N71-26796
NASA CR-118670

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

INTERAGENCY REPORT USGS-205

PRODUCTION OF A HIGH ALTITUDE LAND USE MAP AND DATA BASE FOR BOSTON

by

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December 1970

Prepared by the U.S. Geological Survey (USGS) for the National Aeronautics and Space Administration (NASA) under NASA contract W-13165, Task No. 160-75-01-35-10 . Work performed by Dartmouth College for the USGS Geographic Applications Program under USGS Contract No. 14-08-0001-12640. ~~This report is not to be resubmitted to NTIS by NASA~~.

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. USGS-DO-71-004	2. Govt. Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Production of a high altitude land use map and data base for Boston			5. Report Date: December 1970
			6. Performing Organization Code
7. Author(s): Robert B. Simpson, Dartmouth College			8. Performing Organization Rept. No.: IR-USGS-205
9. Performing Organization Name and Address: U.S. Geological Survey, Geographic Applications Program, Washington, D.C. 20242			10. Project/Task/Work Unit No.: 160-75-01-35-10
			11. Contract/Grant No.: NASA W-13165; USGS 14-08-0001-12640
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, D.C. 20546			13. Type of Report & Period Covered: Interim, June 1970 - Dec. 1970
			14. Sponsoring Agency Code

15. Supplementary Notes

Work performed by Dartmouth College for the USGS Geographic Applications Program under USGS contract No. 14-08-0001-12640

16. Abstracts

Phase I of a project to create an urban land use map and data base for the Boston sector of Megalopolis involved production of the map of the Boston area proper from CIR photography taken at 60,000 feet, and the establishment of an initial computer compatible data base.

The Boston map together with one for Washington, D.C., are designed to serve as prototypes for the proposed national 26-city program in urban change detection, which ultimately will utilize data from the Earth Resources Technology Satellite (ERTS).

In the creation of the Boston map reliance on the photo interpreter and photo laboratory has been emphasized. The data bank uses a basic map cell which is quite small (0.2 km. on a side) and is UTM addressable. An initial experimental drawing of the Boston area urban-rural interface is provided.

17. Key Words and Document Analysis. (a). Descriptors

Land use, Photointerpretation, Data processing

17b. Identifiers/Open-Ended Terms

ERTS

17c. COSATI Field/Group 8F, 5B, 14E

18. Distribution Statement	19. Security Class (This Report)	21. No. of Pages
Unclassified - Unlimited	UNCLASSIFIED	45
	20. Security Class (This Page)	22. Price
	UNCLASSIFIED	$3.00

FORM NBS-867(1-70)

ABSTRACT

This report summarizes the work done during the six months duration of Phase I of a contract to create an urban land use map and data base for the Boston Sector of Megalopolis. It covers production of the map of the Boston area proper from CIR photography taken at 60,000 feet under the NASA Earth Resources Aircraft Program in September 1969, and establishes an initial computer compatible data base.

The Boston map together with one for Washington, D. C., are designed to serve as prototypes for the proposed national 26-city program in urban change detection, which ultimately will utilize data from the Earth Resources Technology Satellite (ERTS).

In the creation of the Boston map reliance on the photo interpreter and photo laboratory has been emphasized. The data bank uses a basic map cell which is quite small (0.2 km. on a side) and is UTM addressable. An initial experimental drawing of the Boston area urban-rural interface is provided.

It is proposed that in Phase II the 1970 census data be used as it becomes available; the map be expanded to include the New Haven area in order to form the broad base required for proper utilization of ERTS imagery; and the data bank be activated to describe the patterns and predict the trends of the urban fringe of this part of Megalopolis.

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PRODUCTION OF A HIGH ALTITUDE LAND USE MAP AND DATA BASE FOR BOSTON

I. INTRODUCTION

The contract was awarded to produce land use map coverage and associated land use and populational data for the Boston area of Megalopolis (Figure 1), based on aerial photography taken at the high altitude of 50-60,000 feet. Phase I of the contract was designed specifically to deal with the urban area of Boston proper, and was to serve as one of two prototypes for a 26-city program of urban-change mapping from high altitude imagery. The other prototype city is Washington, D. C.

It is envisioned that this city mapping program will serve as a bridge between the medium - and low-altitude land use mapping projects of single cities in the past, and the newer multi-city approach which will be initiated with the launch of the ERTS-A satellite in April 1972. Mr. James Wray of the U.S. Geological Survey was designated as the responsible individual for the two-city prototype program, and is the focal point in the exchange of guidance and completed work between the contracting office and the contractor.

Award of the contract for the study of the Boston end of Megalopolis to Dartmouth College was the logical outgrowth of several years of continuous association with the Geographic Applications Program, and of designation of this writer as Principal Investigator for the New England Test Site of the NASA Earth Resources Aircraft Program in 1968.

Although funds for Phase I were not actually available until 8 September 1970, full scale work began on 15 June 1970 in order to take advantage of the three summer months of the academic calendar. Photography used was that taken by the NASA-MSC RB-57 aircraft on its Mission 103, 7 September 1969, from an altitude of 60,000 feet.

The research team included, in addition to the Principal Investigator, Dr. David T. Lindgren, Assistant Professor of Geography at Dartmouth College, in charge of photo interpretation aspects, and Dr. Robert S. Yuill, Assistant Professor of Geography at the State University of New York, Buffalo, in charge of data base aspects, and in residence at Hanover for the summer. Key photo interpreter was William Berentsen, Dartmouth '69, presently

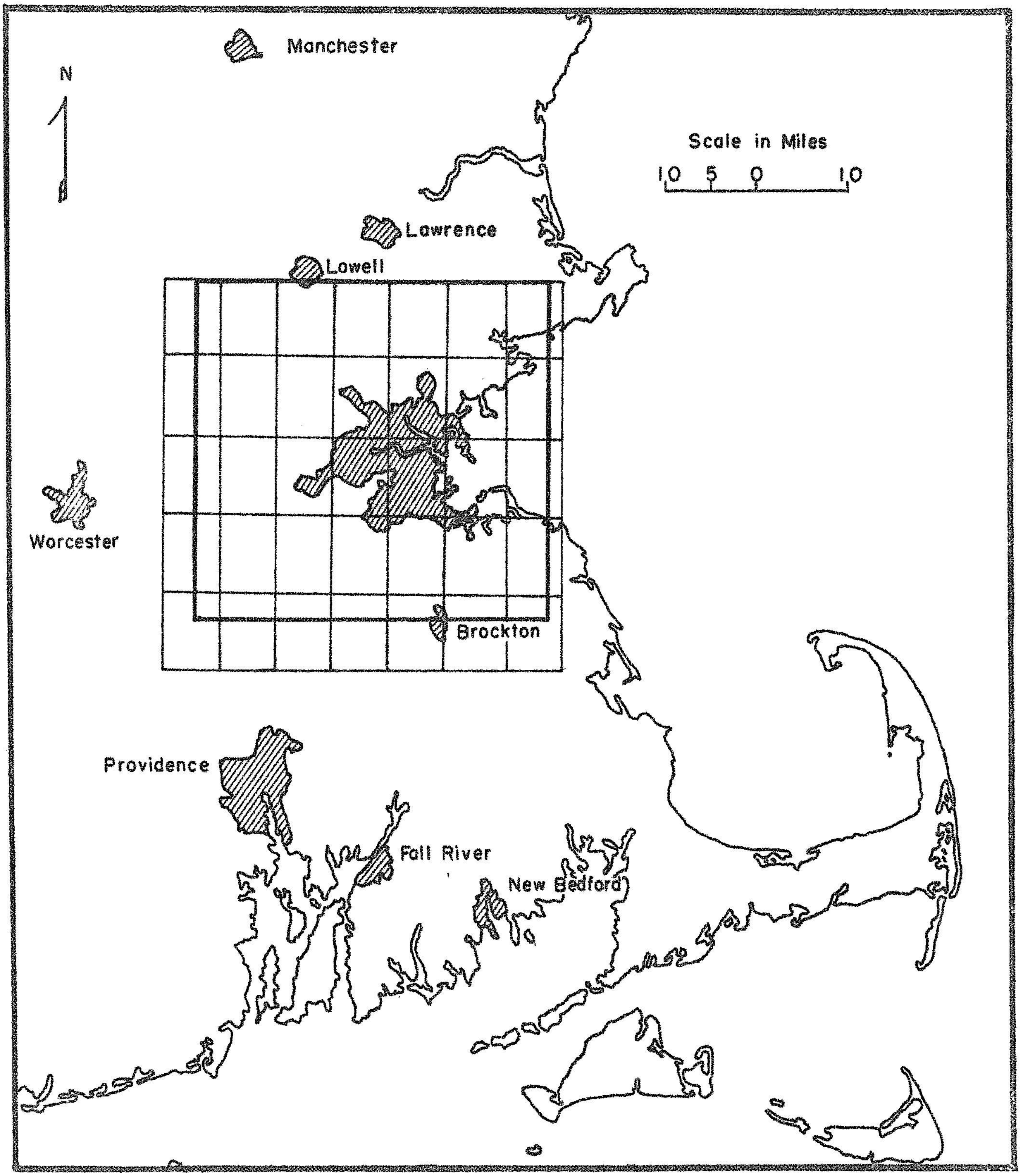

Figure 1. Orientation Map.

The land use map covers the area inclosed in the heavy black square. The smaller rectangles represent the thirty-five 7 1/2-minute topographic quadrangles involved in the study.

a graduate student at Ohio State University. When the undergraduate who was to be the other half of the interpretation team failed to materialize, the project was fortunate to find available the experienced photo interpreters of the Photo Interpretation Corporation, newly organized at Hanover. Although it was originally expected that Professor Robert Barden of Pennsylvania State University would be available as an authority on rural-urban boundary phenomena, his attachment to the team had to be suspended for reasons of economy. John C. Buschmann, Dartmouth '70, has been graduate research assistant since 15 September 1970.

Since the concept of the 26-city urban change program is one of innovation and the contract with Dartmouth calls for a prototype, it was felt desireable to experiment even though ultimate standardization would be necessary in a program involving up to 26 different contractors across the United States.

Accordingly, the approach for Boston was determined to be that which would maximize use of the photo interpreter and the photo laboratory rather than to emphasize cartographic processes. The latter, it was felt, more properly would be emphasized by the U.S. Geological Survey, in-house, in the creation of the Washington D.C. prototype. Thus the initial land use interpretation was plotted directly over the imagery, on a light table, rather than on a topographic base map. Conversion of the resultant land use photo overlay to the scale required for the standardized product was done in the photo lab, rather than as a part of the interpretation process. This tradeoff has resulted in a gain in the opportunity for the interpreter to interpret (directly on the photo), at the price of some loss of scalar accuracy in transferring the interpreters product to traditional topographic map scales by photo laboratory methods.

The second major innovative element in the project was the decision to differentiate data bits in photo interpreation, almost down to the smallest practicable parcel. This meant discriminating down to the size of individual buildings - say 100 feet. In terms of data bank cells, this meant a spacing of UTM addressable data collection points every 0.2 of a kilometer, which is approximately 650 feet.

A chronological listing of the materials furnished the Government under Phase I is contained in Annex A.

II. MAKING THE LAND USE MAP

1. The Legend

Considerable experimentation went into the design of the legend (Table 1). The result was a 24-category legend limited, not by the resolution of the photography, but by the practicalities of symbolization. The small size of the land use parcels mapped made it impossible to differentiate categories by the usual methods of pattern variation (such as cross hatching or stippling) and limited major categories to the eleven land use associations which could be discriminated by color. (Even two of these, differentiated by different shades of red, tended to be indistinguishable after the manuscript had set for a few days, and had to be retouched manually on the photos).

It proved practicable to extend the legend by seven more categories with the addition of a single dot in the center of each major land use association symbol, to highlight relatively large areas of selected "special uses" (see indented items, such as "apartment complex" and "shopping center", in Table 1).

In addition, a traditional pattern differentiation of seven transportation and utility items was possible (see Table 1), bringing the number of items differentiated to the total of 24.

It is regretted that in the case of the major association "vacant land" (non-cultivated land, open land and vacant lots; including pasture, marsh and abandoned farms), the special-symbol dot was not used to indicate land vacant by reason of physical unsuitability (such as marsh or rock). No special use was highlighted within the forest category, either.

2. Photo Interpretation Equipment and Techniques

Workhorse of the interpretation equipment was a Richards elevating light table (GFL-940 MCE) with Bausch and Lomb Zoom-70 stereoscope. This equipment was used up to 16 hours a day for much of the summer. It was used in the binocular, monoscopic mode, and normally at a magnification of only 5X.

Second basic piece of interpretive equipment was a home built light table with several unusual design features, including illumination strong in the 3000-4000 Kelvin range to maximize the CIR magenta hue, and with extra wattage to facilitate working with the slight underexposure which often characterizes the outer margins

TABLE 1

LAND USE LEGEND

<u>(Major Land Use Associations plus selected special uses)</u>.

Residential, single family (yellow)

Residential, multifamily and mixed (orange)
    Apartment complex

Commercial (carmine)
    Shopping center

Industrial (including wholesale warehouses) (heliotrope)
    Extractive gravel pits and quarries

Institutional (including cemeteries) (dark blue)
    Waste disposal (sanitary fill, sewerage plants, junk yards)

Recreational (including outdoor theaters) (light green)
    Golf course

Cultivated land (row crops, cover crops, fallow) (brown)
    Orchard

Non-cultivated land, open land, vacant lots (including pasture, marsh and abandoned farms) (uncolored)

Woodland (dark green)

Water (light blue)
    Small boat anchorage

Transportation and utilities (black)
    Highway with interchanges
    Railroad
    Airport
    Railroad yard
    Transmission line
    Power plant or substation
    Water supply treatment plant

of CIR frames. Optics was a Spencer Cycloptic stereoscope 52 M-1, used in the same mode as the Zoom-70. Both of these instruments have their optics far enough off the light table to permit simultaneous drawing and direct viewing, a great advantage in speed and accuracy.

It should be emphasized that interpretation on both of these sets of equipment was done directly, in the form of transparent land use overlays to the 1:120,000 CIR, cut-film, positive transparencies. For further information on techniques, see Annex B by Dr. Lindgren.

In evaluation of the technique of drawing the land use map as an overlay to an aerial photograph rather than to a topographic sheet, it is felt that this was an unqualified success. The interpreters like it, since it left them free to interpret what they saw and move on, rather than tranuslate what they interpreted to a symbolized map base at a vastly different scale (from 1:120,000 to 1:24,000).

Also, many of the topographic sheets were out-of-date, and would have required extensive "sketching in".

Our careful estimate of interpretation time saved by the method used was "at least 50%". It is recognized that if our self-imposed requirement of detail in interpretation had been relaxed, if the difference in scales between photo and topographic sheets had been less, and if the topographic sheets had been strictly up-to-date, time savings would have been reduced somewhat. Nevertheless, this method produces a much more detailed and accurate map and data bank, along with savings in time and money. The method required only that equipment be available in which the optics is far enough above the light table to permit drawing "beneath the optics".

The Washington, D. C. prototype land use map manuscript, being drawn as an overlay to a topographic map rather than to the photography, was produced at the topographic map scale (1:24,000). Both prototypes presumably have met in the cartographic production facilities of the Topographic Division of the Geological Survey, at a scale of 1:62,500, the Boston version having been photographically enlarged from 1:120,000 and the Washington versions reduced from 1:24,000.

Creation of the manuscript land use map by the equivalent of two full-time interpreters began on 15 June and ended on 9 August, a total of approximately 14 man-weeks. Three additional weeks were used in field checking and on interpretation verification, at the same time that photo laboratory experimentation was in progress. Two additional weeks were consumed in production processing at an industrial color photo laboratory in Boston, so that the final land use map was ready on delivery to Washington about three months after start.

III. COMPILING THE DATA BANK

1. Converting Map Information to Machine Readable Information.

As indicated in Section I above, a major objective of Phase I has been to take full advantage of the tremendous land use discriminatory capability inherent in this RC-8, CIR imagery, even at a scale of 1:120,000.

Accordingly, the basic unit mapped by the interpreter frequently was at the individual building level; the number of separate land use parcels in the map probably exceeds 120,000.

After both a theoretical and practical study which is described in Annex C, it was decided that the basic data bank unit would be a square cell 0.2 kilometers (approximately 650 feet) on a side. At the working scale of the map (1:62,500) these 0.2 x 0.2 kilometer cells are approximately 1/8 inch (0.125 inches) on a side. There are 90,000 of them on the map, each identifiable and re-addressable in terms of the UTM grid, to an accuracy of 0.15 kilometers (approximately 500 feet).

Conversion of the land use map to digital data bank inputs could not begin, of course, until photo prints of the map at scale 1:62,500 became available on 25 September 1970. Utilizing a half-dozen part-time non-professional people, the conversion of the 90,000 data points to land use information was completed in three weeks, on 10 October.

2. Relating the Land Use Data Bank to the 1970 Census

A major aim of the 26-city urban change project will be to integrate the sensor-derived high altitude land use and population density data with the results to the 1970 census. While much essential preparatory work has been completed, the heart of this objective cannot be completed until complete 1970 census data are available, probably early in 1971.

By special arrangement with the Bureau of Census, however, maps of the 1970 census tract boundaries became available in July. Consolidation of the smallest census tracts into slightly larger ones (to increase the statistical accuracy of the land use data associated with each) and drafting of census boundaries on the appropriate 1:24,000 topographic sheets (to improve the dimensional accuracy of the tracts) was begun immediately, and completed in two weeks. Photographic reduction of these census tract boundaries to 1:62,500 scale to match the land use map, and on transparent stable-base material to permit their use over UTM gridded topographic maps, required another two weeks (Figure 2). Since figures for the areas of these tracts were not available and would not be available for many months, they were measured. These area measurements are accurate to within 1.3% on the average; 95% of them are accurate to within 4.7% (see Annex C).

Meanwhile one week was invested in the UTM gridding with a 1-kilometer grid of the 35 pertinent topographic sheets. Three additional weeks elapsed in experimental, and then in production, photo laboratory work, reducing the gridded topographic sheets to the scale 1:62,500.

Final step in the Phase I data bank operation was the manipulation of the 11-category land use associations for the 90,000 data points, to produce summary statistics on land use by census tract for the entire 1,088 square nautical miles of the Boston area. Using the GE-635 computer at the State University of New York, Buffalo, which is the same type as the one used during the summer at Dartmouth, it was possible to program and to convert the data inputs to census tract averages in two weeks of part time work. The results are summarized in a graph (Figure 3).

> Note: In combining the land use of each of the 90,000 grid cells into statistics for land use by census tract, the reliability of the results depends upon the size and shape of the census tract, being most reliable (approximately 95%) in the case of the large and regular-shaped tracts. Furthermore, the reliability of the land use statistics for any tract is high for any land use category which dominates the tract, and is low for any miniscule category. The reliability to be expected for any given combination of tract size and land use percentage can be read off the graph produced by Dr. Yuill as Figure 3 in Annex C.

3. <u>Comment</u>

The data bank has tremendous potential for describing, analyzing and predicting land use and population trends in the Boston area. It holds the key to an evaluation of inter-city land as a disappearing natural resource, and to a timely utilization of similar data to be derived from the Earth Resources Technology Satellite (ERTS) in 1972.

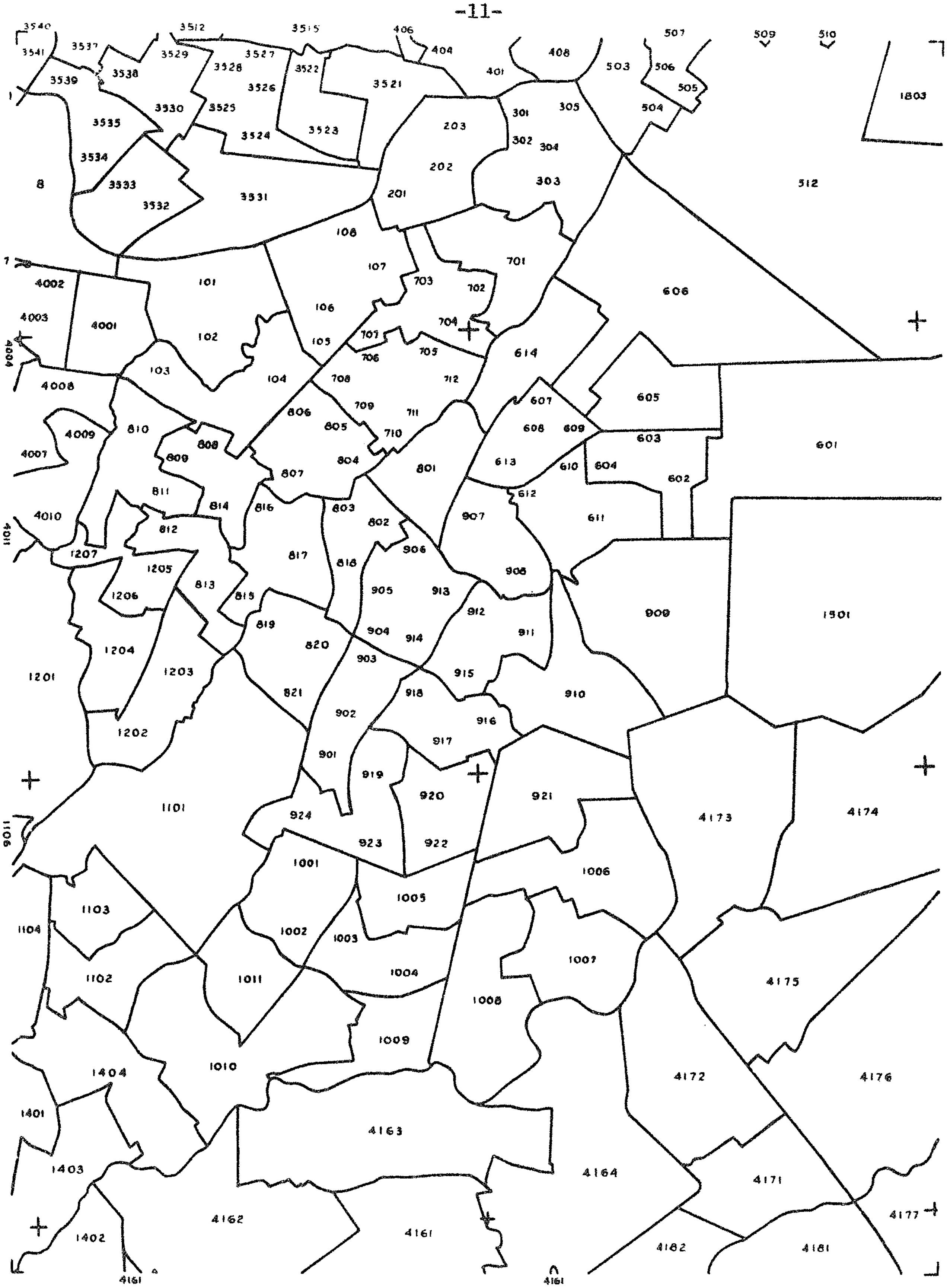

Figure 2. <u>1970 Census Tracts of the Boston, South, Topographic Quadrangle.</u>

Some small tracts have been combined to improve statistical sampling accuracy. At the outer fringes of the Boston area some tracts are ten to twenty times as large as these.

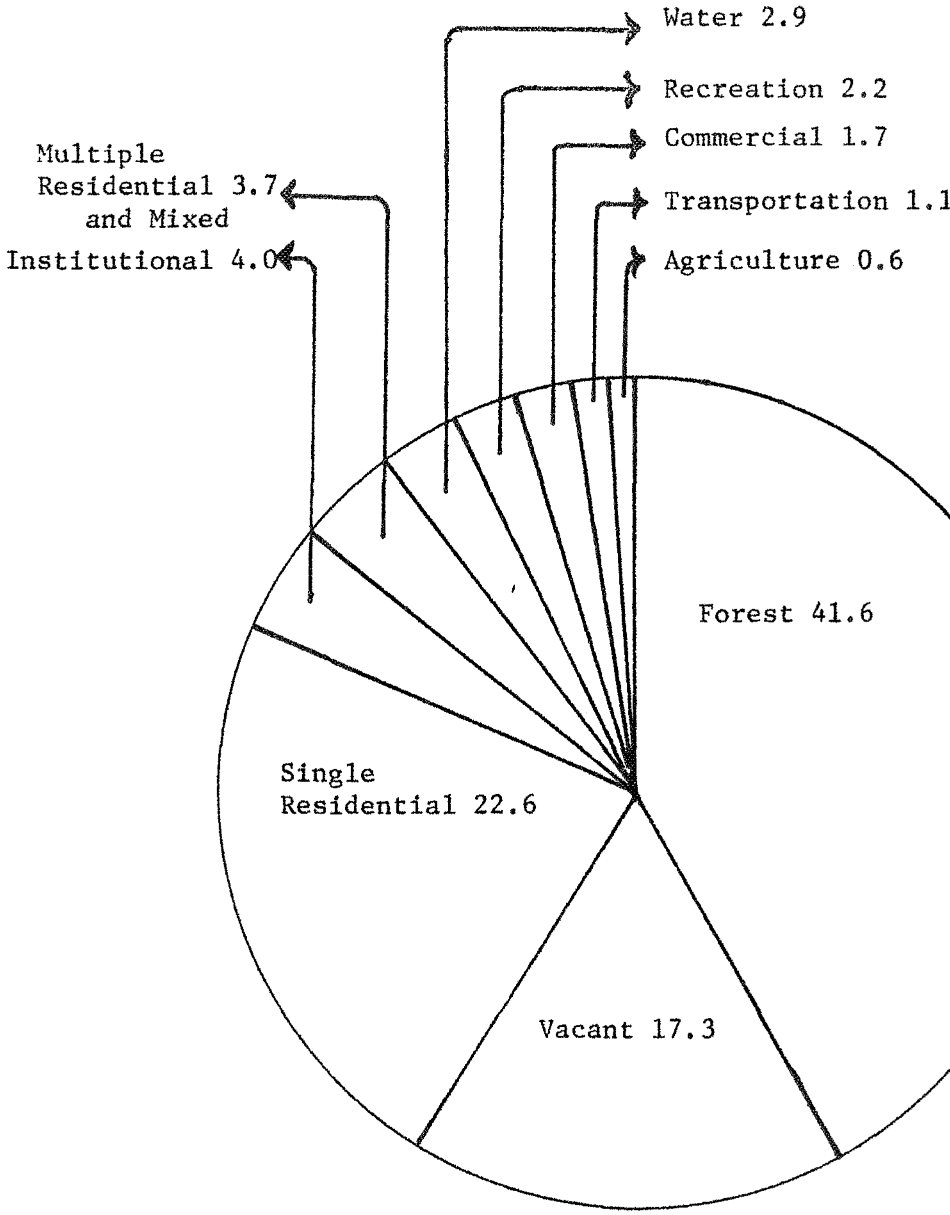

Figure 3. <u>Percentage of the Boston Area in Various Associations of Land Use, 1970</u>

Even in this urban environment unused land occupies almost 2/3 of the landscape.

IV. DRAWING THE URBAN-RURAL INTERFACE

One of the primary objectives of the overall contract is the exploration of the boundary zone between the urban and rural land uses and population densities. After considerable investigation of this phenomenon on the imagery, on the land use map once it was completed, and in the field, it was decided to draw three experimental lines representing the urban-rural interface, as follows:

(1) one based on the land use map, using purity and extensiveness of residential areas as the principal criterion.

(2) one based on a re-study of the actual aerial photography, using rooftop counts times number of people per dwelling in each specific Town as a surrogate for population density, and using the criterion of 1,000 people per square statute mile over an area of at least one square kilometer as the basic criterion for urban status.

(3) one based on the official 1970 census determination of where the urban-rural boundary falls. The census uses a minimum population density of 1,000 per square statute mile for urban status, but the areal unit is an "enumeration district", which is a subdivision of a census tract, rather than a square kilometer.

Unfortunately the data needed to draw line (3) are not yet available. However, on an advance basis a tentative but official Bureau of the Census boundary line has been made available. It shows the maximum possible distance out from the heart of Boston where the interface could fall, based on initial 1970 returns. Attached as Figure 4 is a map showing (1) the latter, preliminary maximum Bureau of Census line, (2) the final official Bureau of Census urban-rural boundary for 1960, and (3) the boundary as developed under this contract from study of land use patterns (item (1) above).

An adequate delineation of this boundary must await (1) the opportunity to manipulate the urban-rural aspects of the 90,000 data points, now that the data bank is complete in this respect, and (b) completion of the official Bureau of Census compilation.

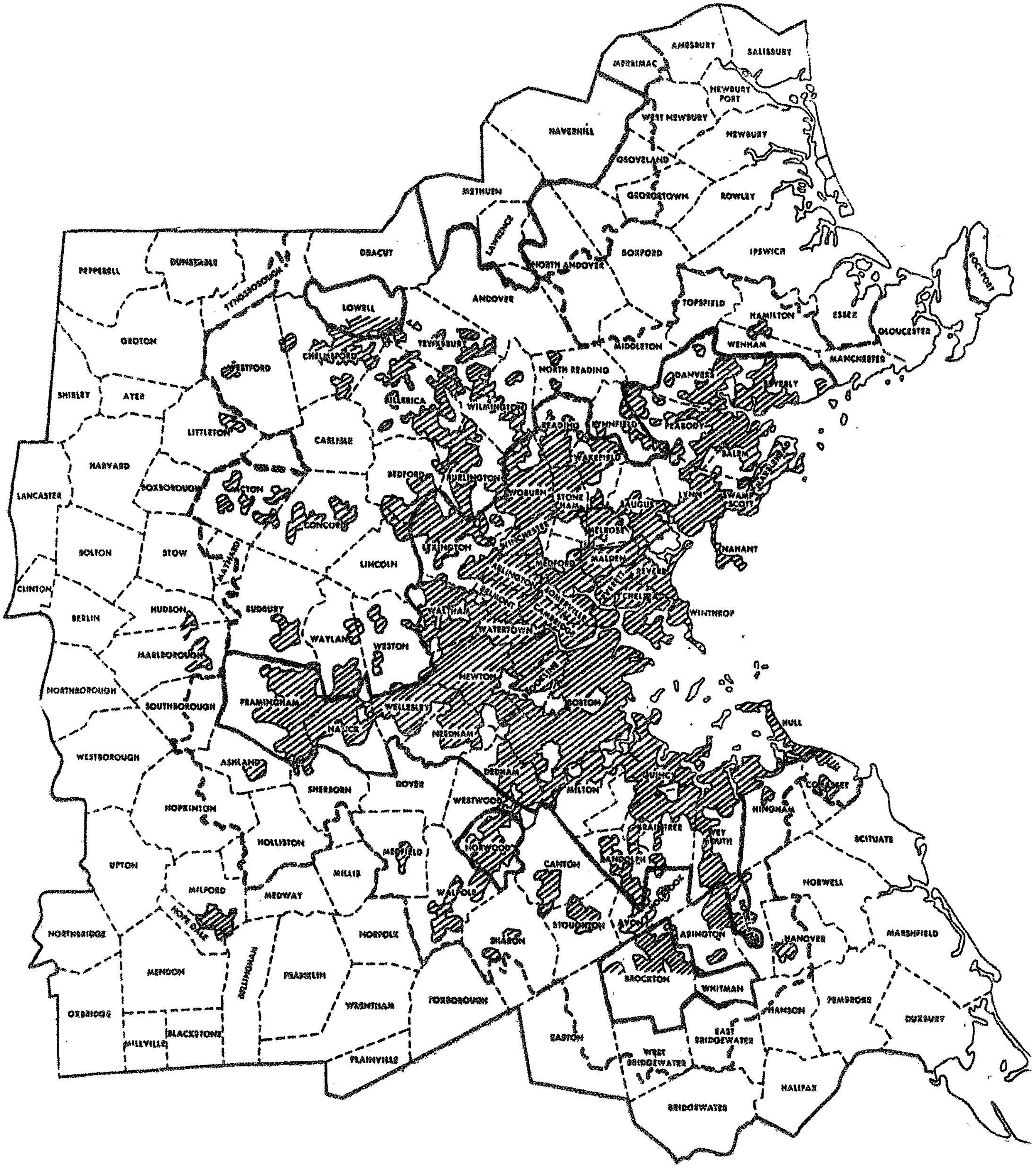

Figure 4. <u>The Urban-Rural Interface in the Boston Area.</u>

The present urban area, as revealed by the land use map, is cross-hatched. The 1960 official Bureau of the Census urbaniz area is shown bounded by the solid line. The concept of the probable outermost limits which the 1970 official Bureau of th Census urbanized area could take is shown by the dashed line.

V. INTERIM INFORMATION ON SOME SPECIFICALLY REQUESTED TOPICS

1. Cost Experience

In order to forward this report prior to the expiration of Phase I on 15 December, cost figures have been cut off on 1 November. The $21,470 spent between 15 June and that date can be allocated among the three principal functional requirements as follows:

TABLE 2

COST BREAKOUT BY FUNCTIONS

To produce the land use map	$ 7,034
To produce the land use numerical data base	9,574
To produce the preliminary urban-rural interface maps	1,130
Total assignable costs (direct and indirect)	$17,738
Non-assignable costs (overall management, equipment, materials, etc.)	3,421
GRAND TOTAL TO 1 NOVEMBER 1970	$21,470

Since the 7-1/2 minute USGS topographic sheet was the basic unit of photo interpretation and other operations, and since it is understood that the topographic quadrangles also will be the basic units for the 26-city program, cost figures have been computed per topographic sheet unit:

Number of topographic sheets involved (including fractional sheets)	35
Number "whole topographic sheet equivalents"	26
Cost per "whole topographic sheet equivalent" ($21,470 ÷ 26)	$ 814

Since this contract experimented with an operation system which maximizes direct use of photography and photo laboratory processing, an attempt has been made to compare costs for this system with those for drawing the land use map on a topographic sheet basis as was done for Washington, D. C. If the basic photo interpretation had been done directly on a 1:24,000 topographic sheet instead of on the photography, and ensuing operations had been modified accordingly, it is estimated that the cost per sheet would have been $1,008 rather than $804. This results from an increased labor (photo interpreter) cost not offset by the modest savings in the photo laboratory.

2. Potential Users and Uses

Time does not permit development of this subject before Phase II. However, active contacts have been made with several of the agencies shown on the attached list (Annex D). It represents agencies which already have made or sponsored significant studies of land use in and around Boston. High priority in the future will be given to developing contacts with them and similar agencies.

3. How to Handle Changes in Land Use during the 1970-72 Interval.

a. Introduction

The present study shows the land use of the Boston area as of 1970. Being based on 9 x 9-inch CIR transparencies at a scale of 1:120,000 (taken at 60,000 feet), it constitutes a bridge towards the Earth Resources Technology Satellite imagery, which also will be in a 9 x 9-inch CIR format, but at a scale of approximately 1:811,000 (and an altitude of 2,618,000 feet). The area covered by a single frame in the present study is the until-now impressive figure of 17 nautical miles on a side. The ERTS imagery will encompass 100 nautical miles on a side, which means that a single frame of the satellite photography will cover an area seven times that of the entire Boston area study. Using this imagery it is probable that any details of internal city patterns will be bonuses. On the other hand the size and shape of the city should be revealed clearly, and studies of intercity patterns will be greatly facilitated.

Maps like the present one of land use of Boston will in effect pull cities having special interest out of the broad background matrix of an ERTS photography or land use map to provide a detailed "zoom" closeup, at scales which until now have been classed as "small" but must in the future be reclassified to "medium large".

The ERTS program includes the capability for simultaneous high altitude aircraft coverage at a scale of 1:100,000. This will provide a "same-scale update" capability for the present (1970), census-contemporaneous maps and their computer data bases. It will permit the ERTS imagery to be interpreted fully, serving the same purpose as ground truth does for low-level photography, and it will facilitate the solution of intermediate scale as well as small scale problems.

b. Three Options

The question remains as to what scale to use for comparisons of the ERTS and RB-57 products. This writer has considered three possibilities: (1) 1:100,000 - the RB-57 scale, (2) 1:811,000 - the ERTS scale, and (3) 1:250,000 - an intermediate scale.

(1) The 100,000 RB-57 scale would require 14X enlargements of ERTS photography, believed to be excessive for photographs taken with conventional, 6-inch focal length mapping cameras. However, the enlarged result would have the advantage of matching the present RB-57 products: both the maps and the data bases with their 0.2 kilometer grid cells.

(2) Since coverage of vast areas at the small scale of 1:811,000 is the heart of the ERTS program, there is powerful logic favoring working at this scale and translating other data down to it. The 0.2 kilometer, 1970 RB-57 data bank cells would be less than 1/100th inch on a side at this scale. Obviously they would have to be multiplied up to 1-kilometer or 2-kilometer grid (1 1/4 mm. and 1/10 inch, respectively, at a 1:811,000 scale).

(3) As a compromise scale 1:250,000 has been considered. It has the advantage of being a widely used scale, and of being truly intermediate: 3.2X the ERTS scale and 1.4X the RB-57 scale. The 0.2 kilometer grid cells of the 1970 map and data base of Boston would be only 1/32 inch on a side at this scale, so should be multiplied up to 1 kilometer (1/6 inch) on a side.

c. Discussion

In advance of a test program it is felt that the intermediate 1:250,000 scale should not be accepted as the only one, since it would not rigorously test the ERTS "natural" scale. Rather it seems probable that working at both the two extreme scales (1:100,000 and 1:811,000) would prove more useful. However a test program to compare the utility of all three scales is called for.

An exhibit having considerable usefulness for comparative evaluation would be one which consisted of side-by-side examples of three versions of the Boston area, each at a scale of 1:811,000 - one from ERTS photography, one from RB-57 photography, and one from the 1972 land use map derived from RB-57 photography. Each picture would be about 3.2" on a side.

An even more informative variant would consist of a similar set of triplets, at the same scale but larger in size, covering the entire New England portion of Megalopolis. Consideration of New England as a natural unit of Megalopolis is based on more than "Yankeeism", for the great northeastern United States urbanized strip tends to break rather evenly into thirds: a New England third, a New York-New Jersey third, and a Delaware-Virginia-Maryland ("Delmarva") third. Each third has its own regional characteristics.

VI. CONCLUSION AND RECOMMENDATIONS

1. Conclusion

The primary objective of Phase I has been the timely creation of a land use map of the Boston area, suitable to provide a base for effectively utilizing information derived from future high altitude aircraft and satellites as well as from the 1970 Census when available. It is believed that this objective has been accomplished.

2. Recommendations

a. That the following techniques, developed or explored experimentally in Phase I, be fully evaluated by the Geographic Applications Program to determine their applicability to the 26-city program:

(1) maximum reliance of photography and the photo laboratory in creating the urban land use maps.

(2) Use of the single-dot technique for expanding a basically color-coded land use mapping legend into symbolization of smaller parcels that can be done by the more common methods of color-screening and pattern variation.

(3) Development of the UTM addressable, small size cell to serve as the basic unit for the urban land use data bank .

b. That the data bank now being completed from the information revealed by the Boston area land use map be utilized fully in Phase II of this contract to explore it as a means of describing, analyzing and predicting land use and population density trends in the Boston area, and of studying intercity land as a disappearing American resource.

c. That the term "Boston Sector of Megalopolis" as used in this contract, be defined during Phase II to include the New Haven "satellite" area in order to provide a data base large enough to realistically evaluate the very large area coverage per frame which the ERTS will provide.

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ANNEXES

ANNEX A

CHRONOLOGICAL LISTING OF MATERIALS

FURNISHED THE GOVERNMENT UNDER THIS CONTRACT

31 July 1970 — Proposed legend for prototype high-altitude land use map of the Boston area (1 page).

5 August — Areas of (1970) Census Tracts in the Boston Area. "Boston census tract combinations", with explanatory notes (19 pages).

8 September — (1) Supplement to Prototype Land Use Map of the Boston Area: Thirty five Topographic Quadrangles. Set of 35 8 x 10-inch b/w photo reductions, to scale 1:62,500, of the 7 1/2-minute quadrangles involved in the study, with a 1-kilometer grid system, UTM oriented, and geographic coordinate tick marks added.

(2) Supplement to Prototype Land Use Map of the Boston Area: 1970 Census Tract Boundaries & Labels. Set of 35 8 x 10-inch, stable-base, transparent overlays for the topographic quadrangles forwarded under (1) above, showing boundaries and labels of the 1970 census tracts.

(3) Six 8 x 10 color prints, being advance samples of the land use maps of six quadrangles, scale 1:100,000. Also photo copy of legend.

18 September — (1) The Prototype Land Use Map of the Boston Area. Set of 35 labelled 8 x 10-inch color prints, retouched, at scale 1:62,500. One for each topographic quadrangle. Plus photographic legend.

(2) Supplements to Prototype Land Use Map of the Boston Area: Maps Nos. 1 and 2 of Limits of the Boston Urban Area, 1970 (Scale 1:120,000). Also explanatory notes.

Map No. 1: Based on the Land Use Map.

Map No. 2: Based directly on the Aerial Photography.

(3) <u>Supplement to Prototype Land Use Map of the Boston Area: Orientation Map.</u>
Drawn on the Boston Sheet (NK 19-4) of Eastern United States, 1:250,000 USGS map series, 1956).

(4) <u>Briefing Exhibits.</u>
Samples of the original 1:24,000 cartography for items shown under (1) and (2) of entry for '8 September above.

1 October

(1) <u>Supplement to the Prototype Land Use Map of the Boston Area: "Technical Notes on the Measurement of Census Tracts and Land Use Areas"</u> by Robert S. Yuill (15 pages).
(Reproduced in this report as Annex C).

(2) <u>Supplement to the Prototype Land Use Map of the Boston Area: Notes on Land Use Photo Interpretation</u> by David T. Lindgren (7 pages).
(Reproduced in this report as Annex B).

(3) <u>Supplement to the Prototype Land Use Map of Boston Area: Exploratory Computerization of Land Use Data for the Wilmington, Massachusetts Quadrangle</u>
Thirteen computer-drawn maps, in 15 x 20-inch format, of various aspects of land use of a sample quadrangle.

(4) Sample "dot-counting" packet.
A transparent UTM-addressable dot grid, affixed to a 1:62,500 color photo panel of the land use map, for compilation of land use statistics. Also included is a sample of the compilation matrix.

7 November

Three 4 x 5-inch negatives of the Lynn quadrangle of the land use map, for pre-publication reporting.

10 November

<u>Supplement to Land Use Map of Boston Area: Land Use in Hectares by Census Tracts</u>
The voluminous machine printout of these computations, for the entire contract area.

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ANNEX B

TECHNICAL NOTES ON THE LAND USE PHOTO INTERPRETATION

by David T. Lindgren

Dartmouth College

EQUIPMENT

The equipment used for the land use interpretation included one Richards elevating light table with a Bausch and Lomb stereoscope; and one home-made light table with a Spencer Cycloptic stereoscope. Although a stereoscopic capability was present, the analysis of the photos was done monoscopically. Checking was frequently done using a 5X hand lens (Kodak Achromatic Magnifier).

GENERAL PROCEDURE

The procedures for the land use interpretation portion of the project were relatively simple. They began by selecting the best photo for each area to be investigated. The selection of photo was based not only upon quality of image but upon the need to center the area under investigation upon the photo. Such centering reduced distortions in the image as much as possible.

Once a piece of acetate had been placed over the photo and secured with masking tape, the boundaries of the USGS sheet to be studied (1:24,000 series) were carefully drawn on the acetate. Transferring the boundaries onto the overlay material was somewhat difficult due in part to the obsolescence of many of the USGS sheets. Features used to fix boundaries had often changed from the time the USGS map was printed.

The next step was to consult adjacent sheets and to trace in the major transportation lines -- rails, roads and powerlines. This completed, interpretation of land use began, working from upper left hand corner to lower right (for comments on interpretation see next section). Upon completion of the interpretation, adjacent interpretations were examined in order coordinate land uses across the borders of sheets.

ANALYSIS OF LEGEND CATEGORIES

Residential

The most difficult choice was whether the dwelling was a single or multi-family residence. In making this decision the relevant factors were relative size of structure, relative location of structure, and presence and quality of vegetation. Large apartment complexes were outlined in black.

Forestland

The only problem in this category was discriminating between forest land and brush land. The latter was rather common and was recorded as vacant; swamp land (forested marshland) was recorded as forestland.

Recreational

This category included a variety of activities. In addition to parks it included golf courses, drive-in movies, beaches, athletic fields, race tracks and marinas.

Cultivated Land

This category referred exclusively to row crops, fallow fields, and orchards. Hayfields, hay crops and cover crops of all kinds were recorded as vacant land since it was difficult to ascertain whether such lands were actively used. Furthermore since very few grains are raised in the metropolitan Boston area the decision to record only row crops and orchards was a valid one. Largest (commercial) orchards were outlined in black.

Institutional

This category was interpreted broadly to include all public or governmental type property. Schools, hospitals, churches and city halls were all recorded as institutional, as were military installations. A major difficulty was the inability to determine the limits of many institutional land uses. The photos frequently revealed no clues to the boundaries of military reservations or state health institutions. Institutional land use, therefore, may well be under-enumerated.

Commercial

The commercial land use category was used for retail and service activities as well as those entertainment facilities not recorded under recreational. Indoor activities such as bowling, the theater, and pool halls were recorded as commercial whereas outdoor activities (golf courses, drive-in movies, beaches, etc.) were recorded as recreational.

Some commercial establishments were unquestionably missed, particularly those attached to, or converted from, private homes and scattered throughout predominantly residential areas. Such establishments would include professional offices, corner groceries and insurance offices to name just a few. Other commercial establishments may have been misinterpreted as light industry. Parking lots provided one of the most helpful keys. By coincidence the imagery was taken on a mid-Saturday morning. Therefore, the empty parking lots were usually indicative of industry or schools. Full or partially full parking lots usually implied commercial establishments. A secondary key of some importance was relative location.

Industrial

Industrial land uses were most apt to be confused with commercial (see preceding explanation of (commercial land use). Keys such as proximity to transportation lines and material storage were helpful. Research and development types of industries were occasionally confused with junior high schools.

Miscellaneous Comments

Railroads were identified easily. However, several abandoned lines caused momentary problems, and it is possible that a few recently abandoned lines have slipped through.

Highways were, of course, very numerous. The only ones shown on the overlays were those with major interchanges or in several instances, important limited access highways.

Airports were circled in black and the runways, taxiways and buildings were also marked in black. Military airports had a further blue border around them reflecting their institutional status.

Streams - only the largest were delineated.

Marshes (non-forested wetlands) were marked as vacant land.

URBAN INTERPRETATION

The urbanized area (City of Boston proper, and inner suburbs) was the most difficult to interpret. The sheer number of buildings per photo to examine was at times overwhelming. Furthermore, the interpreter was constantly faced with making the two most difficult decisions-single family or multi-family, and commercial or industrial.

The question of single-family or multi-family was, in reality, not a difficult one in the central city. The difficulty arose in the inner suburbs where the predominantly multi-family residences such as the well known New England "3-deckers", began to merge with the almost exclusively single family residences of the suburbs. The line between the two is both difficult to define and critical to the land use study.

The problem of commercial versus industrial land uses was found throughout the urbanized area. Particularly troublesome were ribbon-developments of mixed commercial-industrial activities. Also difficult were the old industrial districts found within the city of Boston and the inner suburbs. Again, commercial establishments are found within such districts but they are extremely difficult to recognize.

Institutional land uses were probably the next most numerous. Colleges, hospitals and religious institutions occupy a great deal of the city. While such institutions were readily identified, their boundaries were frequently difficult to ascertain. Most churches and public schools were identified but many public buildings were either missed or included within commercial business districts.

Recreational land uses, in particular golf courses, were readily identified. The regularity of the spacing of golf courses was surprising. Land values and population density appear to be important factors in this pattern.

The only remaining land uses of significance were related to transportation. Airports, railroad yards and highway interchanges occupied a significant portion of urban land uses. These were relatively easy to identify.

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ANNEX C

TECHNICAL NOTES ON THE MEASUREMENT OF CENSUS TRACTS AND LAND USE AREAS

by

Robert S. Yuill

State University of New York, Buffalo

One of the requirements of the Dartmouth Project on Remote Sensing is to relate the data obtained from photo interpretation to the data of the 1970 census. Specifically, the 1970 census tracts are designated as the areal subdivisions of the region and the various proportions of different land use within each are to be calculated. There are two facets to the measurement, the determination of (1) the tract areas, and (2) the land uses within the tracts. The measurement procedures and accuracies of each factor are considered in these notes.

MEASUREMENT OF CENSUS TRACT AREAS

Measurement Base

A number of preliminary steps were taken to provide an accurate base from which the tract measurements could be made. The official tract boundaries of the Boston Region[1] were transferred to USGS topographical sheets at the same scale of 1:24,000. The topographic maps are preferable for area measurements because locations are controlled to national map accuracy standards. The locational precision is not an essential requirement for census enumeration maps.

After the transfer, the tract boundaries were modified in three ways:

1. Very small census tracts were combined to form larger areal units with an attempt made to have the minimum area be approximately one square kilometer. This size represents a threshold level below which measurements of area become difficult and subject to greater possible error. The principal areas affected were in the densely populated parts of Boston.

2. Census tract boundaries along the edges of the study area were often cut by the specified latitude and longitude boundaries. The census tracts were thus truncated and only the portions of the tract areas within the study region were measured.

3. Certain tracts along the Atlantic coast had considerable areas of ocean within their boundaries, or no oceanward bounds were shown on the census maps. For these cases the land area only was measured. This modification was also applied to tracts along major estuaries which met two criteria: (1) at least 20% of the tract was water; (2) this water area was not surrounded by land - such as in the case of a lake.

Area Measurements

The census tract areas were measured by dot planimeter. Semi-automatic processing devices were not readily available, and of the various hand techniques (polar planimeter, grid planimeter), the dot count is operationally the simplest. It is also somewhat faster according to some authors [2] which is an important consideration with a large number of areas to be determined.

One criticism of the dot planimeter has been that it is relatively inaccurate with respect to other modes of measurement. [3] Frolov and Maling, however, have concluded that the theoretical accuracy of point counting techniques can be quite good. They have shown that the order of accuracy is related to the number of points counted and have suggested a minimum of 100 points per area to yield an accuracy of about 1.5% from the true value. [4]

A further complication of measurement is that both the size and shape of an area greatly influence the accuracy of measurement. The combination of small census tracts was designed as a control to limit inaccuracies due to the size of area measured. With respect to shape, it has been shown both by Frolov and Maling [5] and by Gierhart [6] that the more serpentine or less compact an area, the greater the relative inaccuracy of measurement. A convenient index with which to express the compactness is (P/A), the perimeter of a figure divided by its area. [7]

As indicated above, the expected accuracy of measurement for a given figure will be directly related to the number of points used to compute the area and inversely to the P/A index. To establish the relationships, a series of measurements was made on six experimental figures which were varied both in size and in shape. The area of each figure was then measured 40 times by superimposing a dot planimeter with a random orientation for each count. The dot counting procedure differed from those used by the above authors in that points falling on the boundary were considered. The convention was followed that the dots touching the boundary line were summed and half that sum added to the number of dots counted within the area.

Following the standard assumption that measurement errors are normally distributed,[8] the mean area and standard deviation were calculated for each of the six experimental figures. The normal curve thus generated can be interpreted as showing the probability that an area measurement of the same figure (under the same conditions) would be within certain tolerance limits. For example, under these conditions, the probability that a given measurement would be within two standard deviations (2S) of the mean would be .95. The (2S) value can be expressed as a percentage of the mean ($Y = (2S \times 100)/\bar{X}$).

The Y value calculated for each experimental figure is assumed to be a function of the point count and the P/A index of that figure. The relationship can be made explicit in the form of a multiple regression equation with Y as the dependent variable, and the point count and index as the independent variables. The regression equation reads:

$$Y = 3.98 - 0.00227N + 1.18I + e$$

Where: $Y = (2S \times 100)/\bar{X})$

N = No. of points used to measure area (independent variable)

I = P/A index (independent variable)

e = Error term

The two independent variables appear to account for most of the variation in Y since $R^2 = 0.92$. Given this relationship, an expected reliability can then be indicated for the measurement of any individual census tract area.

The census tracts were measured with one of two dot planimeters to insure a sufficiently large point count for the smaller areas. 97.2% of the tract areas were measured with point counts greater than 125. The planimeter was randomly oriented for the count of each area.

Two series of samples were drawn from the measured tracts to estimate the expected overall accuracy. In the first series, four tracts were selected which could be expected to be subject to the greatest fluctuation of measurement. The criteria for selection were that the tracts were small and non-compact, as exemplified by tract number 1205 (Figure 1).

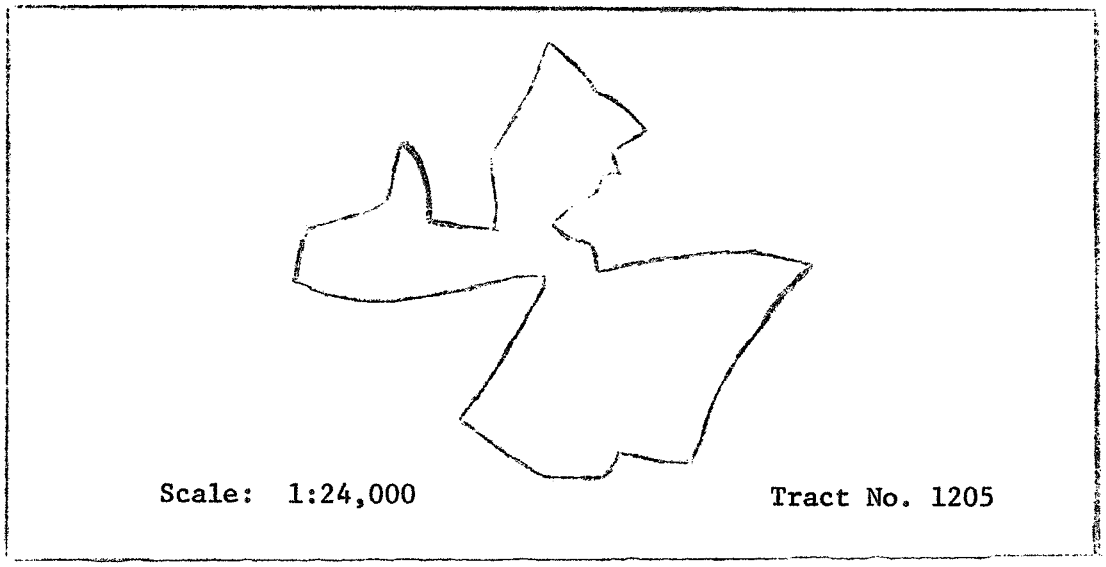

Figure 1. Example of a Small Non-compact Census Tract.

Table 1 shows the point counts, P/A ratios, and the expected range within which a measurement could be expected to fall 95% of the time (Y) for the four tracts.

Table 1

Tract No.	Point Count	P/A Index	Expected Error Range (Y)
103	151	2.938	4.01%
810	240	3.505	2.66
812	267	4.045	2.68
1205	178	4.339	5.05

The worst expected measurement error indicated by this sample would be about 5%.

The aim of the second sample series was to represent the average errors of the tract measurements. A random sample of 10 tracts was taken and the expected error calculations made. The mean expected error (Y) of the sample was 1.32% with a standard deviation of 1.73. If this sample is representative of the whole, then the accuracy of the tract area measurements can be expressed as follows:

A. The average error of tract measurement is 1.32%.
B. 68% of the tract measurements are within 3.05% of the true value.
C. 95% of the tract measurements are within 4.7% of the true value.

The two sample series appear to corroborate each other. The expected worst error calculated from the random sample is approximately equal to the errors calculated for some of the smallest and most non-compact census tracts of the Boston Region.

MEASUREMENT OF LAND USE PROPORTIONS

Factors Determining Measurement Procedures

The area of each land use within a census tract can be ascertained by a variety of techniques or procedures. The choice of measurement procedure is made by a consideration of three principal factors:

1. An important objective of any research activity is to obtain accurate and precise data. One of the best methods of approaching this goal or approximating it is to record or measure the entire population within the universe of investigation. Since this is often not possible, generalization or sampling techniques are necessary. Unfortunately, the statistical accuracies of areal sampling procedures are not as well established as they are for linear data.[9]

2. The second criterion is that of location. With areal or two dimensional data the importance of this aspect of measurement becomes considerably enhanced. Ideally, the exact location and spatial extent of each unit or parcel of land is accurately described in recording the data.[10] This is not always feasible, so there is necessitated a generalization of location within larger areas such as square miles, counties, or census tracts.

3. The last criterion of available resources is probably the most critical of the three for it determines some of the limiting parameters of the first two criteria. If a project has either a great length of time or massive technical support, the goals of precise data and accurate location may be approximated. Otherwise the limitations of the project often necessitate accepting data with lower levels of accuracy than would be desired.

Requirements and Resources of the Remote Sensing Project

The most accurate mensuration of the land area in the Boston Urban Region would entail the measurement of each parcel of land within each census tract. With the amount of detail that was derived from the photo interpretation, the areas of at least 120,000 parcels would have to be determined, most of which are highly irregular, and many of which are extremely small. Measurement of land use by this approach is consequently beyond the resources of the project. The alternative is then a sampling procedure.

The requirement of grouping data by census tract carries with it an inherent limitation of locational accuracy. Locational information is lost when land use is generalized or summed into census tract areas. This becomes particularly important in the outer margins of the urban area where census tracts may cover 10 or more square kilometers. It is precisely in these regions, however, that the urban-rural fringe occurs. Since defining the location of the fringe is one of the requirements of the project, locations generalized into census tracts are not sufficiently accurate. Thus the procedure for determining the land use proportions should be a sampling technique which preserves locational identities.

Sampling Procedure

The regular lattice or checkerboard was chosen as the basic areal sample design. Although it has been indicated that unaligned sampling procedures (particularly stratified) yield results that are unbiased with respect to spatial periodicities, [11] (and thus are presumably more representative of the parent population), those procedures require considerably more time and effort. Further, the very random elements which may produce a more representative sample of land use also reduce the locational accuracy of each datum point.

The sample lattice or grid is based upon and oriented to the Universal Transverse Mercator (UTM) coordinate system. This projection provides a unified square metric grid (1 kilometer interval) over the entire study region. The primary advantages of the UTM grid are that being metric it is easily subdivided and the coordinates are expressed in terms of basic earth dimensions. [12]

A sampling interval of 0.2 kilometers appeared to be the best compromise between fine resolution and the resources of the project. Although the detail of the photo interpretation seemingly warrents a finer sampling resolution, a 0.2 kilometer grid yields a sample point approximately every 650 feet, which is extremely fine with respect to the total dimensions of the study region. At this interval, the sample yields approximately 90,000 data points.

A finer sampling interval would greatly increase the amount of data to be collected and analyzed, and thus inordinately strain the resources of the project.

Locational Reliability

The dot grid (photographically reduced from a scale of 1:24,000) used for sampling was superimposed and registered upon color photographs (scale: 1:62,500) of the land use overlays. Due to some scale variation in the original CIR imagery and distortions from the various photographic processes, some error may be expected in the locations of the sample points. By careful registration of the sampling grid, the locational variation of each sample point can be kept within about .15 kilometers.

Considered as a grid, the sampling mechanism retains the important aspect of relative location. For example, Figure 2 shows some land use parcels within a hypothetical census tract typical of the Boston Region. Whether or not there is some error in the registration of the grid, the data will still clearly show that there is a relative concentration of forest in the upper part of the census tract. If the forest concentration happened to spill over into adjacent census tracts, the grid sample could thus indicate the spatial concentration and location whereas grouping the same data by census tract might obsecure the concentration.

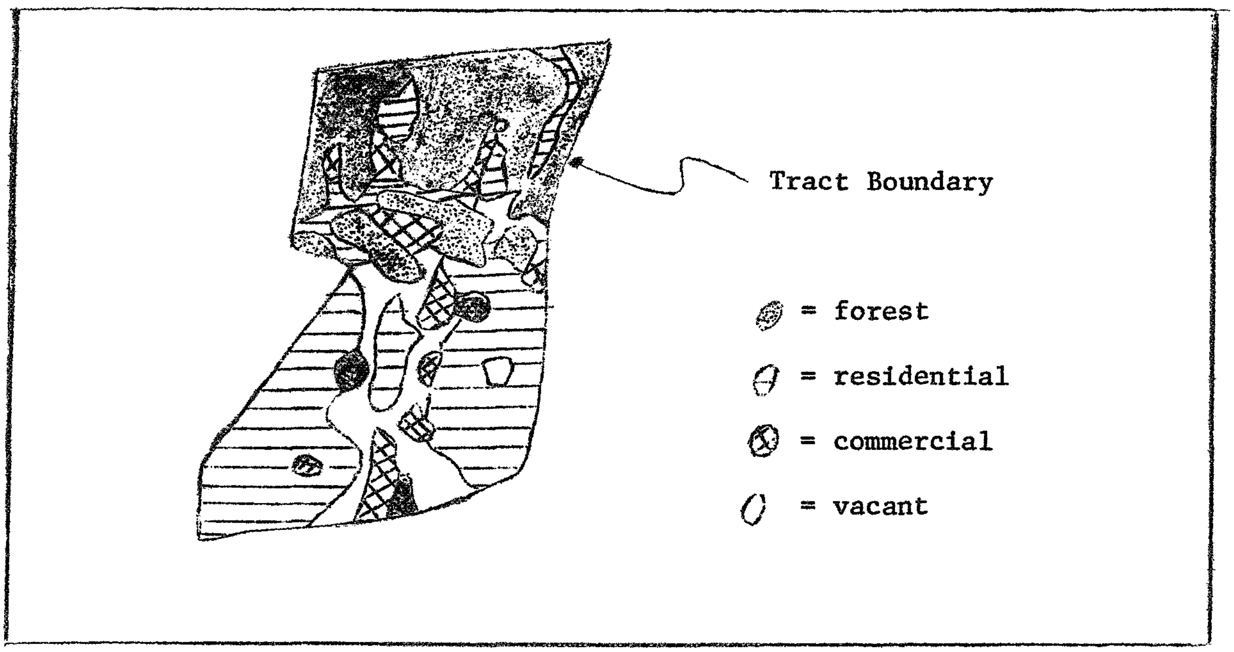

Figure 2. Land Use Parcels in a Typical Census Tract.

Land Use Reliability

If the 90,000 points of the sample grid were allocated equally to the 486 census tracts (and portions of tracts) within the study area, the mean sample per tract would be 185 points. There is, however, a considerable dispersion about this mean (see Table 2) with half the tracts having 75 sample points or less. Since these sample points record eleven different types of land uses, the relative sparseness of points for the smaller tracts becomes readily apparent. Some empirical tests were therefore run to indicate what reliability might be expected.

Table 2

Distribution of Census Tracts by Sample Size

Sample Points per Tract	Per Cent of Tracts
0 - 25	10.52
26 - 50	29.28
51 - 75	10.10
76 - 100	7.63
101 - 150	8.87
151 - 200	9.27
201 - 300	7.63
301 - 500	8.25
501+	8.45

A four kilometer square on the Wilmington Quadrangle land use overlay was selected for the test situation. Approximations to the true values of the land use proportions of the sample area were calculated from an initial sample of 3600 points. These points were obtained by randomly superimposing a 0.2 kilometer dot grid a number of times over the test area.

Thirty test samples were drawn using square dot grids, each covering an area of approximately 2.4 kilometers square and randomly placed within the test area. Ten samples were taken in each of three densities: 144, 36, and 16 points. For each sample, the land use percentages were calculated and the deviation from the 'true' value of each land use determined. The deviations were subsequently averaged within each of the three density categories; representative averages are shown in Table 3.

Table 3

Variations in Land Use Measurements

Land Use	'True' proportion of test area	Mean Variations of Categories from 'true' values		
		144 pts.	36 pts.	16 pts.
Residential	50.17%	6.1%	9.8%	12.6%
Forest	38.44	5.7	12.9	16.1
Vacant	7.08	19.2	42.1	70.9
Industrial	1.69	37.2	93.0	150.1

It is obvious that the reliability of each land use proportion is directly related to the number of sample points in the census tract. It therefore follows (and is corroborated by Table 3) that thos land uses which occupy the greatest portions of a census tract are the most accurately represented. From the values of Table 3 can be derived the series of reliability curves shown in Figure 3. These curves represent the average error to be expected given (1) the size of a census tract, and (2) the approximate percentage of that tract occupied by the land use. For example, if a census tract had an area of four square kilometers and a land use covered about 7% of that area, an average error of 23% could be expected in its sampled value; for a land use occupying 50% of the same area, the expected error would be only 6.5%.

The expected errors of land use proportions indicated by Figure 3 and Table 3 are somewhat larger than could be desired, especially for the smaller tracts. Against this must be balanced a gain in locational accuracy within the census tracts. The measurement procedures described above are thus essentially a compromise among various demands. This compromise, however, was deemed to yield the most return for the resources of the Remote Sensing Project.

Buffalo, New York
8 September 1970

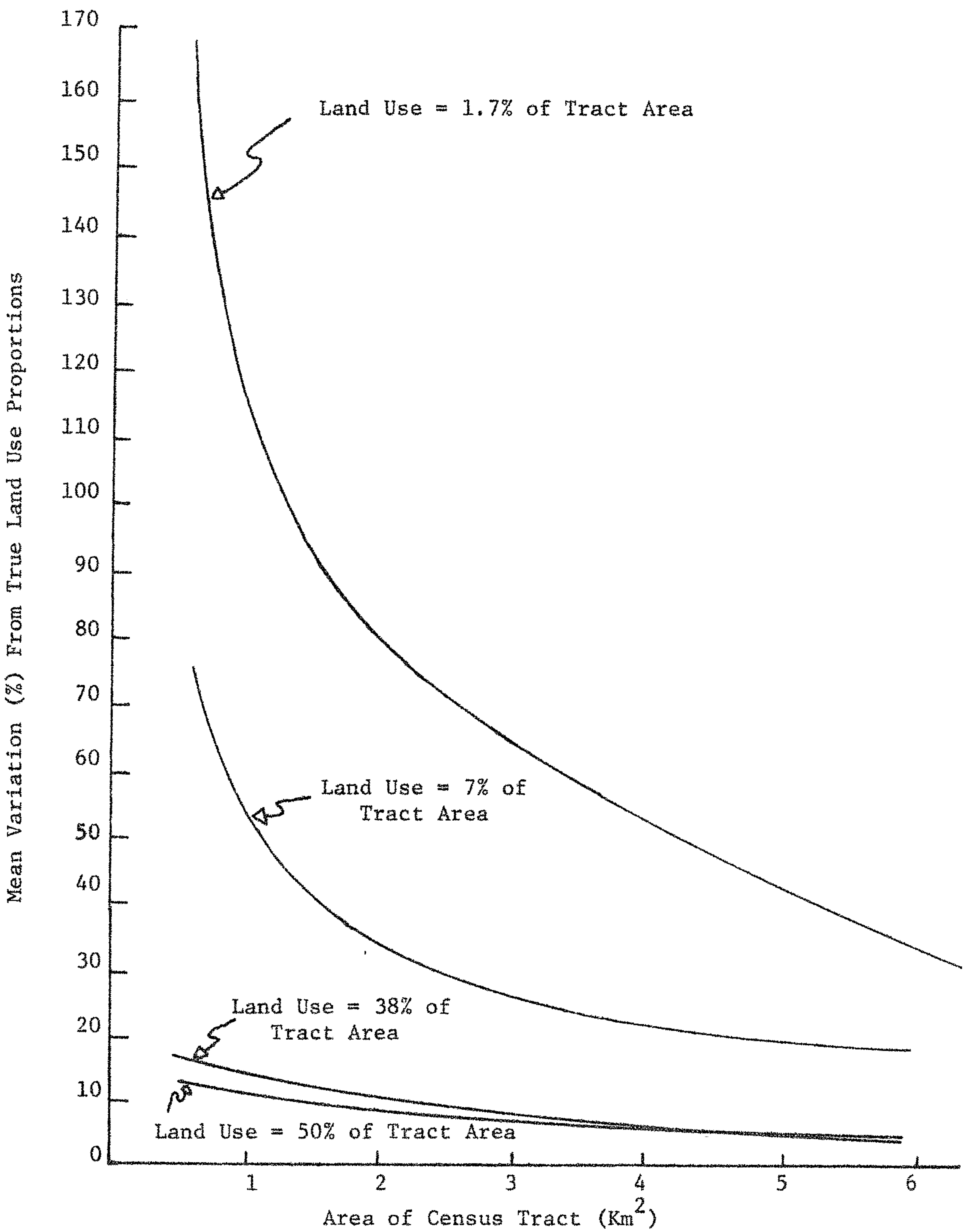

Figure 3. Reliability of Land Use Measurements for Different Tract Sizes and Land Use Proportions.

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11. King, Leslie J., Statistical Analysis in Geography, Prentice-Hall, Englewood Cliffs, 1969, p. 64.

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ANNEX D

Potential Users and Uses

A. PLANNING AGENCIES: REGIONAL, STATE AND LOCAL

* Metropolitan Area Planning Council

44 School Street, Boston 02108
Mr. Richard M. Dougherty, Executive Director
Basis for Interest: sponsor of Comprehensive Land Use Inventory Report, 1967; producer of Population of Cities and Towns in Metropolitan Boston, Projected to 1990 (1968); major successor to the Greater Boston Economic Study Committee, which produced the two studies Land Use in Greater Boston in 1960 and Industrial Land Needs through 1980, both in 1962.

* Eastern Massachusetts Regional Planning Project

Massachusetts Department of Public Works, 80 Broad Street, Boston
Basis for Interest: principal sponsor of Comprehensive Land Use Inventory Report, 1967; major successor to the Commonwealth of Massachusetts Mass Transportation Commission, which produced the Boston Regional Survey, under Melvin R. Levin, in 1963.

* Massachusetts Department of Commerce and Development

100 Cambridge Street, Boston 02202
Mr. William T. Tsaffaras, Director Bureau of Research and Statistics
Basis for Interest: sponsor of the Comprehensive Land Use Inventory Report, 1967.

* New England Regional Commission

58 Court Street, Boston 02108
Mr. Stewart Lamprey, Federal Co-Chairman
Basis for Interest: sponsor of Review of Regional Economic Research and Planning in New England, 1965.

* Massachusetts Bay Transportation Authority

Basis for Interest: sponsor of Comprehensive Land Use Inventory Report, 1967.

* <u>New England River Basins Commission</u>

1665 Post Office & Court House Building, Boston 02109
Mr. Frank Gregg, Chairman
Basis for Interest: sponsor of the <u>Southeastern New England Comprehensive Study</u> now in progress.

* <u>United Community Services of Metropolitan Boston</u>

Mason Memorial Building, 14 Sommerset Street, Boston 02108
Mr. Donald D. Dobbin, Research Director
Basis for Interest: key contact for U.S. Bureau of Census in census tract delineation.

B. <u>AREA INDUSTRIAL DEVELOPERS AND REALTORS</u>, such as:

Cabot, Cabot and Forbes
R. M. Bradley & Co., Inc.
Nordblom and Associates

C. <u>AREA PLANNING-CONSULTANT AGENCIES</u>, such as:

Arthur D. Little, Inc. Cambridge (which did the study <u>Projective Economic Studies of New England</u> for the U.S. Army Corps of Engineers in 1964)
The Planning Service Group, Boston (which did the study <u>Industrial Land Needs thru 1980</u> for the Greater Boston Economics Study Commission in 1962).
Vogt, Ivers and Associates, Cincinnati (which did the <u>Comprehensive Land Use Inventory Report</u> for the Eastern Massachusetts Regional Planning Project in 1967).

D. <u>AREA BUSINESSES</u>, such as:

First National Bank of Boston
Stop and Shop, Inc.
Boston Edison Company
(All of these were represented on the Greater Boston Economic Study Committee when it prepared the study and map <u>Land Use in Greater Boston in 1960</u> (1962).

E. <u>AREA ACADEMIC INSTITUTIONS</u> such as:

Harvard University: Laboratory of Computer Graphics & Spatial Analysis
Basis for Interest: participated in the Bureau of Census <u>Census Use Study</u>, (New Haven 1969)
Massachusetts Institute of Technology: Department of City and Regional Planning.
Basis for Interest: representation on Greater Boston Economic Study Commission and successor organizations.

Dartmouth College: Department of Geography, Project in Remote Sensing
Basis for Interest: prepared the Prototype High Altitude Land Use Map of the Boston Area (1970)

F. FEDERAL GOVERNMENT AGENCIES which have already financed land use planning studies and actions in the Boston area, such as:

U.S. Department of Interior Geological Survey (Geographic Applications Program)[1]

U.S. Department of Housing & Urban Development Urban Renewal Administration[2]

U.S. Department of Commerce
Bureau of Public Roads[2]
Bureau of the Census[3]

U.S. Department of Health, Education & Welfare[3]

U.S. Department of Transportation[3]

U.S. Department of the Army
Office of Civil Defense[3]

G. Among the various potential uses of a land use map of the Boston area, the following come quickly to mind. (No attempt has been made to thoroughly explore this subject during Phase I).

1. Principally, as a prototype for the 26 - city Atlas of Urban Change by the Geographic Applications Program USGS, Department of Interior to be updated later by high altitude aircraft and satellite.

2. As one end of a time-lapse study of the land use changes in the Boston area, 1960-70. The 1960 data are available in map form as well as text,in the Greater Boston Economic Study Committee's Land Use in the Greater Boston Area in 1960.

3. As partial basis for a study of the origin and evolution of an urban problem area in Boston, the South End.

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[1] Prototype High Altitude Land Use Map of the Boston Area, 1970

[2] Comprehensive Land Use Inventory, 1967

[3] Census Use Study (New Haven), 1969

4. For study of urban sprawl settlement patterns, and of intercity land as a disappearing resource.

5. For studies of relative effectiveness of various remote sensors for delineation of the rural-urban interface, and central city patterns.

6. For production of future population growth dimensions and densities in the Boston area (indicated by the U.S. Department of Commerce Bureau of the Census Census Use Study No. 9 as needed by more local planning agencies than any other kind of data included in the Census).

7. As partial basis for revision of the zoning and tax ordnances of the towns of the Boston urban field, every one of which has a planning board.

8. As basis for delineation of urban area boundaries for the 1:250,000 scale U.S. Geological Survey topographic quadrangles.

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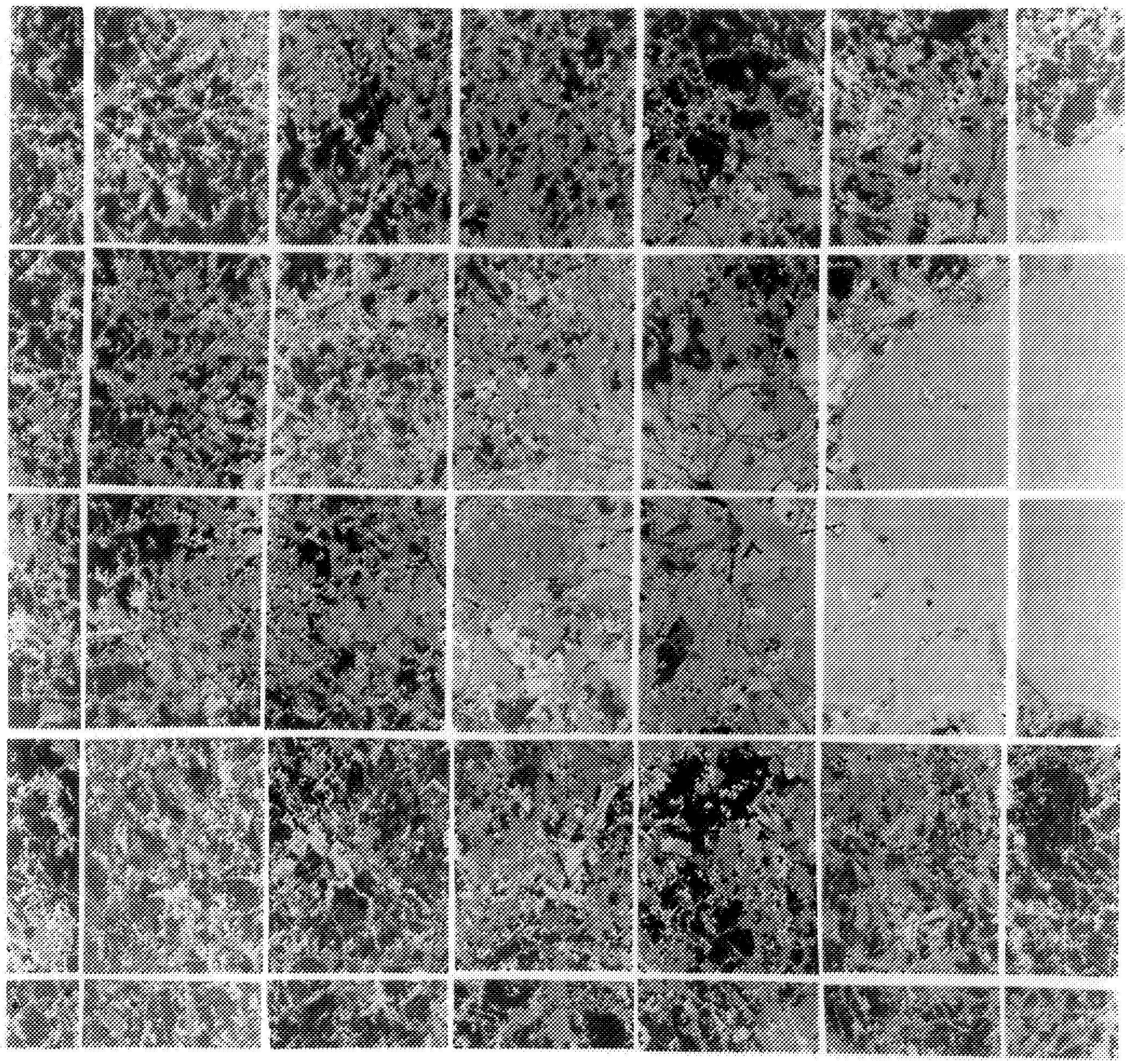

LAND USE MAP OF BOSTON

Advance photo mosaic made from the draft version of the 35 individual panels which compose the map. For legend see page 7. Actual map is being drawn at 1:62,500, approximately 8X this photo.