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INVESTIGATION OF LAND USE OF NORTHERN MEGALOPOLIS USING ERTS–1 IMAGERY

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Supplementary Report

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This report supplements the Type III ("Final") Report, title as above, authors Simpson, Lindgren, Ruml and Goldstein, dated Aug 73, which covered the period 15 June to 15 July 73 under this same contract.

16. Abstract

Evaluation of ERTS mapping. Maps manually compiled from unenhanced and CCT-enhanced ERTS images and from high altitude aerial photography are compared with a map compiled from low altitude photography. In spite of large extraneous differences, the degree of correspondence varies directly with altitude of platform, degree of enhancement and area of land use category. Using a rigorous cell-by-cell comparison, unenhanced ERTS averages a 58% correspondence compared to high altitude aircraft's 69%. Among Level I categories, Builtup corresponded closest (unenhanced ERTS 85%, high altitude aircraft 92%). Among Level II categories Commercial-Industrial-Institutional was closest (unenhanced ERTS 84%, high altitude aircraft 100%). Miniscule Agriculture fared worst.

Planners Needs. Principal needs of state level planners in New England will be met with maps having one builtup category and 8-10 undeveloped categories, and with grid cells of 1/4 and 1/25 sq. km.

Towards a Megalopolitan Model. Consistent patterns are found in the dominant land uses surrounding Megalopolitan city centers, and in the intensivity decay rates across the region in general.

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PREFACE

Objective

This supplementary report concentrates on an evaluation of the previously reported land use map and data base for northern Megalopolis, on an initial exploration of its possible applications, and on a look at the ERTS-type requirements of New England planners today.

Scope

The area consists of the three states Massachusetts, Connecticut and Rhode Island. The test site for product evaluation is a 94-square-kilometer, heavily urbanized area around New Haven. On it the maps compiled from both unenhanced and CCT-enhanced ERTS images, as well as from high altitude aerial photography are compared both statistically and visually with a map compiled from low altitude photography.

The look at the currently expressed ERTS-type needs of planners in six-state New England summarizes the consensus of planners at both the state and interstate levels.

The initial exploration of some possible applications of ERTS data concentrates on the decrease in intensivity of land use with increasing distance from city centers.

Conclusions

The report concludes that ERTS land use mapping, in spite of portraying Megalopolis more accurately and dramatically than the best past efforts, is in danger of falling into the category of being too revolutionary for many planners and too conventional for many electronics engineers.

It states that two alternative solutions are implied: one is to improve the ERTS product to the level where it will be completely accepted by planners, and the other is to increase support for the present somewhat primitive product through education, cost-sharing and legislation.

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INTRODUCTION

In June, 1973, the twelve month period originally contracted for study of ERTS-1 by the Dartmouth College Project in Remote Sensing ended and a Type III ("final") report was rendered.[1]

However, ERTS-1 imagery in proper format had not become available until January 1973 and the report was in most respects a Type II ("interim") one, so an extension was granted by NASA to cover the six-month period 15 December 1973 to 15 June 1974. The present report covers that period. Although designed to stand independently, this report can best be read with reference to the earlier publication.

The objectives of the entire investigation have been 1) to map and digitize the land use of the northern one-third of Megalopolis and 2) to evaluate ERTS as a planning tool.

The first objective, to map and digitize the northern third of Megalopolis, was fully covered in the preceding report. Recipients of the first fifteen copies of that document received a gatefold color print of the final map and recipients of other copies were given a black-and-white version of it. Since that time a new photo process developed by a local laboratory has permitted much better technical reproduction of the original full-color map than was possible from any known source a year ago. Accordingly, the first fifteen copies of this supplemental report contain a new reproduction of the original map (Fig.

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[1] Robert B. Simpson, David T. Lindgren, David J. Ruml and William Goldstein, <u>Investigation of Land Use of Northern Megalopolis Using ERTS-1 Imagery</u> (Hanover, N.H.: Dartmouth College Project in Remote Sensing, August 1973), 56 pp.

1).[1] Readers who are interested in the enhanced color contrast of this new map can write directly to the originating photo lab[2] for additional information.

The second objective of the continuing ERTS-1 investigation by the DCPRS was to evaluate ERTS as a planning tool. To that end the earlier report contained three things: 1) an evaluation of cost- and time-effectiveness, in some detail, 2) a brief summary of how the ERTS-1 map compared to other land use maps prepared from different source materials, 3) an introductory, generalized statement as to the kind of remotely sensed information planners need, and 4) suggestions as to preliminary urban geographic type derivatives which could be developed from the ERTS map.

During the six months extension, primary emphasis has been directed towards a quantitative evaluation of how the original ERTS-derived map of the three New England states compares with other contemporaneous land use maps covering parts of the same area. This evaluation is summarized in Chapter II of this report.

The utility of the ERTS-type manually-derived land use map to New England planners is the subject of Chapter III. Introductory application of the ERTS-derived computer data bank to the decrease in intensivity of land use with increasing distance from the cities is introduced in Chapter IV, and Appendix A adds a new detail or two to the subject of cost- and time-effectiveness of ERTS.

This six month collaboration, like the twelve-month contract before it, has involved the full-time effort of a research assistant, William Goldstein, and the part-time efforts of the Principal Investigator, Robert B. Simpson, and the Associate Investigator, David T. Lindgren. Professor Van H. English did the cartography.

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[1] Figure 1 has been omitted entirely from all copies of the present report except the first fifteen.

[2] Hathorn/Olson, 34 South Main Street, Hanover, New Hampshire 03755

II COMPARISON OF LAND USE DATA: ERTS VS AERIAL PHOTOGRAPHY

The preceding report on this investigation included a brief section (Section IIIA, pp. 18-21) on comparability of the ERTS-1 product with that of an official 55-category State of Connecticut land use map completed in 1972 at a cost of well over a million dollars from low-level aircraft photography.

In the earlier report, opportunity was afforded simply to compare visually our ERTS map at scale 1:250,000 with a reduced and simplified eleven-category version of the official Connecticut map at the same scale.

We now have completed a more thorough quantified comparison of these two maps, and added others.

1. Statistical

One of the main purposes of the ERTS-1 extension was to statistically compare the land use data acquired by ERTS to that acquired by other sensor platforms. In order to accomplish this four separate data bases were generated from four different interpretations of the same geographical area, referred to herein as the New Haven test site (Figure 2). The comparison was a three-step process: 1) acquisition (by photointerpretation) and computerization of test site data; 2) transfer of data to a common geographical base; and 3) cell-by-cell and area-by-area comparison of individual land use data bases.

Of the four data bases two already were interpreted at the beginning of this contract. The first was provided by the state of Connecticut from low-altitude black and white photography taken in 1970. This official state land use map was compiled at scale 1:24,000 on a base composed of 7 1/2 minute USGS topographic quadrangles. A grid representing 1/25 square kilometer was drawn and placed over the topographic sheet. The 55 land use categories, of which only forty were found within the New Haven test site (Table 1, Column A), were then numerically coded into the computer by the majority land use of each grid cell.

The second data base was not only already interpreted but computerized as well. Under USGS Contract No. 14-08-0001-12958 a 1600-

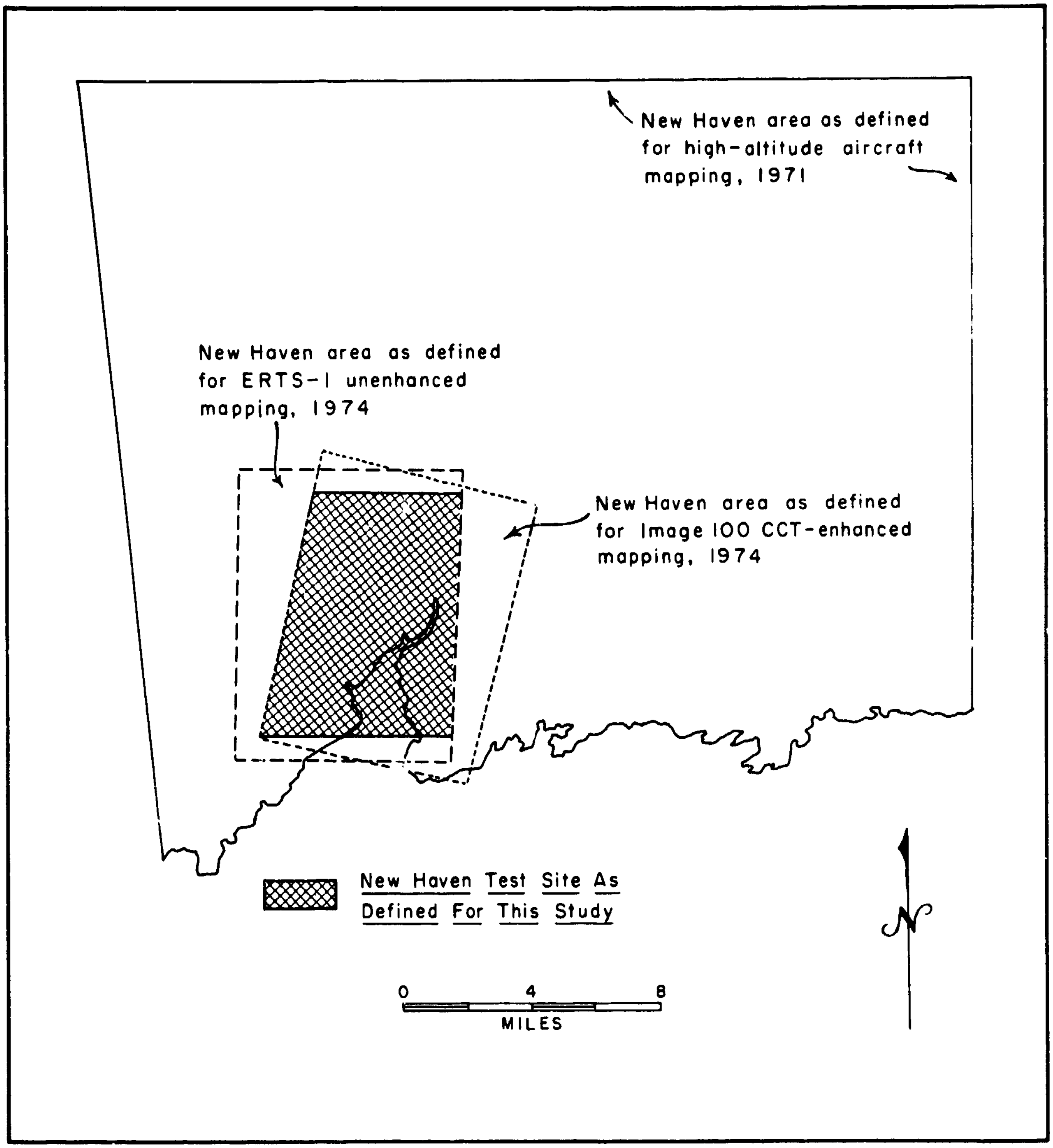

Figure 2. Identification Map.

Table 1

Aggregation of Land Use
Categories by Sensor Platform

A. LOW ALTITUDE A/C	B. HIGH ALTITUDE A/C	C. ERTS	D. FINAL CATEGORIES
Forest lands Commercial forest products Camp grounds	Woodland Orchard	Woodland	WOODLAND
Urban high residential Urban low residential Suburban high residential Suburban low residential Estate residential	Residential, single family Residential, multifamily & mixed	Residential: high density Residential: low density	RESIDENTIAL
Golf courses Cemeteries Athletic fields Parks- leisure & ornamental Swimming areas Other outdoor recreation	Recreational	Developed open space (urban)	VELOPED OPEN SPACE (URB)

(continued on next page)

Table 1 (Cont.)

A. LOW ALTITUDE A/C	B. HIGH ALTITUDE A/C	C. ERTS	D. FINAL CATEGORIES
General trades & services Marinas Hospitals Military reservations Primary & secondary education General cultural & entertainment Higher education Churches & monasteries Sports assembly (stadiums, etc.) Drive-in theatres, open-air concerts General light manufacturing General heavy manufacturing Electric power plants Water treatment plants Sewer treatment plants Sand and gravel pits Solid waste disposal Under construction	Commercial Industrial Institutional Extractive	Commercial-industrial-institutional-extractive	COMMERCIAL-INDUSTRIAL INSTITUTIONAL
Highway right-of-way Railroad Airports	Transportation & utilities	Transportation & utilities	TRANSPORTATIONAL
Open lands Abandoned gravel pits & quarries	Non-cultivated land, open land	Rural, open land	RURAL OPEN LAND
Wetlands	Marshland	Marshland	MARSHLAND
Active agricultural production	Cultivated land	Agriculture (row crops & fallow)	AGRICULTURE
Water	Water	Water	WATER

square kilometer area surrounding New Haven had been manually interpreted using 1:130,000 scale color-infrared photography; the land use data had subsequently been computerized into a data base of 40,000 cells, each one denoting the majority use of a 1/25 square kilometer cell. This data base, hereafter referred to as the "high-altitude aircraft" base, consisted of 14 categories of land use (Table 1, Column B). This grid and the one used to computerize the low-altitude aircraft base were identical, thus making possible a cell-by-cell comparison of the two data bases.

The third land use base was derived from the manual photointerpretation of an unenhanced photo-laboratory-produced ERTS-1 color composite of the 1600-square kilometer New Haven test site, photographically enlarged to a scale of 1:250,000. The nine-category interpretation (Table 1, Column C) was done directly onto the transparency, and subsequently transferred using a Bausch and Lomb Zoom Transfer Scope to the same 1:62,500 topographic base as the high- and low-altitude aircraft base maps. After completing the final ERTS interpretation at the standard scale of 1:62,500, the base map was computerized in the same manner as previously described. It was possible to compare this product with the two preceding ones on a cell-by-cell basis.

The fourth base was produced from the manual photointerpretation of a photographically enlarged 35-mm. slide, taken of the cathode ray tube display of General Electric's Image 100, showing a portion of the New Haven test site. The scale of this fourth-generation reproduction was approximately 1:62,500, but because of the distortion inherent in the cathode ray tube, an exact scale applicable to the whole scene could not be determined. The color-coded nine-category (same as unenhanced ERTS-1) land use map was gridded and the data read into the computer. However, because of the distortions in this base a cell-by-cell matchup with the three other bases was not attempted.

With the four data bases completed the final test site upon which all the statistical analyses were performed was derived, using a series of DCPRS-developed software which extracted from each separate base the area shared in common by all four data bases. This polygon measures 94-square kilometers in area, or 2,350 1/25 square-kilometer observation cells of land use.

There were two types of comparisons made with the data. The first consisted of aggregating the three individual legends (low altitude, high altitude, and ERTS) into one compatible nine-category land use legend (Table 1, Column D). Subsequently, each of the four data bases was examined under program control to determine the percentage of each land use in each data base (Table 2).

The second series of statistics was an actual cell-by-cell comparison of the three compatible data bases- low altitude aircraft, high altitude aircraft, and ERTS unenhanced (Table 3). The ERTS enhanced data base was not included in this comparison because of the distortion problems mentioned previously. The three comparisons actually undertaken were ERTS vs low altitude, high altitude vs low altitude, and less importantly, ERTS vs high altitude.

The original matrices ranged from 14 x 55 for the high-altitude aircraft vs low-altitude aircraft comparison to 9 x 14 for the ERTS vs high-altitude aircraft comparison. To generate the final statistics, the categories were collapsed and combined into the final nine.

Before discussing the results of the comparisons four important qualifications should be made about the statistics. First, a different land use classification had been used in the generation of each data base. The number of land use categories ranged from 55 for the low-altitude aircraft data to as few as 9 for ERTS. This resulted in a number of problems as to which of the nine categories should receive one or another of the 55 categories to be aggregated. Second, different photointerpreters working under different ground rules were used in the acquisition of each data base. Thus, even if the land use classifications had been identical each photointerpreter would have applied them somewhat differently, but with different classifications as well, the assignment of land use categories inevitably varied. Third, the imagery used in the preparation of the data bases was acquired at different dates; the high-and low-altitude aircraft photography was taken during 1970, while the ERTS imagery was acquired in 1972. Although a two-year difference is not great, some land use changes were bound to have occurred during

Table 2

New Haven Test Site: Correspondence Attained Between ERTS, High-Altitude Aircraft and Low-Altitude Aircraft Data for Each Land Use Category by Square Kilometers and Percent

Land Use Category*	Unenhanced ERTS		Enhanced ERTS		High Alt. A/C		Low-Alt. A/C	
	Sq. km.	%	Sq. km.	%	Sq. km.	%	Sq. km.	%
I URBAN AND BUILTUP	72.34	+8	77.72	+15	72.56	+8	66.72	100
II Residential	54.92	+24	49.60	+16	44.84	+7	41.56	100
II Commercial-Industrial-Institutional	14.46	-18	20.36	+13	17.72	0	17.64	100
II Transportational	1.52	-64	2.84	-33	4.04	-5	4.24	100
II Developed Open Space	1.44	-56	4.92	+33	5.96	+45	3.28	100
I WOODLAND	12.96	+104	8.24	+24	7.32	+14	6.28	100
I MARSHLAND	5.68	+11	3.56	-29	5.32	+5	5.04	100
I WATER	2.52	-11	4.44	+56	2.96	+4	2.84	100
I RURAL OPEN LAND	0.12	-	3.92	-68	5.16	-58	12.36	100
I AGRICULTURAL LAND	0.00	-	0.24	-66	0.20	-72	0.72	100

*Roman numerals indicate the "level" of categorization shown in the latest preliminary draft of a Federal government classification system

Table 3

New Haven Test Site: Cell-by-Cell Comparison of Unenhanced ERTS Data, High-Altitude Aircraft Data and Low-Altitude Aircraft Data by Land Use Category

Land Use Category	Unenhanced ERTS vs. Low-Alt. A/C			High-Altitude A/C vs. Low-Altitude A/C			Enhanced ERTS vs. High-Altitude A/C		
	# cells ERTS	# cells agreeing	% agreement	# cells high-alt.	# cells agreeing	% agreement	# cells ERTS	# cells agreeing	% agreement
I URBAN AND BUILTUP	1,804	1,139	63	1,809	1,288	71	1,804	1,251	69
II Residential	1,372	875	64	1,121	901	80	1,372	974	71
II Commercial-Industrial-Institutional	358	220	61	440	284	65	358	223	62
II Transportational	38	30	79	100	75	75	38	33	87
II Developed Open Space	36	14	39	148	28	19	36	21	58
I WOODLAND	324	112	35	183	95	52	324	117	36
I MARSHLAND	142	66	46	132	106	80	142	68	48
I WATER	58	38	66	73	46	63	58	37	64
I RURAL OPEN LAND	3	0	0	129	77	60	3	0	0
I AGRICULTURAL LAND	0	0	0	5	2	40	0	0	0
Totals	2,331	1,355	58	2,331	1,614	69	2,331	1,473	63

that period. And finally, the comparison assumes the low-altitude data to be entirely correct. In any data acquisition program errors occur. These qualifications, then, while not sufficient to negate the value of the statistics, most certainly account for many of the discrepancies.

Table 2 illustrates the degree of correspondence attained in the "overall" (not cell-by-cell) figures for each land use category when the ERTS and high-altitude aircraft data are compared with the low-altitude aircraft data. As expected, in both the Level I and Level II land use categories the high-altitude aircraft data correspond most closely to the low-altitude aircraft data, followed by the enhanced-ERTS data. The poorest correspondence is between the low-altitude aircraft data and the unenhanced ERTS.

Specifically, there is good correspondence (only an 8% disparity) between both the unenhanced ERTS and low-altitude aircraft data, and between the high-altitude aircraft and low-altitude aircraft data in the Urban and Builtup category. However within the Level II urban categories the high-altitude data improve in correspondence while the ERTS data worsen. Furthermore in all four Level II categories the enhanced ERTS data correspond more closely to the low-altitude data than the unenhanced ERTS data. The only urban category for which high-altitude data do not correspond well (45% discrepancy) is the Developed Open Space. This latter category is basically an ERTS-derived category for which it is difficult to determine equivalents within the aircraft data bases.

All three of the data bases contain more Woodland than the low-altitude data base. The high-altitude base exceeds the low-altitude base by 14%, the enhanced ERTS exceeds it by 24%, and the unenhanced ERTS by 104%. Apparently the lower the resolution, the greater the overenumeration of Woodland. With lower resolution many wooded residential and recreational areas would appear as woodland.

Both the Marshland and Water categories were reliably recorded by high-altitude aircraft (a +5 and +4 disparity respectively) and by ERTS (+11 and -11 discrepancies). The enhanced ERTS, however, underenumerates marshland by 29% while overenumerating water by 56%.

There is little correspondence of data within the Rural Open Land category regardless of the data platform. Again this is an ERTS-derived category for which there are no direct equivalents among the non-ERTS data bases.

Finally there is little data correspondence between sensor platforms within the Agricultural Land category. There are a number of reasons for this. First, there is little agriculture in the New Haven test site, and that which does occur is conducted on a small scale. It is very difficult to detect such small parcels from ERTS. In addition there are problems of definition with this category. The ERTS category referred exclusively to row crops, while the low-altitude base included cover crops and active pasture land.

Table 3 compares three combinations of land use on a rigorous cell-by-cell (rather than overall) basis. The three combinations are the unenhanced ERTS vs the low-altitude aircraft data, the high-altitude aircraft vs the low-altitude aircraft data, and the enhanced ERTS vs the high-altitude aircraft data. Again as expected and on the average, the high-altitude aircraft data base corresponds more closely to the low-altitude aircraft data base (69%) than does the unenhanced ERTS (58%).

Considering only the unenhanced ERTS and high-altitude aircraft comparisons with low-altitude aircraft data, it can be seen that the high-altitude data have a higher agreement percentage than ERTS in the Urban and Builtup category (71% to 63%), the Residential category (80% to 64%), and the Commercial-Industrial-Institutional category (65% to 61%). The unenhanced ERTS has the higher percentage agreement in the Transportation category (79% to 75%) but the high-altitude base has more than twice as many cells of agreement (75 to 30). There is poor agreement in both cases with Developed Open Space. As mentioned previously this is an ERTS-derived category for which it is difficult to determine equivalents among the aircraft data.

Woodland, which was vastly overenumerated from the unenhanced ERTS, shows only a 35% agreement on the cell-by-cell comparison as against a 52% agreement for the high-altitude data. Nevertheless, the unenhanced ERTS has the larger number of cells in agreement (112 to 95).

The high-altitude data agree 80% of the time with the low-altitude base in the Marshland category. Unenhanced ERTS data, however, displayed only a 46% agreement. This is not too surprising since the marshland tracts within the test site are with one or two exceptions relatively small.

In the Water category unenhanced ERTS data has a higher percentage of agreement (66% to 63%) but both are surprisingly low. Some water may appear in the Marshland category which in both instances is overenumerated.

The last two categories, Rural Open Land and Agricultural Land actually show no agreement for the unenhanced ERTS data. There are, in fact, only 3 cells within the New Haven Test Site recorded as Rural Open Land, and this is an ERTS-derived category; there are no cells of Agricultural Land recorded. There is greater agreement with the high-altitude data although there are only 2 cells of Agricultural Land in agreement. The agreement for the Rural Open Land while reasonably high (60%) must be used carefully since there was great difficulty in selecting land use equivalents from among the aircraft data bases.

In conclusion, the statistical comparisons of the ERTS-acquired land use data with those acquired by aircraft do not reveal anything new. They do, however, provide statistical substantiation for many of the points made earlier in reference to ERTS.[1] It remains our

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[1] In the preceding report on this contract. See also Robert B. Simpson and David T. Lindgren, "Land Use of Northern Megalopolis, "Symposium of Significant Results Obtained from the Earth Resources Technology Satellite-1, vol. I: Technical Presentations. Proceedings of a Symposium held by Goddard Space Flight Center at New Carrollton, Maryland, March 5-9, 1973 (Washington, D.C.: National Aeronautics and Space Administration, 1973), pp. 973-980; and David T. Lindgren, Robert B. Simpson and William Goldstein, "An Evaluation of ERTS Imagery for Acquiring Land Use Data of Northern Megalopolis," to be published in forthcoming NASA volume on the Third ERTS Symposium, Washington, D.C., December 1973.

contention that ERTS can be an excellent source of land use information for large areas, but for the level of land use information needed by substate planning agencies it is inadequate and must be strongly supported by aircraft data.

2. Cartographic

In addition to the numerical comparisons, a number of computer maps of the New Haven test site have been generated in order to permit visual inspection of where specifically the data bases differ. On the following pages Table 4 and Figures 3 through 6 show the four different versions of the nine-category land use map. In addition, at the back of this volume as Figures B-1 through B-4 are reproduced selected single-category land use maps of the test site in four versions each. They probably are even more useful than Figures 3 to 6 in making an intuitive appraisal of the four different remote sensing mapping techniques.

TABLE 4

LAND USE CATEGORIES FOR THE NEW HAVEN TEST SITE

█████ █████ █████	COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL
ØØØØØ ØØØØØ ØØØØØ	TRANSPORTATIONAL
θθθθθ θθθθθ θθθθθ	RESIDENTIAL
XXXXX XXXXX XXXXX	DEVELOPED OPEN SPACE (URBAN)
+++++ +++++ +++++	AGRICULTURAL
===== ===== =====	RURAL OPEN LAND (WITH OR WITHOUT RESIDENCES)
,,,,, ,,,,, ,,,,,	MARSHLAND
••••• ••••• •••••	WOODLAND
(BLANK)	WATER

Figure 3. (See Table 4 for legend)

NINE CATEGORIES
ERTS, UNENHANCED

NEW HAVEN SITE

Figure 4. (See Table 4 for legend)

Figure 5. (See Table 4 for legend)

NINE CATEGORIES
A/C, HIGH ALTITUDE NEW HAVEN SITE

Figure 6. (See Table 4 for legend)

NINE CATEGORIES
A/C, LOW ALTITUDE NEW HAVEN SITE

III NEW ENGLAND PLANNERS AND ERTS: AN APPRAISAL, 1974

Traditionally land use management in the New England states, as in the rest of the US, has been the responsibility of local authorities. Following passage of the Standard State Zoning Enabling Act of 1922 and The Standard City Planning Enabling Act of 1928 a multitude of codes and ordinances were established by local governments to control land use. Unfortunately the two enabling acts have proven "both theoretically and mechanically incapable of handling the numerous changes that have occurred on land use management practices".[1] The Federal Government has responded, therefore, by proposing legislation designed to strengthen the state's role in the planning process. Under the provisions of these bills, of which the most important are the Coastal Zone Management Act of 1972, the Flood Disaster Protection Act of 1973 and the controversial National Land Use Policy Act, a variety of land use and environmental data must be acquired and updated on a systematic basis in order to provide support for the planning process. Conventional field survey methods of data gathering simply appear too inefficient for such a task and thus alternative data acquisition systems such as ERTS are being evaluated by planners.

Ironically it has been the proposed National Land Use Policy Act, only recently defeated by vote of the House of Representatives, which has had perhaps the most significant impact upon the state planning process. The bill, which would have required states to establish a state-wide planning program within five years, would also have authorized an expenditure of up to $100 million per year for grants to states. Anticipating the eventual passage of this bill many states have undertaken steps to establish computerized land use information systems.

Although New England state and regional planning agencies

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[1] American Law Institute, A Model Land Development Code, Tentative Draft No. 1 (Philadelphia, Pennsylvania: 1968), Article 3, p. 52; quoted in Lee Guernsey, "Proposed State Land Use Policy Guidelines," Proceedings, Association of American Geographers (Washington, D.C., 1973), p. 89.

frequently differ as to the specific types of data required, there is a general consensus that any information system should serve the following functions:

inventory
change assessment
prediction

An important question is to what extent ERTS can contribute to the fulfillment of those functions.

Inventory. As an absolute minimum an information system must include a complete inventory of a state's land and water resources. Although much of this information may already have been acquired by various state and local agencies, there are often great difficulties aggregating it because of differences in scale, categorization, and time of acquisition. ERTS, therefore, can be an important means of establishing a reliable, up-to-date land use inventory.

Most land use information systems utilize the grid system as the basis for quantifying and storing data. Although such a system is quite adequate for generalized types of information it is not sufficient for the more detailed kinds of information which are site specific. Thus a truly effective information system must be capable of providing not only areal data but point and line data as well. Furthermore the system should be able to handle the data gathered on the basis of such geopolitical units as census tracts, townships and school districts.

From the viewpoint of such an information system ERTS would be most applicable in providing areal data over relatively large areas, i.e., states or groups of states. It has been demonstrated that ERTS is quite capable of providing reliable land use data in perhaps as many as 14-18 categories,[1] although for statewide planning 10-12 probably would be sufficient. Although a number of urban categories can be recognized from ERTS, most state planners appear less concerned about the urban categories than the undeveloped ones. Thus a single

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[1] David T. Lindgren and Robert B. Simpson, "Land Use and Mapping," Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1, Volume II, Summary of Results. (Greenbelt, Maryland: Goddard Space Flight Center, May 1973), p. 100.

builtup category would probably be sufficient at the statewide level if accompanied by 8 or 10 undeveloped categories. This would be quite compatible with Level I or the U.S. Geological Survey's land use classification system for use with remote sensor data.[1] Level II data, that is, the subdivision of the Level I categories into a number of more detailed categories, would preferably be the responsibility of substate planning levels, and would be acquired both by aircraft overflights and ground survey methods.

Although agreement on this point is not unanimous it would appear that for statewide planning purposes a minimum parcel size for the acquisition of areal data would be 1/4 square kilometer (62 acres). This would certainly be sufficient for states like New Hampshire and Maine which have vast tracts of woodland. Thus, for a state the size of New Hampshire there would be more than 96,000 data points, and if several types of data were recorded for each point the total amount of information would be considerable. Still some planners have expressed a desire for more detailed information in urbanized areas. For these areas a minumum parcel size of 1/25 square kilometer (10 acres) would be recommended. At this scale a city the size of metropolitan Boston would alone have almost 100,000 data points; if used for the entire state of New Hampshire the number of data points would exceed 600,000.

Change Assessment. The purpose of the land use inventory is not only to illustrate how land is being utilized in the various regions of the state, but perhaps more importantly to provide a base against which change in land use can be compared. Monitoring both the amount as well as the type of change is an important first step in identifying the factors most responsible for the conversion of land from rural to urbanized uses. Only when such factors have been identified will it be possible to prepare the legislation necessary for orderly land development. In the meantime the monitoring of change can be employed to evaluate the effectiveness of present land use legislation.

Cloud-free ERTS imagery of the New England states is obtained

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[1] Preliminary draft revision, for review purposes only, July 1974.

about once a season, which is far more frequent than is necessary for land use change detection. Such detection at the statewide level would be required only about once every two years. With a 1/4-square kilometer, or 62-acre, data cell a change in land use of at least 35 acres is required to affect the predominant use of any cell. It would be expected that few such changes would occur in any two year period. However, with a 1/25 square kilometer, or 10-acre, data cell only a 5 or 6 acre change would affect the predominant land use. A considerable number of these changes would occur within a two year span.[1] Furthermore these changes should be quite visible since the ground scarring resulting from new construction would not have been completely obscured by the regrowth of vegetation in such a short time-span.

Prediction. Over a number of years the monitoring of land use change should aid in the development of reasonably sophisticated land development models which would incorporate such variables as migration, employment opportunities, housing market, land values, taxes, and zoning. An important application of such models is prediction. Ultimately the effectiveness of a land development model's predictive capability can be evaluated by comparing predicted change with the actual land use change as revealed by ERTS. If this can be done successfully then the ultimate application of the model, evaluating the impact of new legislation on land use development, can be simulated by introducing it into the model. This should vastly improve the legislative process and result in the preparation of legislation most necessary for orderly land development.

In addition to the rather general concern over land use, New England state planners have manifested a very specific interest in "wetlands," primarily because of the passage of the Coastal Zone Management Act (1972). The purpose of this act is to encourage states to exercise authority over the lands and waters in the coastal zone and to establish an effective management program for its protection and development. The Federal Government is authorized to provide fin-

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[1] David T. Lindgren, Robert B. Simpson and William D. Goldstein, Land Use Change Detection in the Boston and New Haven areas: 1970-1972, (Hanover, NH: Dartmouth College Project in Remote Sensing, January 1974).

ancial assistance to states interested in establishing such a program.[1]

Among the provisions of the act, states are required to identify the boundaries of the coastal zone which will be subject to the management program and to inventory and designate areas of particular concern within the zone. In an attempt to meet these requirements planners in states which have extensive areas of wetlands, and this includes most of the New England states, have turned to ERTS. They see in ERTS not only the opportunity to inventory their coastal zone resources, but to monitor development in the coastal zone once the necessary management programs have been established.

And finally the Flood Disaster Protection Act of 1973 has also generated an interest in ERTS, although not so much for state planners as for the New England River Basins Commission. The purpose of this act is to provide individuals living in flood-prone areas with an opportunity to purchase flood insurance sufficient to cover losses in the event of a major flood. To be eligible for the program, however, states must prepare flood plain ordinances which will avoid, or at least reduce, future flood losses. Communities not adopting such ordinances will be dropped from the National Flood Insurance Program.

Under the provisions of this act states are directed to "accelerate the identification of risk zones within flood-prone and mudslide-prone areas... in order to makd known the degree of hazard within each such zone at the earliest possible date."[2] In accordance with these provisions the New England River Basins Commission has begun to delineate the flood plains of major rivers, map land use on these plains, and produce flood hazard maps. With hundreds of miles of rivers to map in this manner, ERTS should provide an excellent data source along with available aircraft photography.

In addition to the aforementioned legislation the other important factor hastening the use of ERTS data by New England planners has been the energy crisis. No region of the United States is so fuel-poor or

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[1] U.S. Congress, Senate, <u>Coastal Zone Management Act of 1972</u>, Pub. L. 92-583, 92nd Cong., 1972, S. 3507.

[2] U.S. Congress, House <u>Flood Disaster Protection Act of 1973</u>, H.R. 8449, p. 8.

so dependent upon imported fuel. As a result New England energy costs are the most expensive in the U.S. In the aftermath of the Arab oil-boycott each of the New England states has attempted to improve its own energy situation. Witness New Hampshire's flirtation with Aristotle Onasis, who was interested in building an Olympic Oil Company refinery on Durham Point, New Hampshire. Although environmental interests were successful in halting construction at that site, pressure for a New England oil refinery, as well as for the construction of additional nuclear power plants continues.

With the fear that individual decisions by the various New England states may result in either duplication of effort or poorly located facilities, several organizations including the New England Regional Commission have called for region-wide planning. As a first step land use information for the entire New England region is needed, if sites are to be evaluated for nuclear-power plants and oil refineries as well as for corridors for transmission lines and pipe lines.

At least for the present the best source for such information is ERTS. The very attributes of ERTS are what are most needed here--- the provision of several categories of land use for a large area (six states) in a short period of time. The alternative of having each state provide the data is a poor one. Even if all six states already possessed such data, which they do not, there would be problems in aggregating them due to differences in scale, categorization, and date of acquisition. ERTS would appear to be the only present alternative.

In conclusion, New England planners are increasingly becoming aware of ERTS and its capabilities. These same planners are faced with a broad range of tasks, but frequently with too few financial resources to carry them through successfully. Thus a remote sensing system such as ERTS, which has the capability of providing a number of types of environmental data at frequent intervals and doing so at little cost to the states, is bound to be received favorably.

There are two problems which must be resolved, however, before planners completely gear up for using ERTS. The first is resolution. A resolution of 200-300 feet is simply too large for the needs of most planners. Although machine processing of data has been able to improve resolution somewhat it is still not enough to satisfy them, and ERTS-B will be little help since it will largely duplicate ERTS-1. The best solution is the 30-foot resolution proposed for EOS.

The second problem is primarily a political one. Simply stated it is: "will ERTS and its successors be functioning long enough, to warrant the development of a planning program dependent upon satellite data?" There is little assurance of this at present, and the frequent changes in the ERTS-B launch date do little to improve the situation. Only when planners can see a definite schedule of satellite launchings, and can depend upon regularly acquiring remote sensing data, will they be prepared to modify their planning systems accordingly.

IV DECLINE IN LAND USE INTENSITY AWAY FROM THE CITIES

For the DCPRS the main goal of land use mapping using ERTS has been to develop an effective but inexpensive tool for the study of changing land use in the "urban field," that is in the zone of influence around an urban area, in this case Megalopolis.

A first small step in this direction now has been taken through a first look at the decline in intensity of land use with increasing distance from Megalopolitan city centers, measured both in kilometers (close-in) and in hours of driving time (farther out).

1. Changes with Distance

This subject was introduced in the preceding report (pp. 23-24). The Von Thunen model[1] for Boston shown in that report as Figure 10 now has been duplicated for nine additional Megalopolitan cities, and reproduced here as Figures 7-9. The graphic for Boston (in Fig. 7 of this report) is an abridged version of Figure 10 in the earlier report, this time with only the dominant land use appearing.

The Von Thunen chart for Providence, Rhode Island (also in Fig. 7 herein) can be taken as the prototype for New England cities. Note that three types of land use dominate successively outward from the center of Providence, namely commercial-industrial-institutional, high-density residential, low-density residential, and finally woodland. The same sequence is repeated for the other three cities of the 500,000-and-larger population group namely Hartford, Springfield, and Boston. The sequence is repeated again in the diagrams for the cities of the 500,000 to 200,000 population category (Fig. 8), and even among the cities of less than 200,000 population (Fig. 9). The major deviation among all these varied cases is that in some of them one or even two bands are missing. No new dominant bands appear. Distance from city center to the regional matrix zone of woodland is in all cases 20 kilometers or less.

Thus there is a characteristic Von Thunen pattern to the cities of New England, epitomized by Providence, Rhode Island. In no case

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[1] Peter Hall, ed., Von Thunen's Isolated State (London: Pergammon Press, 1966).

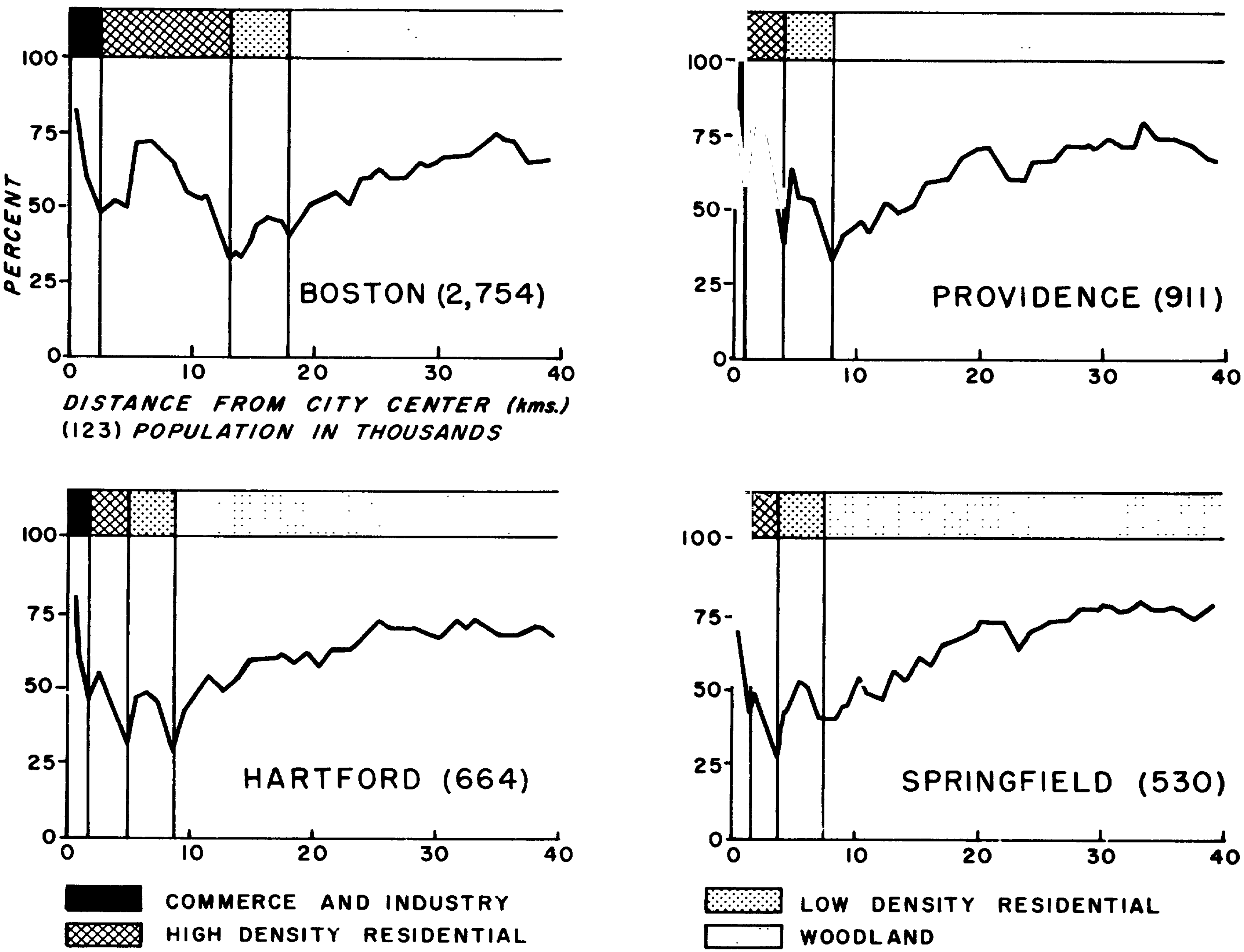

Figure 7. Dominating Land Uses, Cities of More Than 500,000 Population.

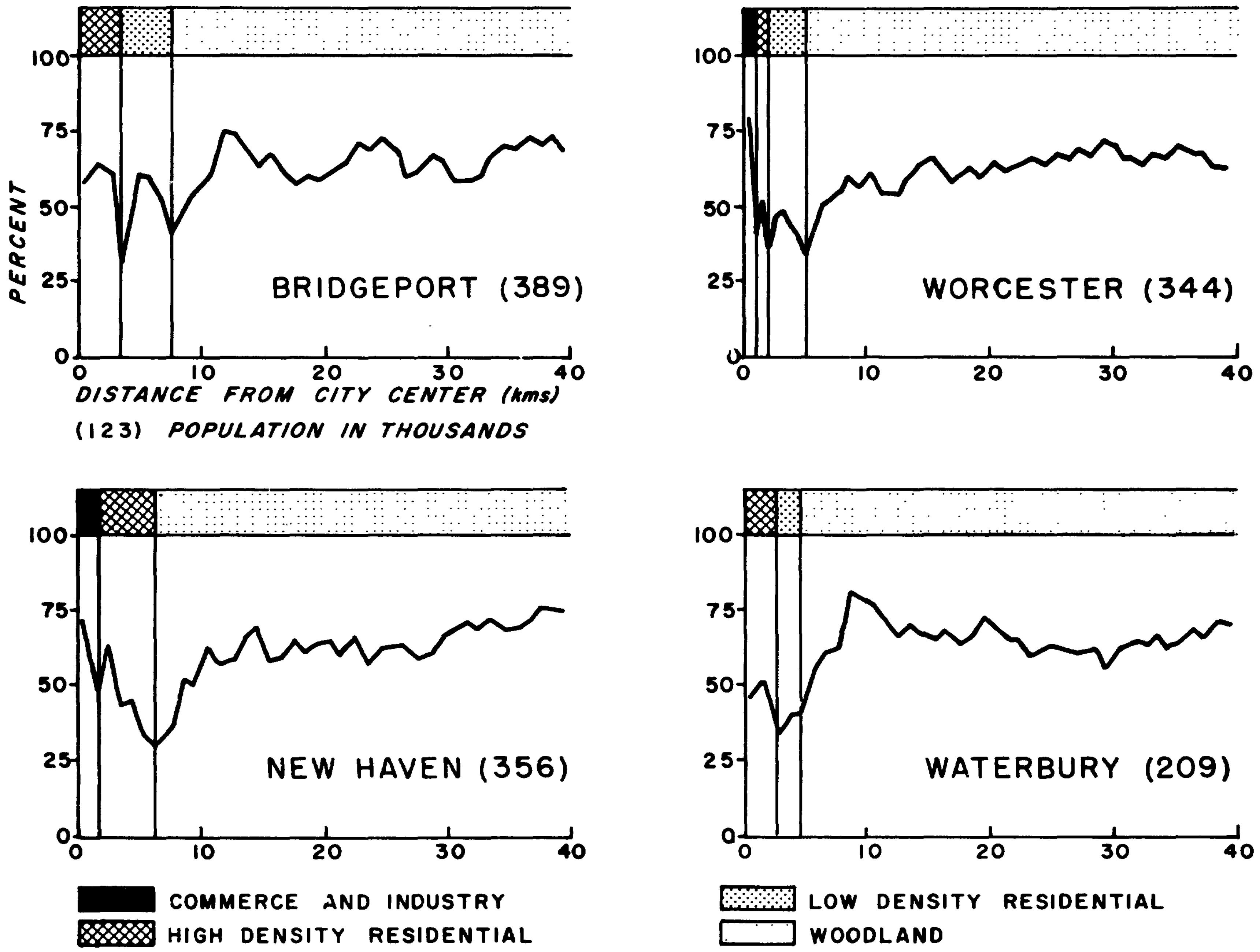

Figure 8. Dominating Land Uses, Cities of 500,000 to 200,000 Population.

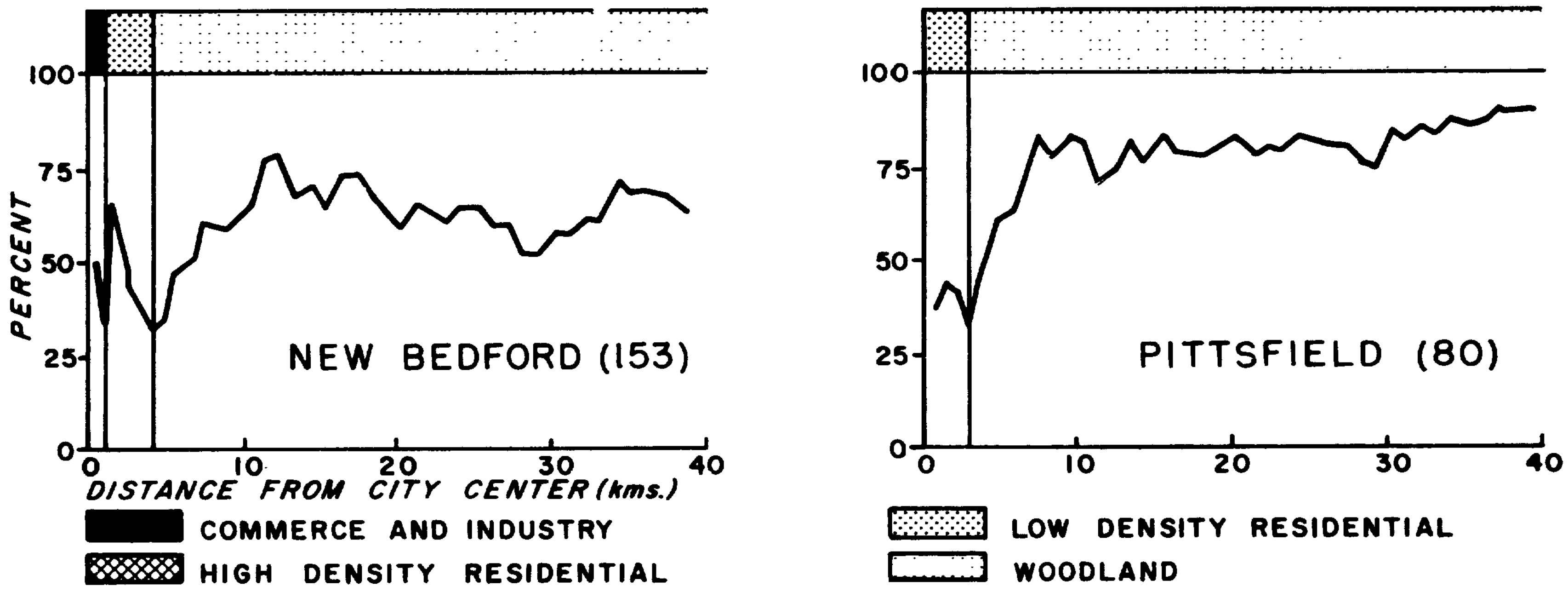

Figure 9. Dominating Land Uses, Cities of Less Than 200,000 Population.

does agriculture, the use towards which the original Von Thunen model was directed, attain dominant status.

The Von Thunen rings have value as models in the city proper, but do not accurately reflect land use intensities in New England once the woodland-dominated zone is attained. In fact, we experimented with the drawing of similar rings around the ten megalopolitan cities mentioned in the preceding paragraph, printing 1-kilometer land use intensity bands out from each of them, like ripples spreading from a dropped pebble, until they met the bands from other cities.

The results were not meaningful. Much of New England consists of a uniform woodland pattern but occasional concentric bands indicating more intensive land use show up at intervals as a result of the "saturation" of these bands with intensive land use due to the presence of one or more cities somewhere within the circular domain of each. For example, both Worcester, Massachusetts, and Providence, Rhode Island lie in the same kilometer band outside of Boston, and both produce an erroneous high-intensity land use ring in areas that are semi-wilderness.

In an attempt to diminish this type of error, we experimented with subdividing the concentric rings into sectors of, for example, 5° width on the circumference of the circles. This method solved the saturation problem, but produced a set of patterns having little geographic significance.

At this point, we abandoned the precise zonal circles as a technique for studying change outward from the city, and turned to driving time from the center of the city as a possible more meaningful parameter.

2. Changes with Driving Time

Although Von Thunen rings with their circular boundaries have some value as models, each ring includes variations in land use intensity which tend to increase in magnitude with distance from the city center, to the extent that the utility of the models is limited beyond the city proper. A quick look at the Boston area on the overall land use map (Fig. 1) confirms that beyond Route 128, 25 kilometers out from the center of Boston, each concentric zone would embrace a variety of both high- and low-density uses. It also reveals a tendency for high density functions to flank major transportation routes, and for the low density uses to occupy the pockets of less accessible land between the outward radiating highways. For this reason travel time zones should make a better basis for modelling in the area beyond the compact suburbs. Automobile travel times appear to be an appropriate delineator of this parameter.

In Figure 10 and Table 5 the relationship between automobile driving time and intensity of land use across all of southern New England, but centering on Boston and New York City, is summarized. It will be noted that this method, like the kilometer-distance method, produces roughly concentric zones around the cities of reference, but in this case travel time zones swing far outward along the interstate highways and fall back towards the cities in the intervening spaces.

In this study, driving time has been based on a speed of 57 miles per hour on the interstates. The inner (0 to 1/2 hour) zone for New York City is omitted, since all of it lies outside the study area.

Intensivity of land use for each driving-time zone is derived from the study's data bank, which contains the dominant land use of each 1/4-square kilometer in the three states. The land use data were called out of the bank by counties, and assigned to driving-time zones by reference to the three-state computerized land use map (Fig. 6 of the preceding study).

The driving time vs land use map (Fig. 10) shows that the histogram pattern of land use intensities out from Boston declines sharply and consistently with time, until the 1 1/2 hour time-zone, which includes the urbanized Connecticut Valley is attained. Here intensivity rises, to drop off again steeply beyond the Connecticut Valley, in the 2+ hour time zone.

Similar patterns prevail coming out of New York, although average intensities are higher and there tends to be a one-time-zone lag in comparison with Boston (the histogram for the 1/2-1 hour band out of New York resembles that for 0-1/2 hour band out of smaller Boston). This lag is eliminated by the time the Connecticut Valley is reached, 1 1/2 hours from each city center. Here the intensity patterns are similar whether the point of origin is Boston or New York.

An interesting feature of Figure 10 is the revelation that the anomolous semi-wilderness woodland area in the south central part of

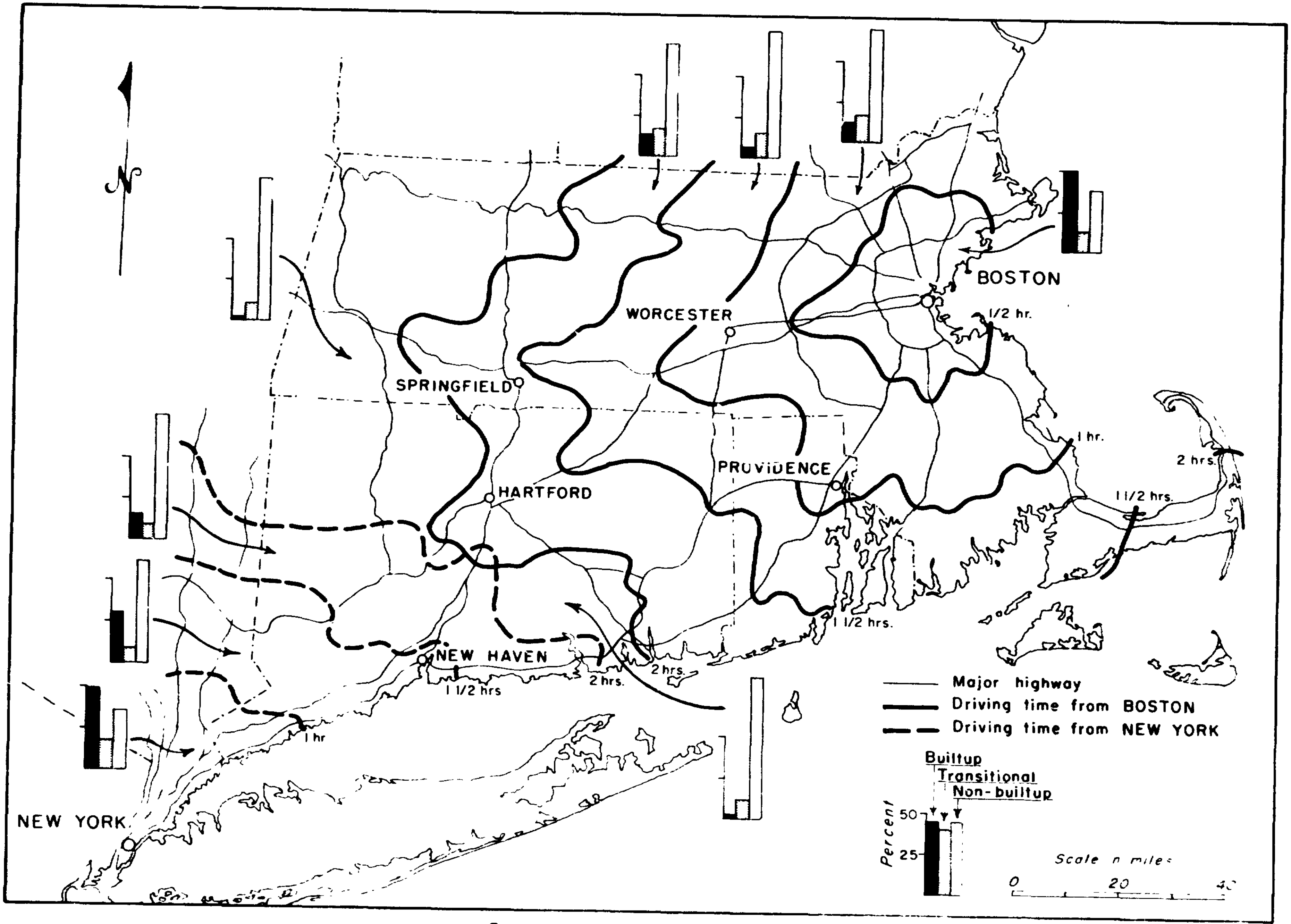

Figure 10. Driving Time and Land Use.

Table 5

Driving Time from Boston and New York City vs Land Use Intensity
(States of Massachusetts, Connecticut and Rhode Island)

	Builtup		Transitional		Non-Builtup		Total	
	Sq. km.	%	Sq. km.	%	Sq. km.	%	Sq. km.	%
FROM BOSTON								
0-1/2 hr.	1,127	50.2	294	13.1	824	36.7	2,245	100
1/2-1	856	13.3	1,092	16.9	4,501	69.8	6,449	100
1-1 1/2	605	6.8	1,301	14.6	6,978	78.5	8,884	99.9
1 1/2-2	993	13.0	1,293	16.9	5,376	70.2	7,662	100.1
FROM N.Y.								
0-1/2 hr.	(n.a.)		(n.a.)		(n.a.)		(n.a.)	
1/2-1	152	48.0	53	16.8	111	35.1	316	99.9
1-1 1/2	499	29.7	143	8.5	1,038	61.8	1,680	100
1 1/2-2	216	15.0	125	8.7	1,097	76.2	1,438	99.9
FROM BOSTON + N.Y.								
2+ hrs.	128	2.1	684	11.0	5,384	86.9	6,196	100
(W. Mass.-N.W. Conn. part)	(86)	(1.7)	(550)	(11.1)	(4,306)	(87.1)	(4,942)	(99.9
(S.C. Conn. part)	(42)	(3.3)	(134)	(10.7)	(1,078)	(85.9)	(1,254)	(99.9

urbanized Connecticut, which constitutes the greatest break in the megalopolitan axis between Washington and Boston, lies at the driving time "watershed" between New York and Boston (2+ hours from both places). In the literature the existence of this more primitive area near the axis of major transportation lines is explained largely in local economic terms.

A future desirable step in the analysis of land use vs accessibility will be to investigate de-intensification of land use with kilometers and driving time, not just out of New York and Boston, but out from the entire, almost continuous linear chain of northern Megalopolis, and to project the data well beyond the three-state boundaries into adjacent states.

V CONCLUSION: IS THE ERTS PRODUCT GOOD ENOUGH?

Oversimplifying, let us take the color-coded three-state map reported in this paper as the product. The answer is "No. It is not good enough."

The product portrays Megalopolis more accurately and dramatically than the era-opening multistate maps of Megalopolis laboriously built up from political-unit statistics by Jean Gottman.[1] The ERTS product is detailed and accurate enough to be enlarged 10 times and still stand comparison with a map, also derived from remote sensing and reduced 5 times, that cost 100 times as much and took years rather than months to complete. The ERTS product has the capability to provide land use data cheaply and rapidly for the analysis of the tremendous fields of influence of cities such as New York and Boston. It was compiled using conventional techniques and equipment of the kind available to any low budget agency.

But on the other hand the ERTS product falls into that never-never land where conventional planners may rate it as too revolutionary, and electronics engineers rate it as too conventional. It is not good enough because the overview function which it does satisfactorily is not yet in great demand, and the metropolitan- and substate-level detail which the market now requires finds it only 50-85% accurate on a block-by-block basis. And finally, the ERTS product is not good enough because there is no assurance of a continuing source of data.

Two alternate solutions are implied. One is to improve the product, so that it will accomplish its overview function even better, and the local area tasks more adequately. The other is to increase the demand for the present primitive product, by education, cost-sharing and legislation. The present Federal program already includes studies and planning in both areas, but the action appears to be very moderate in the latter area, and as yet almost non-existent in the former one.

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[1] Jean Gottman, Megalopolis: The Urbanized Northeastern Seaboard of the United States (New York: The Twentieth Century Fund, 1961), 810 pp.

Appendices

APPENDIX A

COST- AND TIME-EFFECTIVENESS OF ERTS LAND USE MAPPING

In the preceding report we included a section (Chapter III, pp. 22-27) on the cost-and time-effectiveness of mapping from unenhanced ERTS imagery versus photography from high-altitude and medium-altitude aircraft. It is now possible to augment this data with figures for the cost of mapping using CCT-enhanced ERTS imagery, and also to include an indication of the type of product to be expected from each of these interpretation systems.

It appears (Table A-1) that digital enhancement of the ERTS imagery by processing under - system which also improves cartographic conformity, such as the IBM system, will increase the cost of land use map compilation from about $1.06 per square mile to $1.28 per square mile (21%). This increase in cost will not affect interpretation time, but will increase the degree of correspondence of the product to one derived from larger-scale imagery. Overall, comparing satellite-derived maps with aircraft-derived ones, and generalizing broadly, a change from aircraft to ERTS may reduce money costs tenfold while reducing the degree of conformity to large-scale maps by a lesser amount. Stated in another way, it can still be maintained (as it was in the earlier report) that if land use pattern differences such as these shown in Figures B-1 through B-4 of this report are acceptable, an order of magnitude savings can be realized by basic reliance on ERTS rather than aircraft.

Table A-1

Cost- and Time-Effectiveness

(An expansion of Table 3 page 25 of the preceding report on this project See it for details as to most derivations)

	Cost ($/sq. mi.)		Time (interpretation hours/ 1,000 sq. mi.)		Degree of Correspondence (to official Connecticut low-altitude map)[1]	
	$	ratio	hrs.	ratio	index figure (1-100)	ratio
ERTS-1						
Unenhanced	$1.06	1:	45 hrs.	1:	51	1:
CCT-enhanced	1.38[2]	1.3:	45 hrs.	1:	63	1.2:
Average	$1.22	1.2:	45 hrs.	1:	57	1.1:
Aircraft						
High-altitude	$10.46	10:	328 hrs.	7:	74	1.5:
Med.-altitude	15.50	16:	1,380	31:	--	--
Low-altitude	--	-	--	--	100	2.0:
Average	$12.98	13:	854 hrs.	19:	87	1.8:

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[1] NOT A DIRECT MEASURE OF ACCURACY OR QUALITY OF PRODUCT. The official Connecticut low-altitide land use map was assigned an index number of 100, and each other land use map an index number from 1 to 100 depending on how closely it approached the low-altitude map in one thing: number of square miles of each category of land use. The categories and their definitions are only superficially alike, having been arrived at by different agencies, at different times, for different purposes, from drastically different types of imagery. See text for discussion.

(footnotes continued on next page)

Table A-1 (cont.)

[2] The \$0.32/sq. mi. additional cost for enhancement (\$1.38-\$1.06) is derived from a commercial estimate to enhance a single set of ERTS imagery for the State of New Hampshire (9,300 sq. mi.) as follows:

computer costs	\$0.27/sq. mi.[a]
photo lab costs	0.05/sq. mi.[b]

[a] the computer costs for enhancement were estimated as follows: a typical charge for computer manipulation of the computer-compatible tapes for one ERTS scene, (to provide reformatting of tapes, LaPlacian edge enhancement, and grey scale adjustment on a Litton format) is \$1,000, a nominal cost of \$0.10/sq. mi. But an entire target area seldom lies within the boundaries of a single ERTS scene. In the New Hampshire case enhancement of 2 1/2 frames was required to cover 9,300 sq. mi., an average cost of \$0.27/sq. mi.

[b] conversion of the enhanced black-and-white film at scale 1:100,000 to CIR transparencies at 1:100,000 led to photo lab costs estimated at \$500, an average of \$0.054/sq. mi.

Appendix B

SELECTED COMPARATIVE COMPUTER
MAPS, NEW HAVEN TEST SITE

The following pages provide an opportunity to compare visually, category by category, what was compared visually melded in Figures 3 through 6, and numerically in Tables 2 and 3. Only four of the nine categories have been selected for illustrative purposes.

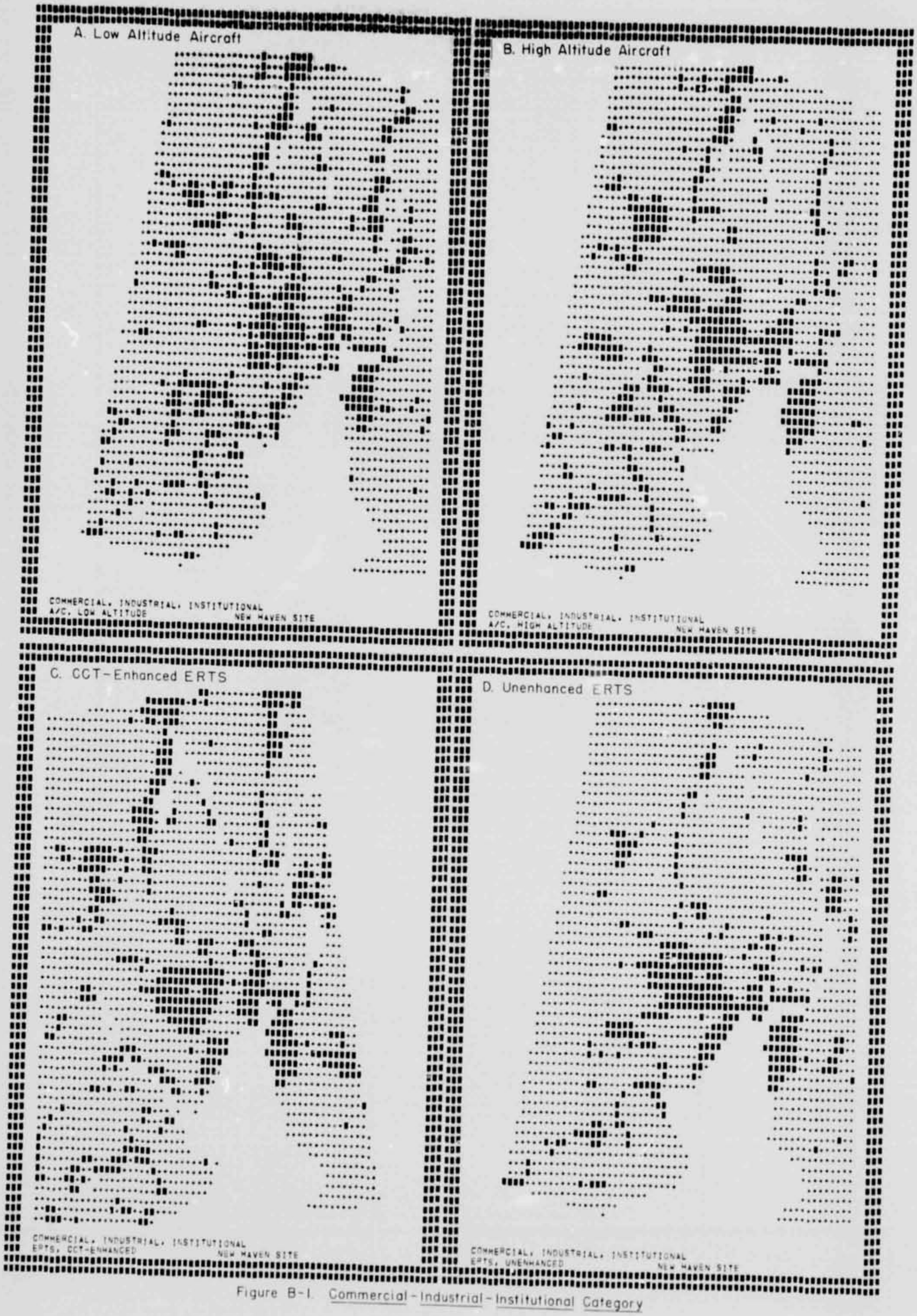

Figure B-1. Commercial-Industrial-Institutional Category

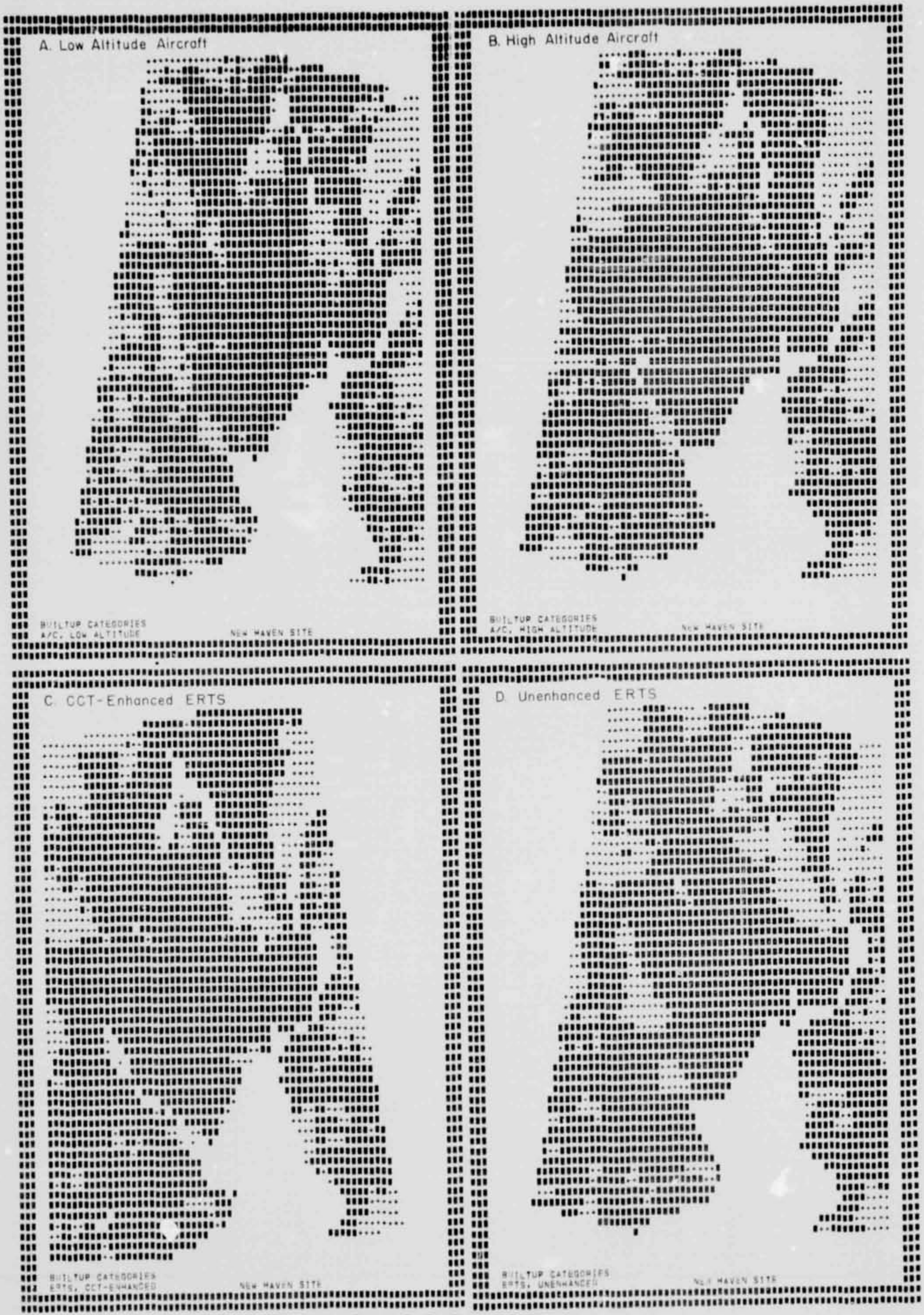

Figure B-2. Builtup Categories

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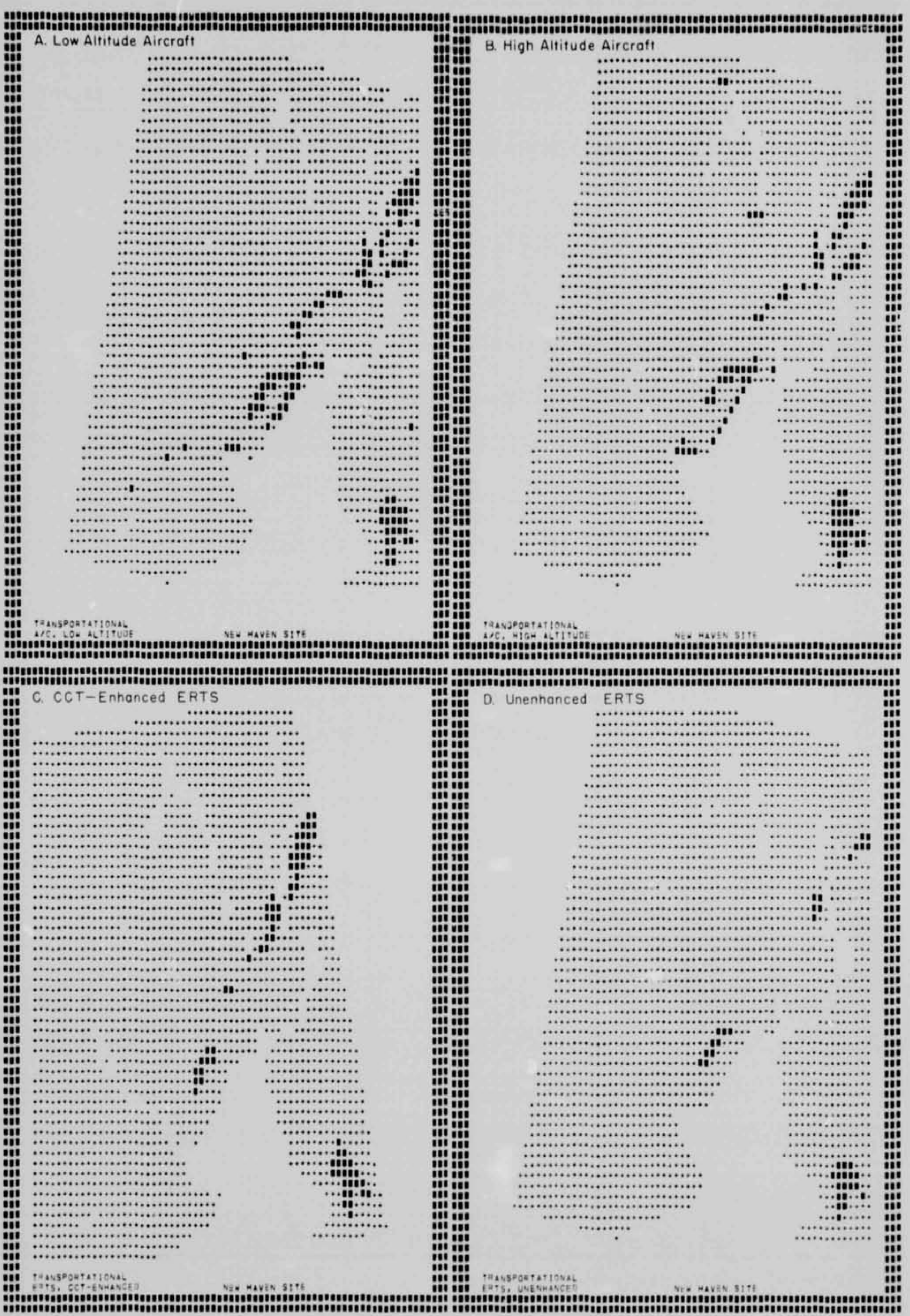

A. Low Altitude Aircraft

B. High Altitude Aircraft

C. CCT-Enhanced ERTS

D. Unenhanced ERTS

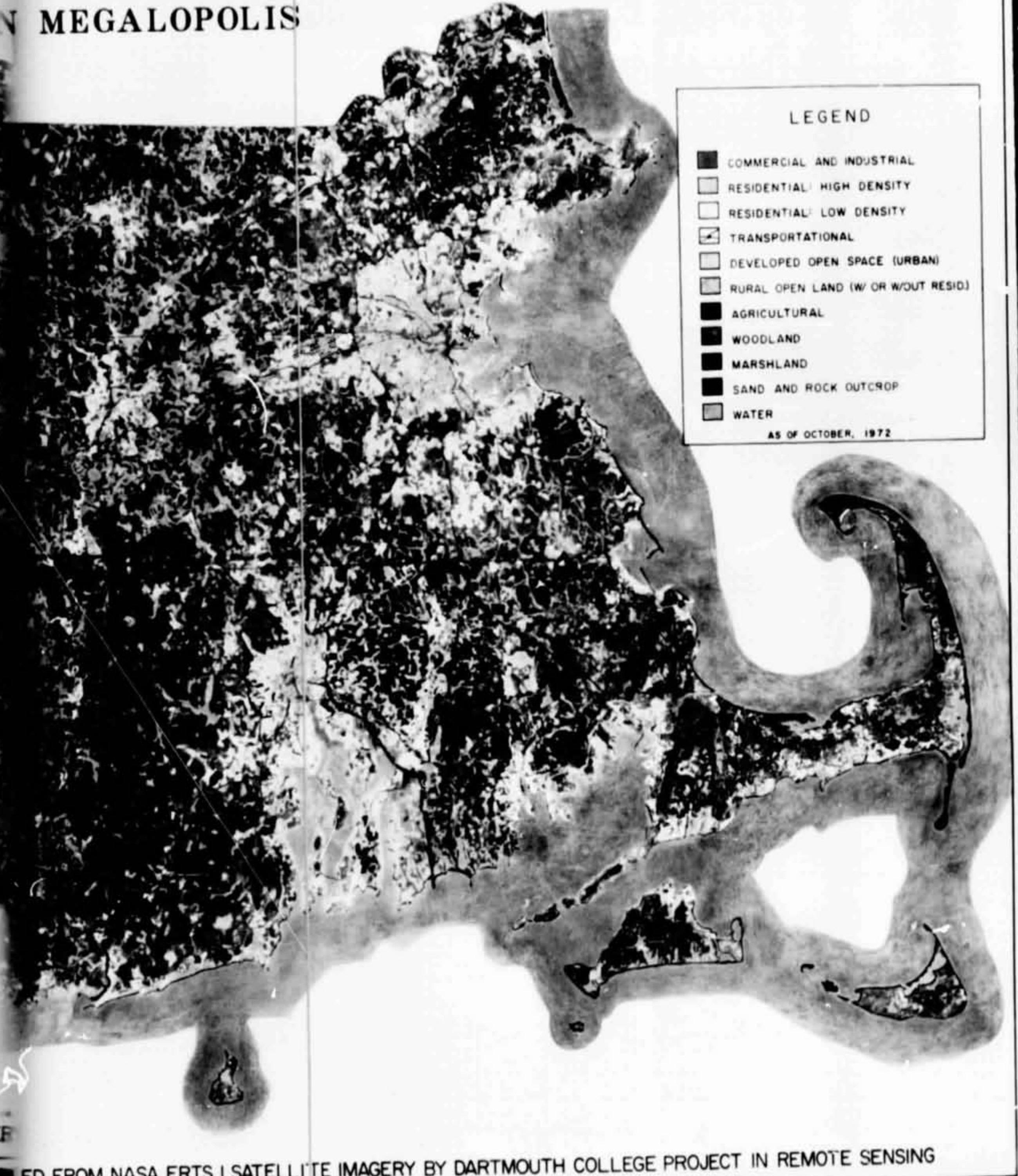
Figure B-3. Transportational Categories

Figure B-4. <u>Water</u>

LAND USE IN NORTHERN MEGALOPOLIS

COMPILED FROM NASA ERTS I SATELLITE IMAGER

N MEGALOPOLIS



LED FROM NASA ERTS I SATELLITE IMAGERY BY DARTMOUTH COLLEGE PROJECT IN REMOTE SENSING

FOLDOUT FRAM