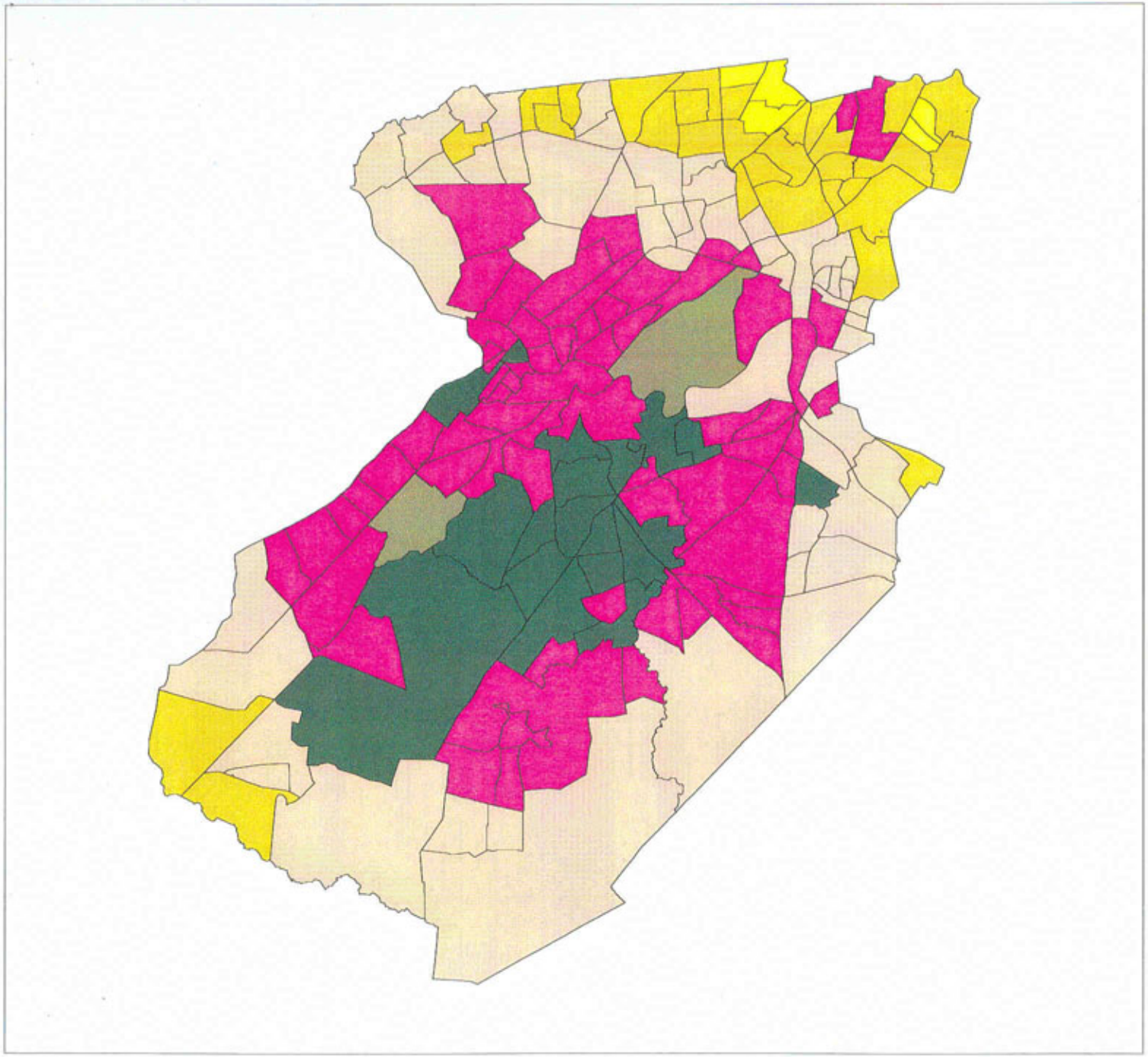
	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	7	11	27	18	6	69
Commercial	332	517	1,406	1,323	889	4,467
Education	8	16	61	61	36	182
Government	0	0	1	0	0	1
Industrial	127	158	515	536	361	1,697
Religion	5	18	58	45	24	150
Residential	22,755	47,748	59,523	27,138	10,890	168,054
Total State	23,234	48,468	61,591	29,121	12,206	174,620
Study region	23,234	48,468	61,591	29,121	12,206	174,620

Study Region : midd

Scenario : upg7

APPENDIX M

Magnitude 7 with upgraded geology, no liquefaction



4 0 4 8 12 16 20 Miles

Study Region:

Middlesex County

Scenario Description:

7.0 Upgrade Scenario With Default Liquefaction

Percentage Of Buildings With Moderate and Greater Damage

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100

NEW JERSEY GEOLOGICAL SURVEY 1835

Data from the HAZUS GIS software and the New Jersey Geological Survey.
July 22, 2003

HAZUS99 SR-2 Loss Estimation

Estimated Economic Loss ($ Billions)

Category	Description	Range
General Building Stock	Building Damage	4.40 - 17.70
	Building Contents	1.60 - 6.50
	Business Interruption	1.40 - 5.70
Infrastructure	Lifelines Damage	
	Total	7.50 - 29.90

Estimated Building Damage(Thousands of Buildings)

Description	Residential	Commercial	Other	Total
Minor	50 - 200	1 - 3	< 1.0	60 - 200
Major	18 - 70	1 - 4	< 1.0	19 - 80
Total	70 - 300	2 - 8	< 1.0	80 - 300

Estimated Casualties : Day Time

Severity Level	Description	# Persons
Level 1	Medical Aid	7,000 - 27,000
Level 2	Hospital Care	1,900 - 8,000
Level 3	Life-threatening	300 - 1,200
Level 4	Fatalities	600 - 2,000

Estimated Shelter Needs

Type	Households	People
Displaced Households	16,000 - 65,000	
Public Shelter		10,000 - 41,000

Comments :

Disclaimer:
The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, goetechnical, and observed ground motion data.

Earthquake Information

Location :

Origin Time:

Magnitude : 7.0

Epicenter Latitude/Longitude :
40.4364 / -74.4283

Depth & Type :

Fault Name :

Maximum PGA : 1.20

Ground Motion /Attenuation :

Information Sources:

Comments :

Population and Building Exposure (1996 D&B) (1990 Census)

Population: 672,000

Building Exposure : ($ Millions)

Residential	26,500
Commerical	7,300
Other	3,500
Total	37,300

State: New Jersey

Counties :
- Middlesex

Major Metro Area :

upg 17

Time of report: July 17, 2003 11:24 am

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

System	Component	Number of Locations				
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 % After Day 1	With Functionality > 50 % After Day 7
Highway	Roads	70			70	70
	Bridges	936	543	245	336	399
	Tunnels	2	1	0	2	2
Railways	Tracks	0			301	301
	Bridges	1	1	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	2	2	1	0	0
Light Rail	Tracks	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	0	0	0	0	0
Ferry	Facilities	0	0	0	0	0
Port	Facilities	6	0	0	6	6
Airport	Facilities	28	25	9	0	14
	Runways	4	0	0	4	4

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8-10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	0	0	0	0	0
Waste Water	3	3	1	0	0
Natural Gas	0	3	1	0	0
Oil Systems	8	7	2	0	0
Electrical Power	4	4	2	0	1
Communication	28	26	8	0	14
Total	51	43	14	0	15

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	112	62	16
Total	112	62	16

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	238,974	177,113	172,568	162,227	54,383	0
Electric Power	238,974	223,704	212,056	179,207	44,066	0

Building Damage By General Occupancy

July 17, 2003

	Square Footage (Thousand. sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
New Jersey						
Middlesex						
Agriculture	1,500	6.23	10.67	22.46	15.62	10.60
Commercial	112,426	9.14	12.79	30.24	27.05	19.59
Education	5,402	7.51	9.67	23.22	21.12	14.84
Government	1,424	9.21	11.31	29.32	29.01	20.66
Industrial	45,607	8.97	11.21	28.97	28.63	20.63
Religion	3,212	8.15	14.25	24.24	18.55	12.92
Residential	345,636	12.84	26.78	35.21	16.77	7.69
State Average	515,207	8.86	13.81	27.67	22.39	15.27
Study Region Average	515,207	8.86	13.81	27.67	22.39	15.27

Building Damage by Count by General Occupancy

July 17, 2003

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
New Jersey						
Middlesex						
Agriculture	7	11	27	18	6	69
Commercial	344	532	1,430	1,293	876	4,475
Education	8	16	62	61	36	183
Government	0	0	1	0	0	1
Industrial	128	160	531	530	354	1,703
Religion	6	18	58	41	23	146
Residential	23,001	48,415	60,464	25,755	10,418	168,053
Total State	23,494	49,152	62,573	27,698	11,713	174,630
Study region	23,494	49,152	62,573	27,698	11,713	174,630

APPENDIX N

Seismic velocity data

Abbreviations are:

P-Wave=compressional wave
S-Wave=shear wave
gp spc = distance of geophone from source (feet)
pick = arrival time of wave at geophone (milliseconds)
int time = interval travel time between geophone (milliseconds)
int vel = interval velocity--wave velocity between geophones (feet/second)
avg vel = wave velocity calculated by averaging the interval velocities
regression velocity = wave velocity calculated from best-fit line to first arrivals

MIDDLESEX COUNTY SHEAR WAVE SEISMIC

	S wave ft/sec regression-avg	P wave ft/sec regression-avg
New Road	1507-1634 layer 1	2660-3075 layer 1
	n/a	5970-6014 layer 2
Thompson Park	1998-1887 layer 1	2940-3302 layer1
Pigeon Swamp	974-1008 layer 1	1536-1680 layer 1
Helmetta Blvd.	723-762 layer 1	1288-1472 layer 1
	2087-2095 layer 1	7179-7299 layer 2
Crescent Ave	674-675 layer 1	1287-1366 layer 1
	1172-1282 layer 2	6923-8378 layer 2
Marlboro Road	638-607 layer 1	1082-1138 layer 1
	1799-1811 layer 2	3333-3612 layer 2
Texas Road	1252-1240 layer 1	3298-4379 layer 1
Pension Road	768-823 layer1	1369-1487 layer 1
	2122- 2076 layer 2	8537-9354 layer 2
Old Bridge G.C.	838-842 layer 1	1804-2126 layer 1
	1315-1388 layer 2	4062-6659 layer 2
Phillips Park	778-819 layer 1	1101-1129 layer 1
	1179-1263 layer 2	6914-8623 layer 2
Jernee Mill Rd	448-448 layer 1	1804-2126 layer 1
	632-630 layer 2	3681-5489 layer 2
River Rd	771-779 layer 1	1682-1832 layer 1
	2857-3179 layer 2	7473-9264 layer 2

New Road

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
0				ft/sec		ft/sec
6	8.85	8.85	677.9661017	**3075.422896**	0.37595	**2659.911336**
12	12.1	3.25	1846.153846			
18	14.65	2.55	2352.941176			
24	15.55	0.9	6666.666667			
30	18.7	3.15	1904.761905			
36	20.5	1.8	3333.333333			
42	21.6	1.1	5454.545455	**6014.012303**	0.1675	**5970.149254**
48	22.55	0.95	6315.789474			
54	23.3	0.75	8000			
60	24.7	1.4	4285.714286			

S-WAVE

0	5.5					
6	8.5	3	2000	**1634.902427**	0.66359	**1506.951712**
12	13.6	5.1	1176.470588			
18	18.45	4.85	1237.113402			
24	22.35	3.9	1538.461538			
30	26.45	4.1	1463.414634			
36	29.1	2.65	2264.150943			
42	32.5	3.4	1764.705882			

Thompson Park

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
				ft/sec		ft/sec
0	1.7					
6	8.7	7	857.1428571	**3301.810311**	0.34015	**2939.86637**
12	10.5	1.8	3333.333333			
18	11.6	1.1	5454.545455			
24	13	1.4	4285.714286			
30	15.2	2.2	2727.272727			
36	17.7	2.5	2400			
42	19.1	1.4	4285.714286			
48	21.5	2.4	2500			
54	23.3	1.8	3333.333333			
60	24.5	1.2	5000			
66	27.3	2.8	2142.857143			

S-WAVE

0	8.3					
6	14.1	5.8	1034.482759	**1886.448465**	0.50047	**1998.136935**
12	17.9	3.8	1578.947368			
18	21.2	3.3	1818.181818			
24	23.1	7	857.1428571			
30	27.7	4.6	1304.347826			
36	29.9	2.2	2727.272727			
42	32.8	2.9	2068.965517			
48	35.2	2.4	2500			
54	37.3	2.1	2857.142857			
60	40.4	3.1	1935.483871			
66	43.3	2.9	2068.965517			

Pigeon Swamp

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
				ft/sec		ft/sec
0	4.7					
6	10.1	5.4	1111.111111	**1679.508864**	0.65105	**1535.982814**
12	16.4	6.3	952.3809524			
18	19.6	3.2	1875			
24	22.8	3.2	1875			
30	25.4	2.6	2307.692308			
36	28.9	3.5	1714.285714			
42	33.5	4.6	1304.347826			
48	38.8	5.3	1132.075472			
54	41.7	2.9	2068.965517			
60	46.4	4.7	1276.595745			
66	48.5	2.1	2857.142857			

S-WAVE

0	18.3					
6	23.3	5	1200	**1008.289045**	1.02657	**974.1144414**
12	30.8	7.5	800			
18	37.1	6.3	952.3809524			
24	42.8	7	857.1428571			
30	49.6	6.8	882.3529412			
36	54.6	5	1200			
42	62.5	7.9	759.4936709			
48	67.6	5.1	1176.470588			
54	74.3	6.7	895.5223881			
60	80.1	5.8	1034.482759			
66	84.6	4.5	1333.333333			

Helmetta Blvd

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL	SLOPE	REGRESSION VELOCITY
				ft/sec		ft/sec
0	8.7					
6	17.7	9	666.6666667	**1471.861472**	0.77667	**1287.553648**
12	22.1	4.4	1363.636364			
18	24.9	2.8	2142.857143			
24	28.4	3.5	1714.285714			
30	29.5	1.1	5454.545455	**7296.536797**	0.13929	**7179.487179**
36	30.3	0.8	7500			
42	31.4	1.1	5454.545455			
48	32	0.6	10000			
54	32.6	0.6	10000			
60	33.5	0.9	6666.666667			
66	34.5	1	6000			

S-WAVE

0	9.3					
6	24.1	14.8	405.4054054	**762.9293902**	1.38238	**723.389597**
12	30.1	6	1000			
18	37.2	7.1	845.0704225			
24	46	8.8	681.8181818			
30	52.8	6.8	882.3529412			
36	57.5	4.7	1276.595745	**2095.401512**	0.47917	**2086.956522**
42	59	1.5	4000			
48	62.8	3.8	1578.947368			
54	65.3	2.5	2400			
60	67.9	2.6	2307.692308			
66	70.6	2.7	2222.222222			

Crescent Ave

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL	SLOPE	REGRESSION VELOCITY
				ft/sec		ft/sec
0	14.6					
6	18.9	4.3	1395.348837	**1365.997913**	0.77667	**1287.553648**
12	25	6.1	983.6065574			
18	29.1	4.1	1463.414634			
24	32.8	3.7	1621.621622			
30	33.3	0.5	12000	**8377.860235**	0.14444	**6923.076923**
36	34	0.7	8571.428571			
42	34.4	0.4	15000			
48	35.3	0.9	6666.666667			
54	36.7	1.4	4285.714286			
60	37.8	1.1	5454.545455			
66	38.7	0.9	6666.666667			

S-WAVE

0	13.3					
6	22	8.7	689.6551724	**674.4979159**	1.48333	**674.1573034**
12	31.1	9.1	659.3406593			
18	36.1	5	1200	**1281.90617**	0.85354	**1171.597633**
24	39.4	3.3	1818.181818			
30	46.4	7	857.1428571			
36	51.1	4.7	1276.595745			
42	59.3	8.2	731.7073171			
48	63	3.7	1621.621622			
54	67.8	4.8	1250			
60	71.8	4	1500			
66	75					

Marlboro Road

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL	SLOPE	REGRESSION VELOCITY
0	9.1			ft/sec		ft/sec
6	20.4	11.3	530.9734513	**1137.632306**	0.92381	**1082.474227**
12	26	5.6	1071.428571			
18	31	5	1200			
24	34.8	3.8	1578.947368			
30	40.2	5.4	1111.111111			
36	44.7	4.5	1333.333333			
42	47	2.3	2608.695652	**3612.040134**	0.3	**3333.333333**
48	48.3	1.3	4615.384615			

S-WAVE

0	15.1					
6	27.3	12.2	491.8032787	**607.5922433**	1.56667	**638.2978723**
12	34.8	7.5	800			
18	46.1	11.3	530.9734513			
24	50.3	4.2	1428.571429	**1811.024031**	0.55575	**1799.357372**
30	53.2	2.9	2068.965517			
36	57.4	4.2	1428.571429			
42	62	4.6	1304.347826			
48	64.7	2.7	2222.222222			
54	66.7	2	3000			
60	71.6	4.9	1224.489796			
66	72.8					

Texas Road

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
				ft/sec		ft/sec
0	12.2					
6	14.1	1.9	3157.894737	**4379.428387**	0.30318	**3298.350825**
12	16.2	2.1	2857.142857			
18	19.5	3.3	1818.181818			
24	22.8	3.3	1818.181818			
30	24.6	1.8	3333.333333			
36	25.7	1.1	5454.545455			
42	26.5	0.8	7500			
48	27.9	1.4	4285.714286			
54	28.5	0.6	10000			
60	30.3	1.8	3333.333333			
66	31.6	1.3	4615.384615			

S-WAVE

0	18.9					
6	26	7.1	845.0704225	**1240.154006**	0.79859	**1252.213509**
12	31.1	5.1	1176.470588			
18	38.8	7.7	779.2207792			
24	44.8	6	1000			
30	49.5	4.7	1276.595745			
36	53.1	3.6	1666.666667			
42	57	3.9	1538.461538			
48	61.4	4.4	1363.636364			
54	65.2	3.8	1578.947368			
60	70.3	5.1	1176.470588			

Pension Road

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
0	8.4			ft/sec		ft/sec
6	12.7	4.3	1395.348837	**1486.699457**	0.73048	**1368.970013**
12	17.5	4.8	1250			
18	23.3	5.8	1034.482759			
24	26.4	3.1	1935.483871			
30	29.7	3.3	1818.181818			
36	31.2	1.5	4000	**9353.535354**	0.11714	**8536.585366**
42	31.8	0.6	10000			
48	32.7	0.9	6666.666667			
54	33.1	0.4	15000			
60	34.2	1.1	5454.545455			
66	34.6	0.4	15000			

S-WAVE

0	11.1					
6	22.8	11.7	512.8205128	**823.6819086**	1.30167	**768.2458387**
12	29.4	6.6	909.0909091			
18	37.5	8.1	740.7407407			
24	42.8	5.3	1132.075472	**2076.508736**	0.47112	**2122.607221**
30	46.7	3.9	1538.461538			
36	48.8	2.1	2857.142857			
48	53.3	4.5	2666.666667			
54	55.7	2.4	2500			
60	59.1	3.4	1764.705882			

Old Bridge Golf Course

P-WAVE

gp spc	pick	int time	int vel.	**AVG VEL**	SLOPE	**REGRESSION VELOCITY**
0	5.5			ft/sec		ft/sec
6	10.8	5.3	1132.075472	**2126.56547**	0.55429	**1804.123711**
12	15.8	5	1200			
18	17.8	2	3000			
24	20.6	2.8	2142.857143			
30	22.5	1.9	3157.894737			
36	23.3	0.8	7500	**6659.432673**	0.24619	**4061.895551**
42	24	0.7	8571.428571			
48	25.9	1.9	3157.894737			
54	28.1	2.2	2727.272727			
60	28.5	0.4	15000			
66	30.5	2	3000			

S-WAVE

0	11.1					
6	18.2	7.1	845.0704225	**841.9389642**	1.19333	**837.9888268**
12	26.1	7.9	759.4936709			
18	32.4	6.3	952.3809524			
24	39.8	7.4	810.8108108			
30	45.1	5.3	1132.075472	**1387.851926**	0.76071	**1314.553991**
36	48.9	3.8	1578.947368			
42	52.7	3.8	1578.947368			
48	57.9	5.2	1153.846154			
54	61.7	3.8	1578.947368			
60	66.3	4.6	1304.347826			
66	73.2					

Phillips Park

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL ft/sec	SLOPE	REGRESSION VELOCITY ft/sec
0	7.7					
6	14	6.3	952.3809524	**1129.148629**	0.90833	**1100.917431**
12	19.6	5.6	1071.428571			
18	24	4.4	1363.636364			
24	26.5	2.5	2400	**8628.205128**	0.14464	**6913.580247**
30	27.8	1.3	4615.384615			
36	29	1.2	5000			
42	29.8	0.8	7500			
48	30.3	0.5	12000			
54	31.6	1.3	4615.384615			
60	31.9	0.3	20000			
66	32.8	0.9	6666.666667			

S-WAVE

0	11.3					
6	18.6	7.3	821.9178082	**819.5183227**	1.285	**778.2101167**
12	28.5	9.9	606.0606061			
18	35.3	6.8	882.3529412			
24	41.5	6.2	967.7419355			
30	45.8	4.3	1395.348837	**1263.170495**	0.84821	**1178.947368**
36	52.9	7.1	845.0704225			
42	59	6.1	983.6065574			
48	63.6	4.6	1304.347826			
54	68.5	4.9	1224.489796			
60	71.6	3.1	1935.483871			
66	76.8	5.2	1153.846154			

Jernee Mill RD

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL ft/sec	SLOPE	REGRESSION VELOCITY ft/sec
0	5.5					
6	10.8	5.3	1132.075472	**2126.56547**	0.55429	**1804.123711**
12	15.8	5	1200			
18	17.8	2	3000			
24	20.6	2.8	2142.857143			
30	22.5	1.9	3157.894737			
36	23.3	0.8	7500	**5489.149009**	0.27167	**3680.981595**
42	24	0.7	8571.428571			
48	25.9	1.9	3157.894737			
54	28.1	2.2	2727.272727			

S-WAVE

0	13					
6	25.9	12.9	465.1162791	**448.3854777**	2.23333	**447.761194**
12	39.8	13.9	431.6546763			
18	51.5	11.7	512.8205128	**629.6232682**	1.58333	**631.5789474**
24	61.8	10.3	582.5242718			
30	69.4	7.6	789.4736842			
36	78.8	9.4	638.2978723			
42	88.4	9.6	625			

River Rd

P-WAVE

gp spc	pick	int time	int vel.	AVG VEL	SLOPE	REGRESSION VELOCITY
0	9.5			ft/sec		ft/sec
6	13.1	3.6	1666.666667	**1832.340371**	0.59429	**1682.692308**
12	17.2	4.1	1463.414634			
18	21.8	4.6	1304.347826			
24	24	2.2	2727.272727			
30	27	3	2000			
36	27.9	0.9	6666.666667	**9264.285714**	0.13381	**7473.309609**
42	28.4	0.5	12000			
48	29	0.6	10000			
54	29.5	0.5	12000			
60	31.1	1.6	3750			
66	31.8	0.7	8571.428571			

S-WAVE

0	24.1					
6	33	8.9	674.1573034	**779.5234081**	1.29702	**770.9958697**
12	41.6	8.6	697.6744186			
18	49.2	7.6	789.4736842			
24	55.2	7	857.1428571			
30	65.1	9.9	606.0606061			
36	70.8	5.7	1052.631579			
42	73.8	3	2000	**3178.959276**	0.35	**2857.142857**
48	76.8	3	2000			
54	78.4	1.6	3750			
60	80.1	1.7	3529.411765			
66	81.4	1.3	4615.384615			

SEISMIC SOIL CLASS MAP FOR MIDDLESEX COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey
for the
New Jersey State Police, Office of Emergency Management

2003

Soil Class C--very dense soil and soft rock. Shear wave velocity between 360 and 760 m/s (HAZUS number 3).

Soil Class D--stiff soil. Shear wave velocity between 180 and 360 m/s (HAZUS number 4).

Soil Class E--soft soil. Shear wave velocity less than 180 m/s (HAZUS number 5).

The soil class designations are defined in the 1997 National Earthquake Hazards Reduction Program (NEHRP) Provisions. Soil classes were assigned using Standard Penetration Test data and geologic map data from Stanford (1999) according to the procedures described in sections 4.1.2.1, 4.1.2.2., and 4.1.2.3 of the NEHRP Provisions (Federal Emergency Management Agency, 1998). Equation 4.1.2.3-2 was used to assign soil class in layered cases.

This map shows the extent of natural soils. Man-made fill overlies these soils (particularly soil class E) in many urban areas. This fill includes a wide range of materials. The behavior of fill during seismic shaking should be assessed on a site-specific basis.

REFERENCES CITED

Federal Emergency Management Agency, 1998, NEHRP recommended provisions for seismic regulations for new buildings and other structures, part 1--provisions: prepared by the National Institute of Building Sciences, FEMA 302, p. 33-41.

Stanford, S. D., 1999, Environmental geology of Middlesex County, New Jersey: surficial geology: N. J. Geological Survey Open File Map 27, scale 1:48,000.

SCALE 1:48000

2 1 0 2 MILES

2000 0 2000 4000 6000 8000 10,000 12,000 14,000 FEET

2 1 0 2 KILOMETERS

SOIL LIQUEFACTION SUSCEPTIBILITY FOR MIDDLESEX COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey
for the
New Jersey State Police, Office of Emergency Management

2003

- Category 1--very low
- Category 2--low
- Category 3--moderate
- Category 4--high

Categories are from the HAZUS User's Manual, Table 9.1 (National Institute of Building Sciences, 1997). Geologic data are from Stanford (1999).

This map shows the liquefaction susceptiblity of natural soils. Man-made fill overlies these soils (particularly those in Category 4) in some areas. While most fill has a low liquefaction susceptiblity, uncompacted sand and silt fill may liquefy. The behavior of fill during seismic shaking should be assessed on a site-specific basis.

REFERENCES CITED

National Institute of Building Sciences, 1997, HAZUS user's manual: Washington, D. C., National Institute of Building Sciences Publication 5200.

Stanford, S. D., 1999, Environmental geology of Middlesex County, New Jersey: surficial geology: N. J. Geological Survey Open File Map 27, scale 1:48,000.

SCALE 1:48000

2 1 0 2 MILES

2000 0 2000 4000 6000 8000 10,000 12,000 14,000 FEET

2 1 0 2 KILOMETERS

LANDSLIDE SUSCEPTIBILITY FOR MIDDLESEX COUNTY, NEW JERSEY

Prepared by Scott D. Stanford, New Jersey Geological Survey
for the
New Jersey State Police, Office of Emergency Management

2003

None--HAZUS number 0

Landslide Class B III--weakly cemented rock and soil, slope angle 10-15 degrees (HAZUS number 3)

Landslide Class B IV--weakly cemented rock and soil, slope angle 15-20 degrees (HAZUS number 4)

Landslide Class CVI--shales and clayey soil, slope angle 10-15 degrees (HAZUS number 8)

Landslide Class CVII--shales and clayey soil, slope angle 15-20 degrees (HAZUS number 9)

Landslide classes are from the HAZUS User's Manual, Table 9.2 (National Institute of Building Sciences, 1997). Slope angles were measured from the following *U. S. Geological Survey 7.5 minute quadrangles: Bound Brook*, Freehold, Hightstown, Jamesburg, Monmouth Junction, Princeton, Plainfield, and Perth Amboy (all with 20-foot contour interval), and Arthur Kill, New Brunswick, South Amboy, and Keyport (10-foot contour interval). In former sand and clay pits where the base-map topography has been altered, slope angles are estimated from aerial photography and field observations. Slope materials are from Stanford (1999).

REFERENCES CITED

National Institute of Building Sciences, 1997, HAZUS user's manual: Washington, D. C., National Institute of Building Sciences Publication 5200.

Stanford, S. D., 1999, Environmental geology of Middlesex County, New Jersey: surficial geology: N. J. Geological Survey Open File Map 27, scale 1:48,000.

SCALE 1:48000

2 1 0 2 MILES

2000 0 2000 4000 6000 8000 10,000 12,000 14,000 FEET

2 1 0 2 KILOMETERS