To my wife Sula
and my son Lambos.

Text cut off in original

A SURVEY OF URBAN OPEN SPACE USING COLOUR INFRA-RED AERIAL PHOTOGRAPHS

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SUMMARY

There has been a dramatic change in the U.K. government policy regarding the establishment of new towns. The emphasis is now on the redevelopment of existing cities rather than on building new ones. This has created an urgent need to carry out detailed surveys and inventories of many aspects of urban land use in metropolitan areas: this study concentrates on just one aspect - urban open space.

In the first stage a comparison was made between 1:10,000 scale black and white and 1:10,000 scale colour infra-red aerial photographs, to compare the type and amount of open space information which could be obtained from these two sources. The advantages of using colour infra-red photography were clearly demonstrated in this comparison.

The second stage was the use of colour infra-red photography as the sole source of data to survey and map the urban open space of a sample area in Merseyside Metropolitan County. This sample area comprised eleven ¼km^2 squares, on each of which a 20m x 20m grid cell was placed to record, directly from the photography, 625 sets of data. Each set of data recorded the type and amount of open space, its surface cover, maintenance status and management. The data recorded were fed into a computer and a suite of programs was developed to provide output in both computer map and statistical form, for each of the eleven ¼km^2 sample areas.

The third stage involved a comparison of open space data with socio-economic status. Merseyside County Planning Authority had previously conducted a socio-economic survey of the county, and this information was used to identify the socio-economic status of the population in the eleven ¼km^2 areas of this project. This comparison revealed many interesting and useful relationships between the provision of urban open space and socio-economic status.

Key words: Urban Open Space
: Air Photo Interpretation
: Socio-Economic Status
: Urban Planning
: Colour Infra-red photography

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CONTENTS

LIST OF FIGURES

Figures Page

Figures

Page

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER 1

GENERAL REMARKS ON AERIAL PHOTOGRAPHS

1.1 Introduction

The term 'Remote Sensing' refers to a variety of spaceborn sensors including not only the conventional aerial camera with its panchromatic and colour films but also such exotic sensors as side-looking radar (SLAR) and Thermal Infrared. While each of these sensors has displayed some potential for urban environmental analysis, two in particular, Black and White (BW) and Colour Infrared (CIR) photography appear to have more immediate utility than the rest.

This chapter will include brief descriptions of a number of aspects referring to aerial photography in general, and will present the 'state of the art' on the use of BW and CIR photography in particular, with emphasis on their photographic characteristics, applications, limitations and photo-interpretation.

1.2 Brief History

The first pictures from the air were of Paris taken in October 1858 by the photographer Gaspard Felix Tournachon riding in his balloon over the French capital. Tournachon is known by the pseudonym Nadar (fig. 1.1).

In 1859 Colonel Aimé Loussadet of the French Army Engineer Corps took pictures from the air with a plate camera for map making purposes, and he developed mathematical methods and instruments for analysing the photographs and compiling maps.

By 1900 the photographic process had become more reliable and the equipment more compact. This progress proceeded concurrently with the development of cameras with multiple lenses, which could obtain complete coverage of the area visible from the camera station in the air, as well as panoramic cameras fitted with sighting telescope, compass and level.

The discovery of the principle of the floating mark, and of practical methods of measuring and observing by means of stereo pairs of photographs, led to the development of high-precision instruments used today for plotting accurate plans with contour lines. A description of the applications and techniques in photogrammetry is beyond the scope of this thesis.

Military requirements in wartime led to the development of aerial photography in the 1914-18 war for reconnaissance purposes and for mapping. At the start of the war, a Zeppelin captured in France was found to contain an aerial camera, and later some aeroplanes were equipped with aerial cameras. In between the wars, aerial photography and survey techniques were developed to a point where they could be applied on an operational basis.

In the United States, several private firms started in this field. In the 1930's the Geological Society and the Tennessee Valley Authority mapped an area of 40,000 square miles, the entire Tennessee River Basin which was one of the first air survey projects to cover such a vast area. In Europe, the emphasis was on making large scale maps of relatively small areas.

During the second world war there was a substantial demand for aerial survey and maps, and this led to further considerable improvements in equipment, instruments and methods.

1.3 The electromagnetic spectrum

Solar energy is the earth's principal source of incoming natural radiation; however thermal patterns produced by vulcanism and other non solar emissions also may be imaged by infrared systems. Solar energy strikes the earth's surface and is either absorbed or reflected (Figure 1.2). The sun emits a continuum of wavelengths over a sizeable distribution of the spectrum. Part of the energy propagated is lost via interactions with the atmosphere, while the rest continues to the target (earth). It can be seen from the transmission graph (Fig. 1.3) that the atmosphere has well defined 'windows', which will permit the passage of certain wavelengths, while others are restricted. For example good atmospheric windows occur in the visible and near infra-red parts of the spectrum. The human eye records only the visible spectrum (Fig. 1.4).

The energy, in the form of photons (or quanta of light) generated by the sun, reacts with matter i.e. atmosphere, target (object), filter and film, and when a photon strikes matter it can be either absorbed, emitted, scattered or reflected.

Because absorption, emission, scatter and reflection are selective with regard to wavelength, and are specific for that kind of matter, depending on its atomic and molecular structure, it is possible to identify an object from a photograph which is sufficiently detailed.

The fact that the final recorded image is dependent on wavelength, permits both prediction of the appearance of an object on a photograph, and the detection of different objects using different wavebands, as in multispectral remote sensing which exploits unique energy signatures.

However, the interaction between photons and matter is never predictable, since scatter occurs before and after contact with the object and also at the object itself. Also, the atmosphere contributes to the total energy hitting the object, so the true reflected signal may be affected by radiation from other sources.

1.31 Scatter

The atmosphere through which the rays reflected by the object pass is not considered to be a homogeneous optical medium; it has a variable density and it contains molecular particles of dust, water vapour and other impurities. The combined effect of these particles, which can be of the size close to the wavelength of light, is the 'scatter' of light rays called the 'atmospheric haze'. The photographic consequence of haze is twofold. Firstly, some of the rays reflected by the objects do not reach the photographic camera, and secondly some rays which are not reflected by the objects being photographed, but by small particles of the atmosphere, will enter the lens and reach the emulsion. This results in the absolute and relative decrease of light intensity reaching the photographic emulsion and in a decrease of sharpness or definition of the images.

The amount of scatter is influenced by the physical characteristics of the atmosphere (the size, quantity and quality of particles) and can be expressed by formula:

$$\text{Scatter} = K\left(\frac{1}{\lambda}\right)$$

where K is the term defining the physical property of the atmosphere and λ is the wavelength of light. Thus the shorter the wavelength of light the more it will scatter. White light is composed of different wavelengths of light (colours) and its short wavelength components - ultraviolet and blue - will be most scattered. It is understandable that if these components are filtered out, the effects of scatter are reduced.

1.32 Reflectance

The amount of reflection from the object depends on the angle of incidence, on surface roughness, on the intensity of light energy incident on the object and on the object's absorption characteristics with respect to wavelength i.e. spectral reflectance, which varies considerably within the visible spectrum, fresh snow being capable of 70-90% reflectance and coniferous forests as low as 2-3% (Fig. 1.5).

1.4 Definition of terms

1.41 Remote Sensing

Remote Sensing is 'the recording of data related to phenomena separated by some intervening distance from the recording instrument' and 'Remote Sensors are information-gathering devices not in intimate contact with the subject under investigation' (Estes, 1966). Here we are primarily concerned with phenomena on the ground for which data are obtained by airborne instruments. The following groups of Remote Sensors can be recognized:

a. Sensors using visible (and the near visible infrared) light, record types of tonal and textural variation (visible to the eye) and produce an optical image or photograph. These sensors have high resolution capabilities, but effective operation is restricted to conditions of adequate light and good weather. Panchromatic photography and false colour (CIR) belong to this category.

b. Thermal Infrared sensors register the thermal emission of objects electronically to produce an image. These sensors are not limited to daylight operation and they possess some ability to penetrate haze, but the resolution level is lower than for conventional (visible light) systems. The thermal sensors may prove to be useful in the study of air and water pollution if the pollutants studied are known to create thermal differences of a sufficiently large scale to be identified.

c. Multispectral scanners register the spectral signature electronically. The reflected and radiated energy in several wavelength regions are recorded separately and continuously. The spatial resolution is poor, but the possibilities of automatic data processing can be highly rewarding for large-area, small-scale surveys.

d. Microwave and radar sensors transmit and receive pulses. Essentially the roughness of the object surface is measured and recorded electronically: the resolution capability is low and the image scale small, but the systems work under virtually any weather conditions. The main advantage which radar possesses over other remote sensors (aside from weather independence) is the ability to monitor rapidly changing situations where the timing of the overflight is critical and the required time lag between observation and interpretation is short. A potential application therefore is in traffic-flow studies. Also the gross pattern of land use can be identified, but still with insufficient accuracy for most planning applications.

The most used, conventional remote sensor is the aerial camera used in a vertical position, with panchromatic film and giving black and white negatives as output. From these negatives, positive paper-copy contact prints are made: the normal aerial photograph.

1.42 Photogrammetry and Photointerpretation

Photogrammetry is a relatively wide subject; it embraces such metric properties as size, shape, position and movement. The vertical aerial photo shows a picture of the terrain which is often compared with a topographic map. It should be noted, however, that there is only a relative similarity, as a map represents the terrain after cartographic procedures have been applied - such as selection, classification, generalization, symbolization and information addition and the map therefore includes a number of subjective elements. The aerial photo however is a real-world representation of visible objects, subjected to a medium-specific selection and transmission of information in the process of terrain-representation. The information, therefore, is in a certain sense coded, but a large part can be recognized with little or even no training.

There are two, partially overlapping, main uses of aerial photographs. Photogrammetry is the first group of uses. With photogrammetric techniques, aerial photos are transformed into topographic and other base maps. With the aim of attaining a high degree of geometric and locational accuracy in the representation of objects in the map, very sophisticated instruments are used by highly trained operators. The photogrammetric method is very efficient in terms of speed, accuracy and economy, with mapping on the basis of field surveys only. The metric aspect on which photogrammetry concentrates also has value for various techniques used in the field of photointerpretation.

The second group of uses is Photointerpretation. In this group the aerial photograph is used as a tool to collect information on phenomena which are represented in the photo image. The interpretation of the information contained in the photo image can be done from various scientific viewpoints, concentrating upon the semantic features, that is, stressing the meaning of the observed phenomena. Photointerpretation can be described, therefore, as a technique for the gathering of data for diverse scientific disciplines (unlike photogrammetry, which is a cartographic technique). It should be stressed that photointerpretation can function as only part of an information collection process, very often a sample field check must be made to check the reliability and to collect supplementary information. This use of aerial photographs can give high savings in both time and money, but here it is much more difficult than in the field of photogrammetry to define exactly how, when and where the use will be efficient. The value of the use of photointerpretation has been extensively proved in the fields of vegetation, soils, geology, (including engineering and mining exploration), geomorphology, hydrology, and in the field of the natural resources.

In Appendix 1.I other technical aspects of aerial photography are discussed, such as scale, form in which aerial photographs are available, equipment used for photointerpretation, production and usefulness of photomosaics and orthophotos and some details on oblique aerial photographs.

1.5 Characteristics of aerial photographs

1.51 Spectral response on Black and White photography

For aerial photography, conventional panchromatic film with increased red sensitivity is used. This film is sensitive for all wavelengths in the spectrum of visible light and a small part of the near - visible infrared (400-600nm), and represents the spectral response pattern of terrain features in grey tone values. It is agreed by most authorities that its use with a minus blue filter to reduce haze, gives the best film-filter combination for general purpose use. Black and white film has high resolution, though for some purposes its use is restricted by the fact that colours in nature are reproduced by a limited number of recognizable shades of grey.

Other remote sensing materials, except false colour film, will not be dealt with extensively here.

1.52 Stereo Image

Two aerial photographs of the same terrain, but taken from different camera positions (overlapping aerial photographs), will together give information on the third dimension: the height (or depth). For stereoscopic observation various types of stereoscopes are used and the obtained image is extremely useful for most interpretation purposes.

Also height measurements can be determined easily with an accuracy which is mainly dependent on flying height, instruments used and the operator's skill.

1.53 Quality

A particular interpreter's need or application will determine what minimum quality will be acceptable, but in general the highest quality possible should be aimed at for multiple use of the aerial photographs.

The primary characteristics governing quality are:

a) Tone contrast (the difference in brightness between the image and its background or adjacent objects). If this is insufficient, small details sometimes cannot be seen.

b) Image sharpness (the abruptness with which the tone changes). The visibility of the exact boundaries of the features in the image will influence the possibilities of identification of objects, e.g. lots, buildings, etc.

c) Stereoscopic parallax (the displacement of apparent position of terrain objects with respect to a terrain reference point due to a shift in camera position). Insufficient parallax will make detection of height differences more difficult or impossible.

d) Resolution (the ability to render a sharply defined image, measured in lines per millimetre). It refers to the capability of the photographic system to distinguish between small objects.

As complicated measurements of quality are hardly feasible, a practical method is by comparing different (series of) aerial photographs, finding out whether specific details can be detected or not (for example: buildings, cars, fences, garbage heaps, street lamps). Good photographs can, for easier examination, be satisfactorily enlarged to 6 or 8 times. There is always a high loss of quality in reproducing photos from a second negative (photo to photo).

1.54 Types of photographic emulsion

Within the group of conventional aerial photographs (optically recorded images), several types of film emulsion exist, and they vary in speed, resolution, contrast and wavelength.

a) Panchromatic film is the most common one, being a single emulsion film.

b) Panchromatic Infrared film has a sensitivity that is extended into the near-visible infrared range of the spectrum, because certain objects or phenomena, for example various trees, crop types and vegetation can be identified using their infrared reflective properties, but are indistinguishable when the entire visible light range is used.

c) Colour film portrays the terrain in its original colours. Recognition of objects can be easier for inexperienced observers, but colour film can be used to facilitate interpretation of specific features which could otherwise hardly be seen. The higher cost of colour aerial photographs is a serious restriction for more general use. This film together with false colour are multi-emulsion films of more than one sensitive layer.

d) False Colour film uses the technique of contrasting colour differences to accentuate certain features on the basis of their reflective properties. Applications can be found in the earth sciences (vegetation studies, especially plant diseases), and in military uses (camouflage detection). The properties of this film and the applications in environmental research will be discussed separately in this chapter.

1.6 Practical use and interpretation of aerial photographs

1.61 Introduction

The kind of interpretation possible will depend to a large extent upon the general and the specific knowledge of the interpreter, that is upon his "reference level" (Vink, 1964). On the basis of an increasing specialization, different stages or classes of photointerpretation can be distinguished.

1.62 Classes of photointerpretation

The first step in photointerpretation is to detect, recognise and identify objects visible in the photo image (a procedure also used in photogrammetry). This is the simplest class of photointerpretation and can be done with a reference level of elementary interpretation knowledge (Class I). A more complicated photointerpretation process also involves analysis in the sense of the delineation of groups of objects or elements which have a separate individuality for the photointerpretation, e.g. certain land use types. In this class (Class II) the interpreter must have a certain level of specialized knowledge of a specific science as well as of interpretation.

The most difficult process is correlative photointerpretation. In order to make an interpretation of, or to collect information on, largely invisible objects (or better: elements in the landscape) use is made too of deduction, classification and idealization. The interpretation must be done by an expert in a specific discipline, who also has considerable knowledge and experience in photointerpretation (Class III).

The reason for this division into interpretation classes is to present a pragmatic organizational approach, or as already stated, to indicate the practical limitations in the process of interpretation.

1.63 Other factors affecting photointerpretation results

The visibility of different objects in the photo image varies considerably: this is due to two main factors:

1. The inherent visibility of objects, and
2. The type, scale and quality of photographs.

The "visibility" of objects in aerial photographs is never a direct visibility, but is a representation in the photo image. The inherent visibility of objects such as buildings, roads and water bodies is high, whereas it is low for such urban activities as identifying the function of certain buildings. By using the proper photointerpretation techniques and field checks it is often possible to collect the information required.

The "type, scale and quality" of aerial photographs determine, for a certain visibility of objects, to what extent they can be detected. Many objects which can be detected easily on large scale photos (vehicles, trees) cannot be seen on small scale photos. Also the film-filter combination, inclination of camera axis (vertical or oblique), camera lens, image quality (detail contrast, overall density) and time of exposure can have a marked influence on the extent to which detection is possible. In general, the accuracy with which any particular discrete land use unit can be identified from aerial photographs depends upon a number of variable factors as those listed by Collins (1976). This list includes:

i) the quality and scale of the photography
ii) the identification of units included in the notation
iii) the notation used
iv) the types of land use which exist in the area under study

v) the expertise of the interpreter and his knowledge of the land use types in the area of study

vi) the methods and equipment used to extract the information

vii) the method by which the accuracy of the work is calculated

Although these factors can each be considered separately, they are in fact interrelated. An approximate rule is that for individual objects to be identified on the aerial photographs the object should be at least 0.5mm in size at photo scale. However, features exhibiting a linear pattern may be readily visible even if they are dimensionally smaller than this.

The optimum photography for urban research depends mainly on the purpose of the survey. In practice the scale is the most relevant and controllable variable. In any event the high degree of geometric accuracy required for photogrammetry is certainly not necessary for all interpretation purposes, such as the qualitative analysis of urban areas, therefore normal uncorrected aerial photographs can be used. For quantitative analysis (measurement of area, height and length), it is necessary to be aware of the differences between the terrestrial spatial situation and its photo image, but for most planning purposes the normal aerial photographs can be considered to be an adequate representation of the spatial characteristics of the terrain.

1.7 Colour Infra-red aerial photography (CIR).

1.71 General remarks

Infra-red film is available in either black and white or colour, of which the colour version is of more interest since more colours can be differentiated than shades of grey. Initially this film was described as a "false colour" reversal film, originally designed for camouflage detection purposes by distinguishing between live and dead or simulated vegetation. The film is known by several different names, and may be referred to as Ektachrome infra-red, Aero-camouflage detection film, false colour film; these names are all synonymous.

CIR film has three emulsion layers, the top of which is sensitive to the near infra-red wave band between 720 and 900 millimicrons. The other two layers are sensitive to reflected radiation in the green and red sectors of the visible spectrum.

Colour infra-red film differs from the ordinary colour film in several significant respects. Firstly, the top emulsion layer of CIR film is sensitive to infra-red radiation. The entire infra-red portion of the spectrum includes wavelengths which range from 720 to 320,000 and more millimicrons. Since CIR aerial photography seldom includes wavelengths longer than 900 millimicrons it is perhaps more accurate to refer to CIR as "near - infra-red" aerial photography (Lindgren, 1971a). Secondly, the middle emulsion layer is sensitive to green light in the 500-570 millimicron range, while the bottom layer is sensitive to red light in the 640-680 millimicron range. In colour and CIR films the same three dyes are used - yellow, magenta and cyan - but the CIR film includes longer wavelengths.

The film is normally used with yellow blocking filters to cut out unwanted blue light hence only reflected green, red and infra-red wavelengths are allowed to reach the emulsion layers (Fig. 1.6). Details of the processing and storage of this film are given on Appendix 1.II.

1.72 Photointerpretation of Colour Infra-red Aerial photography.

The false colour aerial photograph is a particularly valuable tool for the interpretation of vegetation and detecting moisture contents, as healthy vegetation strongly reflects infra-red radiation and water largely absorbs it.

With their different infra-red reflective characteristics different leaf and vegetation types vary markedly in false colour. Deciduous trees and grassland are recorded in bright shades of red and magenta. Conifers, having less high infra-red reflectance appear as purplish red or bluish. Before deciding to use false colour film, however, a number of limitations should be considered, including weather conditions, filters to be used, storage of the film, time of day to be used, etc. Details on each of these factors are given below:

1. Under optimum conditions (fair, dry weather with clear sky) a Wratten No. 12 filter (yellow) must be used.

   When, however, there is excessive haze and water vapour in the atmosphere, slightly more filtration of the blue wavelengths may be required in the form of a Wratten No. 15 filter (deep yellow). The use of these filters means more light is required to sensitize the film layers. At certain periods of the year and at certain latitudes such conditions are found only infrequently.

2. The damaging effect age has upon the film has to be taken into consideration. The infra-red-sensitive cyan layer tends to decrease in speed as the film ages and the speed of the green sensitive yellow layer increases slightly. As the film ages its colour balance shifts towards cyan. If the film is kept at room temperature its balance will eventually pass the point of optimum

discrimination. However, this effect can be reduced considerably by refrigeration, or almost eliminated by storage in a freezer.

3. A further limitation of CIR photography results from its shadow enchancement. Although shadow enchancement may sometimes be an asset, there are other times when it is a liability. It is, for example, very difficult to see details in shaded areas. This is particularly bothersome in either heavily wooded areas or in urbanized areas where there are numerous multi-storied buildings.
4. Finally, there is a depth penetration consideration when using CIR film for the analysis of water bodies, because infra-red energy is absorbed by the first few inches of water. Vegetation on the surface of the water tends to show up brilliant red, while that of equal vigour beneath the surface shows as various tones of blue (Scherz, 1971). It has been found however that if the film is overexposed (Anderson, 1969) or if a Wratten 61 filter is used (Strandberg, 1966) the submerged vegetation will be more easily visible.

1.73 Application of CIR aerial photography in Environmental Research.

1.731 Introduction

Research using CIR aerial photography in various aspects of the environment has been carried out quite extensively, and many authors have emphasized the potential applications and advantages of the material and they strongly recommended its use (Marshal, 1968). A number of applications of CIR photography in Urban and Regional planning will be discussed in the next chapter. A review of environmental applications of CIR aerial photography in Agriculture, Forestry, Pollution, Terrain Analysis and Soils is given in Appendix 1.III.

1.732 Behaviour of CIR film

There is a conflict in opinion as to how this film behaves from place to place, purpose to purpose and time to time; and many papers expressing conflicting results and interpretations have been published, especially related to the study of vegetation damage and disease. Benson and Sims (1967) reported that they had not, in their experience in Australia, obtained the results they had predicted from a study of the available literature. To a slightest change in plant vigour the CIR film responds differently and this phenomenon is not completely understood. Some believe that changes in the infra-red reflectivity is due to chlorophyll content of the leaves (Benson and Sims, 1970) and others believe that infra-red reflectance of plants is from the mesophyll tissues underlying the chlorophyll layer in the leaves (Cochrane, 1968). He also indicated that other factors affecting infra-red reflectance include the age of the leaf, and if damaged the length of time the leaf has been damaged. A good discussion of this topic is given by several authors including Kipling (1969), Hilderbrandt and Kenneveg (1970), Stellingwerf (1969).

The fact is that there is no satisfying explanation for this lack of unanimity. This is because factors which affect the quality of photointerpretation, such as exposure and processing of the film, and applications to different aspects of the environment, differ according to place, time and personnel who make use of the film, and usually the conclusions are generalized.

It must be emphasized that before any operational use is made of CIR photography, the need to establish ground truth should be considered, and a variety of landscape types and conditions should be of known spectral response in the image.

Figure 1.1 NADAR'S BALLOON

Caricature by H. Daumier of Nadar's balloon exploits (after L. Duel, 1973)

Figure 1.2 ENERGY FLOW

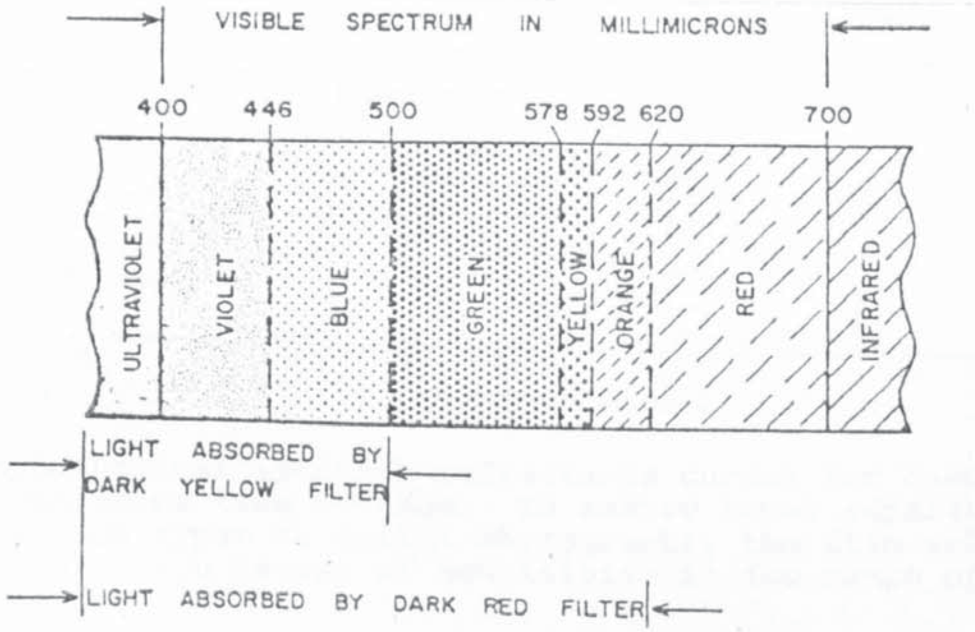
Generalized diagram of energy flow for passive sensor system (after R. Holz, 1973)

Figure 1.3 THE ELECTROMAGNETIC SPECTRUM

Characteristics of the Electromagnetic Spectrum which are of significance in Remote Sensing.

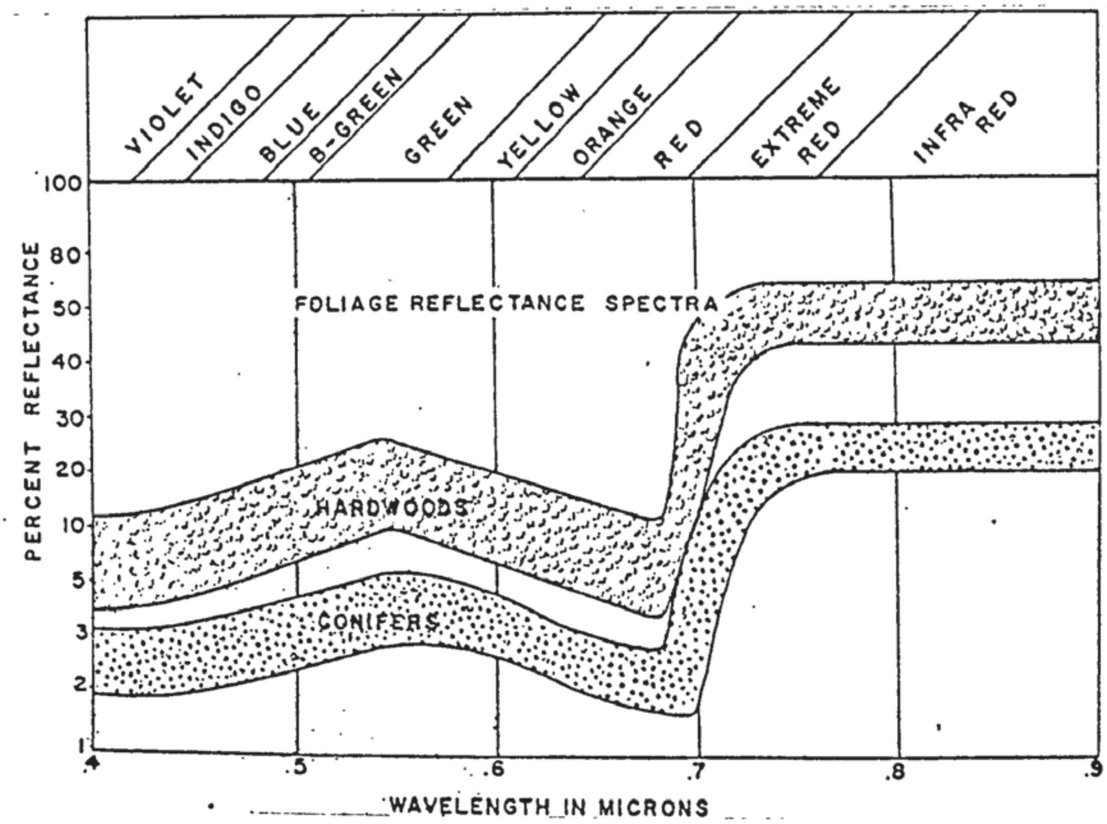
Source: Subcommittee 1, Photointerpretation Committee, American Society of Photogrammetry, "Basic Matter and Energy Relationships Involved in Remote Reconnaissance", Photogrammetric Engineering, Vol. XX1X, No. 5, September 1963.

Figure 1.4 THE VISIBLE SPECTRUM



Schematic diagram of the visible spectrum. Colour divisions are for illustrative purposes only; hues actually blend continuously from one wavelength to another.

Figure 1.5 SPECTRAL REFLECTANCE OF HARDWOOD AND CONIFEROUS TREES



Hypothetical spectral reflectance curves for hardwood versus coniferous tree foliage. To assure tonal separation of these foliage types on aerial photographs, the film selected should have a high degree of sensitivity in the range of 0.7 to 0.9 micron.

Figure 1.6 PRINCIPLES OF OPERATION OF COLOUR INFRA-RED FILM, (after N. Fritz, 1967)

CIR film, without filter.............	blue	green	red	Infrared
CIR film, with yellow filter.........		green	red	Infrared
Colour of dye layer in film..........		yellow	magenta	cyan
Colour of resultant photograph.......		Blue	Green	Red

CHAPTER 2

URBAN APPLICATIONS OF REMOTE SENSING

2.1 Introduction

The systematic use of aerial photographs and particularly of photointerpretation in urban areas is of relatively recent date. The application to urban studies has been delayed for various reasons, which are indicated briefly here.

The first is that aerial photography proved to be extremely effective as a reconnaissance technique, and permitted the survey of vast, remote, hardly accessible and rather unknown areas, which would otherwise not have been mapped for a long time. Cities on the other hand have been relatively small and of easy access so they could be surveyed in traditional ways without great inconvenience.

Secondly, the application of aerial photography has been actively stimulated by economic interests, this explains the early development of photogeology and the general use of photography in natural surveys. Because of this the concern of governments was concentrated on such surveys, and not on urban survey which did not appear to offer such benefits. The systematic application of remote sensing techniques in recording and monitoring urban systems was not considered as very useful even at a local government level.

In the third place, the city shows a dense concentration of cultural and physical features, and human activities within a limited area, which requires a highly detailed survey and large scale photography, hence city surveys hardly fit into a multipurpose scheme. Also the absence of a traditional framework, in topographical mapping and natural resource surveys, has resulted in less application in urban situations.

Due to the rapidly increasing, and worldwide urbanization process caused by growth, migration to the city and fundamental changes of a socioeconomic nature, the urban area has gradually become a specialized field of study and a multidisciplinary meeting place of town planners, urban geographers, architects, sociologists and others interested in specific urban phenomena and problems.

Whether the planner uses aerial photographs as a source of data depends mainly on his knowledge of air photo interpretation techniques, the type of data the planner requires, and the availability of the necessary aerial photography.

The most extensive and commercially well established use of aerial photography in urban areas is for the purpose of topographical and cadastral mapping. Aerial photographs are used mainly as a source of geometric information with photointerpretation as a secondary data source for map updating. This seems to be a standard procedure, in common use throughout the world, (Grey et al, 1973). This chapter, which deals with a number of examples of applied photointerpretation for urban purposes, serves as an illustration only and is not intended to be exhaustive.

The main emphasis will be given to black and white, colour and colour infrared photography and their applications on various scales to urban planning. A number of experimental applications will be mentioned in a representative way, although some research has been carried out with multispectral photography, radar and thermal applications related to urban planning.

2.2 The Uses of Remote Sensing Techniques in Urban Planning in USA

2.21 Studies in Housing Quality and Dwelling Unit Estimation

The use of remote sensing for urban data acquisition is a new idea, dating from the late forties and fifties with the studies of Branch (1948), Witenstein (1952, 55, 56), Green (1955, 56, 57) and Hadfield (1963). Such studies had important implications in the USA for similar research studies in the years which followed. A number of these studies which utilized aerial photography to evaluate housing quality and other aspects of the urban environment are reviewed.

Green (1956 and 1957) used black and white aerial photographs to derive data on the social structure of a city, by relating it to the physical spatial structure. He found a statistical association between a number of physical and sociological variables in Birmingham, Alabama. Green found that whereas high statistical association did exist between each of his four physical data categories and several sociological variables, any one category of photo-data alone had limited predictive value and so he combined various categories of social and physical data. Green's study was the first of its kind. He used 1:7,500 scale panchromatic photographs and examined 17 residential sub areas recording several categories of housing types. The major errors which were revealed in this study were three. Firstly dwelling units per block were underestimated by 7%; secondly single unit detached structures were overestimated by 8%, and thirdly the amount of error increased in areas having a higher prevalence of multi-unit structures.

S.H. Hadfield's study in Chicago (1963) also included a system for estimating dwelling units. The photos in this instance were at a scale of 1:4,800, and dwellings were classified simply as single family or multiple-family. The estimates made from the photos were checked for accuracy in two ways: census data and field surveys. Hadfield found from his investigation that the original aerial survey showed 10% fewer dwelling units than the cenus count. However, where the field survey was used to provide a correction factor, the difference between the aerial survey and the census count was reduced to only 0.4%. The development of Hadfield's correction is not described in detail.

The results in Binsell's study in Chicago (1967) were similar to Green's (1955). Binsell underestimated dwelling units by 15.7% and the single detached dwellings were over-estimated by 4.3%. The degree of error was found to increase with the prevalence of multi-unit residential structures.

Mumbower and Donoghue (1967) emphasised the possibility of evaluating the quality of individual housing units in each block using 1:10,000 to 1:20,000 and 1:30,000 scale panchromatic and colour aerial photographs, covering nine cities east of Mississippi.

Manji (1968) used 1:10,000 scale photography and attempted to delimit poverty areas with a detailed photointerpretation of residential areas. The photointerpretation was validated by comparison with census data. The poverty areas could be identified by certain indicators such as debris, junk-yards, warehouses and small businesses.

Wellar (1968) used low altitude multiband photography to identify low housing quality areas. Each factor in the American Public Health Association (APHA) survey appraisal method was evaluated as a potential item for measurement on aerial photographs, together with additional factors considered to be indicators of poor housing quality. The presence of litter, garbage, wrecked or derelict cars, and piles of lumber and rubbish in the neighbourhood on both occupied and vacant lots proved to be the best single indicators of low quality housing. Other environmental features associated with low quality housing included a lack of landscaping, together with the presence of weeds on vacant lots and the existence of non-residential hazards and nuisances, primarily industrial plants and warehouses.

In the same year (1968), Bowden reported the use of colour infra-red photography at the smaller scale of 1:60,000 to differentiate the quality of a broad range of residential neighbourhoods in an area centred over downtown Los Angeles. When census data on income and home values were correlated with residential classifications based on CIR aerial photographs, it was found that four broad categories of housing quality could be identified.

Mullens (1969) attempted to correlate environmental health indices with photographic surrogates and a number of socioeconomic variables. However, the ability to evaluate "housing quality" by using remote sensing data has been widely demonstrated. Mullens used low-altitude, large scale, colour infra-red aerial photographs to differentiate and classify types of residential areas in Los Angeles on the basis of characteristics of the physical environment. He investigated the hypothesis that since socioeconomic characteristics of large urban populations are associated with specific types of residential environments, it would be possible to associate characteristics of the physical environment with socioeconomic variables within such environments.

The residential areas in his investigation were mostly low and middle income housing. In general, Mullens found that surrogates which were good indicators for a socioeconomic variable were also good indices for most of the other socioeconomic variables examined. Then he grouped the study areas into four categories on the basis of ranking the areas by socioeconomic variables, and ranking the areas by values of photographic surrogates. A high correlation of 0.83 existed between the ranking produced by the total socioeconomic ranks and the ranking produced by the total of all surrogate ranks.

Senger (1969) sought to test the validity of the relationships, established by Mullens, between the socioeconomic characteristics of the population and the photographic surrogates from colour infra-red imagery in a contrasting urban environment. This contrast was expected either to increase the significance of the Los Angeles study or to point out its limitations. The results of Senger's investigation confirmed the validity of the methodology developed by Mullens but has shown that further research is necessary to test the criteria using different scales of photography and in different areas.

Data gathered from a survey conducted in Los Angeles by the County Health Department in the Spring of 1968 was used by Horton and Marble (1970) and Moore (1970) to evaluate housing quality. They used 37 structural and environmental variables which they divided into two groups - those potentially measurable by remote sensing and those not measurable by this technique. Analysis showed that "for each basic housing element, the variables acting as indicators of that element tend to be highly correlated with other variables within the element". The authors rejected the idea of estimating overall housing quality at the parcel level based only upon remote sensor observation of environmental variables. At the block level, however, they found that the structure variables were associated with a number of variables, primarily those which identify the level of upkeep of lots and the existence of land uses incompatible with residential development. They concluded that overall housing quality, then, may be estimated at the block level by using the environmental subset.

Lindgren (1971a) used photointerpretation keys developed by Binsell (1967) and applied them systematically to three test blocks selected in Chelsea and East Boston. The main purpose of his work was to estimate the number of residential structures and the number of dwelling units. He concluded that results can be obtained (from scales as small as 1:20,000) having a statistically significant confidence level of 99% using colour infra-red photography. He commented that CIR photography is the most effective film for studying high-density residential areas. Much greater detail can be obtained from its use and even in built-up areas, detail is sharper than with panchromatic or natural colour films. Comparisons between these types of photography are not given.

Davis et al (1972) used conventional sub-orbital black and white aerial photography at a scale of 1:23,000 and sub-orbital colour infra-red photography at a scale of about 1:190,000 to examine a middle and low income residential area at Austin, Texas. The investigation showed that poverty areas can be delineated from the imagery, and that suitable environmental indicators of urban blight form useful parameters in determining "housing quality". The evaluation resulted in the identification of 18 indicators or image signatures of different socioeconomic class. Some of the signatures reflecting class differences were dwelling size, shape, density, geographic pattern and uniformity, quality and quantity of vegetation in the open spaces surrounding the house and vacant lots. Using factor analysis they employed 16 socioeconomic variables to substantiate the findings of the remote sensing method. The areas designated as blighted and those as middle and upper class were the same by the remote sensing and factorial analysis methodologies. The factorial design validated the conclusions obtained from the remote sensing imagery. They concluded as follows: "Remote sensing is a useful tool in the quantitative and qualitative measurement of an area's characteristics. The location, spatial arrangement, density and character of the housing units have ecological meaning in that exterior characteristics are surrogate measures for interior characteristics".

Rush and Vernon (1975) attempted to identify health status areas through the use of low-level colour photography taken at scales 1:6,000 and 1:12,000 in October 1970. Eleven land use categories were identified and residential land use was further broken down into quality and density levels, thus making a total of 22 designations (density: high, medium, low and quality: subjectively evaluated as excellent, good, fair and poor), The important part in this study was the fact that the evaluation of Residential Environmental Quality was based on such things as roof condition, and private and public open spaces in particular. It is to be emphasized that apart from the "roof conditions of the buildings" all the other factors which determined "quality" were associated with the open space. In general three groups of data were used: data by photointerpretation, census data and health data (mortality rate, morbidity rates for tuberculosis, etc.). The objective then was to determine if data from aerial photographs were as highly related to health outcomes as the more traditional census data. The data gathered by remote sensing was found to be as good as census data in determining rates of health outcomes.

2.22 Studies in Urban Land Use and Urban Change

In the field of urban land use mapping, extended research in the USA and elsewhere has demonstrated that urban land use surveys can satisfactorily be conducted from aerial photography with only a minimum of field checking. In addition, changes in the urban space can be monitored by repetitive photography.

From the urban point of view one of the most important projects has been the "Census Cities Project" whose purpose has been to evaluate the applicability of photography from high altitude aircraft and earth orbiting satellites to urban land use change detection. As a part of this programme twenty six US cities were designated as test sites, and for twenty of them the US Air Force Weather Service and NASA's Manned Spacecraft Centre acquired multi-spectral, high-altitude photography. The project sought to evaluate high altitude photography as a land use acquisition tool. The basic data from the overflights were colour infra-red photographs at image scales of 1:100,000 or 1:120,000. Lindgren (1973) has emphasized the two particularly useful qualities of the infra-red film, which for the first time was used systematically in urban applications. Firstly, if a minus blue filter is used with colour infra-red film it imparts to it a haze penetration capability. Secondly, vegetation, which is highly infra-red reflective, appears reddish on colour infra-red film; cultural features, on the other hand, appear blue. The contrast between cultural and natural features is very great.

The Boston study (Simpson et al 1972) together with the Washington D.C. study (Mallon, 1972) served as two of the prototypes for the Census Cities Project.

In the Boston study land use maps were produced to serve as bases of comparison for detecting urban change using ERTS-A imagery and to evaluate the utility of high altitude 1:120,000 scale photography. The authors extended the investigation by converting the information from the land use map to a machine retrievable form for the Boston Metropolitan area. The 93,000 point data set was obtained by superimposing a dot-grid over the conventional map. Comparing the land use map with the data points they emphasized the fact that the land use map is considerably more detailed since the data points represent much smaller areal units than enumeration districts. They indicated that the advantages of computer graphics were flexibility and selectivity. This form of land use map presentation is also suitable for direct further manipulation such as aggregation into different areal units. In addition they emphasized the importance of the fact that the data matrix was recorded on a general co-ordinate system. The data points are thus relocatable and it is relatively easy to compare the land use information with other types of spatial distribution.

In February 1971 a remote sensing systematic project was initiated in the Metropolitan Washington Council of Governments (COG), a Regional Planning Organization for the 15 major local county and city governments, (Mallon, 1972). The research objective was designed to investigate, consistent with the research assignments, how remote sensing, black and white and colour infra-red photography could be effectively utilized in the regional planning "user" environment; i.e. to improve the usefulness of the information base, and to assess time and cost reduction of data collection.

The project's work programme identified principal areas of application of remote sensing derived data to planning programmes, and participated in support of several of these. Mallon (1972) describing the results states: "the study results from seventeen selected census tracts in Northern Virginia, indicated the existence of considerable amounts of incomplete, out-of-date and in some cases erroneous land use data in the current COG data base, the principle sources of which are the tax roles from the local jurisdictions.......The use of aerial photography (colour infra-red) and its unique qualities at scales of 1:100,000 and 1:120,000 have made it possible for the study to achieve results which, under the handicaps of scale and urban congestion, would have been less rewarding had ordinary black and white photography been used". These scales of photography proved satisfactory, particularly in suburban areas, for identifying and quantifying housing stock. Mallon concluded that types of investigation involving such data as building density, presence or absence of vegetation, curbing, vacant lots between buildings, and off-street parking are observable on relatively larger scale imagery only, such as 1:15,000 or 1:20,000 (at the smallest) and that colour infra-red photography is an "absolute requirement".

As to the size of the objects which have been identified from high altitude aerial photographs, Lindgren, Simpson and Urlm (1973), referring to the Boston Study, indicated that while in the beginning it was anticipated that perhaps as many as nine classes of land use would be identifiable on the imagery; as it has turned out some 14-18 classes of land use have been identified. This success results in part from the better than expected resolution of the imagery. Objects as small as 300 feet and linear features as narrow as 50 feet have been consistently identified. But, in spite of this success the minimum parcel size at present limits the usefulness of the data to metropolitan area or regional planners. Data are far too gross for municipal planners. Rawling (1971), after using 1:83,000 scale black and white, colour and colour infra-red photography of varying quality, demonstrated a successful example of the use of remote sensing to monitoring the elements of systematic urban land use change. The evidence of his study in detecting changes, not only in the urban fringe but in the inner areas as well, would seem to suggest the immediate realisable potential of remote sensing systems. This potential is, as yet, very much underutilized.

For the city of Las Cruces, New Mexico, Osterhoudt (1972) in his study based on land use mapping with photo-interpretation suggested that aerial photographs offer a relatively easy and inexpensive method of developing a land use data base for comparative studies. The photomosaic map and the land use overlays form a common starting point from which the interested layman and professional alike can approach the physical, economic, social and institutional problems of land use. When Osterhoudt compared 1947 aerial photography with 1967 he found that the city in 1967 was 20% larger than the planned one, and only an additional 198 acres of agricultural land would have been preserved. The differences in agricultural production and its multiplier effect on the community would have been relatively small.

In the multiband approach, the use of multiband descrimination methods to determine environmental quality and land use in urban areas is fairly new. Marble and Thomas (1966) made an attempt to use multispectral photography for urban analysis with very limited results because of the lack of the appropriate quality of the data. Holter (1970) gives a thorough theoretical review of multispectral aerial photography, but does not refer to urban applications. Palgen (1970) states:"Some method for automated processing (Automated Pattern Recognition) appears to be necessary to master the task of evaluating so much data available by remotely sensed imageries in the States". In his approach he utilized, through textural parameters, multispectral aerial photography to provide measurements, related to urban quality, for pattern recognition acquired through the use of Optical Fourier Transforms (see Manual of Remote Sensing, Vol. 1, pp 649-653). He based his considerations on Bowden's (1968) findings, ".........the central business district tends to reflect somewhere near 0.6 micrometers,........while the areas of deteriorating housing (zones of discard) tend toward 0.65 micrometers.....". Bowden also indicated that "......heavy industry responds on a longer part of the visible spectrum than light industry or commercial activities, and residential areas have their maximum reflectance at even shorter wavelengths". According to Palgen (1970) these findings are not fully exploited by Bowden (1970), Mullens (1969) or Senger (1969). Palgen's work was a three phase study of which only the first two phases were published and he emphasized that these phases were dealing with the "confirmation of the concept". In the end he says, as an introduction to the third phase, that: ".......we are seeking ways to 'describe' features present on the transforms that may be statistically related to the subscene urban quality and use. Validation of these descriptors necessitates the use of larger sizes of samples and extensive computer processing.......". This last phase of his study was to be directed toward the development of an automated system for urban land use classification utilizing the concepts already established. Two years before, in 1968, in a thorough review of the literature on automated pictorial pattern recognition techniques, Palgen (1968) suggested that automated urban analysis is still inferior to the human interpreter.

In an attempt to measure urban growth, Holz and Boyer (1972) emphasized the potential usefulness of ERTS-1 (LANDSAT) imagery and the applicability of Apollo-VI near vertical black and white photography in their study of the Dallas-Fort Worth urban areas. They suggested that the sequential multispectral imagery obtained would enable careful monitoring of many aspects of city growth.

Another, more recent, study by Mausel, Leivo and Lewellen (1976) at the metropolitan level, named as SIKRCOG study (Southwestern Indiana and Kentucky Regional Council of Governments) has introduced the characteristics and potential of using machine (computer) processing of multispectral data obtained from LANDSAT-1, for developing general land use information. Among the advantages of using this approach they have indicated the following: (1) lowest cost, (2) great objectivity (......in a computer-assisted land use classification, many of the subjective human errors are larely removed), (3) short analysis time, (4) uniformity in data quality, (5) versatility in displaying classification results, and (6) ease of future updating and land use monitoring. In addition they accepted the fact that currently this approach does not provide all the kinds of land use data that planners may require to satisfy all their responsibilities, and that the only practical way for the planners to classify certain specific kinds of land use is by visual inspection or analysis of large scale aerial photography. Aerial photo interpretation remains the most used and versatile source of remotely sensed land use information. In terms of costs and benefits they concluded that machine-assisted processing of LANDSAT multispectral data is less expensive than the costs of purchasing and interpreting aerial photographs for land use classification of large areas (a minimum of several hundred square miles).

2.23 Studies in Population Estimation

In the field of population estimation from aerial photographs Kraus, Senger and Ryerson (1974) have classified the contributors in three categories according to the detail exhibited and size of the area covered, in (a) Generalized, (2) Semi-detailed and (3) Detailed.

In the first category the works of Wellar (1969), Holz, Huff and Mayfield (1969), Anderson and Anderson (1973) are included as they appeared to be the least detailed and accurate.

Those studies normally utilized high altitude or satellite imageries as data sources and postulated a functional relationship between built-up urban areal extent and population size. In the category of semi-detailed studies the work of Collins and El-Beik (1971) represents the major contribution to this approach. Elsewhere in this chapter this work is described in detail. The work of Kraus et al (1974) also belongs to this category. The error rate in these studies varies from the level of 9% (underestimation) up to 7% (overestimation).

In the third category of "Detailed studies", the works of Green (1956), Porter (1956), Eyre et al (1970), Hsu (1971) and Dueker and Horton (1971) are included. In these studies low altitude photography as data source has been utilized and they are the most accurate studies to date with error rates of $\pm$ 4.5%. Details of these studies on population estimation are given in Appendix 2.I.

2.24 Studies in Municipal Inspection

A brief mention should be made of some of the applications of aerial photography in municipal inspection cases, where in many instances the responsible agencies were, due to insufficient funds and manpower, unable to inspect activities in urban areas for which they were responsible. In rapidly growing urban and suburban communities it is often extremely difficult for taxing authorities to keep their information on personal property up to date. Aerial photographs can quickly reveal the presence of new buildings, swimming pools, landscaping and paving, each of which adds to the value of personal property (Rex, 1963). It has been estimated that the additional taxes generated from the improvements found on the photography will more than exceed the cost of obtaining the photography.

In terms of urban environmental quality of air and of water pollution, a few municipal agencies in the USA have begun to utilize remote sensing techniques, though the majority of such applications are still in the research stage. In the area of atmospheric pollution, techniques for data acquisition and analysis have been developed by Veress (1970) and Barringer et al (1968). In the field of water pollution detection using remote sensing techniques, the studies of Strandberg (1969) and Scherz (1972) appear as major contributions in the field (see Appendix 2.II).

2.25 Studies in Open Space, Urban Landscape and Recreation

A study much more oriented to open space and recreation in urban areas has been carried out by Dunn (1972) in which she identifies a number of remote sensing application opportunities in urban open space and recreation planning, and emphasizes that remote sensing applications in these fields have not been adequately explored. Referring to the potentialities of remote sensing technology she states: "while the lack of sufficient planning information has always been regrettable the dramatic acceleration of the rate of change in urban social and physical environments has made the condition progressively intolerable. The increasing lack of contemporary policy and managerial decision making, and the widening scope and lengthening impact of its effect mandates that new technologies replace the myopic methods, and that they be integrated rapidly into the information gathering and analysing phase of the planning process". In her study she compares four independent studies conducted in 1970, which two years later provided simultaneous data and information for urban open space and recreational planning:

1. The US Department of Commerce and Bureau of the Census
2. The US Department of the Interior's Earth Resources Observation System (EROS)
3. National Recreation and Park Association (NRPA) gathered national data, and
4. NRPA conducted ground inventory and analysis of public and private open space and recreation resources in the 25 largest cities in the Country (U.S.A.).

The EROS flights included eight of the cities selected from the twenty five, and visual inspection of colour infrared 1:50,000 scale enlargements was revealing. Small and large urban parks, golf courses, streets lined or not with trees, playing fields and a wide variety of recreational facilities were easily identified. She reasonably speculated that the inventory of urban open space resources by remote sensing will replace ground observation altogether. Finally she concluded that presently both high altitude aircraft photography and satellite imagery consistently confirm optimistic preliminary forecasts regarding the potential of remote sensing to urban open space and recreational planning.

In the Metropolitan Washington D.C. study (Mallon, 1972) which was initiated within the Washington COG, an important part was an Open Space Study of twenty two areas comprising about 176,000 acres of open spaces classified by the council as "Areas of Maximum Environmental Quality (MEQA's). Survey data were required on the extent of urbanizing influences affecting these MEQA's for current status data needs as well as for providing a base for comparison with data from future surveys. Colour infra-red photography was used at a scale of 1:120,000, dated September 1970, flown by NASA for the USGS (United States Geological Surveys). The Open Space Study occupied some three or four weeks and it has been estimated that conducting a similar survey using conventional data acquisition methods might have consumed more than "a year's time".

Lindgren (1971b) emphasized the usefulness of colour infra-red films in detecting health of vegetation and particularly trees in urban open spaces. The capabilities of this film to detect vegetation disease have been recognized for several years. In the States cities have begun to use colour infra-red film in an attempt to monitor the health of shade trees. Denver has effectively used colour infra-red film to defend its shade trees from an attack of Dutch Elm disease. The elms,which number over 200,000, represent about 60% of the city's shade trees. When the disease struck in 1969, CIR photography was used to detect the dead and dying trees. The rapid removal of stricken trees has at least slowed the spread of the disease. Other cities in the USA have begun to monitor the impact of smog and salt upon the health of municipal trees and other urban vegetation.

In a series of reports Witenstein (1956) has emphasized the usefulness of aerial photographs in the development of a methodology for urban analysis. He indicated that apart from the potential of the technique as a tool in land use surveys and analysis of growth dynamics, the air photo gives to the administrator a general perspective of the open-land use, recreational uses and vacant land situation in the city.

Such data can direct zoning policies, acquisition of new parks and facilities to meet the needs of a growing population. Such measurements are considered as "well within the required accuracy for planning".

Dill (1963), in a study carried out in North Hampshire, attempted to identify the possible application of air-photo analysis to aid in outdoor recreation site selection. He indicated that aerial photographs can provide up-to-date information and can be used in three ways:

1. To make estimates of the overall site potential for a large area,
2. To identify and locate possible sites, and
3. To make detailed studies of individual sites to assist in final site selection, technical planning and final presentation.

Many recreational problems have been studied and documented by the Outdoor Recreation Resources Review Commission (ORRRC) in the USA in a series of reports (1962, Report to the President), issued in the sixties. Several of these reports recommend the use of aerial photographs.

An extended landscape and recreation sites evaluation study has been carried out by MacConnel and Stoll (1969). The problem was to develop the recreational potential of the Connecticut River without destroying its aesthetic value. They emphasized the fact that very limited research has been done to determine the advantages and limitations of the technique of remote sensing for this purpose. Similar attempts to evaluate the use of aerial photography for recreation and open space planning have been made by Colwell (1950) and MacConnel (1956). MacConnell and Stoll (1969) used 1:12,000 and 1:20,000 black and white aerial photographs, taken with a time lapse of 10 to 13 years, to determine past use and development trends. They developed a classification system capable of describing the nature of the land itself, the vegetation of the landscape and the land use of other features which would be of value to those interested in the river and the land near it. They then transferred the information to USGS maps and reproduced the maps of the river for planning agencies. They have also prepared statistical summaries of this information by political units, and have made recommendations for recreational development of the river. Their land use classification based on current condition and use of the land consisted of seven large groups: Agricultural or Open Lands, Forest Lands, Wetlands, Mining, Exposed Rock or Waste Disposal Areas, Urban Outdoor Recreation Facilities and River Bank and Edge of River Bed, including 9, 40, 9, 6, 12, 14 and 26 subclasses, respectively. The minimum size land unit identified on the aerial photography was restricted to the map space required to display a map symbol. The size was half an acre in Massachusetts and Connecticut, and one acre in Vermont and New Hampshire.

This classification system which was a mixture of vegetation coverage, land use, landscape features and land condition factors, resulted in the production of a series of maps overloaded with information. The authors indicated that those maps "included nearly everything of interest to planners in the study area". They concluded that the aerial photographs proved invaluable for analysing the recreational potential of the Connecticut River, and illustrated the scope, variety and invaluable nature of information which can be derived from such analysis over any period of time for which aerial photographs exist.

For a similar purpose (to identify recreational potential of areas with sufficient accuracy, using aerial photographs to reduce the cost of recreation site surveys) in Michigan, Olson, Tombaugh and Davis (1969) carried out a survey based on the physical characteristics of the area and data from other sources. They developed a number of standards for use during the study which reflected requirements for specific activity types and particularly for boating, swimming and camping. They used 1:20,000 scale black and white and 1:15,840 scale colour infra-red photographs and concluded that sites could be identified with sufficient accuracy to make co-ordinated air-photo/ground inventory methods more economical than ground methods alone. Three major types of error in the air photo work are identified, 1) errors due to unrealistic or ambiguous standards of classification, 2) errors due to failure to separate clearly the inventory and management decision-making functions, (in many cases the site considered most desirable during inventory, proved unavailable or unacceptable for other reasons), 3) errors due to inexperience of the interpreter.

The number of studies related to open space, recreation and landscape evaluation is considerable. In most of them, carried out by governmental or private organizations in USA, aerial photographs are used not systematically but only as a supplementary tool. Work in the landscape evaluation field, such as that of Leopold (1969) in landscape aesthetics where infra-red high altitude photography was used to evaluate the Hell's Canyon Landscape, again proved the advantages of the technique. Jacobs and Way (1968), in their systematic study at Harvard to evaluate the landscape of Martha's Vineyard, based their information on aerial photographs and field work, using the techniques and notation developed by Lynch (1960). The purpose of this study was to identify the potential of the landscape for visual absorption of land use activities. McCarthy, Boots and Niemann (1973) evaluating ERTS-1 colour infra-red imagery emphasized the usefulness of the technique as a tool for landscape architects when such problems arise, as vegetation identification, small scale pattern delineation, predominant and specific species identification and problems of biotic diversity and distribution.

Niemann et al (1970) emphasized very strongly the usefulness of remote sensing techniques to landscape architects and others responsible for the environment:

> "....remote sensing for landscape architects, planners, environmental designers and in general environmental managers, is indeed a point of departure. Those who fail to grasp the ideas and master the tools will be out......"

In the general field of natural resources many inventories using remote sensing techniques have been carried out in the USA and some such studies cover entire states, involving small scale satellite imageries. These studies consisted of smaller co-operative projects carried out by different agencies inside the particular state. Each agency deals with a different aspect of the environment, such as wildlife, urban and regional analysis, and agriculture. Such extended projects are those of Kansas (Barr and Martinko, 1976), Michigan (Hill-Rowley et al, Boylan, Enslin, and Vlasin, 1975), New York State Recreation and Open Space Inventory (Wilson et al, Beevers, Fullen, and

Pieron, 1970), Interdisciplinary research on the application of ERTS-1 data to the Regional Land Use Planning Process within the state of Wisconsin (Clapp et al, Kiefer, McCarthy, and Niemann, 1972), which together with several others is a manifestation of the increasing awareness towards a systematic use of remote sensing for planning purposes.

2.3 The Use of Remote Sensing Techniques in Urban Planning in Europe and the Third World

The pattern of urban and rural land use in Europe has a smaller scale and is more varied and mixed than in the USA. Interpretation techniques developed in American cities cannot always be applied to the more compact European cities, where a long historical development has influenced the relation between form and function. This may make planners doubt the feasibility of surveys with aerial photographs, though the main reason might lie elsewhere.

Brenda White (1971) suggested that the planning profession fails in general to exploit any information category fully, even those which it ranks most important. She also found, during a survey in 1968-69, that British planners rank aerial photography only twelfth in order of importance out of fourteen sources of operational information (see fig. 2.1). Collins (1969) commenting upon the 'potential' of aerial surveying in urban planning has emphasized the reality that "the planner cannot avoid being drawn into the current technological revolution if he is to remain professionally competent to tackle the new and complex problems which exist. The nature of planning problems which confront us in this densely populated land demand increased activity in fundamental research to re-evaluate the data needs of planners and policymakers".

In the U.K., notwithstanding, interesting research results have been obtained in population studies, land use mapping and derelict land inventories by Collins et al (1969d, 1969b, 1970, 1971). In this chapter three studies representing each of the above aspects of the urban environment will be reviewed.

In the population study of Leeds by Collins and El-Beik (1970) which represents the major contribution to this approach, a comparison was made between aerial photography and census data. The census and the enumeration district maps were used initially to obtain population data, and the housing stock was derived from the aerial photographs. From these the population densities were determined of a number of sample enumeration districts containing a single type of housing. Another set of enumeration districts was selected and the housing stock again derived from the aerial photographs. By considering the type and quantity of the housing stock and the population density of each housing type, the population figures were estimated for each enumeration district. The values of these population estimates were then compared with the values recorded in the census. The overall population estimate had an error of only 2% but the estimates for some of the individual enumeration districts showed greater errors. These errors were assessed and analysed and some suggestions were made to improve the methodology used in the study.

In the Urban Land Use study in the city of Leeds, also carried out by Collins and El-Beik (1971), black and white aerial photographs were used at a scale of 1:10,000 to extract as much information as possible relating to the urban land use in general, and industrial activity in particular. The findings of this work did indicate that for air-photo techniques to play a significant role in detailed land use studies, photography at a scale as small as 1:10,000 is only of marginal value. Among other things, the authors concluded that the choice of the scale of air-photography is dependent on economy and that the success of all air-photo studies depends on the detail and character of the items in the developed key and the correspondence between form and function. The authors suggested that the results would be better if large-scale photographs were available and the relationships between form and function were more obvious.

On the other hand, for the regional "derelict" land studies carried out by Collins and Bush (1969a and b) for the West Riding of Yorkshire, the scale of 1:10,000 air cover used was found to be entirely adequate for a very detailed quantitative and qualitative evaluation. In their work they have adopted the term "spoiled" land, which includes all "land which has been so damaged by extractive or other industrial processes that it gives offence to the eye, and is likely to remain so unless subjected to special forms of treatment". Both active and disused sites are included in their survey.

A pilot study, covering 200 square kilometers of the area was carried out to assess the value of 1:10,000 scale black and white photography as a source of information related to "spoiled" land. In the first stage they re-defined spoiled land and compiled a six tier classification of nearly 50 different units. This classification was used in a field survey to annotate six aerial photographs which constituted part of the key which was then used in the photointerpretation.

of the area. They identified and mapped 298 sites and a field check revealed that all were correctly allocated in the first order of the classification; only two were incorrect in the second order, and six were incorrect in the third order. These accuracy figures represent the minimum that can be achieved in the conditions prevailing in this study.

They also extended their work by making a detailed examination of a set of 1:20,000 scale photography taken 5 years previously. With this photography, the compilation of a 1:25,000 scale "spoiled" land map covering 100 square kilometers was completed in less than 5 working days!

Collins (1972) commenting on the importance and the potential of this work stated that "this work is now being extended to cover two counties in Great Britain, and will monitor - both quantitatively and qualitatively - the type, rate and amount of change in the spoiled land situation. The information then can be correlated with other environmental/ socio-economic factors such as population migration, environmental quality, land values, and location of new industry, in an attempt to determine the significance of spoiled land in the economic development of the two regions".

The contribution of Lo (1971) in monitoring the city centres of Glasgow and Hong Kong is a major attempt to study and map the three-dimensional aspects of land use in the urban core. He emphasized the fact that in most cases the degree of correspondence between form and function varies from fairly high to low. Where there is a low degree of correspondence, reliability of aerial photographic interpretation is affected negatively. Important factors in this context, however, are the cultural and socio economic background and the location of the activity. A similar study has been carried out by Pollé (1974) for the city of Enschede in Netherlands. He concluded that "although the use of function of many buildings in city centres cannot be reliably established by photointerpretation, the aerial photograph is considered very useful in land use surveys in the inner part of towns. Aerial photography can play a key role in making a survey feasible at all. Many of the practical problems of a survey in a city centre can be efficiently solved".

At this point it is significant to refer to the land use survey undertaken by the Greater London Council, started in 1966, which has proved a time and money consuming project and which in 1973 was still being carried out as if aerial photographs did not exist, (Gebbett, 1972). The situation in other European countries is not much different. A survey of the Netherlands in 1975 (de Bruijn and Dijkstra, 1975) showed that nearly all municipalities with a population of between 90,000 and 175, 000 had recent air cover of a suitable scale (1:2,500 or 1:5,000) at their disposal, but its use was restricted mainly to straightforward ad-hoc applications (see fig. 2.2). Only the use of colour infra-red photography for public vegetation maintenance tended to be used in a more systematic way (Remeyn and De Kock, 1972). A series of reports by S.I.A.B. (Committee for the study of the influence of natural gas on vegetation) related to the quality of urban vegetation, have been published in the Netherlands. The reports published in November 1973 give some insight into the importance of urban green areas and street trees in human society, and show how modern technology in the use of "false colour" films, can be mobilized to monitor the condition of these trees so that remedial measures can be taken promptly. For this project, the Planting Section of the Public Works Department in Amsterdam first commissioned KLM-Aerocarto N.V. of The Hague to take a number of photographs of urban districts where there were problems with street trees, and obtained some useful information relevant to research into the effects of gas leakage and high water-tables. The results of the Amsterdam photographs were surprisingly good and led to the S.I.A.B. commissioning infra-red aerial photographs of several natural gas 'test sites' that had been in operation in The Hague since 1968.

In the field of urban land use mapping using aerial photographs, the USEMAP (Urban Surveys Experimental Method for Analysing Photo-interpretation) method which was developed at ITC-Enschede in Netherlands by de Bruijn (1974) and in parts of which the author of this thesis had the opportunity to participate, is an important contribution in the field. USEMAP is a computer operated system, using a grid cell as its basic spatial information unit. The whole project was carried out in two stages, USEMAP 1 and USEMAP II. Experience of the first version (USEMAP I) showed that the development of a simple basic system to test interpreter's reactions was possible, and it gave useful experience for developing the specifications. USEMAP I, in general, took place in the years 1972/73 and was used for an urban land use study of the city of Enschede from aerial photography of 1963 and 1972. Interpretations were registered on a 100 x 166m grid. To control interpretation quality, two independent interpretations were made for each year. The programme produced maps and a list of photointerpretation errors which proved useful for specific training feedback on interpretation mistakes.

After correction, lineprinter maps and tables of the land use were available for both years, giving a satisfactory picture of the city structure. Also a change-map 1963/1972 was produced, giving some insight of land use changes over a 10 year period. Overall accuracy of maps and tables was estimated to be sufficient for many urban planning needs (see fig. 2.3).

USEMAP II performed the same routines as USEMAP I, but in a more sophisticated way. Also a large range of options was added that could be used for simulating planning applications. The second stage took place in the years 1973-75. The selection of the size of the grid cell was a crucial point: many different cell dimensions were used and generally little argument is used to explain a particular choice. During the operation of data recording on coding forms the grid cell was not superimposed on the aerial photographs but it was always superimposed on orthophotomaps of which the usefulness was emphasized.

In France the use of photointerpretation techniques for traffic purposes seems an established commercial operation, but no articles have been published so far about this operational use (CETE-AIX, 1975). In the same country studies on land use suitability for urban development, quality and type of buildings, open space use, effect of water on the ground surface, are common (Dubuisson, 1973).

In West Germany aerial photographs are frequently used for urban purposes. The planning authorities of the Ruhr industrial connurbations are systematically using aerial photography and other remote sensing techniques, especially for land use mapping, development control and environmental pollution purposes. The Ruhr Authority renews its photography at three year intervals and a research programme has been carried out to assess the usefulness of multispectral scanning and thermography for urban/regional surveys (SVR Report, 1972). Also, in the Netherlands thermography studies have been carried out by NIWARS (1972) in an experimental way and successfully a leak has been detected in a district heating system. Some studies in the field of monitoring different aspects in the urban environment with remote sensing have been carried out in Japan, and collection of data with aerial photography is now practised in cities of the Third World, (see Appendix 2.III).

2.4 Conclusion

Although the approaches discussed have been tried in different places, using different methodologies, material and scale, and have shown mixed results and recommendations, the capability of utilizing remote sensing techniques to evaluate urban environments in general, and open space in particular, has been demonstrated. In many of the investigations described, open space, and the amount and condition of urban vegetation coverage, was a constantly present indicator in determining residential environmental quality and socioeconomic status, but was mostly used together with other indicators of the physical environment, open space playing only a small part in these studies. One conclusion could be that during the last few years research has focussed strongly on multispectral scanning from satelities with emphasis on regional and metropolitan (large area) surveys. Consequently less attention has been paid to local urban (small area) surveys concerned with the daily perceived space, including those nearest to the people: open spaces such as gardens, neighbourhood parks, streets and seminatural environments of the urban fringe.

In most of the studies carried out which deal with remote sensing applications in urban areas, open space is almost always represented as a single, non-sub divided unit in the classification. As a result, open space is examined not separately and extensively, but mostly within an urban land use integrated survey system. Also the fact that individual units of open space have been examined separately, as in the case of vacant and derelict land, recreation grounds, urban vegetation, water pollution, parking surveys and various landscape studies, validates the argument that open space has not been seen as a holistic entity and has not been surveyed or investigated in that way as a separate land resource and as an important indicator of the quality of the environment.

In many studies the classification systems designed to be applied in photointerpretation overlap each other and many classes of land use in a Transportation, Residential, Industrial or Agricultural model could very well fit in an Open Space model and vice versa. This usually happens with streets (Transportation Open Space), private gardens (Residential Open Space), mineral extraction sites (Industrial Open Space) and allotments or horticulture (Agriculture Open Space). It is obvious that the compilation of a classification system depends on the purpose for which the system is developed. But, even in such cases where an attempt has been made to classify urban open space, the term is usually meant to be very narrowly interpreted and defined, with the result that the park, the square, the sports ground and the urban woodland or botanical garden are included as the only open space units in the urban scene. In this study urban open space will not be examined under such a narrow definition but will include almost every piece of open land inside the urban area.

Another conclusion must be that remote sensed data (photographic or non-photographic) are not yet used in an operational, basic, or supplementary standard input to the modern urban planning process. Aerial photographs are widely used on an ad-hoc basis for various isolated applications (see fig. 2.4). Demonstrated capability and actual use of the majority of remote sensing systems are not yet in agreement. Horton (1974) supports these statements when he asserts that the majority of the applications of remote sensing technology in urban areas have two characteristics:

"(1) the applications are quasi-experimental, in the sense that large scale and continuing demonstration projects utilizing remote sensing methods have not been carried out; and

(2) adjustments in interpretation techniques and data translation models often are necessary when applied in different cities"

More research is required in order to bridge the gap between potential and actual applications of imagery, paying more attention to organisational and educational aspects, as well as to the very basic question of the specification of the information demand of urban planners and other environmentalists, and the relationship with alternative sources of information.

Figure 2.1 COMPARATIVE RANKING OF OPERATIONAL SOURCES (after B. White, 1971)

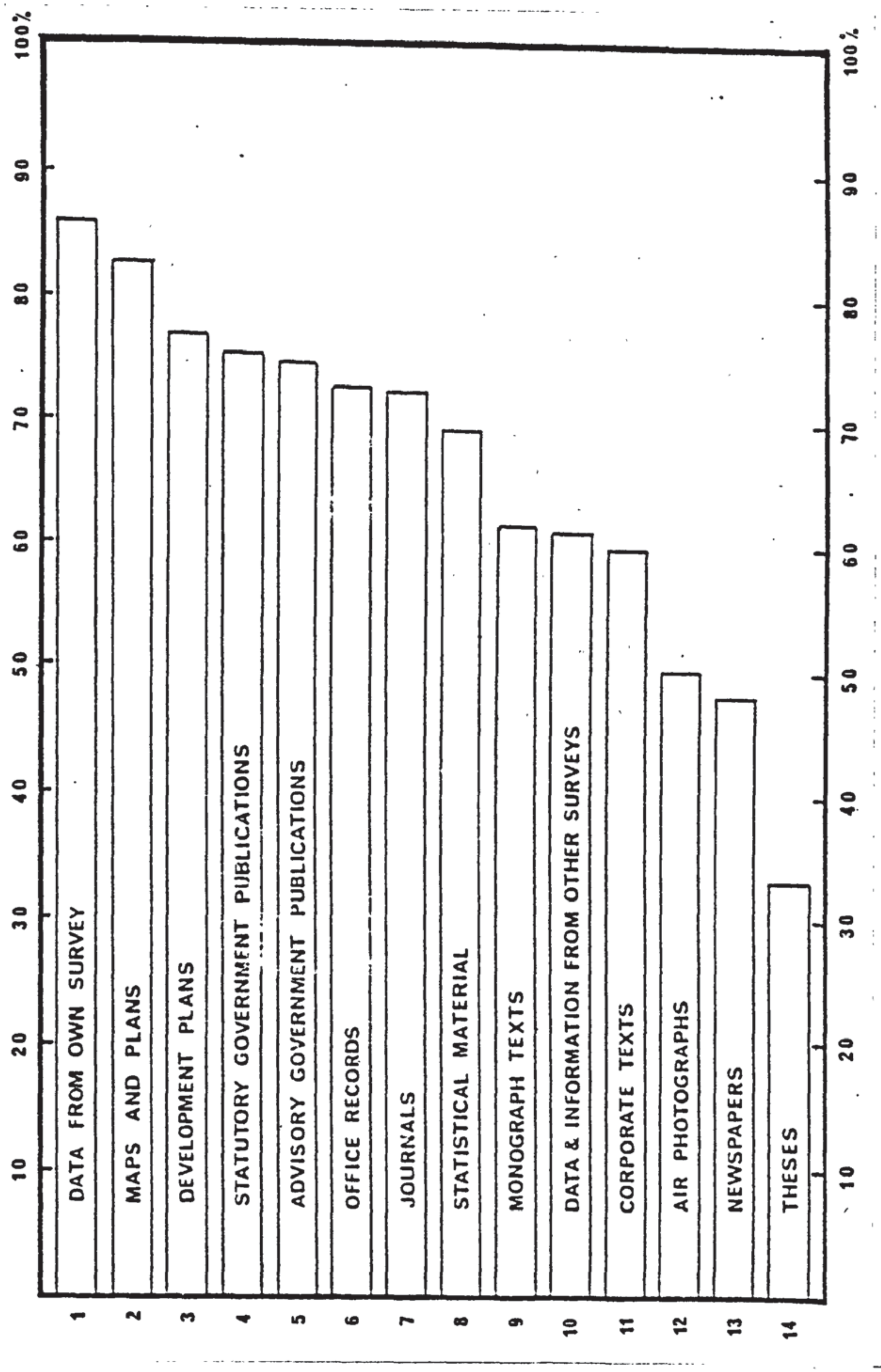
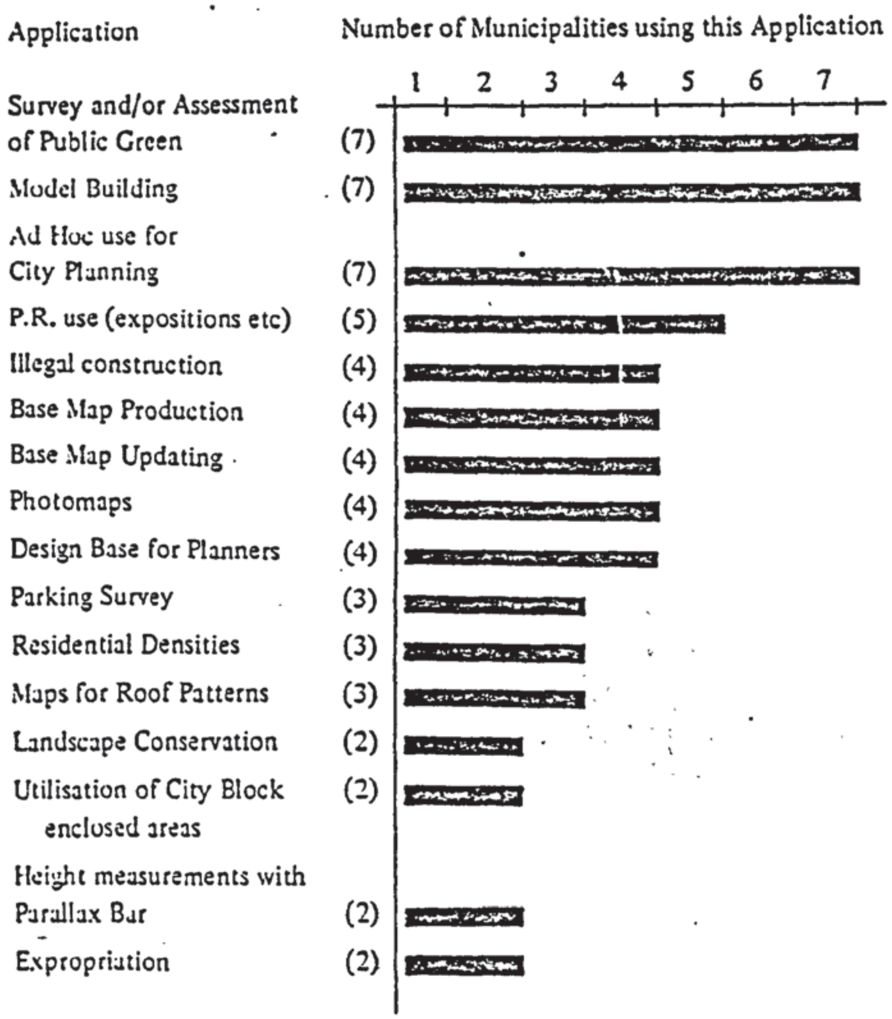


Figure 2.2 USE OF AERIAL PHOTOGRAPHY BY 12 MUNICIPALITIES IN THE NETHERLANDS WITH 90,000-200,000 POPULATION (after ITC - Journal, 1976-2)



Mentioned only by one Municipality:
Traffic Survey, Conservation of Monuments, Illegal Refuse, Industrial Landuse Ratios, Real Estate Tax, Vacant Land Survey, Education

Figure 2.3 LAND USE CHANGES IN ENSCHEDE (after de Bruijn, 1974)

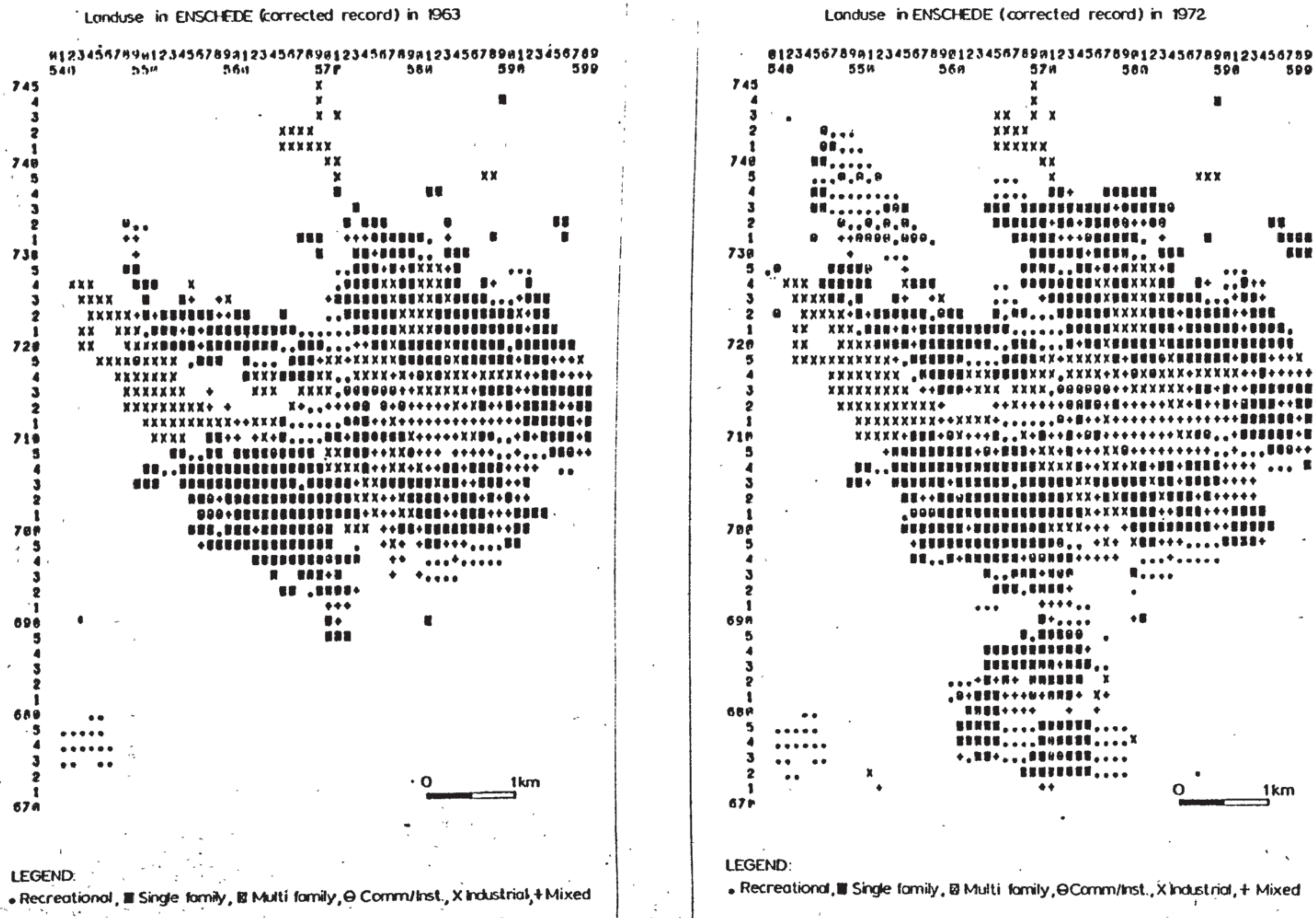
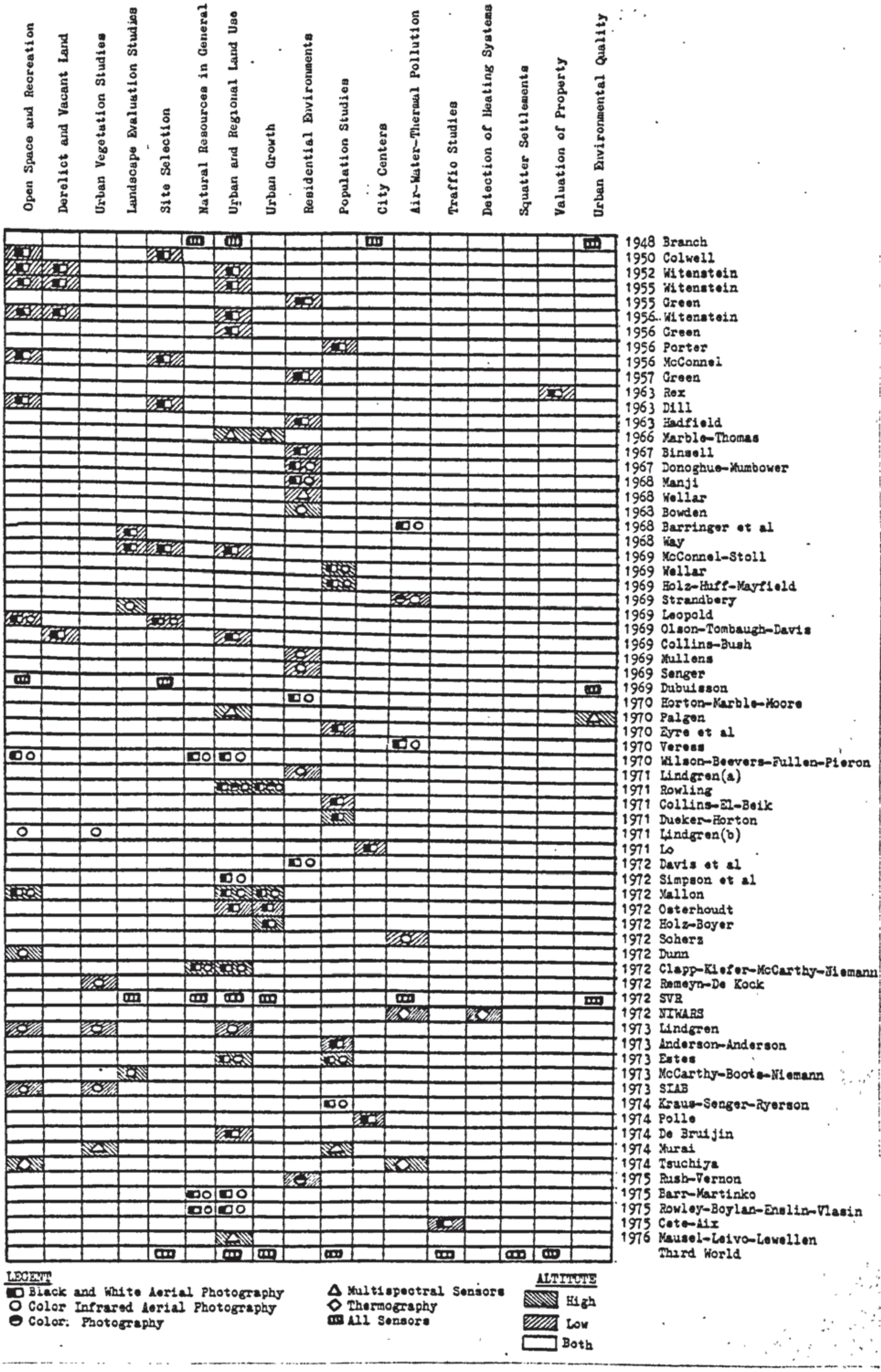


Figure 2.4 MAJOR APPLICATIONS OF REMOTE SENSING IN ENVIRONMENTAL PLANNING SINCE 1948



CHAPTER 3

THE URBAN OPEN SPACE PROBLEM AND SCOPE OF THE STUDY

> "Land is the most precious resource of the metropolitan area. The present patterns of haphazard suburban development are contributing to a tragic waste in the use of a vital resource now being consumed at an alarming rate.
>
> Open space must be preserved to provide parks and recreation, conserve water and other natural processes, prevent building in undesirable locations, prevent erosions and floods and avoid wasteful extension of public services. Open land is also needed to provide resources for future residential development, to protect against undue speculation, and to make it possible for state and regional bodies to control the rate and character of community development"

(President Kennedy's Housing message to Congress, March 9th, 1961)

3.1 Introduction

This chapter considers the problems, associated with the utilization and management of open space in cities, faced today by most planning authorities: how the open space, as an important part of the urban environment, is placed and conceived within a broad concept for improving "environmental quality" in urban areas: how planning authorities have carried out open space surveys in the past and what information they have collected. Special reference is made to the Merseyside Metropolitan Planning Authority to identify their needs in collecting and mapping open space data and with these needs in mind the objectives of this study are outlined in an attempt to develop an operational methodology in collecting this data using remote sensing techniques.

3.2 The Problem

In 1964 the first report of the study of industrial dereliction in Britain "Derelict land" was published by the Civic Trust. Its particular aim was to stimulate the active interest of members of local authorities, and their electors, in land renewal and landscape improvement as a means of removing the scars of the past exploitation of land and the social problems which accompanied it. Many reports have subsequently turned their attention to the subject of urban open land, neglected, misused, or overused, and discussed the land use policies, legislation and attitudes which have produced the 250,000 acres of land estimated to be lying as <u>wasteland</u> - or <u>dormant</u>, using the term introduced by Cantell (1977a). Dormant land includes vacant plots, or land in only temporary use which could be brought into permanent use without major works or reclamation. In other words, land which, to be brought into active use, requires stimulation rather than reclamation. For example, sites of demolished buildings, unused areas of land left over after development, abandoned allotments and abandoned railway sidings.

The urban open land problem includes not only these types of open spaces, but also land occupied by old parklands, common lands and other recreation sites which are partially wastelands in the sense that their original design and intensive care is no longer appropriate to the present surrounding social fabric. In the urban context their original purposes are very different from their present, but the sites have not been explicitly replanned for modern open space or other land uses. Such land resources have to be embodied in a new land use planning process.

Cantell (1977b) expressing his views through the Landscape Research Group; has described the situation as follows:

> "The closely-built towns are becoming an uneven potage of pock-marked streets and deserts of wasted plots. The friendly enclosure of continuously built-up streets in town centres is being eroded by demolition without replacement. The loss is not only visual but the idle spaces represent the break-up or disturbance of communities and businesses. Cumulatively they constitute a significant waste of land particularly on a densely populated island which imports much of its food and builds relentlessly on its farmland"

Alice Coleman's warnings and arguments (e.g. Town and Country Planning Summer School 1977), delivered through several publications and discussions, about the failed environment in the inner cities have been recognised by the policy makers. For instance (Architects' Journal, Feb. 1977) in his speech to the Bristol Conference on Inner Cities the Secretary of State, Peter Shore, emphasized that:

> "The land resources of the nation are not so limitless that existing urban areas can be run down to dereliction, and the land in agricultural use taken for housing and urban development on an even bigger scale"

Alice Coleman in her messages emphasizes the need to control the more sprawling growth into rural areas, which creates even more rural waste land and new "urban" expansion. She indicated once more (Town and Country Planning Summer School 1977) that:

> ".......we cannot afford to sacrifice more farmscape; we cannot afford to permit wasteful urban fringe and we cannot afford to jettison the inner city and displace its land uses outward......
>
> ......The objectives of Classical Planning remain as valid as ever; we need strong-hearted cities with prosperous employment and attractive living environments that attract people instead of repelling them, so that the countryside can be protected instead of invaded"

From the point of view of agricultural economics, Boddington (1973) accepts the fact that there is direct competition between agriculture and urban development for the more fertile land of the country, and he develops a method for assessing the value of agricultural land for cost-benefit purposes. In his conclusions he states:

> "I believe that we are endowed with but limited quantities of good agricultural land and that, because of economic pressures and competition resulting from the locating of higher population densities in agriculturally fertile regions, we stand in danger of transferring, irrevocably, a large proportion of that land to other uses, chiefly urbanisation"

Best and Swinnerton (1975) refer to the type and quality of agricultural land converted to urban land use and state that:

> "The significance of the changing land-use pattern for agriculture in Britain is the concern created over the ability of the Industry to meet the opposing pressures of a decreasing agricultural area and an increasing demand for food. Existing studies on the agricultural land budget attach considerable importance to the need to retain as much of the good agricultural land in food production as possible because of its higher economic capacity and its flexibility and adaptability of use. On the other hand, urban growth not only continues to be the major competitor for farmland in England and Wales, but it is often stated that it tends to absorb the better quality land because of the initial location and development of many settlements and the comparative advantage this land has for building sites. But this assertion has never been adequately tested however"

Most recently Alice Coleman (1978), subdividing the land in five broad categories of use (fig. 3.1), indicates that "there is a great chain-reaction of land use pressures spreading outward like ripples on a pond.....". Such pressures are the "outward pressures" caused by movement of people from high density housing in inner cities to low density development on the outskirts. New development is not consolidated with existing towns but usually sprawls around farmland, inviting trespassers and vandals who eventually make it unfarmable. The displaced people, sometimes as many as three quarters of the 1901 population, have often moved to greenfield sites on former farmscape. Demolition without subsequent re-development has created great 'holes' of unused space in the inner cities.

Some of these empty spaces are soon developed for new and valuable uses, but an increasing amount of open space is left as waste, or as uncared for recreational space, for which current values are low and future use is uncertain.

In addition to this "chain reaction" which effects a stepwise transmission of townscape disasters through rurban fringe, farmscape, marginal fringe and wildscape, there are also the "pressures of recreation in the countryside" (fig. 3.1).

From the point of view of agricultural economics, Alice Coleman suggests that the slogan "We shall always be able to produce more food from less land" is not valid because of the ecological implications involved. Farmers have been under increasing pressure to produce more food from less land and this has resulted in the clearance of agriculturally unproductive ground, such as hedges, copses and verges, often impoverishing ecosystems and reducing natural control of diseases.

The pressures of increased population, and a more intensive exploitation of mineral resources resulted in a serious deterioration of the environment. This deterioration is evidenced by the existence of open pit mining, the tipping of spoil, and deforestation. In the 19th century the rapid growth of an industrial urban society brought to the city dwellers a whole new class of environmental conditions (traffic, poor quality of houses, noise, over-crowding, lack of space, etc.) to which they have had to adapt. As a result the "great outdoors" of the past has become the "remote outdoors" of today's urban dweller.

Man did not adapt sufficiently to such an environment, and the outward movement of population started. This was helped to a great extent by the appearance of railways, the motor vehicle, electricity and telephones, which allowed rapid decentralization of activity. The advancing suburban sprawl created a tendency for plots of land to become vacant and environmental deterioration to occur in the inner city.

It is obvious that before any meaningful plans can be made for improving the quality of the environment (one aspect of which is the open space resource) it is necessary to carry out a census or survey to determine the current situation.

In the context of this research it is necessary to know the type of open space that exists, where it is, how much there is, and how it is utilised and managed. From the recreational and aesthetic point of view protagonists in recreational and landscape studies have been given a free hand to assert the social benefits derived from urban vegetation and open spaces, without feeling the necessity to quote any evidence, especially quantitative, in support of their claims. If we rely on judgment, experience and commonsense, the presence of greenery in urban areas is widely accepted as being of benefit. On the other hand, there is need for a scientific projection of open space demand for recreational and aesthetic purposes.

It is widely accepted that reclamation and revegetation of urban open lands lying dormant, or derelict, would be useful for aesthetic purposes and for informal use as interim greenspace. Further, some people are now recognising that the greater attractiveness of the areas, once they are revegetated, can have a catalytic effect in stimulating their redevelopment and in slowing deterioration of adjacent marginal areas (Richards and Bradshaw, 1976).

Finally, ecologists can often use the interim vegetation types as phytometers to determine more effectively the potentials and limitations of revegetation in redevelopment plans.

Planning authorities have realised the fact that in order to deal with the situation what is required is a survey of the open land resources existing within the urban fabric, the register being revised annually and the area resurveyed every two or three years.

It is anticipated that not only would this information be useful for development control, structure and local plans, and community land schemes including open space provision and management, but also in the process of finding sites for municipal needs and directing private development towards suitable under-utilised lands for infill housing developments, relocation and provision of open spaces etc.

Already many local authorities carry out "monothematic surveys". These include surveys of derelict and despoiled land, of land in active use for mineral workings, of land used for refuse and other non-mineral tipping, and of open lands used for recreation. Each of these subjects is usually examined separately and few attempts have been made to carry out any integrated or "polythematic open land use survey" to include all types of urban open land.

Such a polythematic open space 'use' and 'cover' survey was undertaken in this study. The work was carried out in close co-operation with the Planning Authority of Merseyside Metropolitan County Council to ensure that the end product of the work would provide the information required by them for their particular purposes.

3.3 Urban Open Space and Environmental Quality

Because the tastes of individuals vary genetically, culturally and idiosyncratically, a specific set of indices of environmental quality can be developed for only a single individual: different people assess environmental quality in a variety of ways.

Although academics and professionals are providing us with comparable histories and outlooks, specific enough so that their appreciation of the environment cannot be taken as representative of that held by the general public, it is not possible to achieve full agreement as to just which elements enhance the quality of the environment, and the sign and weight that should be applied to those elements. However, there is positive agreement between the specialists and the public, that the phenomena which influence environmental quality include almost everything that man can experience.

Coppock and Wilson (1974) contains a single definition:

> "Environmental quality is in a very real sense all things to all men, for the quality of an environment is judged by the attitudes of individual men to it, and such judgments are likely to vary with age, culture, education, experience, income and sex - in short, with life style, and personality"

Many of these things or phenomena which determine the quality of the environment are unlikely to be relevant to remote sensing, but they should not be ignored. In other words "a system for remotely sensed indices of environmental quality can effectively inform national or local policies, but it would be ineffective to conceive of such a system as dominating that policy" (Aschmann et al, 1971).

Open space is one of the phenomena in urban areas that can substantially depreciate or enhance the quality of the environment. Open space is a visible and perceptible land resource which can be utilized, under-utilized, unutilized, or be under multiple utilization.

Remote sensing as a technique has its own limitations, though it is possible to sense particular environmental variables, and some "open space quality" variables without the need to carry out field work. On the other hand there are variables, both natural or cultural, which seem unlikely to be identified by remote sensing systems. The subsystem "open space" will be examined here as part of the all-inclusive system "Environment". Open space data relating to the type, amount, location, use and condition will be recorded and analysed in this study.

Aesthetic quality of open space will be excluded as being not a permanent and established reality, but depending very much on intellectual appreciation and external circumstances. Taking a park as an example, it is always a park by configuration and function: it is meant to serve at all seasons and circumstances, but its "aesthetic quality" varies according to the time of year, the weather and level of use. In short, "aesthetic quality" is not something which can be measured objectively, as it depends largely on subjective appreciation and personal tastes and views.

3.4 The Need

It is obvious that in order to solve the problems cited above, an effective method of survey needs to be developed which will provide data for a variety of planning policies related to open space.

The survey should be capable of supplying detailed information about the amount of open space in a metropolitan area, its location in relation to the surrounding land uses and social fabric, its surface cover in terms of vegetation or hard landscaping, its maintenance, and its physical condition as being a determinant factor of its degree of management.

In order for such a survey to be carried out, a methodological framework is needed to produce open space use and surface cover maps, that will be appropriate for widely varying needs at neighbourhood, city and county levels. The technology of remote sensing offers an efficient, rapid, cost effective and timely approach to the collection and mapping of basic open space data.

3.5 Objectives of the Study

The objectives of this study are subdivided into three stages.

Stage 1 is to investigate the value of aerial photography as a data source for surveying and mapping open space.

Stage 2 is to select and develop that method which seems most relevant to the surveying and mapping of open space and carry out a survey of sample areas.

Stage 3 is to use the information derived from stage 2 to identify the provision of open space with the socioeconomic status of the population.

Stage 1

Objective 1 Define open space in urban areas in its all-inclusive, broadest context - rather than in the more usual and limited 'park and recreational' sense.

Objective 2 Compile an open space notation capable of providing the information needed by the planning authority.

Objective 3 Apply the designed notation to extract information from both black and white and false colour aerial photography. Compare the two data sources in order to determine their usefulness in surveying urban open space.

Objective 4 Produce a series of digital maps, together with statistics, of open space. These will also be used in the comparison of black and white and colour infra-red aerial photography as a data source of urban open space.

Stage 2

Objective 5 From the experience and results derived from stage 1, to develop an operational methodology for surveying, mapping and measuring open space provision and condition in a metropolitan area, using colour infra-red or black and white aerial photography.

Objective 6 To use this methodology on selected sample areas to produce: a) maps
and b) statistics
of the provision and condition of urban open space.

Stage 3

Objective 7 To relate the provision and condition of urban open space, derived from aerial photography, with the socioeconomic data supplied by the Metropolitan County Planning Authority.

3.6 Conclusion

The rapid and extensive development of our cities, especially since the last war, has created marked changes in the landscape. Woodlands have been removed, farms and estates have disappeared, and there has been a significant reduction in the number of people actually living in the inner city areas. The scale and extent of these changes have created a whole set of new problems relating to urban development.

The deteriorating situation of many of the city centres has become so serious that it has resulted in a change of government policy in which inner city redevelopment is to take priority over the establishment of new towns in rural areas.

Planning authorities need to undertake open space surveys in urban areas in order to attempt to solve these problems, renew data banks every two or three years and take advantage of such new technologies as remote sensing to collect their information speedily and economically which would enable them to proceed with their planning decision making.

This project is such an attempt, with clearly defined objectives oriented to the requirements of a particular Planning Authority.

Figure 3.1 LAND USE PRESSURES (after A. Coleman, 1978)

CHAPTER 4

DEFINITION OF URBAN OPEN SPACE

4.1 Introduction

In this chapter a number of sources are reviewed to assess different definitions of urban open space. These various definitions are considered in an attempt to derive one suitable for the construction of a notation for use in this study, which will satisfy two main conditions.

i) The notation must fulfil the data requirements of a Metropolitan Planning Authority for its urban planning and redevelopment programmes.

ii) The notation must be relevant to what the data source - in this case aerial photographs - can provide.

4.2 Review of Existing Definitions

A major weakness of the traditional approaches of attempting to define 'urban open space' is the apparent lack of understanding and appreciation of the various functions of open space. Open space is viewed and assessed quite differently by different professional groups. Urban planners, urban geographers, architects and recreation planners view urban open space from their own particular points of view; they use different criteria and arrive at different definitions.

Some of these definitions will be mentioned and discussed here. It is obvious that open spaces in cities serve the community in different ways, recreationally, aesthetically, economically and socially, and people from various disciplines define it differently according to their own interests.

Best and Coppock (1962) both geographers, define open space as

"......the land which embraces both public and private land of residential, industrial or educational character

> and includes allotments, cemeteries and lands in multiple use such as playing fields and golf courses used for grazing"

This definition has a rather narrow and restrictive character, in that it is concerned with selected uses of open space.

Wright et al (1975, 1976), as recreational planners, define open space as:

> "All urban land and water, both publicly and privately owned that is open to the sky, reasonably accessible to freely-chosen activity or visual exploitation, and that serves man and nature, in an educative, aesthetic, productive, protective, recreative way"

In this definition the "degree of accessibility" refers to open spaces which are used specifically for recreation purposes, production, protection, education and aesthetic appreciation. The activities are specified and the spaces have to be reasonably accessible. Other types of open spaces which are not accessible to "freely-chosen" activities, such as fenced pieces of wasteland in the urban area awaiting development, ancillary open spaces associated with industrial and commercial land uses, and a number of others not having any recreational value (waste disposal sites, mineral extraction, etc.) are not covered by this definition.

Reekie (1972), an urban designer, provides us with another definition

> "Open space is the 'Natural Landscape', e.g. fields, moors, hills and valleys, stretches of water, the broad open space which provides the background and setting for man-made structures and connecting

> links of roads, railways and services. Then there is the extension of natural open spaces, the spaces consisting mainly of grass, trees, plants and flowers, into built-up areas, as parks, recreation grounds, public and private gardens. These are the intra open spaces, together with large town squares which may be described as urban open spaces"

Reekie regards urban open space as an 'extension of natural open space into built up areas'. The main factors in his definition are its naturalness, its use and its surface cover.

Definitions of urban open space used by other urban designers and architects often include the aesthetic property of the space. This requires a three dimensional understanding of open space in relation to the structural elements which enclose it. Open space is meaningful to them as an outdoor volume, but its aesthetic value is something absolutely abstract, and very difficult to measure objectively. A three dimensional understanding involves the subjective assessment of such different features as enclosures, views, openness to the sky, and architectural significance of the surrounding building facades. A subjective assessment of these values can best be done on the ground rather than by any of the aerial remote sensing techniques available. Aesthetic evaluation of open space is a subjective ground level task, and although its importance is acknowledged, no attempt has been made to deal with the topic in this thesis.

Lynch (1973) considers open space as any part of the urban land which is open to the public, and gives the following definition, which he calls a "Behavioural Definition":

> "A space is open if it allows people to act freely within it. This is not the case with most urban spaces, of course, interior or exterior, or with commercial farms, single purpose rural reservations, playfields or even with certain carefully tended woods and parks"

This definition, with its condition of access, might satisfy the recreational planner, but it excludes many areas which would be regarded as open space by other environmental disciplines.

Fairbrother (1972), a landscape architect, considers open space as the landscape which is contained by buildings. She subdivides built-up areas into two categories, indoor and outdoor environments, according to their degree of openness to the sky. In the first category she includes the buildings and transport we move in and out of (indoor), and in the second category she includes spaces which are partly roofed - as entrances, awnings, arcades, covered markets etc., (outdoor). For her, the urban landscape (outdoor space) which is contained by the buildings is also subdivided into two categories. The first is the open space which has only an aesthetic value, and it is a

> "......three dimensional positive volume defined by the landscape material"

The second category of the urban landscape includes the open spaces which are

> "......the voids of prairie planning and are not spaces but gaps"
>
> ".....such meaningless voids are not open spaces but merely the areas of plans where nothing happened to

> be drawn - smaller versions of the unplanned
> green of larger development plans"

Tankel (1966), an architect-planner, gives a simple definition of open space

> "I define open space broadly to include not only all land and water in and around urban areas which is not covered by buildings, but the space and light above as well"

This definition is the most inclusive found during the literature search. All land not covered by buildings is included, and there are no restrictions or conditions relating to use, access or ownership.

4.3 The Open Space Definition to be Used in this Study

The definitions of open space reviewed above are in some cases narrow, referring often to specific properties such as extent, access, activity, ownership or aesthetic quality. In other cases the definition is broader and less specific, particularly in terms of the use and type of open space. It is clear that a very broad definition is essential if the notation (compiled from this definition) is to be used in a multidisciplinary manner.

A broad definition of open space is required: one that considers its physical properties yet may not specify its use, activity or ownership. Its uses are of major importance but identical types of open space may have different uses in different areas.

For this particular study the information needs of the Planning Authority were taken into account in selecting the type and amount of open space information to be collected; hence an essential step was to define and classify "urban open space" in relation to these information needs. It was established that the data collected would be applied in a multidisciplinary manner, so the very broadest definition was sought. This resulted in proposing the following definition of urban open space:

> "That land within the urban framework which is not covered by buildings".

4.4 Conclusion

In reviewing the definitions of urban open space it became evident that different disciplines viewed urban open space with different problems in mind. This resulted in many different definitions of urban open space being proposed. A major Metropolitan County Planning Authority is required to collect a wide range of data on urban open space, in order to meet the needs of various professions and disciplines. It was essential therefore that in this study a definition was proposed which would allow the compilation of a notation capable of being used by multidisciplinary groups. The definition had to be clearly defined, and as broad as possible so that it included every type of urban open space that was likely to exist. The definition has also to be unrestricted by conditions - such as those relating to use, activity, accessibility or ownership.

Finally, urban open space needed to be defined in such a way that it was capable of being identified from aerial photography. This requirement also precluded applying conditions - such as accessibility or ownership. For whilst use and activity of urban open space can generally be identified from aerial photography, it is more difficult and often impossible to determine ownership. A definition is proposed which satisfies all these requirements.

CHAPTER 5

STAGE ONE: COMPARISON OF BLACK AND WHITE WITH COLOUR INFRA RED AERIAL PHOTOGRAPHY IN SURVEYING URBAN OPEN SPACE

5.1 Introduction

After defining the problem as the need to acquire, in the most rapid, accurate and cost effective manner, details of the urban open space, and present this information in both statistical and map form in a way which would be of direct and immediate value to the planning authority, and after defining what is meant by the term "open space", the proposed solution was to investigate the extent to which aerial photography might provide the prime source material to supply this data.

Vertical aerial photographs were available at a scale of 1:10,000 in both black and white and colour infra-red, and comparisons were to be made of their relative value for open space surveys. The work flow (Figure 5.1) shows the way in which the first stage of the project was structured in an attempt to fulfil objectives No. 2, 3 and 4 cited in chapter 3, and satisfy the information needs of the Planning Authority.

5.2 The Urban Open Space Notation System

Past efforts in collecting data on open space use and open space cover have been unco-ordinated among the various specialists, academics and governmental officials. In such a situation no development and acceptance of a standardized notation of open space was possible. There is a diversity of developed notation systems and they differ from place to place, in terms of scale, activities included, and in the problems they were meant to solve. Most of the notations of open space developed by various contributors are not suitable for use in aerial photographic surveys since they include considerations of ownership of land and refer also to particular urban environments in different countries and different places within a country.

Table 5.1 shows the difference between two contributions, one American and one British, which shows the differences in scale, activity, and usefulness for surveys of open space.

In cases where a classification system has been developed for urban and regional land use inventory for use with remote sensing techniques, the open space is rarely classified and examined as a separate and integrated land use. Categories of open space such as streets, water bodies, agricultural lands and neglected wastelands, are distributed inside the classification under various major land use headings, such as Transportation, Agriculture, Wildlife and Extractive Industries.

The amount of information that can be obtained from aerial photographs is considerable and there are numerous variations possible in the definition of each item of land use and open space.

The notation of open space developed in this stage of the study is an ad hoc one based on a pilot study using both types of photography (black and white and colour infra red). Taking into consideration the information needs of the planning authority to direct planning policies related to "provision" and "condition" of urban open space, and the capabilities and limitations of the two types of photography being used, the notation of open space shown in Table 5.2 was finally developed.

In the development of an urban open space notation, emphasis has been given to three important properties of open space: activity, extent and surface cover (including its physical condition). In the production of this system several meetings took place with the planners concerned, and several changes were made to the system such as sharpening or broadening definitions, dropping some categories and adding others. Some properties of open space; configuration characteristics and aesthetic quality, have been excluded as being unnecessary and too subjective.

Before a land use survey is undertaken it is quite common for planners to request as much information as it is possible to collect, including variables which are going to be absolutely unnecessary in their decision making. The more aspects of the environment (or environmental variables) included in a notation the more data will be collected, with all the consequent difficulties of data handling. As stated by McDonald (1976) "too much information only serves to confuse the issue and to retard effective decision making".

Open space as representing the outdoor environment in the city is characterised by its particular functions and its physical properties, and by a large number of other characteristics, most of which it is impossible to include in a notation system. The notation of open space is a simple list of "areas"; visible, measurable and mappable in a strictly geographical sense. The notation has to be oriented towards a particular planning problem and amenable to a particular survey technique.

The notation developed here (Table 5.2) contains fourteen major groups which have been subdivided, mostly on the basis of vegetation or non-vegetation coverage, into a total of fifty eight units.

Four categories of open space have been distinguished in terms of vegetation coverage and maintenance:

VEGETATION COVER AND MAINTENANCE CATEGORIES

Category 1: Unvegetated/hardly landscaped open spaces (see plate 5.1).

slabs, concrete, asphalt, sands, gravel, bare soils, etc.

Category 2: Unmanaged or semi-managed (limited management) self-maintained vegetation growth. (See plate 5.2).

not well-cut grasses, rough grasses, natural looking landscapes overrun by heaths, shrubs, scrub and potential woodlands, etc.

Cateogry 3: Managed vegetation (high grade maintainance) (See plate 5.3).

carpet lawns well cut, architectural hedges, symmetrical flowerbeds, young healthy trees ranged in avenues and other ornamental masses.

Category 4: Poorly maintained vegetation/poor vegetation coverage. (See plate 5.4).

overused or damaged lawns used as amenity greens and pitches, scattered semi-established or established vegetation on bare soils or eroded sites, any diseased or damaged vegetation and woods.

5.3 Development of a Key

The pilot study which included observations on both types of aerial photography (black and white and colour infra red) and field work, was completed before the main study of photo-interpretation and data recording. This was done in order to gain some familiarity with the urban landscape as a whole, and to help in the development of the final notation system in which the cover/maintenance categories, and the development of a key would help to make the distinction between different types of surface according to their degree of management.

Familiar types of open space on the ground, such as a golf course or a soccer pitch, where the vegetation coverage varies in terms of maintenance, have been used as a key to identify and classify other types of open space cover and management. On the colour infra red photographs well cut areas of grass, such as the "greens" in golf courses, appear with a purple hue. The "sandy" areas appear white or white bluish. "Hummocks" appear blue changing to reddish purple or purple towards the periphery because of the appearance of undisturbed organic top soil in the middle with some scattered overused grass cover, changing to a uniform well managed grass cover towards the periphery. The "gorse" areas appear red, light red, and dark green as they vary between self-maintained vegetation growth, rough grass and shrubs and heaths.

On the black and white photography the range of tonal variation is very much less, and textural differences are more important in identifying the surface appearance. The effect of this lack of surface distinction on the black and white photography confirms that it is a much less sensitive indicator of vegetation differences.

Figure 5.2 shows the three enumeration districts selected as the sample area for this study. These three districts vary widely in many respects, particularly in housing type and in socioeconomic class of the population.

5.4 Data Extraction and Recording

Using the Carl Zeiss Interpretoscope (Figure 5.3), the black and white aerial photographs were stereoscopically examined to identify those units of open space listed in the notation (Table 5.2). A transparent cross-grid was placed over the photographs so that the data could be recorded on a grid square basis (Figure 5.4). Each grid cell represents a 20m x 20m square at ground scale, and that use which fell under the cross at the centre of the grid was the use recorded for the entire cell.

Figure 5.5 illustrates the procedures followed in recording the data. Where the cross landed cleanly in a particular category then that category was recorded, as in example 1, 2 and 5. Where the cross landed on a boundary between two categories the decision as to which category to record was made according to the system indicated in figure 5.5. The location of each grid cell was recorded on a coding form so that spatial information could easily be retrieved for mapping purposes. When the identification of a certain open space type was beyond doubt, according to the established "set pattern", the land use, two digit, code number was registered on the coding forms (Figure 5.6).

The colour infra red photographs of the three enumeration districts were then stereoscopically examined and similar information was derived from them and entered on the coding forms. The two sets of survey information - one from the black and white photography, the other from the colour infra red photography - were then fed into a computer data bank.

5.41 The use of the Cross Grid

The notation system with its variety of open spaces ranging from the size of a small garden to the much larger open spaces of the urban fringe, and the sçale of the aerial photography used, determined the size of the grid used in this stage of the study. Urban landscape is very diverse and types of land use and cover vary within a few square meters. Some observations on the photography showed that within the area covered by a 20m x 20m grid cell, up to four types of different land uses might occur.

Some consideration was given as to whether to use a grid square or a single point (in the form of a cross) as a basis for recording open space data. In the former case the 'dominant use' of the grid square would be recorded, whereas in the latter case the use directly under the cross would be recorded. It was found that the latter was very much quicker and, unlike the former, did not involve any judgment decisions or estimates of areas (Figure 5.7).

A cross grid of the same size has been successfully tested in the past where it was used in assessing housing types and population densities in very compact urban areas from 1:10,000 black and white photographs (de Bruijn et al, 1976 and personal correspondence). As will be discussed in

Chapter 7 some random tests carried out by other investigators showed that there was no advantage in accuracy in using the 'dominant use' of the grid square. An important factor was the density of the observations - in all the work carried out in this study a density of 625 points per ¼km^2 was used to record the data.

At a subsequent stage a computer programme was developed to carry out a large number of random samples, from 625 to 10 points per ¼km^2, and the results of this were analysed. The aim of this particular part of the investigation was to give the planning authority some idea of the relative accuracies attainable when using grids of varying density.

5.42 The Use of the Computer

Computer programmes were developed to provide a variety of statistical data and grid maps, the latter produced with the aid of a Calcomp plotter. Digitization was carried out directly from the photographs and not from the topographic maps. The topographic maps show the permanent structures inside the building blocks but not the boundary lines between different grades of vegetation cover and their degree of maintenance.

It seemed obvious that updating the available base map and then digitizing would entail a considerable amount of work without a corresponding increase in value because of the nature of the survey (625 observations per ¼km^2), which demands the real image of the physical urban environment to be depicted on the material. The computer was a most valuable tool in the processing of the interpretation work. The programme developed can be used to check the results more quickly and more completely than can one photo-interpreter and can systematically trace specific error types. From the operational point of view the programme enables the planners to get a clear idea of how a computer can be used in the field of open space information storage and processing for urban planning purposes.

In this first part of the study two main programmes were developed (see Appendix 5.I) to produce a set of maps and printouts of statistics.

Four types of Calcomp maps were produced:

1. Calcomp maps based on information derived from photointerpretation of black and white aerial photographs (e.g. Figure 5.8).
2. Calcomp maps based on information derived from photointerpretation of colour infra red aerial photographs (e.g. Figure 5.9).
3. Calcomp maps where the total differences between the photointerpretation of both sets of photography are shown (e.g. Figure 5.10).
4. Calcomp maps where only part of the total differences are shown and classified as "real differences" (e.g. Figure 5.11).

A very wide range of numerical information can be produced on computer printouts. In this study three printouts were produced including the following information in table form: Appendix 5.II, for each of the three sample areas.

Printout 1 (Table 5.II.1)

The programme worked out the areas recorded by photo-interpretation of black and white aerial photography in both hectares and percentages in the following order:

a) Individual open space units

b) Open space groups

c) Other land uses (not open space)

d) Total area surveyed

e) Four cover/maintenance categories

Printout 2 (Table 5.II.2)

The same data referring to the photointerpretation of colour infra red aerial photographs.

Printout 3 (Table 5.II.3)

In this printout differences between black and white (B+W) and colour infra red (CIR) photography are printed both in hectares and percentages in the following order:

a) Area differences between individual open space units (B+W - CIR)

b) Area differences between open space groups (B+W - CIR)

c) Area differences between other land uses (not open space), (B+W - CIR).

d) Area differences between the total sample area surveyed (B+W - CIR).

e) Area differences between the four cover/maintenance categories (B+W - CIR).

f) Three types of differences in interpretation between B+W and CIR aerial photographs are printed from top to bottom in pairs of open space units with their code numbers and their Ordnance Survey Map grid reference numbers. These differences are printed in the following order:

i. Boundary differences

ii. Differences between major groups of open space

iii. Differences within groups of open space.

This information proved helpful in making a detailed comparison of the value of the two sets of aerial photography. In the analysis which followed, these three types of differences were further divided into eight types.

The advantages of using computers are summarised as follows:

1. The photointerpretation results can be compiled much more quickly than by other methods.

2. Manually compiled survey data in rapidly changing urban areas are often obsolete by the time they are published, since it takes so long to collect them and work them out.

3. Approximate results provided quickly are more appreciated than very accurate results which take so long to produce that they are good only as historical evidence.

4. With computerized data more operations are possible (higher operational flexibility), because different cross-tabulations and ratios can be produced which with any other method would take too much time. By deriving such sophisticated data the understanding of urban phenomena can be improved.

5. In order to get a clearer idea of the spatial distribution of certain phenomena mapping the results can easily be done by line-printer graphics

or by using a digital plotter.

6. Computerized data are always in a format which is convenient for incorporation in other urban models, e.g. residential land use, transportation or industrial uses.

5.5. Survey Results

In order to make useful and easily understandable comparisons (as a source of 'open space' data) between the value of black and white and colour infra red aerial photographs, the information was compiled in various ways. The first comparison was based on statistics showing the total amounts of open space recorded in the major categories (groups) only for each of the three enumeration districts (Tables 5.3, 5.4, 5.5). This comparison did not include details of the vegetation, surface cover or condition.

The results clearly show that, at this level of information, there is virtually no difference in the type or amount of open space information which can be derived from the two sources. However, when details of the vegetation cover and its condition are included, then some significant differences do emerge. Table 5.6 indicates that the colour infra red photography is a much more sensitive indicator in identifying the extent to which the vegetation is being managed.

The suite of computer programmes developed, produced Calcomp maps based on all the information fed into the system. Figure 5.8 shows a computer map of open space derived from the black and white photography, whilst Figure 5.9 shows the same area mapped from colour infra red photography. These map symbols relate to the notation of Table 5.2.

Figure 5.10 shows those grid cells which the computer identified as different, between the maps compiled in Figures 5.8 and 5.9, though some of these differences were not true differences in the air photo interpretation but resulted from a variety of other reasons. These included some misorientation of the grid on the two sets of photography because of slight differences in scale and photo tilt, and of land use changes which had occurred between the two sets of photography. These 'apparent' errors (Figure 5.10) were identified and recorded, and another map was compiled (Figure 5.11) showing the 'real' differences in the data collected from the two sets of photography.

The two sets of photography were stereoscopically examined again, only this time one photograph from each set was viewed simultaneously i.e. a black and white photograph on the left with a colour infra red on the right - each covering the same area (Figure 5.12).

Those areas where a difference occurred, between left and right photographs, were noted and the reasons for the difference were recorded on the computer printout (Table 5.II.3). The differences in the information obtained were classified as follows into two major groups and eight sub-groups. The number of occurrences of each type is given in Table 5.7.

1. Apparent Differences (A)
   a. Both decisions possible
   b. Changes in land use
   c. Boundary differences
2. Real Differences (B)
   a. Differences <u>within</u> groups of open space (unit and sub unit level) where B+W was assessed as correct decision

and CIR as in error.

b. Differences within groups of open space (unit and sub unit level) where CIR was assessed as correct decision and B+W as in error.

c. Differences between groups of open space (group and unit level) where B+W was assessed as correct and CIR as in error.

d. Differences between groups of open space (group and unit level) where CIR was assessed as correct and B+W as in error.

e. No clear situation in both photographs: decision not possible and field check is necessary.

5.5.1 Analysis of Differences in Photointerpretation (Table 5.7)

1. Apparent Differences (A)

a. Both decisions possible.

This occurred when the cross fell on a certain land use type on the one photograph whilst the identical cross did not land on the same point on the other photograph - due to orientation difference, slight scale difference, etc. In this case the decision was made using the information on the photograph and by mobilizing the "mental square image" (Figure 5.5).

If for the same grid point on each photo for the B+W photography the decision was A and for the CIR the decision was B, the land use pattern inside the mental square image suggests the possibility of both the decisions being correct. (Figure 5.13). A total of 176 such cases were recorded for the three enumeration districts (Table 5.7).

b. Changes in land use.

Disagreements due to land use changes were recorded.

The B+W aerial photography was 1974 cover and the CIR was 1975 cover: both taken in summer. Changes in land use are likely to occur in a period of one year, and 8 such cases were recorded.

c. Boundary differences.

The perimeters of the three enumeration districts had to be delineated twice, once on the grid superimposed on the B+W photography and once on the grid superimposed on the CIR photography. The same line had to be traced twice by hand which means that different grid cells were left out or included in the two cases. Some such disagreements did occur along the perimeters, 27 cases being recorded.

2. Real Differences (B)

a. Within groups: B+W assessed as correct and CIR as in error.

These were cases where the cross was representing a land use type "beyond doubt" on the B+W photography at the "unit" or "sub unit level" but the identical cross on the CIR photography showed a different land use. In these cases the B+W had to be accepted as correct. No such case was recorded.

b. Within groups: CIR assessed as correct and B+W as in error.

These were cases where the cross represented a land use type "beyond doubt" on the CIR photography at the "unit" or "sub unit level" according to the criteria established, but the identical cross on the B+W photography recorded a different land use. In these cases the CIR was accepted as being correct. A total of 370 such cases were recorded.

c. Between groups: B+W assessed as correct and CIR as in error.

In this instance the open space units were easy to describe but not so easy to allocate to a particular unit in the notation. The results were that a misclassification occurred when using the CIR photography, and 2 such cases were recorded.

d. Between groups: CIR assessed as correct and B+W as in error.

These are very significant differences in which the open space was correctly identified on the CIR and incorrectly identified on the B+W, and 31 such cases were recorded.

e. Field check necessary.

In only two cases was it found that the type of open space could not be identified from either of the two types of photography.

5.6 Conclusions

Selected field work was carried out, and the results used, not only to field check the air photo interpretation results, but also to make some comparisons between field surveys and air photo surveys when carrying out a detailed inventory of urban open space. This comparison clearly indicated the relative advantages of using aerial photographs as the data source in terms of the speed, accuracy, type and depth of detail, and economy which could be obtained.

In general the overall time taken to both identify and map (in digital form) the type, extent and distribution of open space was in the order of one fifth to one tenth the time it took to record similar data by field survey methods.

The problems of accessibility and visibility severely restricted the comprehensiveness of data acquisition during field work: this was particularly the case when mapping private open space. In marked contrast the air photo view allowed 'access' to all existing open space, consequently there were virtually no 'errors of omission'. Whilst it is difficult precisely to quantify the accuracy advantage of the air photo it is quite justified to state that the air photo survey will virtually always be more (sometimes very much more) accurate than the field survey.

With respect to the type of open space data, and the level of detail which can be obtained from the two sources, much depends on whether the comparison is made at group or sub-group level. At group level (Tables 5.2, 5.3, 5.4 and 5.5) within the constraints mentioned above categories can readily be identified on both types of air photo and by field work. At sub-group level (Tables 5.6 and 5.7) where vegetation type and condition are required, the black and white photography is inferior to both the colour infra red and field work. There is however little to choose between the two latter sources - when using the urban open space notation shown in Table 5.2.

The combined effects outlined do clearly indicate that there are considerable economic advantages in using aerial photographs in general, when carrying out inventories and mapping open space, and colour infra red photographs in particular where details of surface cover and vegetation condition are required.

Even if the photography has to be flown specially it is still more economical than carrying out field surveys.

There is also the additional advantage that the photography forms an essential part of a permanent land data bank, and can be used as the prime source for other environmental and land use surveys.

Having established the substantial advantages of using aerial photography as the data source for identifying and mapping urban open space, the relative merits of black and white against colour infra red photography can be pursued.

The cost of obtaining colour infra red photography is approximately double that of black and white, and it requires very much better weather conditions. The CIR material is also more difficult to process, and being reversal film it is generally used direct. Subsequent prints or second generation diapositives tend to be of inferior quality and the production of consistent material is difficult. This is very important if, as is usually the case, many frames of photography are involved and subtle differences in shade or tone are significant. Whether or not it is worth the extra cost and problems involved in using colour infra red film depends on the extent to which vegetation, surface cover and condition are important.

As Tables 5.3, 5.4 and 5.5. indicate, if only the major open space types are to be mapped then there is virtually no advantage in using colour infra red film. If, however, details of the vegetation type, cover and condition are significant (as seen in Table 5.6 and 5.7) then the use of colour infra red film is essential.

Figure 5.1 THE WORK FLOW

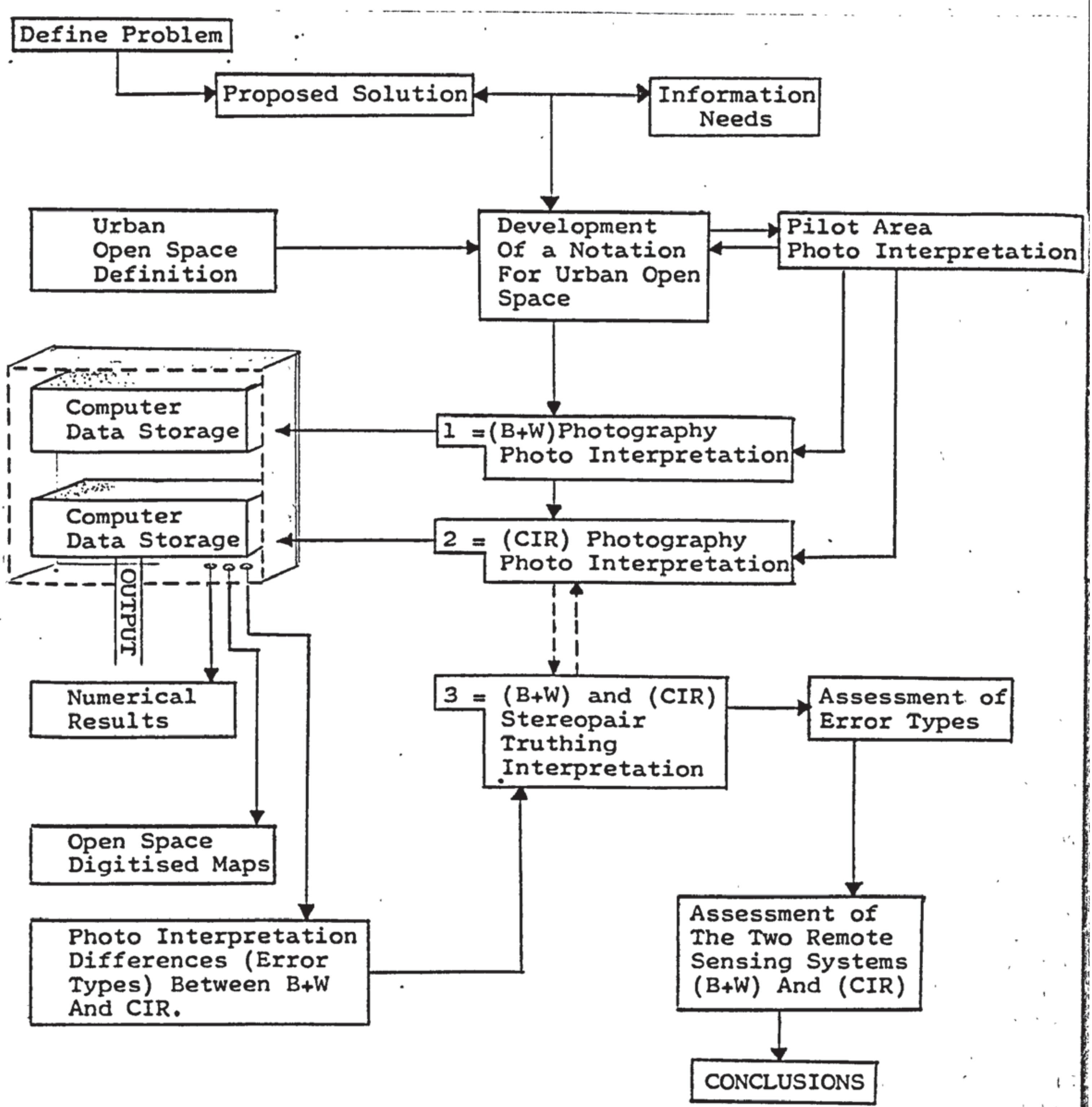


Figure 5.2 THE SAMPLE AREAS (ENUMERATION DISTRICTS)

E.D. 68/1046

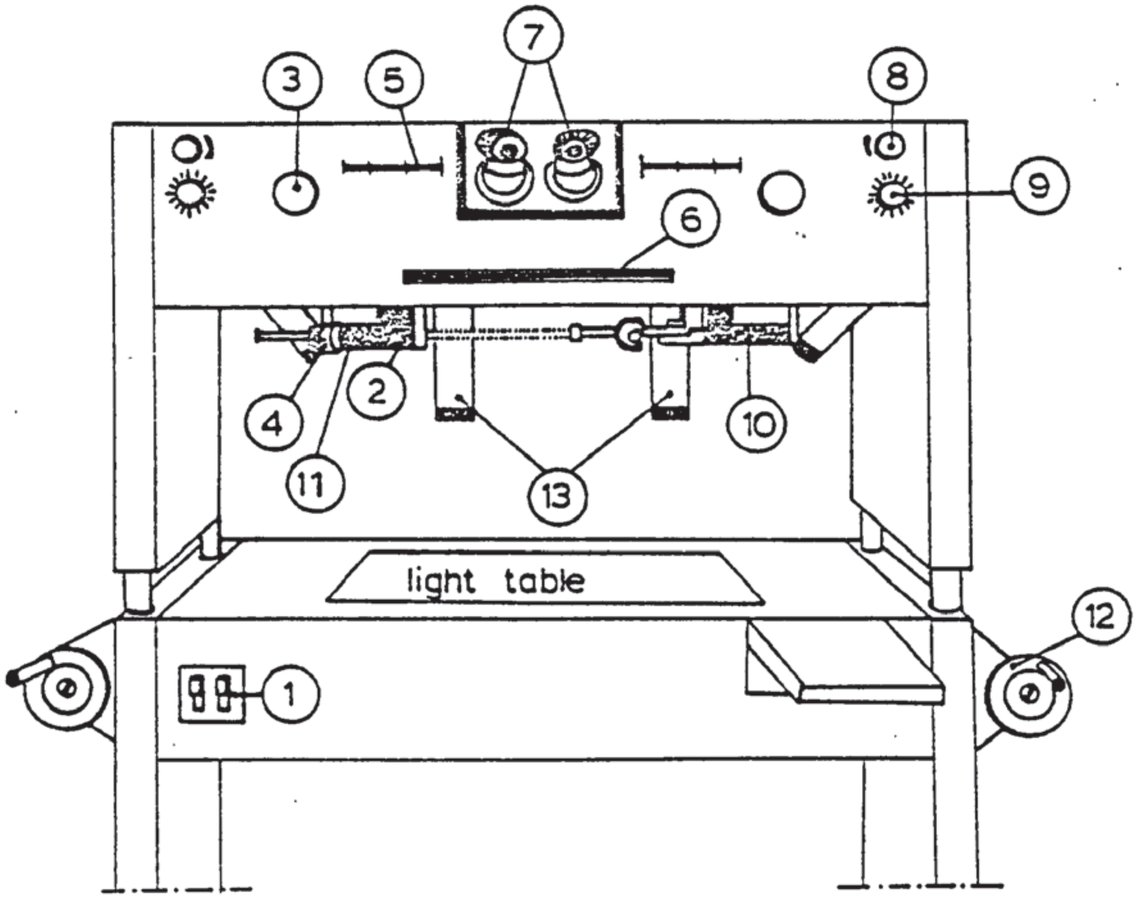
E.D. 44/1054

E.D. 64/1046

Scale 1: 10 000

The three enumeration districts used for the photo-interpretation.

Figure 5.3 THE CARL ZEISS INTERPRETOSCOPE



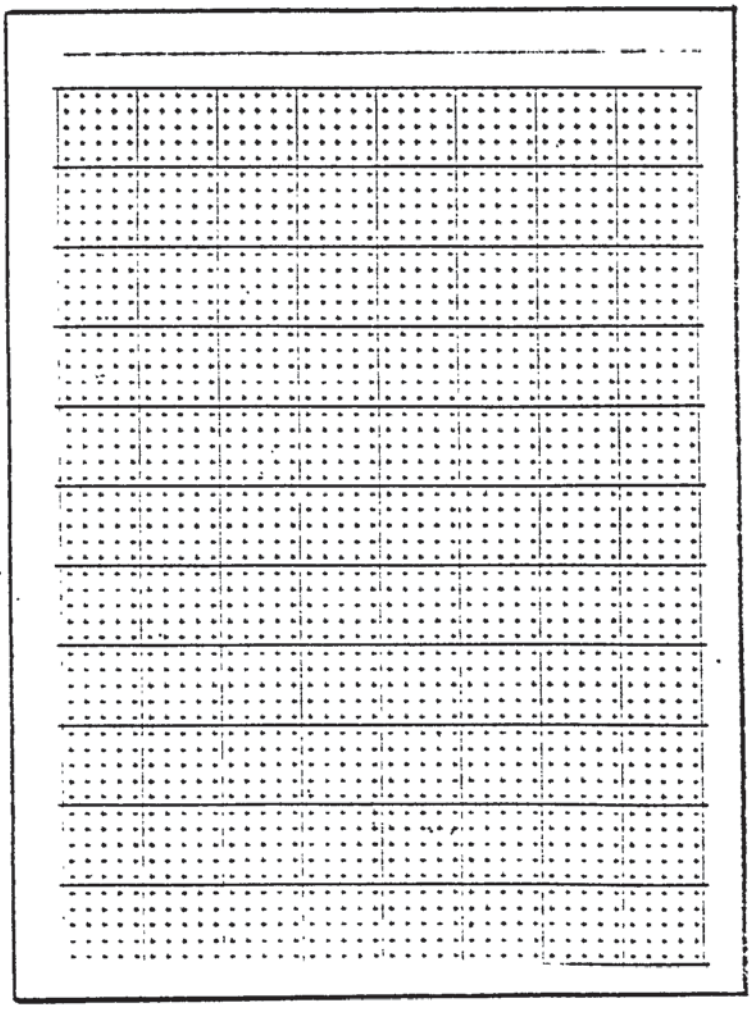
INTERPRETOSCOPE

1. Switches for light-table and toplight
2. Adjustment for x parallax
3. Zoom magnification knob
4. Scale with x parallax readings
5. Zoom magnification scale
6. Base scale
7. Oculars
8. Knob for control of the intensity of the toplights
9. Knob for rotation of the image
10. Adjustment for y parallax
11. Scanning in x- and y direction
12. Roll-film holder
13. Interchangeable lenses for 2-5x and 5-15x magnification.

This instrument enables easy comparison of photographs of the same or different scales. One of the special qualities of the instrument is the magnification range of 2-15 x, which can be set independently for each eye piece. (After Hempenius S.A., 1973)

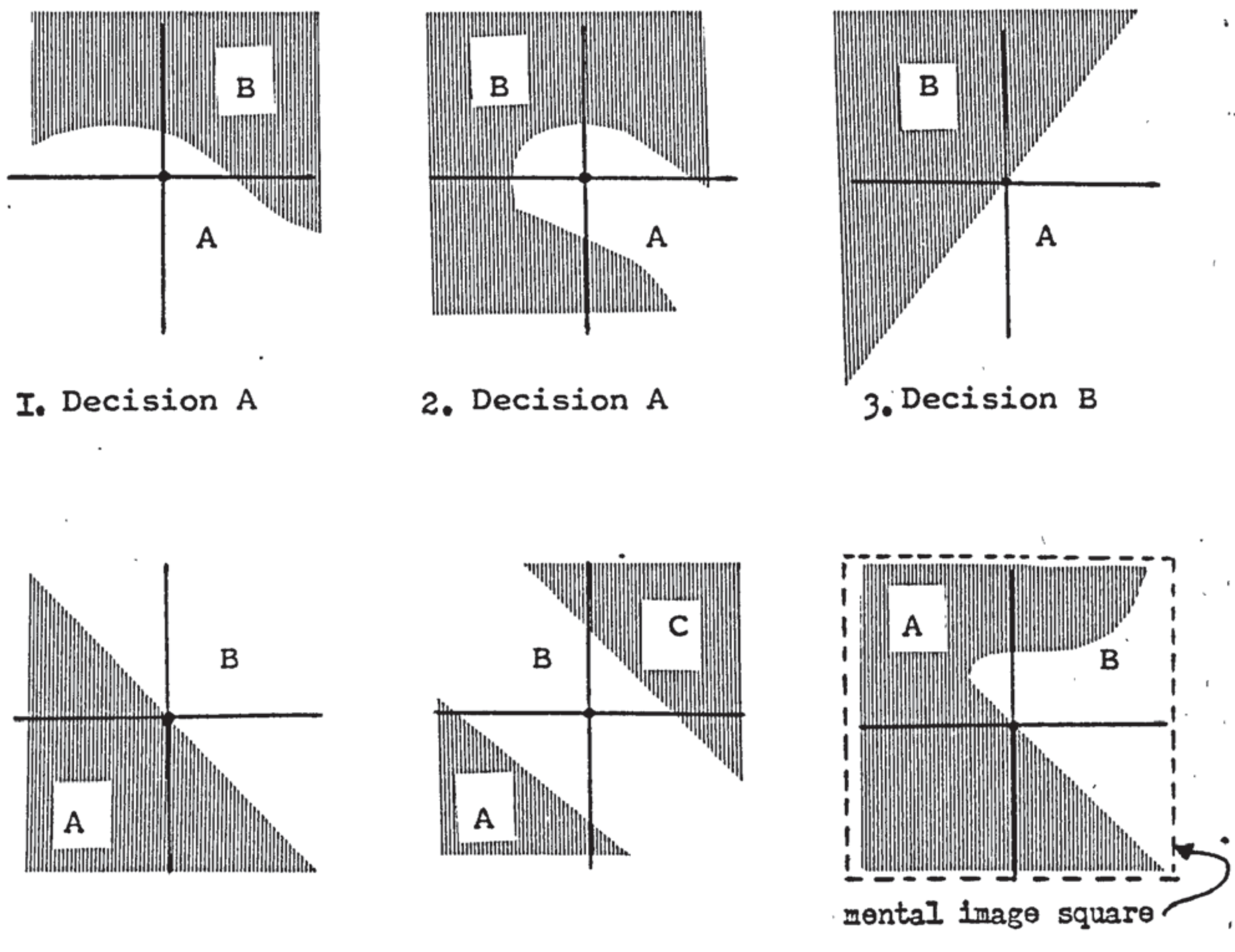
Figure 5.4 CROSS GRID

Scale 1:10,000



A cross grid 100m x 100m squares
20m x 20m crosses
was used for the comparison of Black and White and Colour Infrared aerial photography in surveying urban open space.

Figure 5.5 DECISION MAKING USING THE CROSSES-ESTABLISHED RULES



1. Decision A 2. Decision A 3. Decision B

4. Decision B 5. Decision B 6. Decision A

Figure 5.6 RECORDING OF PHOTOINTERPRETATION DATA ON CODING FORMS.

The University of Aston in Birmingham Computer Centre

ALGOL CODING FORM
PHOTOINTERPRETATION OF B/W PHOTOGRAPHY
ENUMERATION DISTRICT No. 68

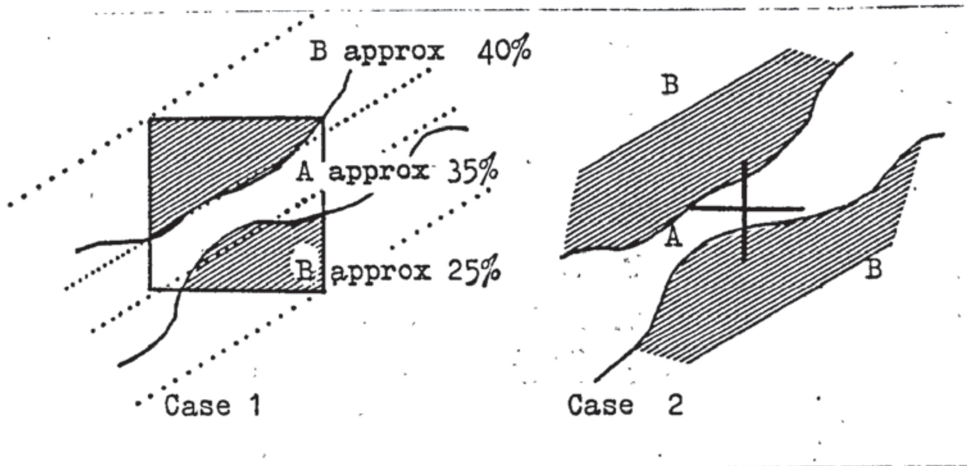
User's No EVP 6024	Telephone 227	Sheet 12 of 21
Job Name MAPS		
CIVIL ENGINEERING	SL. SEKLIZIOTIS.	

Original Coordinates from Ordnance Survey maps

263879	00	00	[illegible]	[illegible]	00	00	00	00	00	00	00	00	00	00	00	00	00	00	15	00	00	15	63	63	00
261878	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	05	00	00	00	00	15
262878	00	00	00	00	00	00	00	00	00	15	00	00	15	02	01	00	15	03	99	99	99	02	99	99	03
263878	15	71	71	63	00	71	99	71	63	00	71	71	63	00	00	63	63	64	00	00	65	64	63	00	00
260877	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	15	00	00	00	15	03
261877	00	00	00	15	03	00	00	15	99	99	00	15	99	03	99	15	99	79	63	03	99	03	03	04	15
262877	99	99	03	03	03	04	03	02	99	02	04	04	04	02	02	03	03	03	99	99	99	04	02	99	99
263877	47	47	03	00	00	03	47	03	00	00	03	04	03	03	00	03	03	03	03	00	99	99	02	99	01
259876	00	00	00	00	00	00	00	00	00	00	00	00	00	00	15	00	00	00	15	99	00	00	15	99	04
260876	00	00	15	99	04	15	15	99	03	03	04	99	02	03	09	01	03	02	02	23	02	02	71	99	23
261876	02	26	03	26	25	23	05	23	25	25	23	25	26	26	26	24	25	26	23	25	26	25	25	25	26
262876	04	03	63	99	01	65	64	64	64	63	24	65	64	65	03	25	25	64	65	65	26	25	64	64	65
263876	99	01	99	99	02	99	02	03	03	04	99	03	03	04	63	03	03	63	64	65	25	64	65	64	64
264876	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	65	00	00	00	00	65	00	00	00	00
259875	00	15	01	99	99	00	02	99	99	03	00	71	03	99	99	00	71	63	03	01	00	63	63	03	01
260875	04	64	62	64	23	02	65	64	64	63	99	02	64	62	42	99	02	15	42	42	02	33	34	42	42
261875	23	23	25	23	26	23	23	23	25	25	25	24	25	24	25	42	23	26	25	25	42	43	25	24	25
262875	23	26	25	25	26	25	23	24	25	25	25	25	25	26	25	26	25	25	25	26	26	26	25	25	25
263875	25	63	64	99	64	25	25	64	64	63	24	25	26	64	64	26	26	25	25	63	26	26	25	25	63
264875	65	00	00	00	00	64	65	00	00	00	63	63	00	00	00	65	63	63	00	00	99	99	99	00	00
259874	00	00	65	63	99	00	00	63	63	63	00	02	02	65	63	99	99	99	63	65	00	02	99	02	63
260874	99	33	32	34	42	63	34	33	33	43	63	34	33	33	33	63	64	34	33	33	63	65	31	33	34
261874	41	42	24	24	25	43	42	42	24	24	42	42	42	43	24	34	42	43	41	43	33	34	42	42	42
262874	25	26	26	25	25	25	26	25	26	25	25	25	26	26	25	25	25	25	24	25	24	25	25	25	25
263874	25	26	25	24	25	25	25	25	25	26	25	25	26	25	25	26	26	25	26	25	26	26	26	25	25

Registration of two digit code numbers each representing a separate open space unit in the notation. The arrangement in rows and columns in the coding forms is compatible with the national km-grid of the Ordnance Survey Maps.

Figure 5.7 SQUARE OR CROSS GRID RECORDING



In case 1 "B" the "dominant land use" of the grid square area is identified and then recorded.

In case 2 the land use "A" which occurs directly under the cross is recorded.

Figure 5.8 OPEN SPACE MAP - DERIVED FROM BLACK AND WHITE AERIAL PHOTOGRAPHS.

ENUMERATION DISTRICT No : 68

AERIAL PHOTOGRAPHY USED : B+W

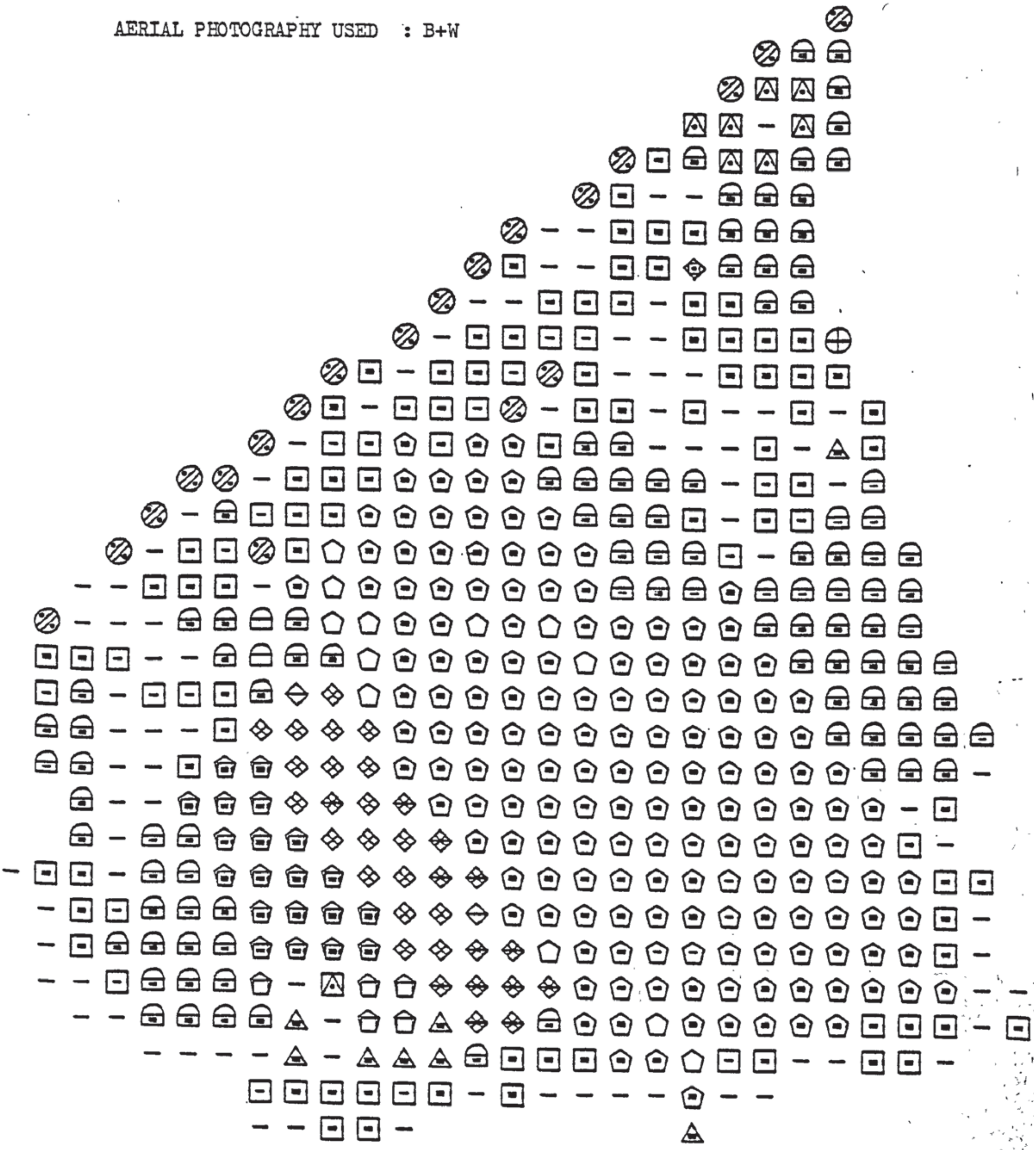


Figure 5.9 OPEN SPACE MAP -DERIVED FROM COLOUR INFRARED AERIAL PHOTOGRAPHY

ENUMERATION DISTRICT No : 68

AERIAL PHOTOGRAPHY USED : CIR

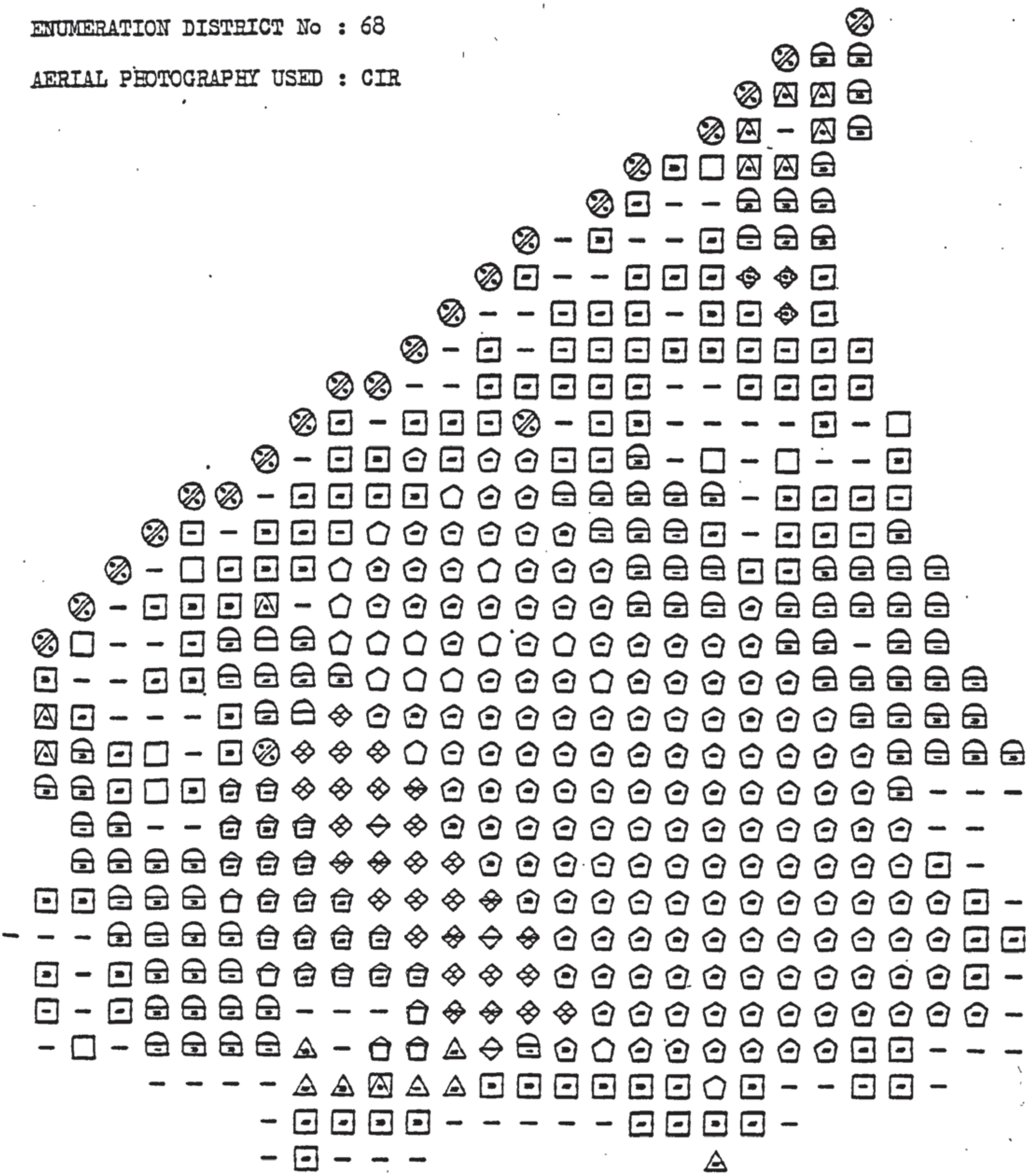
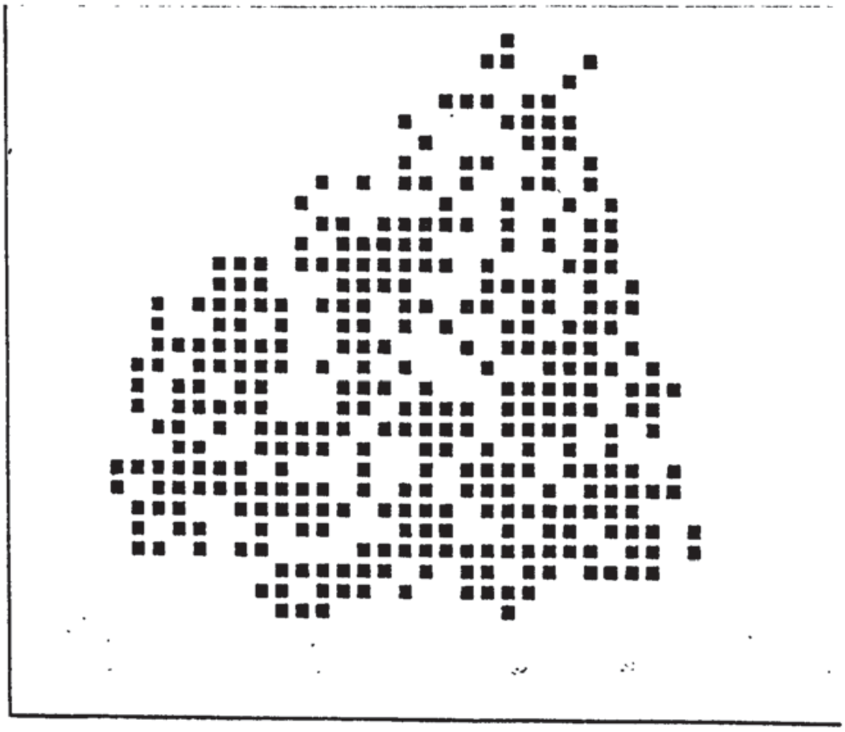
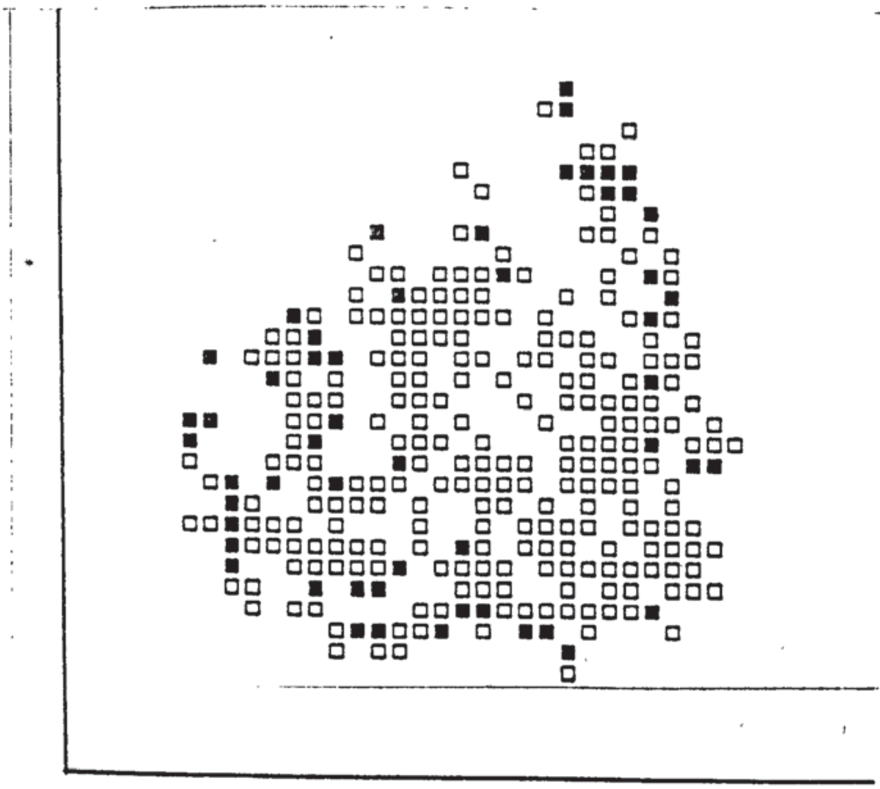


Figure 5.10 TOTAL (REAL AND APPARENT) DIFFERENCES IN INTERPRETATION



Enumeration district 68/1046
Differences between photointerpretation of black and white photography and colour infra-red photography.

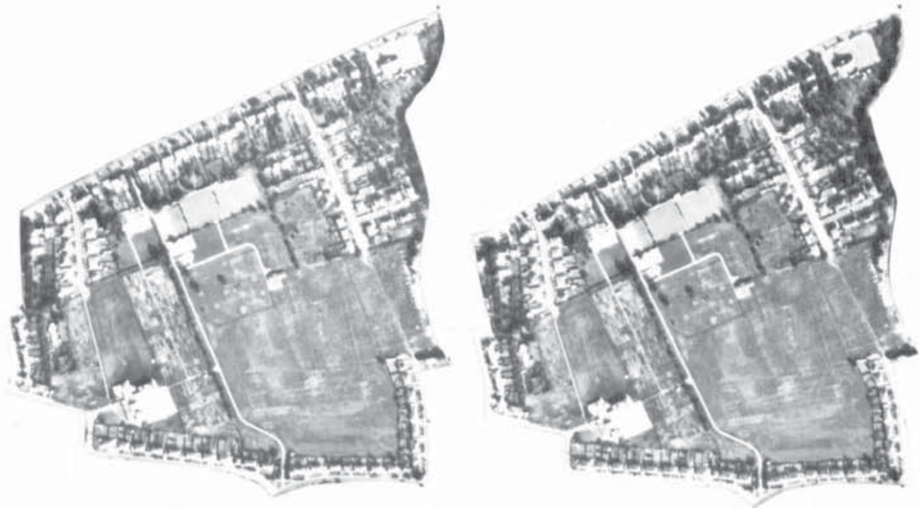
Figure 5.11 REAL DIFFERENCES IN INTERPRETATION



Enumeration district 68/1046
Differences between photointerpretation of black and white photography and colour infra-red photography.

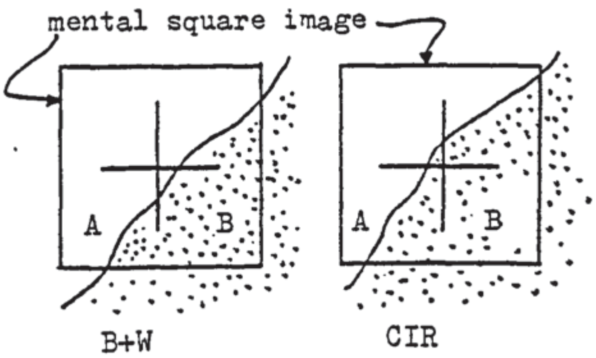
□ Group Differences)
■ Sub-group (or unit) Differences) as per notation in Table 5.2

Figure 5.12 COMPARISON BETWEEN BLACK AND WHITE AND COLOUR INFRA-RED AERIAL PHOTOGRAPHS.



This arrangement allows stereoscopic examination of the enumeration district No. 68 by a pocket stereoscope for each set of photography separately or one photograph from each set simultaneously.

Figure 5.13 DECISION MAKING

<table>
<tr><th>SITUATION ON THE
B+W/CIR STEREOPAIR</th><th>SITUATION ON THE
COMPUTER PRINT-OUT</th></tr>
<tr><td>
</td><td>............   ....
....
B+W SAID A   CIR SAID B
....
....
....
....</td></tr>
</table>

Decision: both possible.

Table 5.1 OPEN SPACE CLASSIFICATION SYSTEMS

after F.I. Burnett (1969) U.K.

A. PLAYING FIELDS & CLUB SPORTS GROUNDS
(i) Club sports grounds - private clubs and works sports clubs.
(ii) Playing fields - publicly owned grounds for organized games.
(iii) School and college playing fields
(iv) Sports centers
(v) Running tracks
(vi) Miniature golf courses.

B. RECREATION GROUNDS - maintained by local authority.

C. PARKS
(i) Formal) mainly publicly owned, but
(ii) Informal) also some private.
(iii) Parkways, or other informal areas - parkways flanking principal roads, and also incidental areas of informal open space.

D. CHILDREN'S PLAYGROUNDS - in individual sites, or occurring with other uses.

E. WOODS & COMMONS
(i) Woods - public and private
(ii) Commons

F. GOLF COURSES - public and private

G. ALLOTMENTS - statutory and non-statutory.

H. MAJOR AREAS OF WATER
(i) Boating
(ii) Swimming
(iii) Fishing
(iv) Amenity

after Tankel (1963) U.S.A.

Classification of Urban Open Space

Scale or level	Present examples of open space (Land)	(Water)
I. STREET		
a. Building site	Yards, courts (i.e., sites less bldgs.)	
b. Group of bldgs.	Rights-of-way, streets, piazzas, plazas, residential commons, tot lots	
II. COMMUNITY		
a. Neighborhood	School grounds, playgrounds, small parks to 10 a.	Ponds, streams
b. Municipality	Parks to 100 a., playfields	
III. COUNTY		
(group of municipalities)	Parks 100–1,000 a. golf courses, minor conservation areas (flood plains, watersheds, wildlife)	Lakes, rivers
IV. REGION		
a. Metropolitan region	Parks over 1,000 a., large conservation areas, major water bodies, private farms, woodland and other land on the urban fringe	Oceans, great river
b. Megalopolis	Coastlines, mountain ranges, milksheds	

These two open space classification systems have been developed in two different countries, the U.K. and the U.S.A.

They were meant to solve different problems and they were mostly based on such properties as scale and activity (right) and recreational activity in particular (left).

A number of characteristics appearing in both systems are not detectable by remote sensing techniques e.g. "private clubs" and "publicly owned grounds" or "private farms".

Table 5.2 URBAN OPEN SPACE NOTATION

PRIVATE GARDENS

1 PRIVATE GARDENS - UNVEGETATED
2 PRIVATE GARDENS - SELF-MAINTAINED VEGETATION
3 PRIVATE GARDENS - MANAGED VEGETATION
4 PRIVATE GARDENS - POORLY MAINTAINED VEGETATION

PUBLIC GARDENS

6 PARKS - UNVEGETATED
7 PARKS - SELF-MAINTAINED VEGETATION
8 PARKS - MANAGED VEGETATION
9 PARKS - POORLY MAINTAINED VEGETATION
10 AMENITY OPEN SPACE - UNVEGETATED
11 AMENITY OPEN SPACE - SELF-MAINTAINED VEGETATION
12 AMENITY OPEN SPACE - MANAGED VEGETATION
13 AMENITY OPEN SPACE - POORLY MAINTAINED VEGETATION

LANDSCAPED OPEN SPACE FOR CIRCULATION

15 STREETS LINED WITH TREES

PLAYSPACE, RECREATION, SPORTS

19 CHILDREN'S PLAYGROUNDS - UNVEGETATED
20 CHILDREN'S PLAYGROUNDS - SELF-MAINTAINED VEGETATION
21 CHILDREN'S PLAYGROUNDS - MANAGED VEGETATION
22 CHILDREN'S PLAYGROUNDS - POORLY MAINTAINED VEGETATION
23 PLAYFIELDS - UNVEGETATED
24 PLAYFIELDS - SELF-MAINTAINED VEGETATION
25 PLAYFIELDS - MANAGED VEGETATION
26 PLAYFIELDS - POORLY MAINTAINED VEGETATION
27 GOLF COURSES - UNVEGETATED
28 GOLF COURSES - SELF-MAINTAINED VEGETATION
29 GOLF COURSES - MANAGED VEGETATION
30 GOLF COURSES - POORLY MAINTAINED VEGETATION
31 EDUCATIONAL PLAY SPACES - UNVEGETATED
32 EDUCATIONAL PLAY SPACES - SELF-MAINTAINED VEGETATION
33 EDUCATIONAL PLAY SPACES - MANAGED VEGETATION
34 EDUCATIONAL PLAY SPACES - POORLY MAINTAINED VEGETATION
35 OTHER RECREATIONAL SPACE

WOODLAND

37 WOODLAND OR CLUMPS OF TREES - HEALTHY
38 WOODLAND OR CLUMPS OF TREES - DAMAGED
40 WOODLAND - UNVEGETATED AREAS

ALLOTMENT GARDENS

41 ALLOTMENTS - AUXILIARY AND UNUSED SPACE
42 ALLOTMENTS - IN USE
43 ALLOTMENTS - NOT IN USE

AGRICULTURE

46 AGRICULTURAL GRASSLAND AND FALLOW
47 AGRICULTURAL CROPLAND, HORTICULTURE, ORCHARDS

UNDISTURBED OPEN SITES

48 ESTABLISHED HEATH
50 SHRUBS - HEALTHY
52 SHRUBS - DAMAGED OR DEFICIENT FOLIAGE
54 SCRUB - HEALTHY
55 SCRUB - DAMAGED OR DEFICIENT FOLIAGE
56 MOSSLAND
57 SAND DUNES
69 MARSHLAND

DERELICT AND SPOILED LAND

58 DERELICT AND SPOILED LAND - UNVEGETATED AREAS
59 DERELICT AND SPOILED LAND - VEGETATION WELL ESTABLISHED
60 DERELICT AND SPOILED LAND - VEGETATION NOT WELL ESTABLISHED
61 DERELICT AND SPOILED LAND - SCATTERED VEGETATION

NEGLECTED WASTE LAND

62 NEGLECTED WASTE LAND - NO VEGETATION
63 NEGLECTED WASTE LAND - VEGETATION WELL ESTABLISHED
64 NEGLECTED WASTE LAND - VEGETATION NOT WELL ESTABLISHED
65 NEGLECTED WASTE LAND - SCATTERED VEGETATION

WATER BODIES

68 OPEN WATER (RIVERS, CANALS, LAKES - NOT RESERVOIRS ETC.)

CEMETERIES

70 CEMETERIES

OTHER OPEN SPACES

71 OTHER OPEN SPACE

OTHER LAND USES (NOT OPEN SPACE)

99 OTHER LAND USES

Table 5.3 OPEN SPACE STATISTICS

E.D.68

URBAN OPEN SPACE GROUPS	PHOTOGRAPHY USED BLACK & WHITE (Ha)	FALSE COLOUR (Truth) (Ha)	DIFFERENCES * ± (Ha)
Private gardens	4.16	4.84	0.68
Public gardens	0.32	0.28	-0.04
Landscaped open space for circulation	0.80	0.88	0.08
Playspace, Recreation, Sports	8.04	7.76	-0.28
Woodland	0.04	0.00	-0.04
Allotment gardens	1.36	1.24	-0.12
Agriculture	0.04	0.12	0.08
Undisturbed open space	0.00	0.00	0.00
Derelict and spoiled land	0.00	0.00	0.00
Neglected waste land	4.20	3.64	-0.56
Water bodies	0.00	0.00	0.00
Cemeteries	0.00	0.00	0.00
Other open spaces	0.32	0.40	0.08
TOTAL OPEN SPACE	19.28	19.16	-00.12
Other land uses	3.52	3.52	0.00
SURVEYED TOTAL AREA	22.80	22.68	-00.12

* + = more area recorded with false colour
− = less area recorded with false colour

Table 5.4 OPEN SPACE STATISTICS

E.D. 44

URBAN OPEN SPACE GROUPS	PHOTOGRAPHY USED		DIFFERENCES *
	BLACK & WHITE (Ha)	FALSE COLOUR (Truth) (Ha)	± (Ha)
Private gardens	4.68	4.68	0.00
Public gardens	0.44	0.56	0.12
Landscaped open space for circulation	0.56	0.44	-0.12
Playspace,recreation,sports	4.56	4.48	-0.08
Woodland	0.00	0.12	0.12
Allotment gardens	0.00	0.00	0.00
Agriculture	0.00	0.00	0.00
Undisturbed open space	0.00	0.00	0.00
Derelict and spoiled land	0.00	0.00	0.00
Neglected waste land	0.88	0.80	-0.08
Water bodies	0.00	0.00	0.00
Cemeteries	0.00	0.00	0.00
Other open spaces	0.36	0.28	0.08
TOTAL OPEN SPACE	11.48	11.36	-0.12
Other land uses	3.88	4.00	0.12
SURVEYED TOTAL AREA	15.36	15.36	0.00

* + = more area recorded with false colour
− = less area recorded with false colour

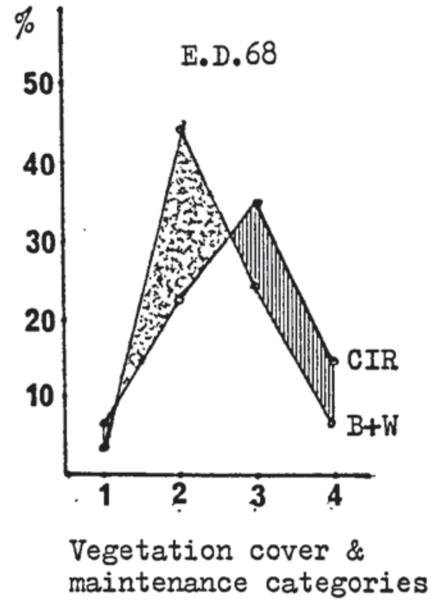
Table 5.5 OPEN SPACE STATISTICS

E.D.64

URBAN OPEN SPACE GROUPS	PHOTOGRAPHY USED		DIFFERENCES *
	BLACK & WHITE (Ha)	FALSE COLOUR (Truth) (Ha)	± (Ha)
Private gardens .	4.44	4.76	0.32
Public gardens	0.04	0.00	-0.04
Landscaped open space for circulation	0.28	0.32	0.04
Playspace,recreation,sports	0.00	0.00	0.00
Woodland	0.00	0.00	0.00
Allotment gardens	0.00	0.00	0.00
Agriculture	0.00	0.00	0.00
Undisturbed open space	0.00	0.00	0.00
Derelict and spoiled land	0.00	0.00	0.00
Neglected waste land	0.00	0.00	0.00
Water bodies	0.00	0.00	0.00
Cemeteries	0.00	0.00	0.00
Other open spaces	0.00	0.00	0.00
TOTAL OPEN SPACE	4.76	5.08	0.32
Other land uses	2.84	2.60	-0.24
SURVEYED TOTAL AREA	7.60	7.68	0.08

* + = more area recorded with false colour
  – = less area recorded with false colour

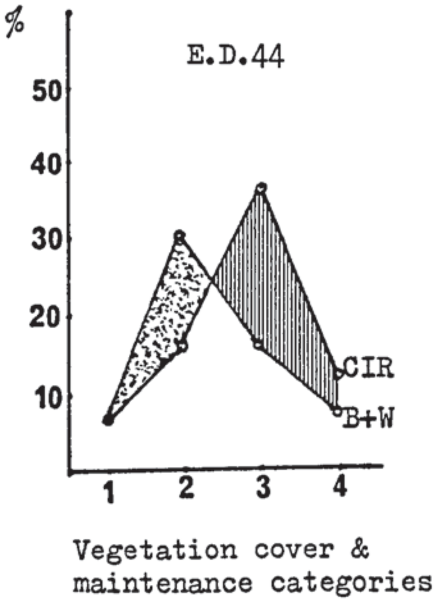
Table 5.6 OPEN SPACE SURFACE STATISTICS



VEGETATION COVER/MAINTENANCE CATEGORY	B+W %	CIR %	DIF. %
1. Total unvegetated open space	3.68	6.35	2.66
2. Total self-maintained vegetation	44.74	22.75	-21.99
3. Total managed vegetation	24.56	34.92	10.36
4. Total poorly maintained vegetation	6.67	14.81	8.15

more area recorded with B+W aerial photographs

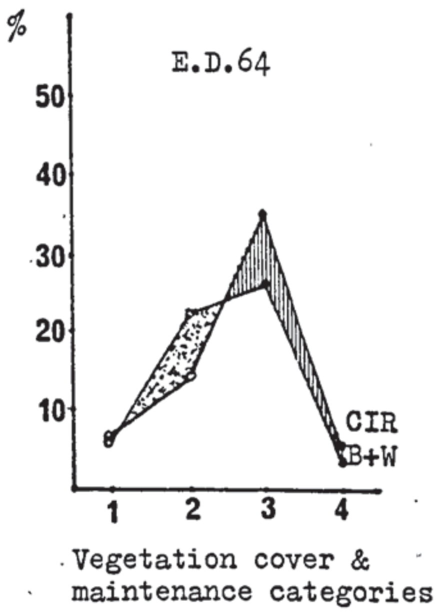
more area recorded with CIR aerial photographs



VEGETATION COVER/MAINTENANCE CATEGORY	B+W %	CIR %	DIF. %
1. Total unvegetated open space	6.77	6.51	-0.26
2. Total self-maintained vegetation	29.69	15.36	-14.32
3. Total managed vegetation	25.52	35.68	10.16
4. Total poorly maintained vegetation	6.77	11.72	4.95

more area recorded with B+W aerial photographs

more area recorded with CIR aerial photographs



VEGETATION COVER/MAINTENANCE CATEGORY	B+W %	CIR %	DIF. %
1. Total unvegetated open space	6.32	6.77	0.55
2. Total self-maintained vegetation	22.63	14.58	-7.70
3. Total managed vegetation	26.32	35.42	9.51
4. Total poorly maintained vegetation	3.68	5.21	1.58

more area recorded with B+W aerial photographs

more area recorded with CIR aerial photographs

Table 5.7 RESULTS OF PHOTO-INTERPRETATION: Analysis of Differences

ENUMERATION DISTRICT	APPARENT DIFFERENCES (A)			REAL DIFFERENCES (B)				FIELD CHECK NEEDED	AGREEMENTS	DISAGREEMENTS	TOTAL OBSERVATIONS PER ENUMERATION DISTRICT
No.	BOTH DECISIONS POSSIBLE (a)	CHANGES IN LAND USE (b)	BOUNDARY DIFFERENCES (c)	DIFF. WITHIN GROUPS (B+W CORRECT) (a)	DIFF. WITHIN GROUPS (CIR CORRECT) (b)	DIFF. BETWEEN GROUPS (B+W CORRECT) (c)	DIFF. BETWEEN GROUPS (CIR CORRECT) (d)	UNCLEAR IN BOTH IMAGES (e)			
68/1046	72	7	7	0	239	0	18	2	225	345	570
64/1046	32	0	10	0	40	0	0	0	108	82	190
44/1054	72	1	10	0	91	2	13	0	194	189	383
TOTALS	176	8	27	0	370	2	31	2	527	616	1143

TOTAL OF APPAR. DIFF: 211

TOTAL OF REAL DIFF : 403

TOTAL OF CIR CORRECT : 401

TOTAL OF B+W CORRECT : 2

B+W : Black and white photography
CIR : Colour infrared photography
DIFF : Differences

Plate 5.1 VEGETATION COVERAGE AND MAINTENANCE CATEGORY 1.

Unvegetated/hardly landscaped open spaces.

Plate 5.2 VEGETATION COVERAGE AND MAINTENANCE CATEGORY 2.

Unmanaged or semi-managed (limited management) selfmaintained vegetation growth.

Plate 5.3 VEGETATION COVERAGE AND MAINTENANCE CATEGORY 3.

Managed vegetation (high grade maintenance)

Plate 5.4 VEGETATION COVERAGE AND MAINTENANCE CATEGORY 4.

Poorly maintained vegetation/poor vegetation coverage.

CHAPTER 6

STAGE 2: REVIEW OF THE SOCIAL AREA ANALYSIS IN THE MERSEYSIDE COUNTY.

6.1 Introduction

Having established the need to use colour infrared film to meet the particular information requirements of the Planning Authority co-operating in this project, the subsequent stages were considered.

This chapter refers to a Social Area Analysis which has been undertaken by the Planning Research Applications Group (PRAG) commissioned by the Merseyside County Planning Department. A socio-economic classification; the result of that work, will be used later in this study as an input to help comparisons with open space information obtained from colour infrared photography and referring to eleven "socio-economically" contrasted areas in the county.

The origins of the Merseyside County-wide Social Area Analysis can be traced to 1968 when the Liverpool Social Malaise Study was carried out.

6.2 The Liverpool Social Malaise Study

In 1968 the then Liverpool County Borough Planning Department carried out the Liverpool Social Malaise Study. This was the first systematic attempt by a local authority in Britain to combine service and census data to evaluate the distribution and intensity of social deprivation within its boundaries.

Although the study was widely recognised for its attempt to quantify social need in a more objective manner than had been attempted before, and although it was widely imitated by other local authorities, with hindsight it was possible to identify four grounds on which the study failed to achieve its declared objectives:

1. The study failed to show the very real differences in the combinations of urban stress due to its concentration on a single aggregate measure of need.
2. The proportion of the city population shown to live in areas of severe need was out of all proportion to the funds available for priority area allocation.
3. Because the analysis was carried out wholly within the Planning Department and because other departments were inadequately involved in the project design, the results of the study had relatively little impact on the decision making process.
4. Because the study was a sequential, one off exercise and because no technical capability was retained within the authority, further research which should have been generated by the interpretation of the results, was never undertaken.

These criticisms are discussed in detail in section 4 of the Liverpool Social Area Study Final Report P.R.A.G. TP-14 (Webber, 1975).

In 1974 the district council became interested in updating and technically improving upon the 1968 Social Malaise Study and sponsored the development of an area classification in conjunction with the Liverpool Inner Area Study Consultants. The objectives of this study were:

1. To identify the significantly different types of residential environment which would be found within the city.
2. To map their spatial distribution.
3. To distinguish the different types of population resident in each type of area.
4. To interpret, from the results, differences in social function and social need between types

of area, and explain these differences in terms of the structure of the urban system in its broadest sense.

The data used to carry out the study were derived from the census. From a total of 300 variables extracted by the standard editing routine a set of 14 particularly useful diagnostic variables were used to group the 1,120 Liverpool enumeration districts* into a set of 418 basic data areas*.

Next a set of forty wider variables was used to group the 418 basic data areas into a set of 25 clusters*. In a third stage of the grouping process the 25 clusters were compressed to form five larger groupings known as families. The criteria used for assessing the similarity of clusters and their arrangement into families were once again all forty variables.

6.21 The Liverpool Social Study Results

By aggregating the 25 clusters the following five types (i.e. families) emerged:

1. A high status* owner-occupied area with stable families.
2. An area of subdivided housing with young people and furnished, privately rented accommodation in small units (rooming house).

*ENUMERATION DISTRICT: The smallest spatial unit for which Small Area Statistics are available.

*BASIC DATA AREA: One or more continguous enumeration districts of similar social character and the unit to which enumeration district data is aggregated prior to further analysis.

*CLUSTER: A set of non-contiguous basic data areas of similar social character.

*STATUS: Is a position based on prestige and a specific style of life, and a status group is a community sharing these in similar degree. While classes are determined economically, status groups are based on a differential distribution of honour and prestige. (Martin, 1970).

3. Inner/older council estates.
4. Outer/more recent council estates.
5. An area of older Victorian terraced housing, mostly privately rented unfurnished and much of it lacking an inside W.C.

A detailed description of the results of the social typology is given in the Final Report of the Liverpool Social Area Study. As a result of the study the Liverpool City Planning Department has become familiar with the nature of each family and cluster, and knowledge of the function which each type performs in the social working of the city has proved of considerable value in subsequent policy discussion and analysis.

It is for this reason that when alternative ways of carrying out a county-wide analysis were being considered, it was decided that the resulting classification should be consistent with the Liverpool typology. Resources involved in interpreting and understanding the Liverpool typology should not be wasted by constructing an entirely separate classification for the whole county.

6.3 The Merseyside County-wide Social Area Analysis

Whilst it would not have been technically possible to carry out a classification of all 3,000 enumeration districts in the county at one time, a method was developed which allowed each enumeration district to be allocated to one of a set of types derived from a prior analysis. The decision was therefore made to extend the Liverpool classification (or typology) by identifying for each enumeration district not in Liverpool, which of the twenty five clusters within the city it was least dissimilar from.

In doing this, the analysts were conscious that types of residential environment might exist in Merseyside which would not have been identified by the Liverpool typology. The first results of the county-wide assessment were therefore examined to discover areas of the county which were consistently poorly described by any of the Liverpool clusters. Two such areas were found in Hoylake, West Kirby, and in Southport. New clusters were synthesised in these two areas and added to the set of twenty five clusters derived from the Liverpool analysis. The assignment was repeated to identify any enumeration districts outside Liverpool which would be more effectively described by either of the two new synthetic clusters.

6.31 The County-wide Social Area Analysis Results

In the county-wide analysis such a large number of enumeration districts were assigned to one of the five clusters within the high status family, and so distinct was this type from other high status clusters, that it was decided to subdivide the family - one of the five which emerged from the Liverpool study - as follows:

1	Areas of high status: owner occupied family housing.	1a	Areas of established high status.
		1b	Areas of modern high status owner occupied development.

Figure 6.1 shows in diagrammatic form the distribution of these six major families, and the percentage of total distribution within each district and for Merseyside as a whole.

As noted in section 6.3, it was also necessary to synthesise two new clusters representing types of residential environment not found within Liverpool. These were designated as a seventh family: retirement areas. Thus, there were then 27 clusters grouped into seven families.

In Table 6.1 the broad characteristics of the seven families are shown (column 2) together with the percentages of the county population (column 1) and the number of clusters which are included in each of them (column 3). Also, table 6.1 shows the effectiveness with which the analysts have differentiated areas with respect to other policy topics. Not only can families be distinguished by deprivation/affluence, but they can be grouped, according to stage in the family cycle, into young and mature stages (column 10) or in terms of centrality into inner intermediate and peripheral areas (column 2). To a certain degree, these types also discriminate areas according to patterns of travel to work (column 8), house tenure (column 5), housing deprivations (column 6), and social minorities (column 7). Separately, in section 6.33, the stratification of status given in column 4 of table 6.1 will be briefly discussed.

In Appendix 6.I is given the performance of the seven Merseyside families on each of the forty grouping criteria.

In Appendix 6.II a detailed interpretation is given of each of the seven families, mainly in terms of housing character.

In Appendix 6.III a detailed description of the characteristics of the twenty seven P.R.A.G. clusters is given.

6.32 The Context of "Social Status" and "Social Class"

Social class is defined by many as "the individual's economic position", and social status as "his standing in the community". Classes are defined according to their relations to the production and acquisition of goods, while status groups are defined in terms of the consumption of goods in order to establish a style of life. Social class can easily be stratified objectively as it is largely based on economic accomplishments but it is difficult to stratify by status since this is decided largely on the basis of non-economic accomplishments. Stratification by status is typically accompanied by some monopolization of cultural or material goods and opportunities; such as certain kinds of artistic activity, style of dress, kind of diet, linguistic difference and particularly land.

Stratification by status is a difficult task as it depends on many characteristics, most of which cannot be quantified. Sociologists are subdivided generally into two groups: those who believe that society is unstratified and neglect social differentiation, and those who believe that no society is "classless" or unstratified. It is not the purpose of this chapter to review these theories, but because stratification is used as a method in social investigation to increase the precision of a survey design, and because it is a means of using knowledge of the population of a particular city in order to make comparisons with a particular environmental variable within the city (in this case open space) the stratification provided by the Merseyside Social Area Analysis Study will be analysed. The 'grades' defined will be used as a source for comparison as they constitute the only available classification of status relevant to this study.

It is obvious that it is difficult to recognise the boundary between economic class and status. Because of this direct relationship between status and class position it was decided, for this study, to use the term "socio-economic-status".

6.33 Stratification of Socio-economic Status in the County-wide Social Area Analysis

Following the description in the analysis of the broad meaning of status and of economic class, a discussion follows which refers particularly to columns 2 and 4 of Table 6.1.

The seven categories in column 2 do not indicate any kind of ranking in the form of an accepted order of "grades". Such a ranking is what defines stratification, but this column provides simply seven different categories which differ in terms of status, housing quality, building age and geographical location in the county. It does not indicate which is the highest or lowest or the best or the worst of these classes.

For purposes of comparison with open space data derived from infrared photography, status, as indicated in column 4 (Table 6.1), seemed to be more helpful than the seven families. A stratification of socioeconomic status is provided in 4 broad categories of high, intermediate, low and very low, which are the product of a further compression of the seven families to these four graded categories of status.

Considering the fact that stratification by status is accompanied by some monopolization of cultural or material goods and opportunities, in this case housing deficiencies, tenure, household types, mobility, employment, education etc., it is realised that there is a direct link between such characteristics of the population and their status class as it is presented in column 4 of table 6.1.

6.34 Further Work in the County Related to Social Area Analysis

Much discussion took place over the possible use of the Social Area Analysis results as a means of generating a framework for sampling and further work to assess the physical environment in selected "problem" residential areas within the urban fabric. So in the beginning of 1977 the county authority selected 11 sample areas and started a study, which is still proceeding, in order to assess the physical condition in these areas in relation to their socioeconomic character.

Apart from such physical environmental variables (in the eleven sample areas) as the condition of buildings, condition of roads and pavements, occurrence of derelict land and litter etc., data on a limited number of units of open space such as amenity areas and front gardens have been collected, but not systematically.

All these data have been collected by field and desk work (some interpretation of aerial photographs) and clearly these variables only give a general indication of the characteristics of the residential areas, and do not take into account such variables as provision and condition of open space, quality of buildings and infrastructure.

Having established, in the first stage of this study, a methodology for the survey of open space in cities using colour infrared photography and after several meetings with senior planning officers of the Metropolitan Planning Authority, it was decided to carry out a detailed survey of open space in those 11 areas, (Figure 6.2) and then compare the findings with the broad categories of "social status" of the population.

6.4 Selection of Sample Areas for Further Analysis

The senior personnel of the Merseyside County Authority decided that it would be of more value to use sample areas based on fixed reference points, than enumeration districts with arbitrary street boundaries since these can change over time. From the Land Utilization Survey it became apparent that a 500 metre sided square based on Ordnance Survey grid lines would provide a useful sampling unit. They also indicated that an area of this size (25 hectares) is not too large to be readily surveyed, but is of sufficient scale to incorporate many of the local services and amenities which relate to a residential area whose quality and condition are of interest.

The 11 areas were sampled using 500 metre squares based on the Social Area Analysis, so that accurate assessments could be made with the socioeconomic characteristics of the population. The sample areas were selected in such a way that all the 27 clusters in the county were represented, and particularly those which included the majority of the population. The planning officials believed that this would help when extrapolating to the whole county the results of the physical environment assessment. It would give also an indication of the proportion of people living in areas which are deficient in different respects. But there was some scepticism about the reliability and consistency of the Social Area Analysis. The size of the sample (the 11 areas), which comprises only 1% of the whole urban county, means that any assessment of the open space situation with these as a basis can be used to provide only a very general indication of the level of resources needed on a metropolitan scale to bring about specified improvements to the outdoor environment.

In the selection of the sample areas an attempt was made to pick a cross-section from the Social Area Analysis clusters, distributed throughout the county and taking in areas of interest such as Local Plan areas, (see Figure 6.2 and Table 6.2).

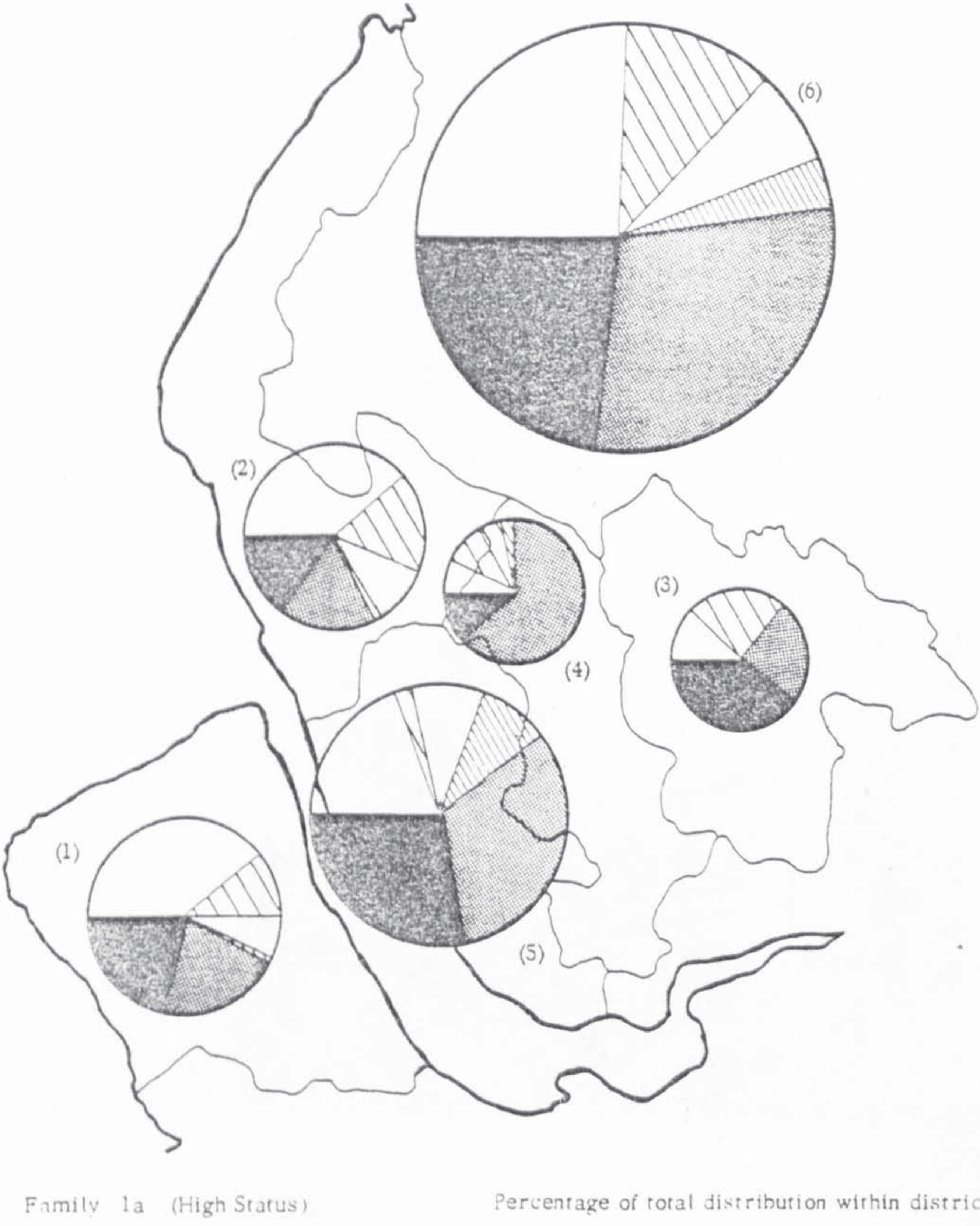
Table 6.2 has been developed by using information from a variety of documents supplied by the county authority related to the Social Area Analysis, and shows the relationship between the 11 sample areas and the 27 clusters, the 4 status categories and percentage of the county population.

6.5 Conclusions

The Social Area Analysis is of considerable importance in that it identified grades of socioeconomic class, and recorded the data in considerable detail.

In the assessment of the physical environment of the 11 sample areas the planners realised that the amount and quality of information they had collected about open space by field work and other methods did not satisfy their needs. As a result of this, it was agreed to use the colour infra-red aerial photographs to obtain these data and subsequently to make comparisons with the socioeconomic information already available.

Figure 6.1 DISTRIBUTION OF THE SIX FAMILIES WITHIN THE COUNTY.



Family 1a (High Status)

1b (New Private)

2 Rooming House

3 Inner Council

4 Outer Council

5 Older Terraced

Percentage of total distribution within district

	1a	1b	2	3	4	5	KEY
Wirral	39	11	7	1	20	21	1
Sefton	39	17	10	1	18	15	2
St. Helens	12	24	0	0	25	39	3
Knowsley	7	15	0	3	64	11	4
Liverpool	19	2	9	9	33	27	5
Merseyside	26	11	7	4	29	23	6

Figure 6.2 MERSEYSIDE COUNTY SHOWING THE LOCATION OF THE ELEVEN SAMPLE AREAS.

Table 6.1 BROAD CHARACTERISTICS OF THE SEVEN FAMILIES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
% of county pop'n	Family	Clusters	Status	Tenure	Housing deficiency	Vulnerable minorities	Travel mode	Employment structure	Household types
22.0	1a Established high status	1 - 4	high	owner occupied			car train	services	pensioner
12.0	1b Recent high status	5	high	owner occupied			car	manufacturing	young families
5.2	2 Rooming house	6 - 10	intermediate	private furnished	sharing	immigrants young mothers		services	single no pensioner
4.1	3 Inner/deprived council estates	11 - 13	very low	council housing	overcrowding	sick unemployed single parents large families	foot	transport	
32.6	4 Outer council estates	14 - 21	low	council housing	overcrowding	large families	bus	manufacturing	mature families
22.0	5 Older terraced	22 - 25	low	private unfurnished	no inside wc no bath	young mothers	foot		young families
2.1	6 Retirement	26 - 27	high	owner occupied		elderly		services	pensioner

Table 6.2 RESIDENTIAL SAMPLE AREAS IN RELATION TO POPULATION SIZE, SOCIOECONOMIC STATUS AND SUBDIVISION IN CLUSTERS.

(1) Map Ref.	(2) Sample Areas	(3) No. of ¼ km^2 squares	(4) Socioeconomic Status	(5) % area of each status class covered by the sample	(6) % of County population in each status category	(7) Clusters included in sampling	(8) No. of clusters
(1) (2) (3) (4) (11)	Birkdale Orrell Moreton Sherdley Park Southport	5	High	0.50%	36.1%	1,2,3,4,5, 26,27	7
(5)	Claughton	1	Intermediate	0.54%	5.2%	6,7,8,9,10	5
(7) (8) (9) (10)	Prescot Woolfall Heath Tranmere Wavertree	4	Low	0.37%	54.6%	14,15,16,17, 18,19,20,21 22,23,24,25	12
(6)	Scotland Road	1	Very low	0.96%	4.1%	11,12,13	3
	TOTAL	11				TOTAL	27

CHAPTER 7

STAGE 2 (CONTINUED):

A SYSTEMATIC SURVEY OF OPEN SPACE

IN ELEVEN SAMPLE AREAS

7.1 Introduction

This chapter refers to a systematic survey of 11 (¼km^2) contrasting areas which, as has been stated in the previous chapter, were selected on the basis of the Social Area Analysis.

Photointerpretation of each area was carried out using colour infra-red aerial photographs. Statistics about each type of open space were printed out by the computer, and Calcomp and manual maps produced showing the condition and distribution of open space in each of the sample areas.

7.2 Purpose of the Survey

The planning authority needed the following information for the eleven sample areas:

1. Statistical information on the provision, (both in hectares and percentages), maintenance and management of open space in each of the eleven sample areas.

2. Calcomp and manual maps for each of the areas showing the condition and spatial distribution of the major open space categories.

7.3 Modifications in the Developed Open Space Notation System

The notation developed in Chapter 5 for the comparison of black and white and colour infra-red photography was assessed again before any further application of it was attempted.

During the several meetings held with the senior planning officers of the Merseyside Planning Authority it was pointed out that some difficulties had emerged during the photo-interpretation stage due to the "multipurpose" notation system employed. In that notation an attempt was made to include four different characteristics of open space:

1. Activity
2. Surface cover
3. Maintenance
4. Condition - which is related to the quality of its management

The differentiation of these characteristics, which are essential in terms of information needs, was not very clear in the notation and this caused some problems when statistical data had to be obtained for each characteristic separately. Acquiring this differentiation proved very time consuming.

It became clear that different characteristics which describe open space should not be combined into a single classification system - if the system is to meet the objectives already outlined. For example, in some land use inventory projects, categories of activity have been combined with measures of intensity of use, e.g. number of dwelling units in a residential block, or with type of ownership, e.g. private or public. In this open space study a similar situation developed during the first stage of the work where a mixing of characteristics restricted the full operational use of the notation system.

In this second stage, instead of combining into one major category of open space several characteristics describing its maintenance and condition, it was decided that each separate dimension (or characteristic) be defined by a separate notation system. In this way a modification of the developed notation to a more applicable form and coding system was feasible.

This approach to open space use description was made possible through the use of automatic data processing facilities. By the use of computer facilities large quantities of detailed, open space information can be maintained or stored. This information can be reorganised into a variety of different groupings, for example private gardens could be assessed singly, or with one or more other open space types in each sample area. This allows complex correlations to be made which will satisfy the specific requirements for a particular problem relating to urban open space planning. The computer, therefore, satisfies directly and immediately the specific requirements of a given policy, and it retains the original detailed data for use in other studies. Most important of all, by the use of computers the actual processing of detailed data can be accomplished in "machine-minutes" or "machine-hours" rather than in "man-months" or "man-years" of labour.

7.31 The "Activity" Categories of Open Space

For the purposes used here the term "activity unit" is defined as an organization unit for performing a special function and occupying identifiable space at a fixed geographical location.

Inasmuch as "activity" is considered to be the most important single land use characteristic for which comparability is desired, a system of categories identifying land use activities was developed based on the original notation system. The main framework of activities at group and unit level is still retained but in a revised order. The activity system was established in a way that would cover each open space use activity and could also be numerically coded in order to facilitate data handling on automatic data processing equipment. This, it was felt, would provide the beginning of a standard system of identification for one specific characteristic of open space. The notation of "open space activity" finally developed is given in Table 7.1 and includes 39 categories at the unit level and 10 categories at the group level.

In developing a system of activity categories, a second major conclusion was reached: that no rigid system for classifying open space activity is feasible for broad application to all urban areas. In the past, as has been demonstrated in Chapter 5 (Table 5.1), open space classification systems have differed one from the other for numerous reasons. However, the most frequent reason for the difference appears to have been an attempt by each city or metropolitan area to reflect in the open space classification system its own economic, social and landscape composition.

In the system proposed in this study, categories may be added, changed or reworded in order to make them more precise and operational - according to various specific planning needs. As field tests demonstrate the need for change, revisions of this notation system can be incorporated in subsequent research projects related to urban open space studies which would be undertaken by the county authorities.

7.32 The "Surface Cover" Categories of Open Space

The second dimension in the revised notation system is the classification by surface type. Surface is defined by two principal properties, "Configuration" which is the geometrical property of the surface as a whole, and "Texture" which "distinguishes the capacity of the surface (of whatever configuration) to reflect light, which in turn derives from the substance of which the surface is formed" (Appleton, 1973). Here a classification by texture has been developed, which subsequently proved very helpful in determining the degree of maintenance of open space and its condition. Sixteen different surface types have been identified and classified according to the type of cover (Table 7.2).

7.33 The "Maintenance" Categories of Open Space

After categorization of open space by activity and surface, a further discussion took place with the county planners concerned, to determine a practical and precise way of recording the maintenance situation of open space. Data on the level of maintenance are required by the authority for planning the development of new and existing open spaces. Such information cannot, however, be derived directly by air photointerpretation.

The framework of the county authority's maintenance programme to develop a particular landscape in the city is summarized and presented here diagrammatically in Figure 7.1 (supplied by the county) and four categories of maintenance are distinguished. This diagram shows all phases of a maintenance programme which have to be undertaken by the authority and refers to a particular open site.

The site at time 0 is cleared (bare soil). In curve No. 1 no maintenance is applied and no vegetation is established. The area is gradually colonized and the biomass slowly accumulates towards a final climax situation approaching (4). Alternatively a grass sward is established (curve No. 2) but no maintenance occurs and the site soon reverts towards the "background" condition. In curve No. 3 there is a sustained increase in biomass due to regular fertilizer applications etc. until a plagioclimax state which is maintained by regular mowing and fertilizer application. Over-use leads to a deterioration in condition reflected in a decreased biomass (4) whilst neglect may initiate progress towards rough grassland (5). Rough grassland may be obtained more directly by low maintenance (e.g. infrequent mowing) from the outset, whilst cessation of maintenance initiates colonization by shrubs and trees leading towards a climax woodland (6), which may be obtained more directly by tree planting at the outset (7).

As an alternative to direct photointerpretation, maintenance data were obtained by analysis of open space use and surface type. Using the Open Space Use Notation (Table 7.1) and Surface Types Notation (Table 7.2) a Maintenance Matrix was developed (Table 7.3). The senior planning officers completed the cells of this matrix using the following notation of Open Space Maintenance:

CODE NUMBER	DEGREE OF MAINTENANCE
1.	H = High Maintenance
2.	L = Low Maintenance
3.	N = Non-Maintenance
4.	X = Should not occur.

Thus particular land use/surface combinations indicate a certain degree of maintenance or non-maintenance.

7.34 The "Management" Categories of Open Space

Maintenance policies are adopted by the authority in order to support and develop a particular landscape. Success in the implementation of such a policy depends on a number of factors such as weather, intensity of use, vandalism, disease, availability of manpower and equipment, legislation, administrative and budgetary control. It is the degree of control of such factors which determines the degree of management. Thus, in the context of open space provision, management may be defined as the action taken to control these factors in order to achieve better conditions of open space.

Condition of open space is determined by the quality of management. Condition is an observable reality in the landscape which it is possible to detect by remote sensing means using colour infra-red photographs. Whilst maintenance and management are policies, and actions taking place in space and time, which are not directly detectable with aerial photographs.

The term "management" will be used here but in the photointerpretation stage "condition" is the characteristic observed and recorded.

Having completed the maintenance matrix an attempt was made by the authority to produce a second matrix (Table 7.4) in which certain land use/surface combinations indicate "a priori" good (+) or bad (-) management and those situations where both alternatives are possible (±).

The management matrix (as did the maintenance matrix) consists of 532 land use/surface combinations of which 35 cases are identified as of a priori good management (+), 131 cases as of a priori bad management (-) and 212 (41.6%) as both alternatives possible (±). In the case of a (±) situation the decision had to be made by photointerpretation.

Finally the two Open Space Condition Categories (indicative of the end product of management) used in the photointerpretation and data recording process were formulated:

CODE NUMBER	CONDITION CATEGORY
1.	Good Condition (= Good management)
2.	Bad Condition (= Bad management)

Each of the Open Space Units and Groups were defined separately and examples are given in Plates 7.1 - 7.9, where a number of different types of Open Space are shown at a group level with their variety of surfaces. Different degrees of maintenance and different Condition Categories are shown as well.

7.35 Summary

A four-dimensional notation was developed which included Open Space Activity, Surface Types, Degree of Maintenance and Condition. This system was then used in the photointerpretation of the 11 sample areas using colour infra-red aerial photographs. A data recording procedure was used similar to that developed in the first stage of the study for the comparison of the two sets of photography. The difference is that, whilst in the previous stage each photointerpretation decision was registered in the coding form as a two digit code number, because a one-dimensional notation system was used, in this stage a six digit code number had to be registered in the coding form for each observation: two digits for open space use, two digits for surface type, one for maintenance and one for condition.

7.4 Photointerpretation of the Sample Areas

This section refers to the photointerpretation procedure, the grid used in this stage, and a detailed description is given of the procedure for data recording on coding forms.

Each ¼km^2 was interpreted separately using the Carl Zeiss Interpretoscope, the grid being superimposed on one photograph of the stereopair. The procedure was similar to the first stage, except that a different grid was used. This time instead of using a "cross-grid" (i.e. a grid of dots) a "square grid" (i.e. a grid of squares) was used covering the same area of 20m x 20m on the ground (Figure 7.2).

7.41 Comparison between Dot Grids and Square Grids

Recent experimental work (Emmott, 1979) concerned with the measurement, on aerial photographs, of changes in urban land use, has indicated that category areas are more precisely determined by means of dot grids than by the estimation of dominant use in grid squares.

In discussing the usefulness of the two grid systems Emmott makes the following comments on the measurement characteristics of grid squares and dot grids:

"Grid Squares:

(a) categories occurring in small or narrow linear units will rarely, if ever, form the dominant land use of a grid square, and will thus be omitted or systematically under-estimated,

(b) the process of judging dominant land use is frequently difficult and always subjective - even on a simple chorochromatic land use map; this difficulty would be very much greater when combining the three processes of photointerpretation, recognition of land use boundaries and judgment of dominant land use in each cell,

(c) the actual linework of the grid would tend to obscure photo details.

Dot Grids:

(a) the relationship of dot count to each category depends on the proportion of the total area occupied by each category, and not on the size or shape of the land use units; thus, there should be no tendency towards systematic under-estimation of categories occupying small units,

(b) no estimation of proportion is required, subjective decisions are limited to the cases in which a dot falls on a boundary; the adoption of a simple convention precludes any tendency to systematic error,

(c) dot grids obscure the minimum of detail, an important consideration when in use directly on aerial photographs"

It would have been desirable, therefore, to have used a simple dot grid for the recording and measurement of open space data. However, the county planning officers preferred the grid square system, and this was therefore used.

7.42 Decision Making and Data Recording

Using the square grid a "dominant use" decision had to be made each time for three different properties of open space: use, surface and condition. The maintenance aspect was taken directly from the maintenance matrix (Table 7.3), and did not involve any decision making by the photointerpreter. The assessment of condition was mainly a photointerpretation task and under 'bad condition' were classified those open spaces which appeared to be neglected, damaged, vandalized or over-used. These included patchy play fields, diseased vegetation, infested grasses, streets needing repair, bare soils, soils partly vegetated covered with litter and dead vegetation, abandoned gardens and polluted waters.

Then a six digit code number for each grid cell was registered in the coding form (Table 7.5). For the eleven sample areas a total of 6,875 such observations were recorded, (625 for each ¼km^2) with the open space data having been recorded using both the colour infra-red aerial photographs and the matrices. All the data were punched on cards and fed to the computer to produce maps and statistics.

7.5 The use of the Computer and Data Handling

Computer programmes were developed to provide statistics and grid maps. Digitization was carried out directly from the photographs and base maps were used only as reference material for orientation purposes. Two programmes were developed: one to produce statistics and one for maps (Appendix 7.1).

7.51 Production of Maps

One type of Calcomp map was produced to show the distribution of the ten major groups of open space in each of the sample areas (Figure 7.3). Ten different symbols were used, taken from the notation developed in the first stage of the study. The complete set of these maps for the 11 areas is given in Appendix 7.II.

A second type of map was produced manually, to show the two categories of open space management (Figure 7.4). This of course does not mean that such maps cannot be produced by the Calcomp Plotter, but the manual production was done to demonstrate the ease with which data, which are recorded on coding forms, can be selected and mapped with different colours or shades for, for example, comparison of open space with status categories. By the use of the "condition" code numbers, registered on the coding forms, a set of such maps for the 11 areas was produced showing the two categories of management as well as the relevant statistics. This set of maps is given in Appendix 7.III.

7.52 Statistical Outputs

To satisfy the requirements of the county planning authority in terms of numerical information, one computer printout was produced to include all the statistics in terms of provision, maintenance and condition of open space and consists of 235 computer printout pages. The numerical results were printed in the following order and are based on grid cell units of 20m x 20m squares.

1. Provision of Open Space for each Sample Area

   Amount of open space and its surface in group and sub-unit level, in ha and %, in "land use/surface matrix" form.

2. High Maintenance of Open Space for Each Sample Area

   Amount of well maintained open space versus its surface in group and sub-unit level, in ha and %, in "land use/surface matrix" form.

3. Low Maintenance of Open Space for Each of the Eleven Sample Areas

   Amount of low maintained open space versus its surface type, in group and sub-unit level, in ha and %, always in "land use/surface matrix" form.

4. Non-Maintained Open Space in each of the Eleven Sample Areas

   Amount of non maintained open space versus its surface, in group and sub-unit level in ha and %, in "land use/surface matrix" form..

5. Good Condition of Open Space in each of the Eleven Sample Areas

   Amount of open space versus its surface in good condition, in ha and %, in a matrix table form.

6. Bad Condition of Open Space in each of the Eleven Sample Areas

   Amount of open space versus its surface in bad condition, in ha and %, in the same matrix form.

7. Averages of Data, Referring to Samples 1, 2, 3, 4 and 11

   A set of six tables in "land use/surface matrix form" have been produced for the sample areas 1, 2, 3, 4 and 11 providing average statistics of the five areas, on Provision, Maintenance (three categories) and Condition of open space (two categories). These samples belong to a High Socioeconomic class in the county.

8. Averages of Data Referring to Samples 7, 8, 9 and 10

   A set of six tables in "land use/surface matrix form" have been printed for the sample areas, 7, 8, 9 and 10 providing average statistics of the four areas, on Provision, Maintenance (three categories) and Condition of open space (two categories). These samples belong to a Low Socioeconomic class in the county.

Table 7.6 is an example of a statistical output in a "land use/surface matrix" form and refers to the provision of open space in sample area No. 1. The numerical results are given in hectares and percentages.

All the above statistics have been printed in the same form. A total of 78 such matrices have been produced in one printout: six for each of the eleven sample areas, six for the average statistics of sample areas No. 1, 2, 3, 4, 11, belonging to high status category and six for the average statistics for samples No. 7, 8, 9 and 10, belonging to low status category. The socioeconomic status categories "Intermediate" and "Very low" are represented by two sample areas No. 5 and No. 6, respectively.

7.6 Conclusion

In this stage an operational methodology has been developed in open space data recording, using a four-dimensional notation system, including open space use, surface cover, maintenance and condition.

Coding open space data in this degree of detail permits flexibility in the use of the data. The coding system (six digits per observation) facilitates the production of a detailed data bank necessary and desirable for day-to-day planning operations. The data can be regrouped or used selectively in a variety of different patterns to fit the needs of special studies and analyses.

The cost of recording and coding open space information at the six-digit level of detail will usually be greater than if the data were recorded and coded at more generalised levels. This extra cost results from the extra time involved in the photointerpretation and coding of the detailed data. On the other hand, such extra costs often can be offset by the greater flexibility and wider utilization of the data.

The ten major open space groups recommended in the notation (Table 7.1) are used in the next stage for a series of comparisons with the four categories of socioeconomic status.

Figure 7.1 A MAINTENANCE POLICY FOR A PARTICULAR URBAN OPEN SITE (supplied by the County Planners).

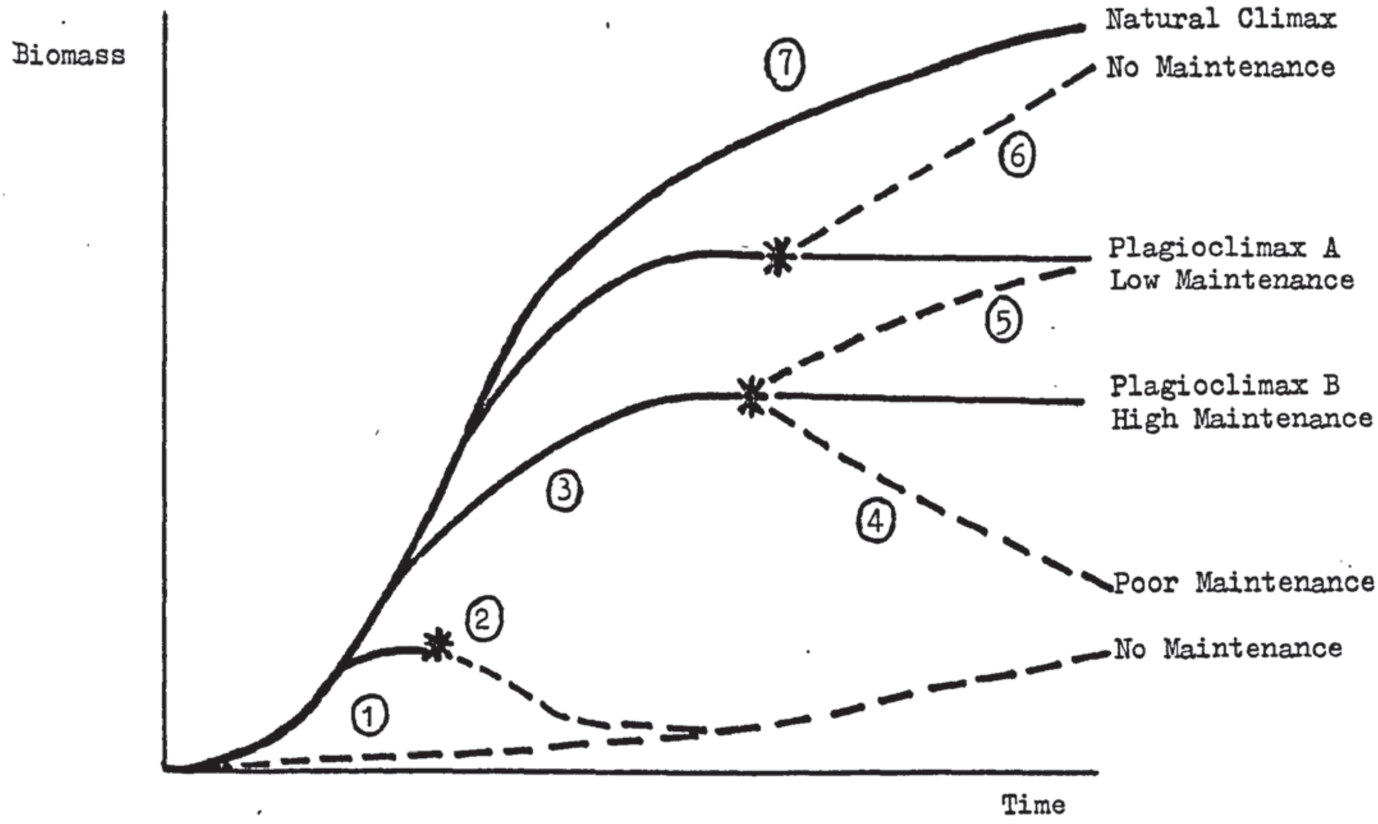
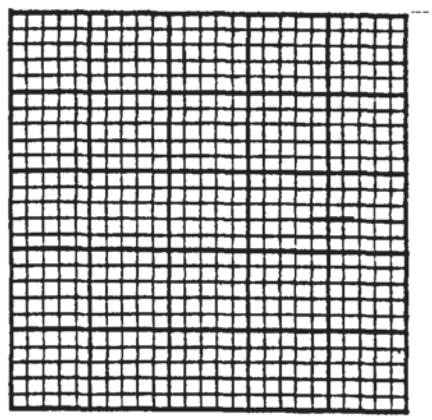


Figure 7.2 SQUARE GRID 20m x 20m



This square grid of 20m x 20m was used in this stage of the study. In each of the cells the "dominant land use" was recorded.

Figure 7.3 OPEN SPACE MAPS - DATA DERIVED FROM COLOUR INFRA-RED PHOTOGRAPHY.

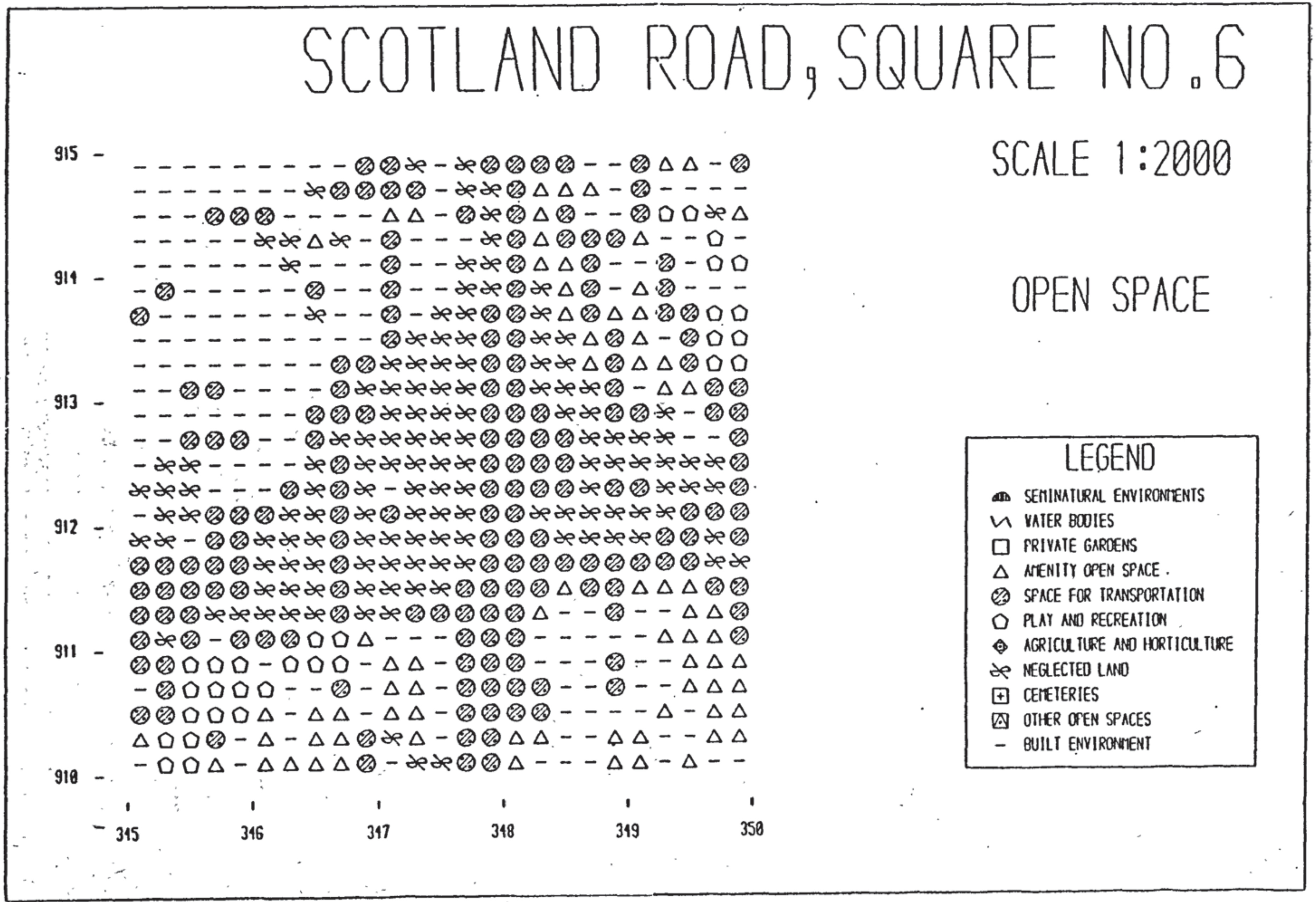
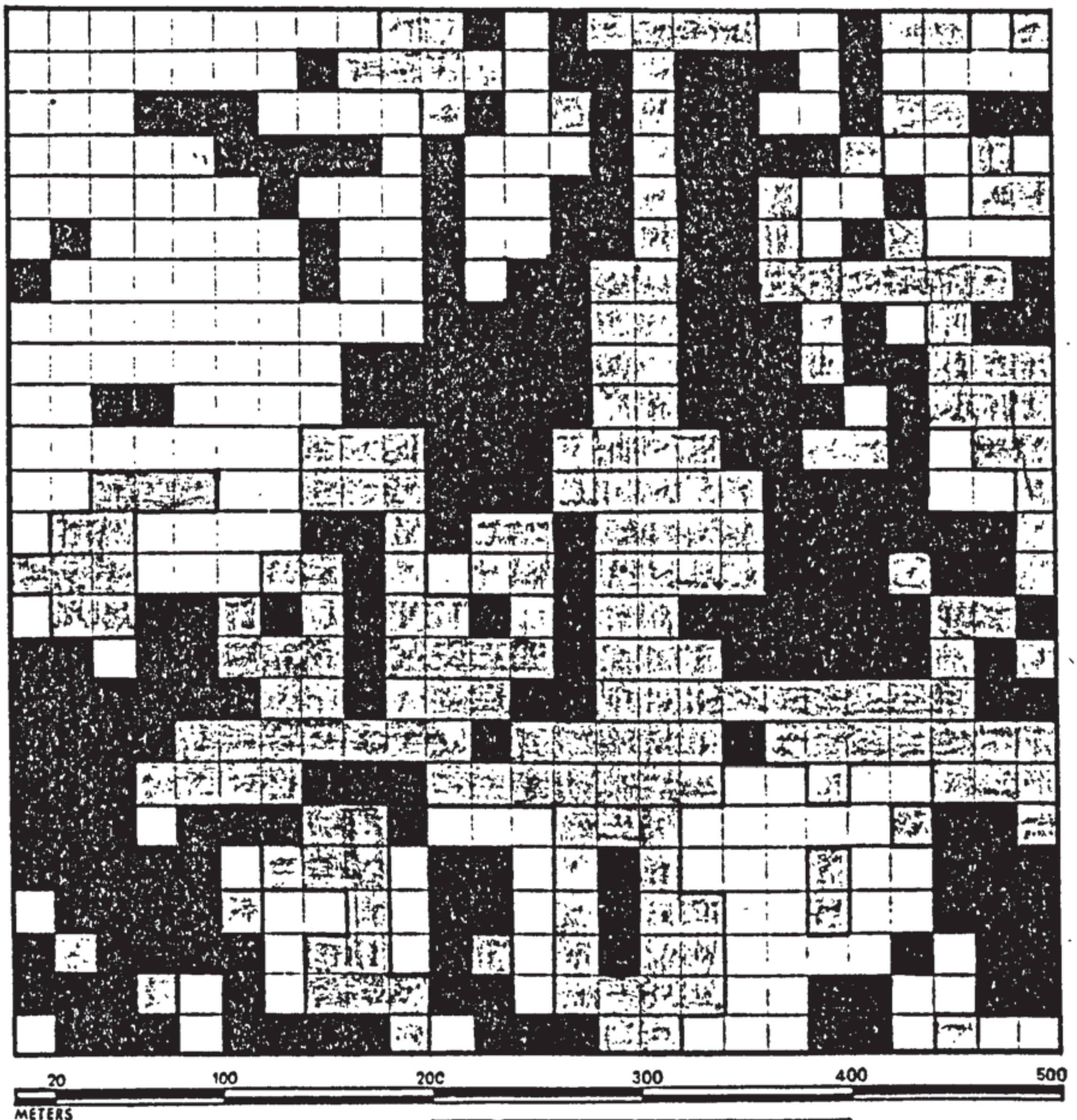


Figure 7.4 OPEN SPACE CONDITION MAPS FROM DATA DERIVED FROM COLOUR INFRA-RED AERIAL PHOTOGRAPHY.

subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: scotland road
quarter kilometre square No.: 6
socioeconomic status: very low



legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
8.32	33.3	9.08	36.3	7.60	30.40

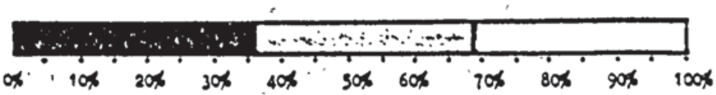


Table 7.1 URBAN OPEN SPACE USE NOTATION SYSTEM

CODE NUMBER	URBAN OPEN SPACE UNITS	
01	Heathland	1. Semi-natural Environments
02	Woodland	
03	Moss-land	
04	Sand Dunes	
05	Beaches	
06	Marshland	
07	Streams and Rivers	2. Water bodies
08	Canals	
09	Lakes and Ponds	
10	Reservoirs	
11	Oceans	
12	Private Gardens	3. Private Gardens
13	Parks	4. Amenity Open Space
14	Amenity Open Space-general access.	
15	Amenity Open Space-limited access, Institutional etc.	
16	Amenity Open Space - Industrial, Commercial.	
17	Streets lined with trees	5. Space for Transportation
18	Streets not lined with trees	
19	Railways	
20	Motorways	
21	Open air car parks	
22	Airfields	
23	Children's Playgrounds	6. Play and Recreation
24	Sportsfields and Stadia	
25	Golf Courses	
26	Educational Playspace	
27	Industrial Sports Facilities	
28	Other Open Air Playspaces	
29	Allotment Gardens	7. Agriculture and Horticulture
30	Agriculture & Horticulture	
31	Industrial/Commercial Ancillary Open Space (other)	8. Neglected land
32	Rough grassland	
33	Scrubland	
34	Derelict land	
35	Mineral Extraction	
36	Waste Disposal Sites	
37	Cleared Land	
38	Cemeteries	9. Cemeteries
39	Other Open Spaces	10. Other
00	Built Environment	

Table 7.2 OPEN SPACE SURFACE CATEGORIES

CODE NUMBER	SURFACES
00	Buildings
01	Asphalt/Concrete
02	Architectural Surfaces
03	Refuse
04	Water
05	Bare Soil
06	Turf grass
07	Rough grass
08	Infested grass
09	Sub-shrubs
10	Shrubs
11	Trees
12	Flowerbeds
13	Vegetables
14	Arable crops
15	Other surfaces

Table 7.3

OPEN SPACE MAINTENANCE CATEGORIES

1. H = High maintenance
2. L = Low maintenance
3. N = No maintenance
0. X = Should not occur

URBAN OPEN SPACE USE

Code	URBAN OPEN SPACE UNITS	SURFACES: 15 OTHER SURFACES	14 ARABLE CROPS	13 VEGETABLES	12 FLOWERBEDS	11 TREES	10 SHRUBS	09 SUB-SHRUBS	08 INFESTED GRASS	07 ROUGH GRASS	06 TURF GRASS	05 BARE SOIL	04 WATER	03 REFUSE	02 ARCHIT./SUR.	01 ASPH./CONCR.	00 BUILDINGS	OPEN SPACE GROUPS
01	HEATHLAND		X	X	X	N	L	L	N	L	X	N	N	N	X	X	X	SEMI-NATURAL ENVIRONMENTS
02	WOODLAND		X	X	X	L	L	L	N	L	X	N	L	N	X	X	X	
03	MOSSLAND		X	X	X	L	L	L	N	L	X	N	N	N	X	X	X	
04	SAND DUNES		X	X	X	L	N	N	N	L	L	N	L	N	L	L	X	
05	BÉACHES		X	X	X	X	X	X	N	X	X	L	X	N	X	X	X	
06	MARSHLAND		X	X	X	N	N	N	N	N	X	X	N	N	X	X	X	
07	STREAMS & RIVERS		X	X	X	X	X	X	N	X	X	X	L	N	X	X	X	WATER BODIES
08	CANALS		X	X	X	X	X	X	N	X	X	X	L	N	X	X	X	
09	LAKES & PONDS		X	X	X	X	X	X	N	X	X	X	L	N	X	X	X	
10	RESERVOIRS		X	X	X	X	X	X	N	X	X	X	H	N	X	X	X	
11	OCEANS		X	X	X	X	X	X	N	X	X	X	N	N	X	X	X	
12	PRIVATE GARDENS		X	H	H	L	L	L	N	L	H	N	H	N	L	L	X	PRIVATE GARDENS
13	PARKS		X	X	H	L	L	L	N	L	H	N	H	N	L	L	X	AMENITY OPEN SPACE
14	AMENITY OPEN SPACE, (general access).		X	X	H	L	L	L	N	L	H	N	H	N	L	L	X	
15	AMENITY OPEN SPACE, (limited access Institutional etc.)		X	X	H	L	L	L	N	L	H	N	H	N	L	L	X	
16	AMENITY OPEN SPACE, (Industrial, Commercial)		X	H	H	L	L	L	N	L	H	N	H	N	L	L	X	
17	STREETS LINED WITH TREES		X	X	H	H	L	L	N	L	H	N	X	N	L	L	X	SPACE FOR TRANSPORTATION
18	STREETS NOT LINED WITH TREES		X	X	H	H	L	L	N	L	H	N	X	N	L	L	X	
19	RAILWAYS, (Land associated with)		X	X	H	H	N	N	N	L	H	N	N	N	L	L	X	
20	MOTORWAYS, (Land associated with)		X	X	H	L	L	L	N	L	H	N	N	N	L	L	X	
21	OPEN AIR CAR PARKS		X	X	H	L	L	L	N	L	H	L	N	N	L	L	X	
22	AIRFIELDS		X	X	H	N	N	N	N	L	H	N	N	N	H	H	X	
23	CHILDREN'S PLAYGROUNDS		X	H	H	L	L	L	N	L	H	N	H	N	H	L	X	PLAY & RECREATION
24	SPORTFIELDS AND STADIA		X	X	H	L	L	L	N	L	H	N	H	N	H	L	X	
25	GOLF COURSES		X	X	H	L	L	L	N	L	H	N	H	N	H	L	X	
26	EDUCATIONAL PLAYSPACE		X	X	H	L	L	L	N	L	H	N	H	N	H	L	X	
27	INDUSTRIAL SPORT FACILITIES		X	X	H	L	L	L	N	L	H	N	H	N	H	L	X	
28	OTHER OPEN AIR PLAYSPACES		X	X	H	L	L	L	N	L	H	N	H	N	H	L	X	
29	ALLOTMENT GARDENS		H	H	H	H	H	H	N	X	X	H	L	N	L	L	X	AGRICULTURE & HORTICULTURE
30	AGRICULTURE & HORTICULTURE		H	H	H	H	H	H	N	H	H	H	L	N	L	L	X	
31	INDUSTRIAL/COMMERCIAL OPEN SPACE, ANCILLARY OPEN SPACE(OTHER)		X	X	X	N	N	N	N	L	H	N	N	N	L	L	X	NEGLECTED LAND
32	ROUGH GRASSLAND		X	X	X	N	N	N	N	L	X	N	N	N	X	X	X	
33	SCRUBLAND		X	X	X	N	N	N	N	N	X	N	N	N	X	X	X	
34	DERELICT LAND		X	X	X	N	N	N	N	X	X	N	N	N	N	N	X	
35	MINERAL EXTRACTION		X	X	X	H	N	N	N	H	H	N	N	N	L	L	X	
36	WASTE DISPOSAL SITES		H	H	H	H	N	N	N	H	H	N	N	H	L	L	X	
37	CLEARED LAND		X	X	H	H	L	L	N	L	H	N	N	N	L	L	X	
38	CEMETERIES		X	X	H	L	L	L	N	L	H	H	H	N	L	L	X	CEMETERIES
39	OTHER OPEN SPACES																	OTHERS

Urban Open Space project/Stamatis Sekliziotis/Civil Engineering/Remote Sensing Unit/Aston University

Table 7.4

MANAGEMENT CATEGORIES:

1. + = Priori good management
2. – = Priori bad management

1/2 ± = Situation where both alternatives are possible

X = Should not occur

SURFACES: 15 OTHER SURFACES, 14 ARABLE CROPS, 13 VEGETABLES, 12 FLOWERBEDS, 11 TREES, 10 SHRUBS, 09 SUB-SHRUBS, 08 INFESTED GRASS, 07 ROUGH GRASS, 06 TURF GRASS, 05 BARE SOIL, 04 WATER, 03 REFUSE, 02 ARCHIT./SUR., 01 ASPH./CONCR., 00 BUILDINGS

URBAN OPEN SPACE USE

15 OTHER SURFACES	14 ARABLE CROPS	13 VEGETABLES	12 FLOWERBEDS	11 TREES	10 SHRUBS	09 SUB-SHRUBS	08 INFESTED GRASS	07 ROUGH GRASS	06 TURF GRASS	05 BARE SOIL	04 WATER	03 REFUSE	02 ARCHIT./SUR.	01 ASPH./CONCR.	00 BUILDINGS		URBAN OPEN SPACE UNITS	OPEN SPACE GROUPS
	X	X	X	–	–	+	±	±	X	–	±	–	X	X	X	01	HEATHLAND	SEMI-NATURAL ENVIRONMENTS
	X	X	X	±	+	+	±	+	X	–	±	–	X	X	X	02	WOODLAND	
	X	X	X	–	–	+	±	+	X	–	±	–	X	X	X	03	MOSSLAND	
	X	X	X	±	–	+	–	+	+	–	+	–	–	–	X	04	SAND DUNES	
	X	X	X	X	X	X	–	X	X	+	X	–	X	X	X	05	BEACHES	
	X	X	X	–	+	+	+	+	X	X	+	–	X	X	X	06	MARSHLAND	
	X	X	X	X	X	X	±	X	X	X	+	–	X	X	X	07	STREAMS & RIVERS	WATER BODIES
	X	X	X	X	X	X	±	X	X	X	+	–	X	X	X	08	CANALS	
	X	X	X	X	X	X	±	X	X	X	+	–	X	X	X	09	LAKES & PONDS	
	X	X	X	X	X	X	–	X	X	X	+	–	X	X	X	10	RESERVOIRS	
	X	X	X	X	X	X	–	X	X	X	+	–	X	X	X	11	OCEANS	
	X	±	±	±	±	±	–	±	±	–	±	–	±	+	X	12	PRIVATE GARDENS	PRIVATE GARDENS
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	13	PARKS	AMENITY OPEN SPACE
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	14	AMENITY OPEN SPACE, (general access).	
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	15	AMENITY OPEN SPACE, (limited access Institutional etc.)	
	X	±	±	±	±	±	–	±	±	–	±	–	±	±	X	16	AMENITY OPEN SPACE, (Industrial, Commercial)	
	X	X	±	±	±	±	–	±	±	–	X	–	±	±	X	17	STREETS LINED WITH TREES	SPACE FOR TRANSPORTATION
	X	X	±	±	±	±	–	±	±	–	X	–	±	±	X	18	STREETS NOT LINED WITH TREES	
	X	X	±	±	+	+	+	±	±	–	–	–	±	±	X	19	RAILWAYS, (Land associated with)	
	X	X	±	±	+	+	+	±	±	–	–	–	±	±	X	20	MOTORWAYS, (Land associated with)	
	X	X	±	±	±	±	±	–	±	–	–	–	±	±	X	21	OPEN AIR CAR PARKS	
	X	X	±	–	–	+	–	±	±	–	–	–	±	±	X	22	AIRFIELDS	
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	23	CHILDREN'S PLAYGROUNDS	PLAY & RECREATION
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	24	SPORTFIELDS AND STADIA	
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	25	GOLF COURSES	
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	26	EDUCATIONAL PLAYSPACE	
	X	±	±	±	±	±	–	±	±	–	±	–	±	±	X	27	INDUSTRIAL SPORT FACILITIES	
	X	X	±	±	±	±	–	±	±	–	±	–	±	±	X	28	OTHER OPEN AIR PLAYSPACES	
	X	±	±	±	±	±	–	–	–	+	–	–	±	±	X	29	ALLOTMENT GARDENS	AGRICULTURE & HORTICULTURE
	±	±	±	±	±	±	–	±	±	±	±	–	±	±	X	30	AGRICULTURE & HORTICULTURE	
	X	±	–	–	–	–	–	±	±	–	–	–	±	±	X	31	INDUSTRIAL/COMMERCIAL OPEN SPACE, ANCILLARY OPEN SPACE(OTHER)	NEGLECTED LAND
	X	X	X	–	–	–	–	–	X	–	–	–	X	X	X	32	ROUGH GRASSLAND	
	X	X	X	–	–	–	–	–	X	–	–	–	X	X	X	33	SCRUBLAND	
	X	X	X	±	±	±	±	X	X	–	±	–	–	–	X	34	DERELICT LAND	
	X	X	X	±	–	–	–	±	±	±	±	–	±	±	X	35	MINERAL EXTRACTION	
	X	X	X	±	±	±	–	±	±	±	–	+	±	±	X	36	WASTE DISPOSAL SITES	
	X	X	±	±	±	±	–	±	±	–	–	–	±	–	X	37	CLEARED LAND	
	X	X	±	±	±	±	–	±	±	+	±	–	±	±	X	38	CEMETERIES	CEMETERIES
																39	OTHER OPEN SPACES	OTHERS

Urban Open Space project/Stamatis Seklisiotis/Civil Engineering/Remote Sensing Unit/Aston University

Table 7.5 RECORDING OF PHOTOINTERPRETATION AND MAINTENANCE DATA ON CODING FORMS.

The University of Aston in Birmingham Computer Centre

EVP 6024 | Sheet 22 of 44

ALGOL CODING FORM

PHOTOINTERPRETATION OF COLOUR INFRARED PHOTOGRAPHY
SAMPLE AREA Nr 6, SCOTLAND ROAD

Name STAMATIS SEKLIZIOTIS

CIVIL ENGINEERING

Original Coordinates from Ordnance Survey Maps

913348	200121	330932	140932	210121	000000	200721	330932	140832	210121	140121	
	200721	330532	330932	140932	180121	210121	330532	330532	140532	180121	
	210721	330832	330532	330932	180122						
913349	150532	180121	000000	000000	000000	140121	180121	180121	260611	260612	
	150532	000000	150121	260612	260612	150532	150532	180121	260611	260611	
	000000	150532	140121	180121	210121						
912345	000000	000000	000000	000000	000000	000000	000000	180121	180121	180121	
	000000	310121	310121	000000	000000	310121	310121	310121	000000	000000	
	000000	310121	310121	210532	210532						
912346	000000	000000	180121	180121	180121	000000	000000	180121	370721	370721	
	000000	000000	370722	180122	370721	000000	180121	370611	180122	370611	
	180121	370612	370611	180122	370611						
912347	370532	370532	370532	370611	200121	370722	370612	370612	370621	200121	
	370122	370611	370611	370832	200121	000000	370611	370611	370832	210121	
	180121	370722	370611	370832	200121						
912348	210121	200611	330532	330532	180121	210121	200611	200611	330932	330932	
	210121	200611	200611	330932	330532	210121	200121	200121	340932	180122	
	210121	330932	330832	340932	340932						
912349	180121	340532	000000	180121	210121	340532	340532	000000	000000	210121	
	340532	340532	370532	370532	180121	180122	370611	370722	370532	210121	
	340532	370612	210121	210121	180122						
911345	310122	310122	000000	210532	210532	210532	210532	210532	210532	210122	
	210532	210532	210532	210532	180121	180122	180122	210532	370721	370721	
	210532	310532	180122	000000	180122						

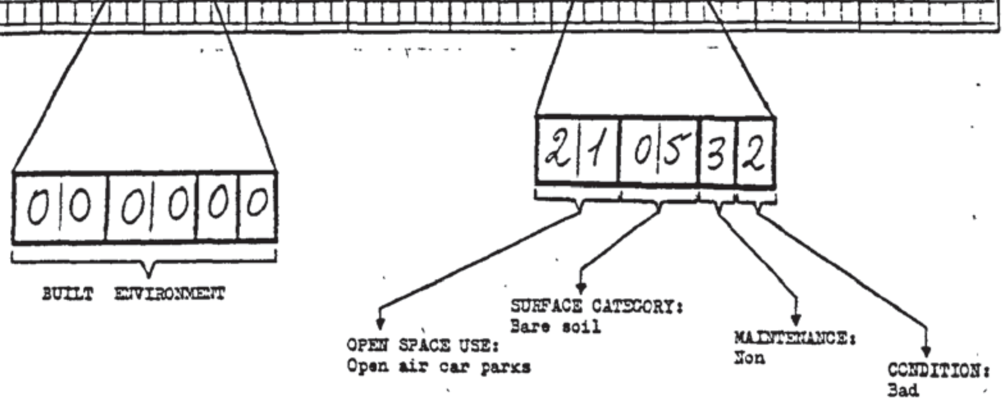


Table 7.6 STATISTICAL OUTPUT IN A "LAND USE/SURFACE MATRIX" FORM.

BIRKDALE,SQUARE [illegible]

PROVISION OF OPEN SPACE

GROUP NO.	GROUP TOTAL	UNIT TOTAL	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	UNIT NO.
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5
1	0,00 0,0	0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
2	0,00 0,0	0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
3	11,10 44,0	11,10 44,0	0,00 0,0	0,00 0,0	0,12 0,5	0,08 0,3	1,08 4,3	1,10 4,4	0,32 2,1	0,06 0,2	1,08 4,1	5,90 23,4	0,04 0,1	0,04 0,1	0,00 0,0	0,06 0,2	0,92 3,7	12
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13
		0,10 0,4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
		1,32 6,1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
4	1,48 6,7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16
		0,29 1,1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17
		3,86 13,4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,12 14,3	18
		3,34 2,2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
5	4,08 16,7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
		0,36 1,4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
6	0,36 1,4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29
7	0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
		0,00 0,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
		0,76 3,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,72 2,9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34
		0,32 1,3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36
8	3,20 12,4	2,12 4,5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37
9	0,00 0,0	0,79 3,0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39
GRAND TOTAL		[illegible]	[illegible]	0,00 0,0	0,12 0,5	0,08 0,3	1,78 3,1	1,14 4,4	0,52 2,1	0,24 1,0	[illegible]	[illegible]	1,72 6,7	[illegible]	0,00 0,0	0,46 5,2	4,17 17,3	

BUILT AREA = 3,92 HA, 11,46%

Plate 7.1 SEMI-NATURAL ENVIRONMENTS

Areas usually outside urban areas or in the urban fringes where no human activity can be identified and covered by natural or semi-natural vegetation communities, consisting of species growing in an "intricate intermingling" (Coleman, 1965). Such areas can be different types of Marshlands, Heathlands, Mosslands, Sand-dunes etc., mostly unenclosed, receiving little or no deliberate human tending. Natural bare land such as beaches and exposed rock is included here.

KEY (as per notation)

01/09/2/1: HEATHLAND/SUB-SHRUBS/LOW MAINTENANCE/GOOD CONDITION.

Plate 7.2 WATER BODIES

Any open waters not belonging to any of the other categories included in the Open Space Notation. In this group are included Oceans, Streams, Rivers, Canals, Reservoirs, Lakes etc.

KEY (as per notation)

11/04/3/1: OCEANS/WATER/NO MAINTENANCE/GOOD CONDITION

Plate 7.3 PRIVATE GARDENS

Any open pieces of land associated with dwelling units or other residential blocks and housing complexes and which are meant to serve only the needs of the people who live in those buildings, as "at home" open air spaces for such various activities as playspace, productive space (vegetable growing etc.), space for relaxation and aesthetic appreciation.

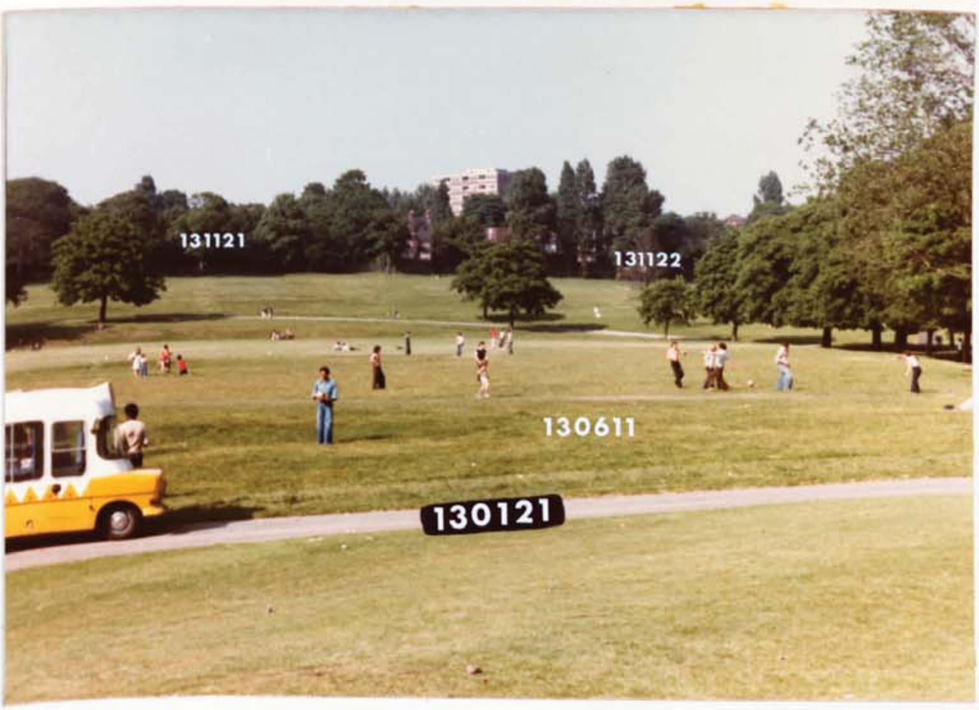
KEY (as per notation)

00/00/0/0: BUILDINGS

12/01/2/1: PRIVATE GARDENS/ASPHALTED SURFACE/LOW MAINTENANCE/ GOOD CONDITION.

12/10/2/1: PRIVATE GARDENS/SHRUBS/LOW MAINTENANCE/GOOD CONDITION.

Plate 7.4 AMENITY OPEN SPACE

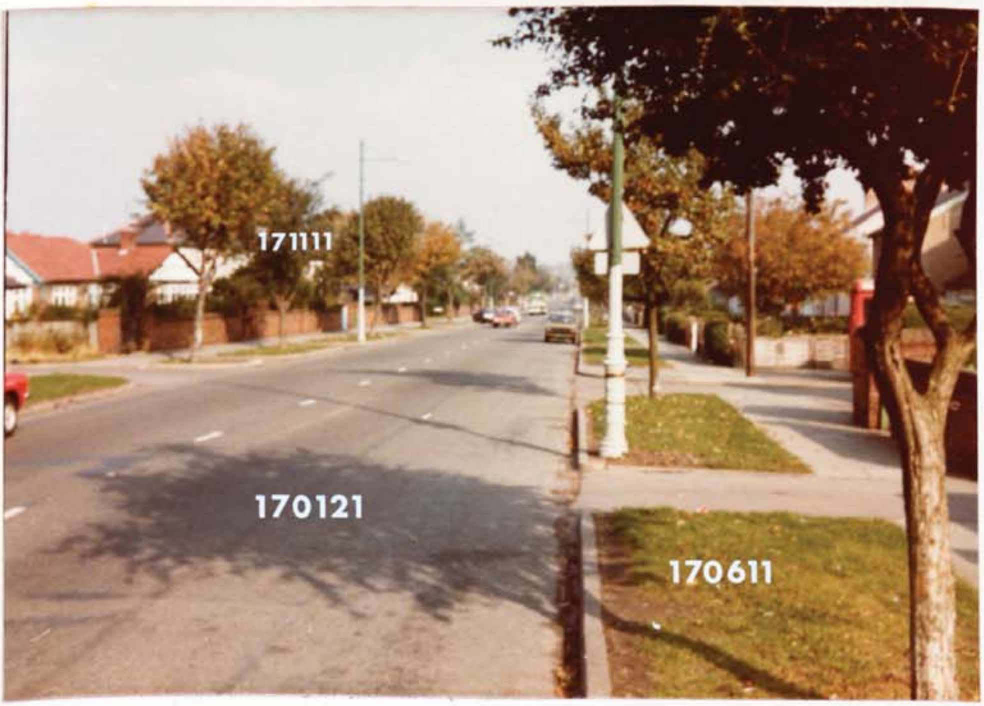


Small or large landscaped or hardly floorscaped open spaces in the city with limited or sometimes without facilities for active recreation, almost of a "short stay" recreational function, most of them designed for aesthetic reasons and to do "Urban Work" as landscaped gaps between building and blocks of flats or others occurring inside building complexes of various uses. Parks are included in this category as being large landscaped areas mainly used for such informal recreation activities as sitting, walking and aesthetic appreciation. Facilities for active recreation as for example children's playgrounds occurring inside parks are classified as "children's playgrounds".

KEY (as per notation)

13/06/1/1: PARKS/TURF GRASS/HIGH MAINTENANCE/GOOD CONDITION
13/01/2/1: PARKS/ASPHALTED SURFACE/LOW MAINTENANCE/GOOD CONDITION
13/11/2/1: PARKS/TREES/LOW MAINTENANCE/GOOD CONDITION
13/11/2/2: PARKS/TREES/LOW MAINTENANCE/BAD CONDITION

Plate 7.5 SPACE FOR TRANSPORTATION

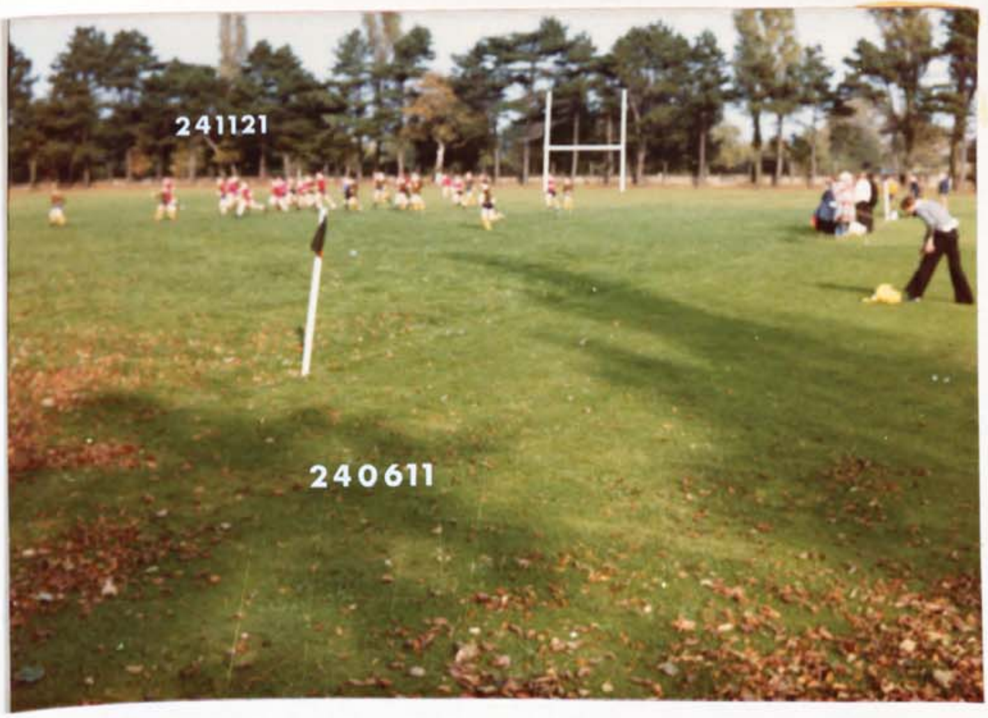


All parts of the Urban Open Air Space which are used for movement both by pedestrians and vehicles. All streets, motorways, car parks, air-fields in use and railways are included in this category. Trees, lawns and any kind of lands which are associated with them are also included in this category. Extended areas of railways and streets not in use (derelict) are classified as "Neglected wastelands". Waterways are considered as "Water Bodies". Spaces of this category penetrating other Open Spaces of the notation are included in this group. Pathways belonging to parks and other open spaces are included in the open space unit to which they belong, if they appear primarily to serve the open space.

KEY (as per notation)

17/01/2/1: STREETS LINED WITH TREES/ASPHALTED/LOW MAINTENANCE/ GOOD CONDITION
17/11/1/1: STREETS LINED WITH TREES/TREES/HIGH MAINTENANCE/ GOOD CONDITION
17/06/1/1: STREETS LINED WITH TREES/TURF GRASS/HIGH MAINTENANCE/ GOOD CONDITION

Plate 7.6 PLAY AND RECREATION

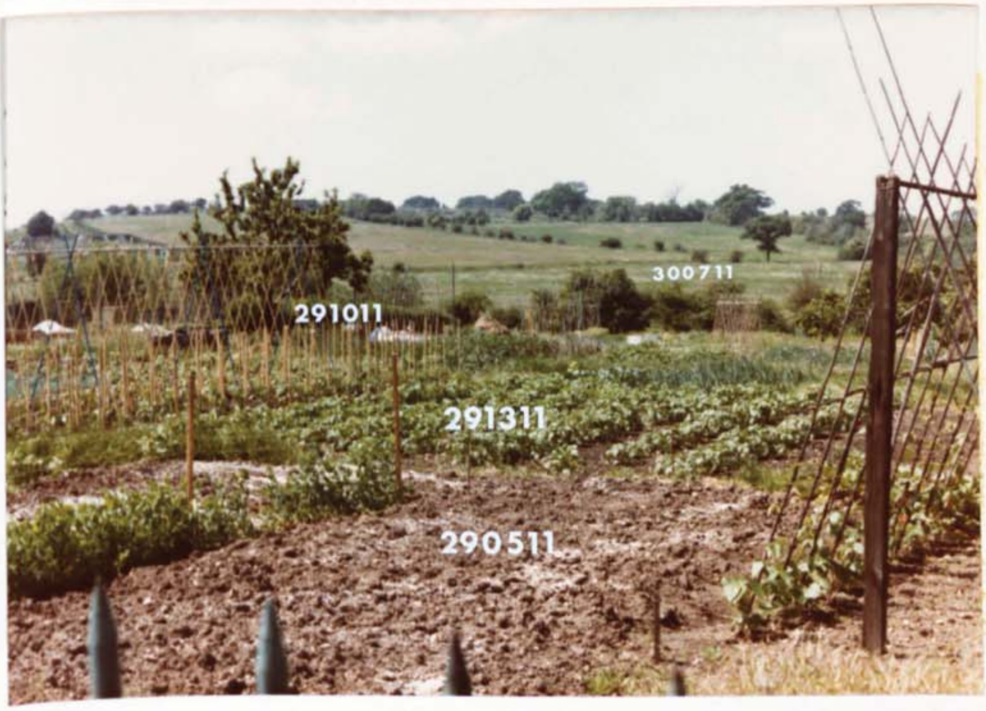


Open spaces where any recreation activity requires a certain measure of organisation, facilities and areas. Usually regular layouts, flat or undulating (golf courses), grassed (football) or tarmac (tennis courts), and any piece of land which gives an indication of being provided for the purpose of sport activity. Sport centres in the form of buildings (covered sport activities) are classified as "buildings", because the activity does not take place in the open air space.

<u>KEY (as per notation)</u>

24/06/1/1: SPORT FIELDS AND STADIA/TURF GRASS/HIGH MAINTENANCE/ GOOD CONDITION
24/11/2/1: SPORT FIELDS AND STADIA/TREES/LOW MAINTENANCE/ GOOD CONDITION

Plate 7.7 AGRICULTURE AND HORTICULTURE



Any form of Arable, Pasture, Horticulture (green houses included) or orchards: Allotment gardens in use belong to this group. Unused Allotments (no indication of the "Use" status which is determined by a uniform vegetable pattern) are classified as "Neglected wasteland".

KEY (as per notation)

29/13/1/1: ALLOTMENT GARDENS/VEGETABLES/HIGH MAINTENANCE/GOOD CONDITION

29/05/1/1: ALLOTMENT GARDENS/BARE SOILS/HIGH MAINTENANCE/GOOD CONDITION

29/10/1/1: ALLOTMENT GARDENS/SHRUBS/HIGH MAINTENANCE/GOOD CONDITION

30/07/1/1: AGRICULTURE/ROUGH GRASS/HIGH MAINTENANCE/GOOD CONDITION

Plate 7.8 NEGLECTED LAND

In this category all Wastelands, Derelict sites and Spoiled lands are included. Wastelands are those vacant plots or lands in temporary use or not which could be brought into permanent use without major works of reclamation: in other words, land which requires stimulation rather than reclamation, to be brought into active use, e.g. demolition sites (cleared lands), unused land left over after development, abandoned allotments, extended areas of abandoned Railway Sidings, pieces of lands covered by scrub or rough grasses inside the urban fabric. Derelict sites are those pieces of land which through the activity and subsequent neglect of man or natural action have become an unutilized land resource. At the time of survey there is no indication of activity and area varies in size from a few square meters up to many hectares. Spoiled lands are pieces of land used for waste disposal, mineral extraction and are under disturbance by the time of survey.

KEY

33/10/3/2: SCRUBLAND/SHRUBS/NO MAINTENANCE/BAD CONDITION
34/01/3/2: DERELICT LAND/ASPH-CONCR/NO MAINTENANCE/BAD CONDITION
32/07/3/2: ROUGH GRASSLAND/ROUGH GRASS/LOW MAINTENANCE/BAD CONDITION
32/05/3/2: ROUGH GRASSLAND/BARE SOIL/NO MAINTENANCE/BAD CONDITION

Plate 7.9 CEMETERIES

Areas of land which are often characterized by a regular, parklike layout, with a system of paths avenues and lanes defining smaller areas where the actual graves are situated. Graveyards of various sizes associated with churches also belong to this category.

KEY (as per notation)

38/11/2/1: CEMETERIES/TREES/LOW MAINTENANCE/GOOD CONDITION
38/08/3/2: CEMETERIES/INFESTED GRASS/NO MAINTENANCE/BAD CONDITION.

CHAPTER 8

STAGE 3: COMPARISON OF OPEN SPACE DATA WITH SOCIOECONOMIC STATUS

8.1 Introduction

This chapter refers to a series of comparisons between the four categories of socioeconomic status, and the ten groups of open space data derived from the survey of the eleven sample areas.

The open space data collected refer to open space at both group level and unit level (see Table 7.1). The comparisons are concerned with the four status categories which emerged from the Social Area Analysis and the ten major groups of open space data derived from the air photo interpretation.

In order to satisfy the Planning Authority's requirements a large amount of detailed information was collected on open space at the unit level, consequently there is a great potential for further manipulation of this data. A variety of comparisons could be carried out to seek relationships between social status and individual open space units. In this chapter such relationships will be examined on a more limited scale, since the aim is to correlate status with only the main groups of open space.

A series of diagrams, together with the set of maps which have already been produced in the survey stage (chapter 7), will be used to illustrate open space distribution, in terms of provision and condition, in areas belonging to different socioeconomic status categories. These diagrams will also provide visual comparisons between different urban areas. Some of these diagrams are histograms produced on a Calcomp plotter using the computer program developed for this purpose. This program is given in Appendix 8.I.

8.2 Open Space Groups and Socioeconomic Status

The information relating to each Open Space Group, derived in the survey carried out in stage 2, (chapter 7) will be examined and used to make comparisons between the four categories of socioeconomic status which emerged from the Social Area Analysis (chapter 6).

It is the purpose of this chapter to make further comparisons between socioeconomic categories of the population, and open space data, not only in terms of provision of open space, but also on data which describes the open space in terms of maintenance and condition. In this context, together with provision, the open space groups will be examined against four different socioeconomic status categories.

Some comparisons will not be considered at all, or will be only briefly discussed e.g. where no data, or limited data have been recorded, simply because particular open space groups did not occur, or only partially occurred in the sample areas surveyed. Such open space groups are "Water Bodies", "Agriculture and Horticulture", Semi-natural Environments" and "Cemeteries". The absence of these groups is due to the geographical location of the sample areas surveyed inside the County, and to the total sample size - which is only 1% of the total urban area in the whole County.

8.21 Semi-natural Environments (Group 1)

This type of open space, although important in terms of environmental quality, did not occur very often in the sample areas, except for a small portion of moderately well maintained Woodland in quite good condition, fully covered with trees and belonging to the Low Socioeconomic Status (Category 3) (Figures 8.1 and 8.2).

8.22 Water Bodies (Group 2)

No Water Bodies were recorded in any of the eleven sample areas.

8.23 Private Gardens (Group 3)

Figure 8.3 shows the relationship between the distribution of private gardens and socioeconomic status. This reveals that in relation to socioeconomic status (Category 1, High to 4, Low) the percentages of open space devoted to private gardens are 36%, 42%, 17% and zero respectively.

It is hard to accept that no private gardens occur in all the other Category 4 areas in the County, but this finding reflects a very poor provision of private gardens in inner areas, where the housing stock consists of old terraces of very poor quality, or fairly recently built blocks of flats with open landscaped land around them.

There is usually a direct relationship between urban form in general (and housing age in particular) with the extent of the area which is devoted to private gardens. Figure 8.3 shows that Category 2, which may appear to be out of step, does in fact accord to this relationship. This is because of the age of the residential dwellings in Category 2. This was formerly a high quality residential area, built at a time when planning control was not very strong, and when land was relatively cheap. Large houses with very large gardens were usual in these middle class areas, in contrast with the situation now, when both buildings and land are relatively substantially more expensive, and planning controls more rigorous. This area is now in decline with the large houses being split into flats, or becoming derelict.

The urban form is different in the Category 3 areas where the common type of housing is in the form of tower blocks, relatively recent council estates, semi-detached houses built between the 1930's and the immediate post war period, and many Victorian terraces of intermediate and poor quality. Such areas are mostly covered by buildings so that the space left has to provide such open space facilities as private gardens, street layouts and recreation. Here the average amount of open space devoted to private gardens is very small.

In the Category 4 sample area the residential buildings are tall blocks of flats, some quite high rise. In such circumstances no provision is made for private gardens: instead there are modestly sized, open, landscaped - mostly grass - areas surrounding the buildings.

Figure 8.4 shows the relationship between maintenance, condition, and type of surface of private gardens, and socioeconomic status. In terms of maintenance the percentages of private gardens in high maintenance in relation to Categories 1, 2 and 3, are 34%, 23% and 33% respectively. Categories 1 and 3 are very similar in relation to the maintenance situation, though the size of the gardens is very much smaller in Category 3.

In terms of surface condition there is a steady decline with decreasing social category of 77%, 66% and 55% respectively of surfaces considered to be in a good condition.

In terms of surface cover, Category 1 has a greater amount of good quality turf grass than Categories 2 and 3. A fine lawn appears to be mandatory in middle class housing areas! Category 1 is alone in having some water surfaces, these are mostly swimming pools, with a few ornamental ponds. The amount of asphalt/concrete cover increases with social category; the forecourts and drives of Category 1 have quite extensive areas of hard surface which are covered with two or three cars, plus caravans and boats. The amount of tree cover varies considerably: 11%, 29% and 6% (Categories 1, 2 and 3 respectively). The main reason for the large extent in Category 2 is related to the size of the building plots and the date and purpose for which the estate was originally developed.

The percentage of the garden in a good condition decreases with status: 77%, 66% and 54% respectively.

The standard of maintenance is not similarly reflected, with status grades 1 and 3 showing strikingly similar patterns in spite of their marked differences in other respects. The low status grade areas have a high proportion of council housing, and some control seems to be evident in garden maintenance. The intermediate status group consists mainly of older rented property, where less control or provision of garden maintenance is evident.

8.24 Amenity Open Space (Group 4)

Figure 8.5 shows the average amount of Amenity Open Space which is provided in each Social Status area. An average of 10% is provided in high status areas which falls to an average of 4% in the intermediate status, and then increases to an average of 7% in low status, and 12% in the very low status areas.

This open space group (4) includes Parks, which differ in many respects from all the other units in this group. Some of these units are easily accessible, useful, and environmentally attractive, while other units have only some one, or even none of these attributes.

The provision of Amenity Open Space needs to be viewed together with the provision of Private Gardens.

Most of the 10% in the high status areas is devoted to parks and communal green spaces within the housing estates. In the intermediate areas there is a very large amount of private gardens, thus there is less need, and less provision for amenity open space; no parks, or industrial and commercial open space. In the low status areas parks are rare, and there is no industrial and commercial open space. However, in the very low status areas, in spite of the absence of parks and private gardens, there is a relatively large amount of amenity open space. Much of this space appears to be communal space under the control of the local authority. This area contains also amenity open space which is connected with industrial and commercial sites.

Figure 8.6 shows the Amenity Open Space situation in terms of maintenance, condition and surface type.

In terms of maintenance there is generally a decline in its quality with decreasing status (with maintenance categories of 45%, 34%, 50% and 3% respectively), except that Category 3 does not fit this trend. As in the case of private gardens this exception is attributed to the controlling interest of the local authority of an area with a high proportion of council dwellings.

A more striking result relates to those areas which appear to receive no maintenance: status 1-1%, and status 4-33%!

The surface condition of amenity open space decreases regularly with decreasing social status for the top three groups, (82%, 76% and 70% respectively) but the very low category drops dramatically to 32%. Although there is a steady increase in the amount of amenity open space, from Category 2 to Category 4, there is a sharp decline in the quality of its surface condition.

The maintenance status is directly related to the surface cover of open space. As can be seen from the data collected, surfaces which require high maintenance are not very evident, or may not occur at all in the lower status areas.

A substantial amount of detailed comparison can be made regarding the type of surface found on the various types of open space in the four socioeconomic classes being considered.

A few major points of particular interest are selected. The very low (Category 4) area has very much less turf and rough grass and substantially more infested grass cover in comparison with each of the other three status categories.

On the other hand the distribution of asphalt and concrete surface with decreasing status is 7%, 16%, 7% and 40% respectively. This abnormally high percentage in the very low category is because much of the communal space which exists in this area has a hard surface. Whilst this reduces very considerably the costs of maintenance it also tends to reduce the quality of the visual environment.

Another major difference is showing in the extent of tree cover. This shows (Figure 8.6) values of 29%, 21%, 23% and 2% respectively with decreasing status. The very low tree cover in category four is probably the most significant cause of the poor visual quality of the townscape.

8.25 Space for Transportation (Group 5)

Much the largest of the units which make up group 5 is streets, and the smaller the size of the building plots, the more dense will the street cover be.

There is a general trend that the amount of land used for transportation increases as the socioeconomic class decreases (Figure 8.7).

The percentage of transport land, from social category 1 to 4 is 22%, 17%, 27% and 31% respectively. The fact that Category 2 does not fit the general trend is because the older properties in this group have very large gardens, therefore the density of housing is less than in Category 1. This results in a less dense street pattern.

The most significant feature - in terms of the condition of the surface of transportation space (Table 8.8) is the general decrease in surface condition with socioeconomic class.

Fieldwork revealed that, particularly in social categories 3 and 4, in the inner urban areas, small neighbourhood streets were used as playgrounds for young children, because of the lack of alternative and suitable play areas near their homes, and the lack or absence of private gardens.

8.26 Play and Recreation (Group 6)

This group includes those areas which are all <u>formally</u> used as recreational or play space. Figure 8.9 shows that Category 1 areas, in spite of the generous provision of private gardens, has more play and recreational space than Categories 2 and 3. Category 2 also has very liberal private garden provision. Although Category 3 has less than Category 4 (1% and 5% respectively) the absence of private gardens in Category 4 is such that it can still be regarded as an area deprived of adequate recreational and play space.

In terms of maintenance, condition and surface cover (Figure 8.10) some striking features are seen.

The general quality of maintenance decreases with social category. The condition of the surface cover follows this pattern, except that Category 2 (again) does not fit in this trend. The most likely reason for this is the fact that Category 2 is most generously provided with private gardens, hence there is likely to be less demand for keeping other play and recreational surfaces in a good condition.

The types of surface show a wide range of differences, with turf grass predominant in Category 1 and totally absent in Category 2 only. On the other hand Category 2 is unique in having trees and shrubs, with a total absence of asphalt and concrete. This can be explained by the fact that the play and recreation facilities in Category 2 are restricted to one unit only - sportsfield and stadia.

Excepting Category 2, there is a general increase in poorer quality grasses with decrease in social category.

Due to the small size of the sample area, and the lack of play and recreational standards, it is difficult to assess whether the space available is sufficient to serve the various needs of the community as a whole. In the Category 4 status area, the density of population is comparatively high, particularly the child (5-14 years) population, and it is fairly obvious that the provision of one or two playgrounds in the area would not be sufficient.

The results of such a situation are that other less desirable areas, such as the streets, local plots of derelict land, and amenity areas, are used for play. It is important to have adequate and suitable play and recreation space; it is also important that this space must be accessible and very close to the houses it purports to serve.

8.27 Agriculture and Horticulture (Group 7)

There is a considerable amount of class 1 agricultural land in the Merseyside Metropolitan County, but the eleven sample squares were chosen from the urban areas. Hence the results of the survey do not reflect the true agricultural and horticultural situation in the County. However this category - together with thirty eight other units - has been included because the aim is to develop a methodology which can be used as a prototype for a total county survey of urban open space.

Only one of the eleven $\frac{1}{4}km^2$ samples: (this was in Category 3) had any agricultural and horticultural land, most of which fell outside the sample square (Figures_8.11 and 8.12).

In view of this there is little of relevance that can be read into the data collected under this heading.

8.28 Neglected Land

A variety of different units occur under this group: these include among others rough grassland, derelict land, mineral extraction, waste disposal sites and cleared land.

Figure 8.13 shows a steady increase in the extent of neglected land, with respect to decreasing social category (7%, 9%, 13% and 23%). This is to be expected for the quality of the environment, both natural and man made is closely linked to the visual quality of the landscape, and this is always very strongly related to the socio economic class of the population.

Different types of neglected land predominate in the four social categories. In Category 1 scrubland, cleared land and rough grassland are most prominent, with only a very small amount of derelict sites. In Category 2, cleared land and scrubland are most prominent, with little derelict land and industrial open areas. Category 3 is also predominently scrubland with a small amount of cleared land. Associated with Category 4, cleared land was most common, and derelict sites and industrial open areas were also quite significant. In all categories there was very little hard surface cover of asphalt or concrete.

In terms of management, condition and surface cover, much of the findings could be anticipated. The management of neglected land is mainly non-existent, or poor: the condition dominantly bad, and the surface cover includes a large amount of bare soil and poor grassland. However, what might appear to be a very negative aspect of the urban environment, has a potentially very positive part to play in urban renewal and improvement programmes. For it is in these neglected land areas - dominantly soft covered, distributed throughout the county but with increasing concentration in the socially deprived areas - that the opportunity to improve the environment is greatest. Already associated work has been carried out to map - from aerial photography - all the derelict land in the Merseyside County.

8.29 Cemeteries (Group 9)

Only one of the sample areas contained a cemetery therefore no comparisons can be made with the situation in the areas of the three other social categories.

8.210 Other Open Spaces (Group 10)

No other open spaces were recorded in the sample areas.

8.3 Summary and Conclusions

This chapter considers the situation for the ten (10) open space groups only, and does not refer to all the data collected at the thirty nine (39) open space units level.

However, in addition to the provision and condition of open space, information is also considered on the management and type of surface cover of the open space.

Figure 8.17 summarises the situation regarding

i) the total amount of open space, and
ii) the amounts in a) good and b) bad condition, with reference to each of the eleven $\frac{1}{4}km^2$ sample areas. Each sample area is annotated (H, I, L, VL) according to its socioeconomic status.

Figure 8.17 shows that the total provision of open space is not directly connected to the socioeconomic class of the population. There is, however, some direct relationship between the overall condition of the open space with social status: the lower the status, the greater the proportion of open space is in a bad condition.

Even at group level it is shown that with certain groups there is a direct relationship between the extent of that group and socioeconomic class of the population e.g. Neglected Land (Figure 8.13).

In other groups some general relationship tendencies are found e.g. Private Gardens (Figure 8.3). In most cases, however, these relationships become clear only when the maintenance, condition and type of surface cover is taken into account e.g. Amenity Open Space (Figures 8.5 and 8.6).

The overall picture of the provision and condition of open space - in relation to the four categories of socio-economic class - can perhaps best be summarised by presenting the material visually.

Figures 8.18 to 8.21 show the Calcomp computer maps of the distribution of open space units. Plates 8.1 to 8.4 are colour infra-red aerial photographs. Plates 8.5 are manual maps showing the condition of the open space

In each case four different sets of data are presented, each relating to one of the four socio-economic categories. The distinctive characteristics of each socio-economic class can be seen.

Class 1 (Figure 8.18, Plate 8.1, Plate 8.5 Area 4)

Plate 8.1 clearly shows a modern, well ordered estate. A prime residential area with good quality houses and bungalows, well provided with private gardens, and nearby parks and other open spaces. A large number of small trees cover the area, with more mature trees in the parks.

Plate 8.5 Area 4 shows as fairly even and not too dense distribution of the built up area, with only a small amount of badly managed open space, and this occurs in blocks of land generally remote from the housing.

Class 2 (Figure 8.19, Plate 8.2 and Plate 8.5 Area 5)

Plate 8.2 shows an area where the houses and building plots are larger than in class 1 area. There are more trees, and they are very much more mature and distributed along the highways as well as in the gardens. Plate 8.5 Area 5, shows a fairly wide distribution of open space which is badly managed.

Class 3 (Figure 8.20, Plate 8.3 and Plate 8.5 Area 10)

Plate 8.3 shows a marked contrast to the previous two areas. The houses are mostly terraced, and interspersed with industry and derelict and degraded land. Private gardens are very small; some are only yards. There is evidence of cleared housing sites and some newer type houses, which suggest that urban redevelopment is taking place. Trees are very scarce indeed, and the houses are so closely packed that streets occupy a large amount of the area. Local, formal recreation areas do not exist. Plate 8.5 Area 10 shows large blocks of land which are badly managed, and confirms the high density of the built up area.

Class 4 (Figure 8.21, Plate 8.4 and Plate 8.5 Area 6)

Plate 8.4 reveals a different landscape. Flats and tower blocks predominate with large amounts of cleared land. This cleared land is either associated with the flats, in which case it is well managed; or is the result of old house clearance, in which case it is unmanaged and neglected.

There is a quite considerable area of small factory units concentrated in one zone. Trees are virtually non existent, and the vegetation of other open space is rather poor. Plate 8.5 Area 6 confirms the very large amount of badly managed open space, and the concentration of residential buildings.

Figure 8.1

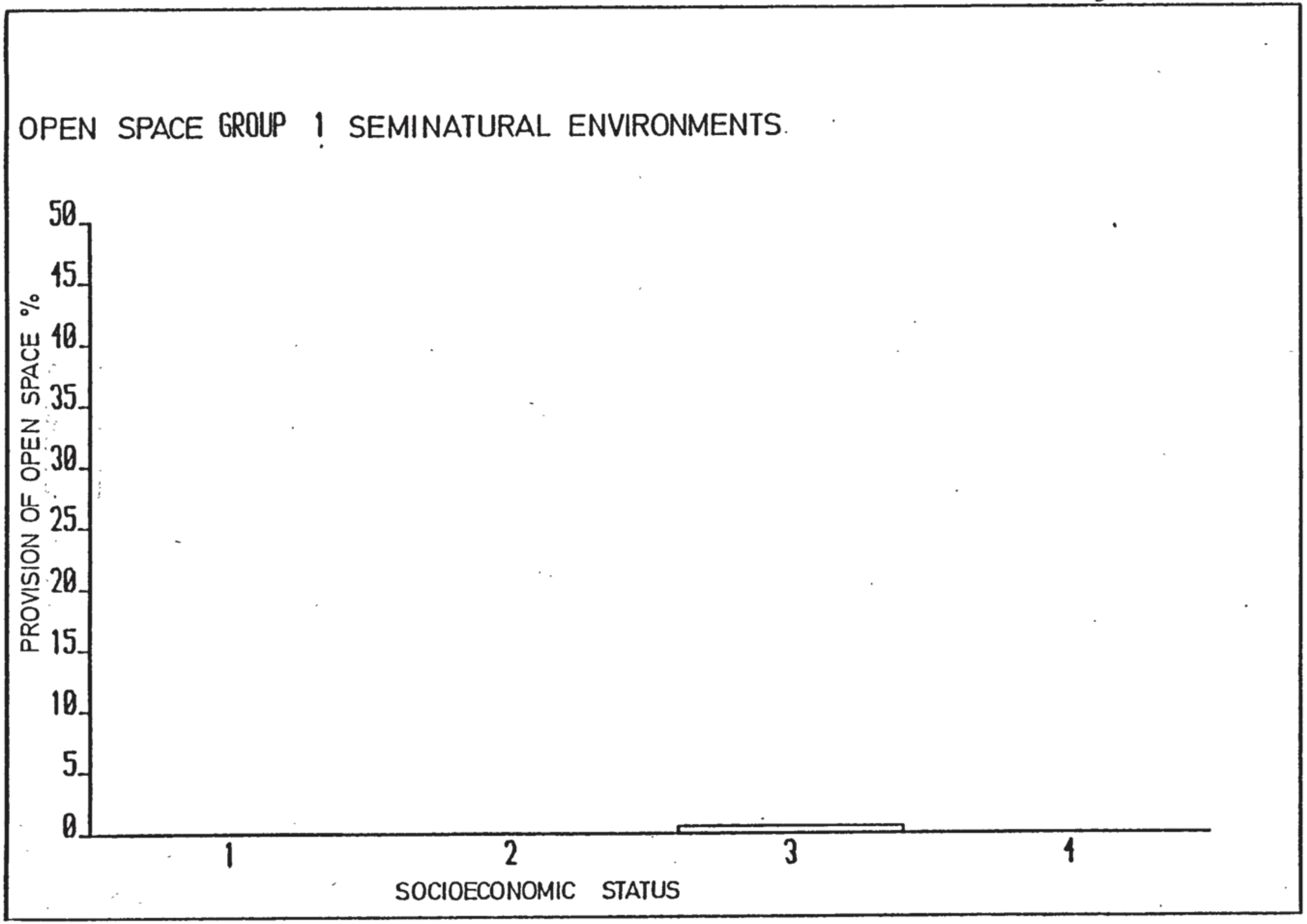

OPEN SPACE GROUP 1 SEMINATURAL ENVIRONMENTS
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.2

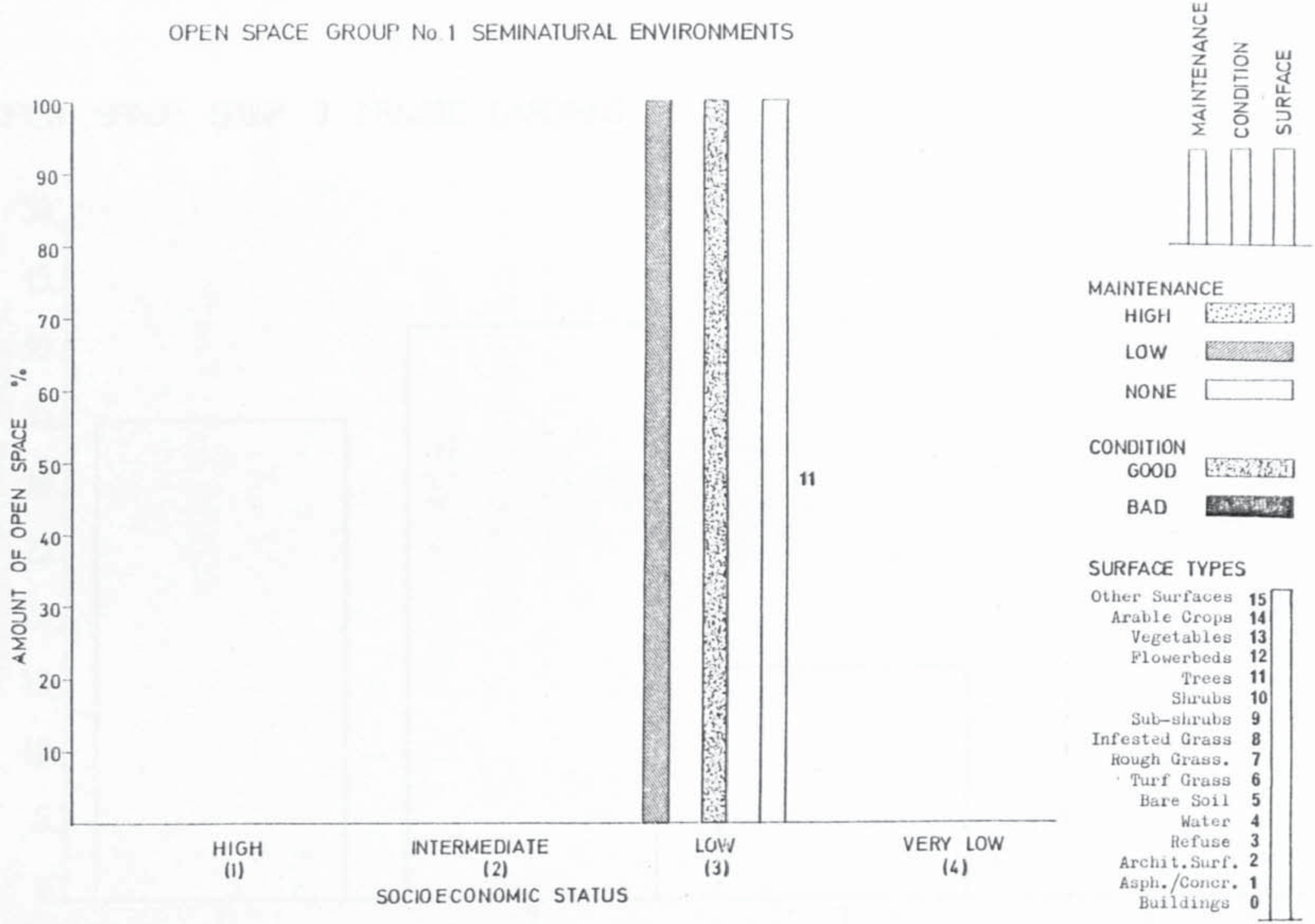

OPEN SPACE GROUP No.1 SEMINATURAL ENVIRONMENTS
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
11
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.3

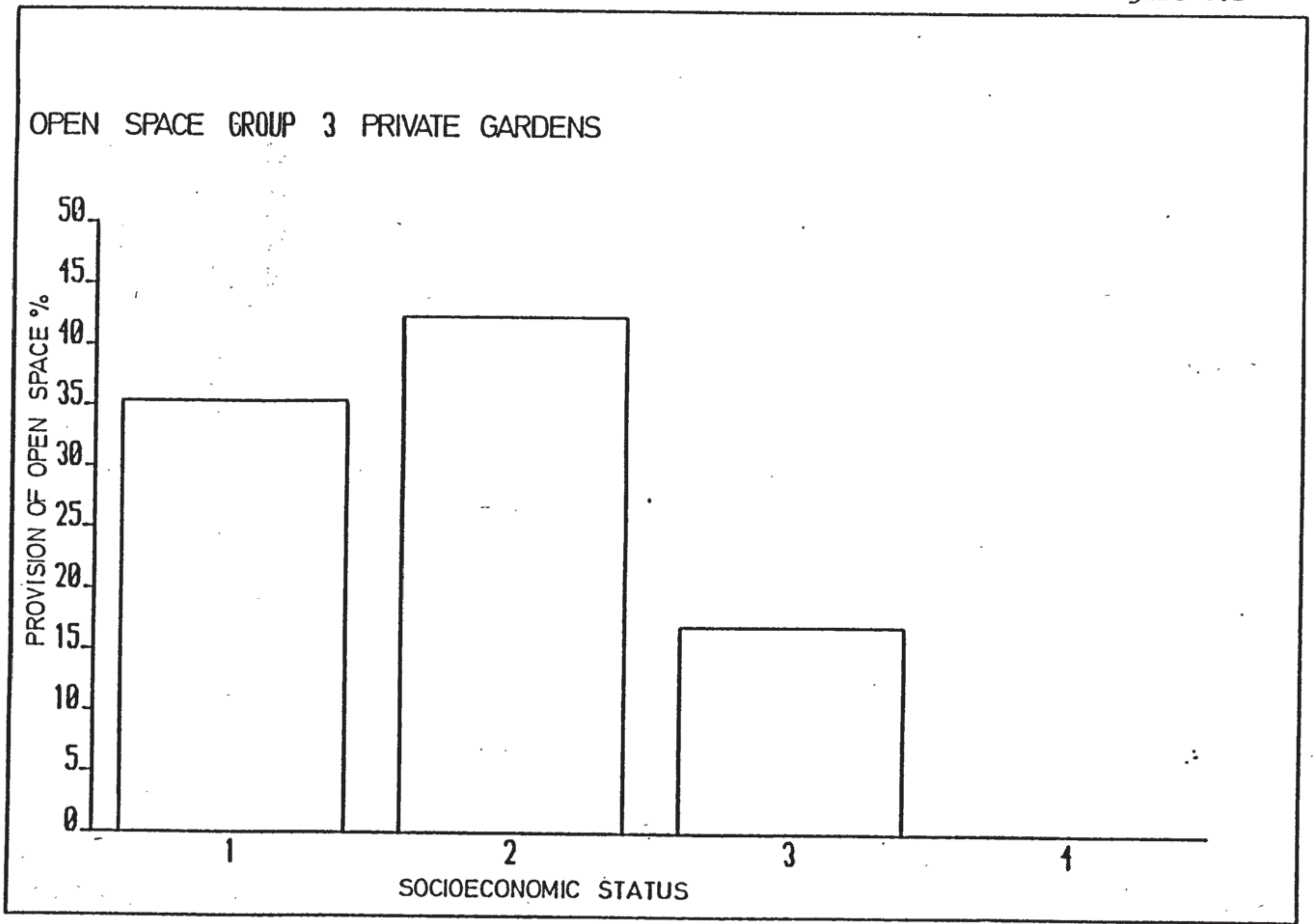

OPEN SPACE GROUP 3 PRIVATE GARDENS
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.4

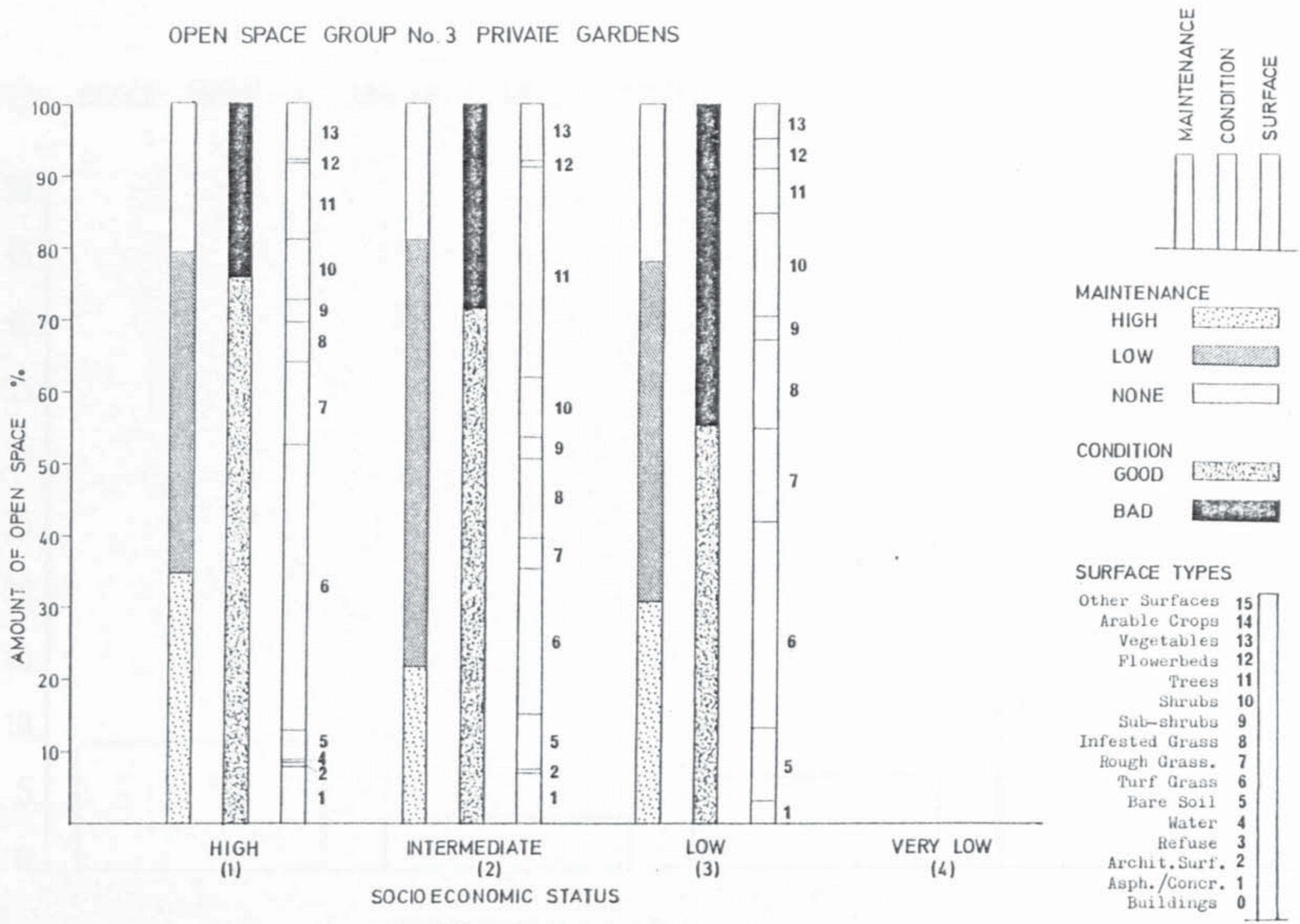

OPEN SPACE GROUP No. 3 PRIVATE GARDENS
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
13
12
11
10
9
8
7
6
5
4
2
1
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIO ECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.5

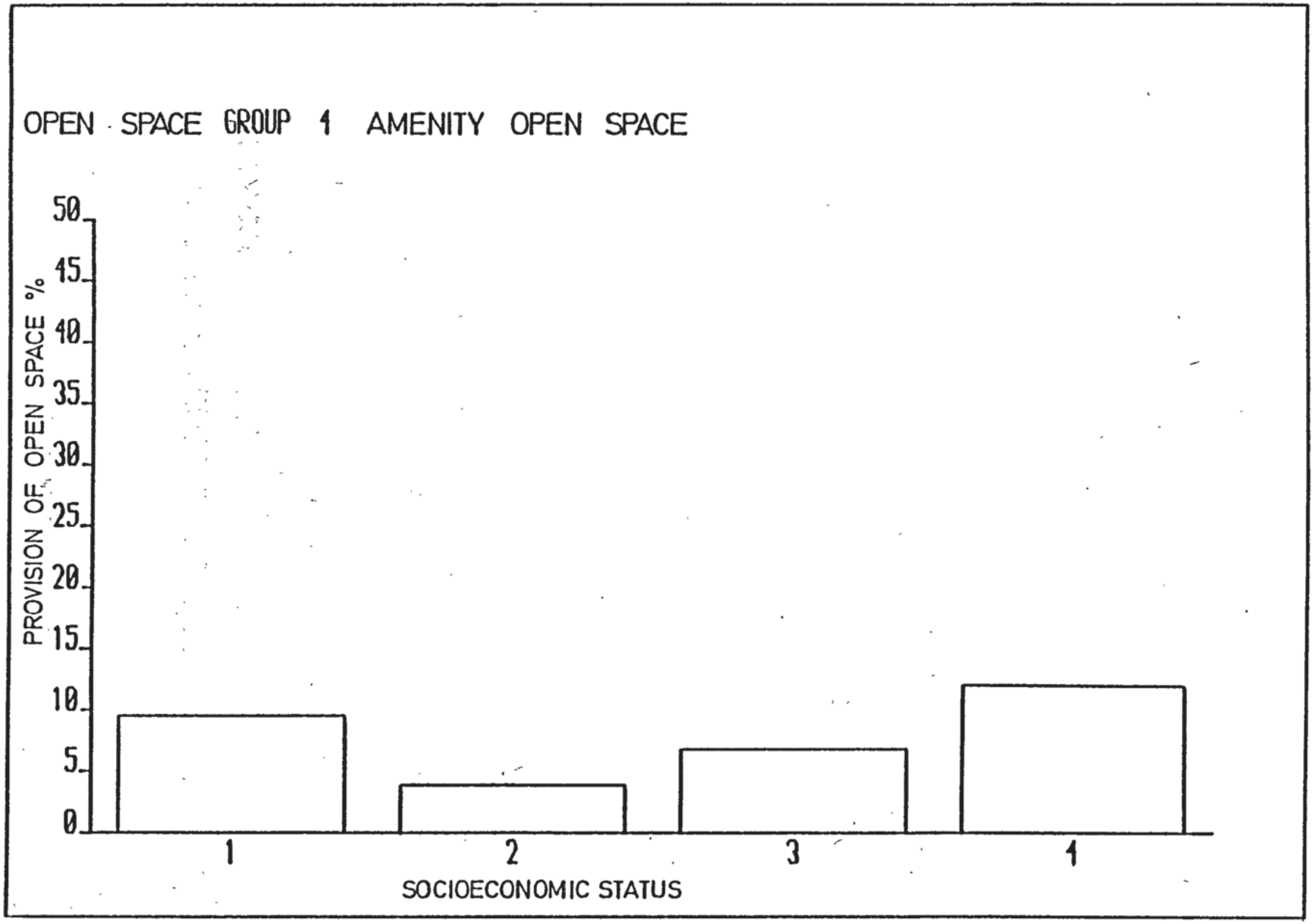
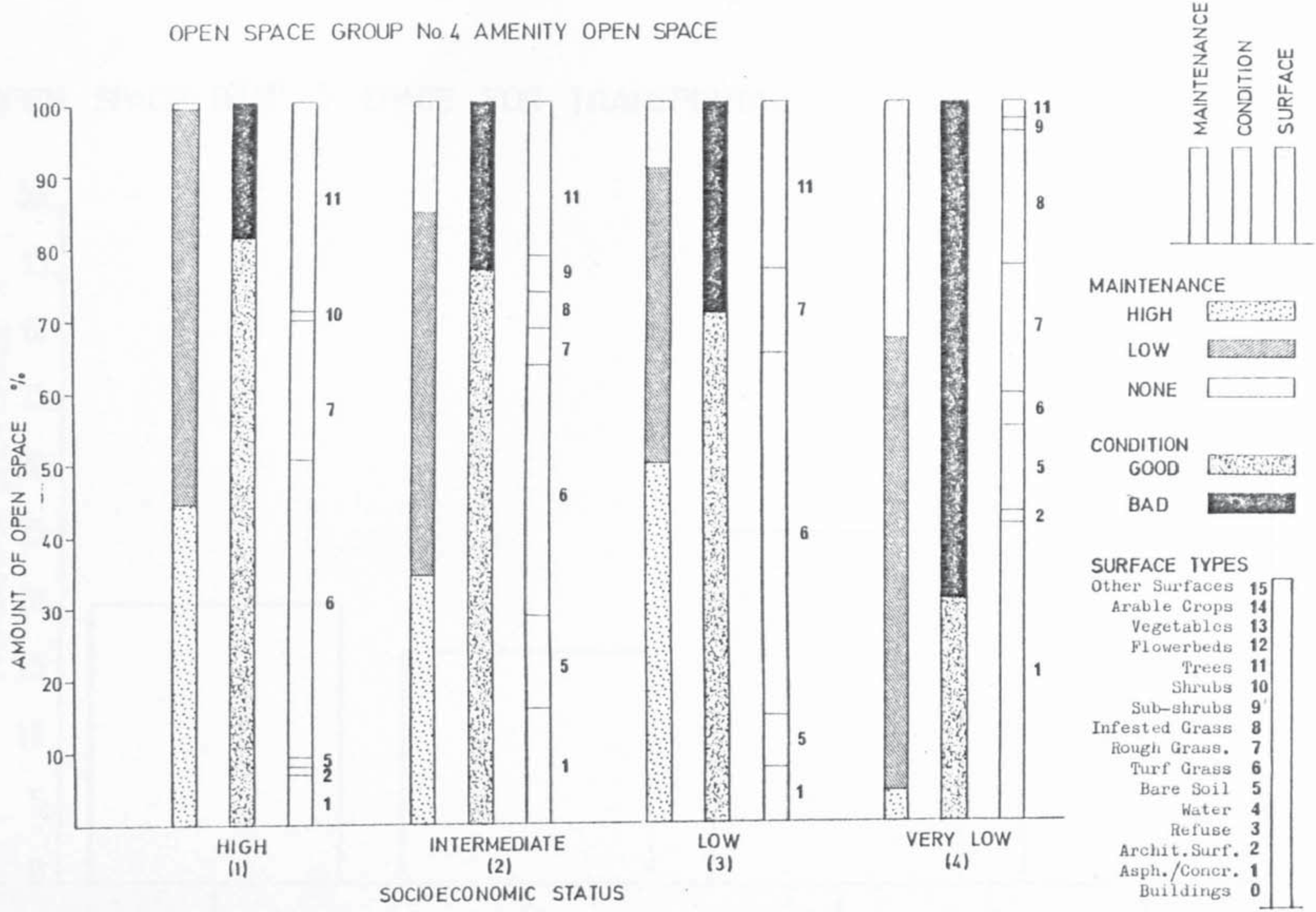

OPEN SPACE GROUP 4 AMENITY OPEN SPACE
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.6



OPEN SPACE GROUP No.4 AMENITY OPEN SPACE
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.7

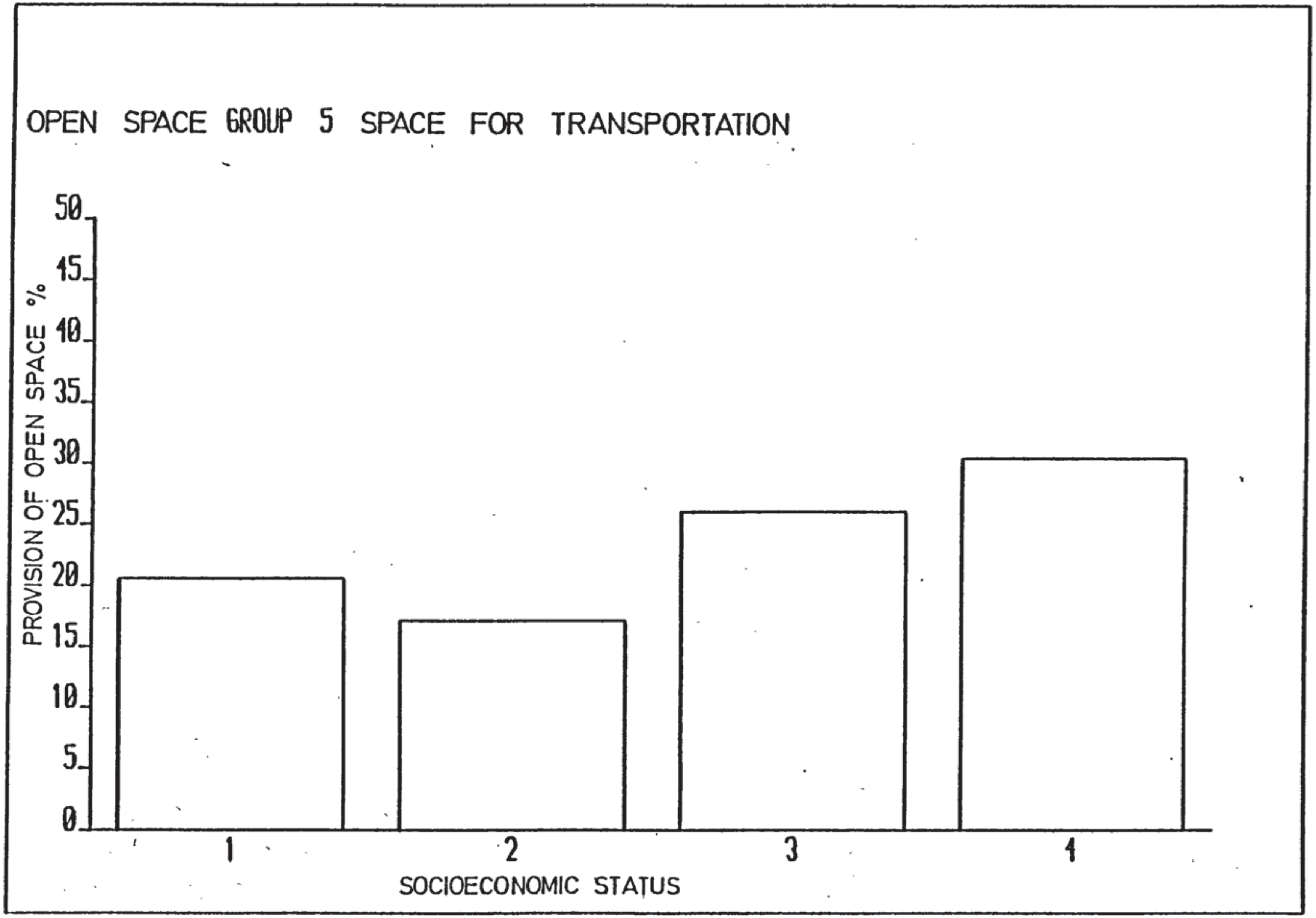
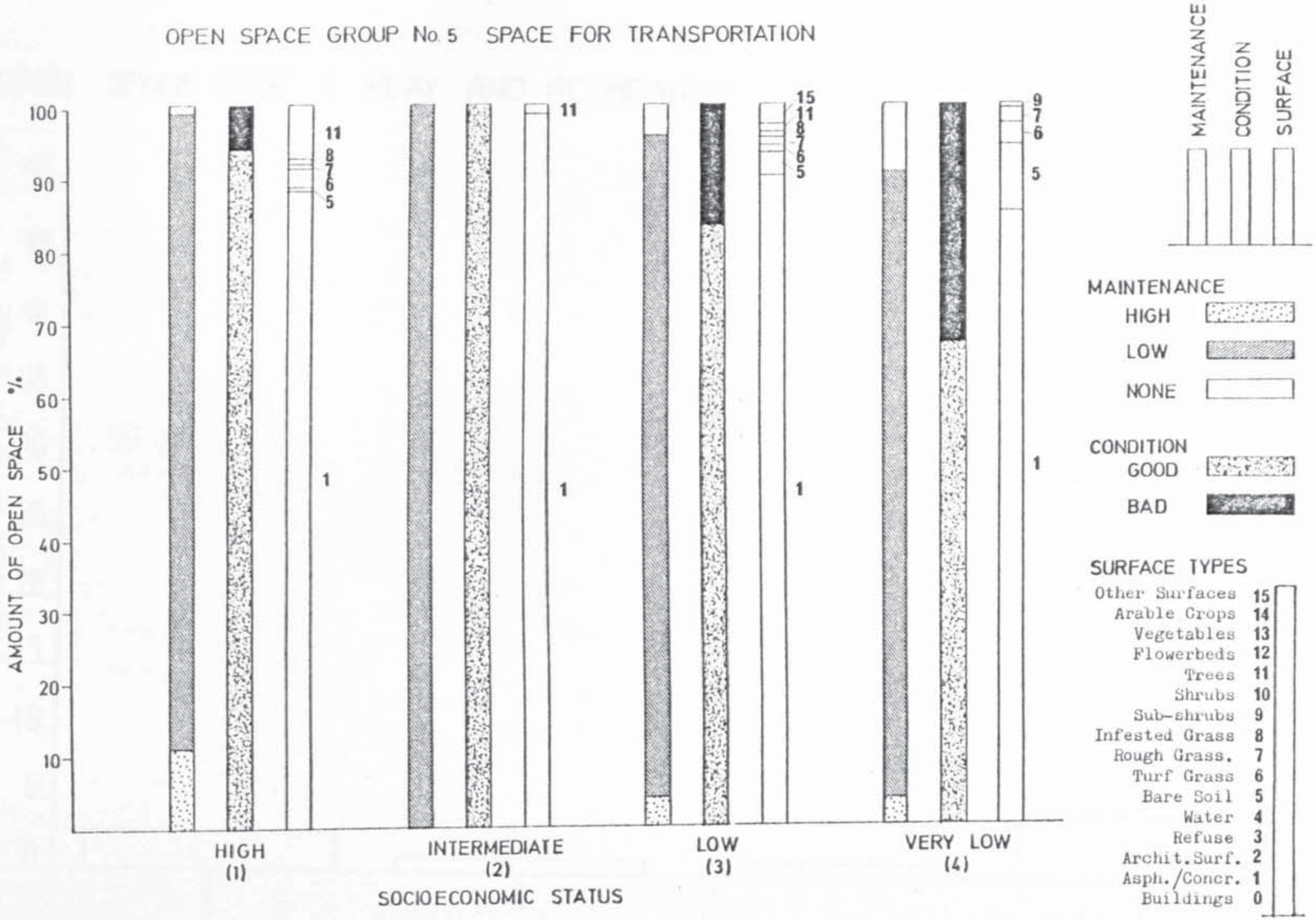

OPEN SPACE GROUP 5 SPACE FOR TRANSPORTATION
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.8



OPEN SPACE GROUP No. 5 SPACE FOR TRANSPORTATION
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
11
8
7
6
5
1
15
9
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.9

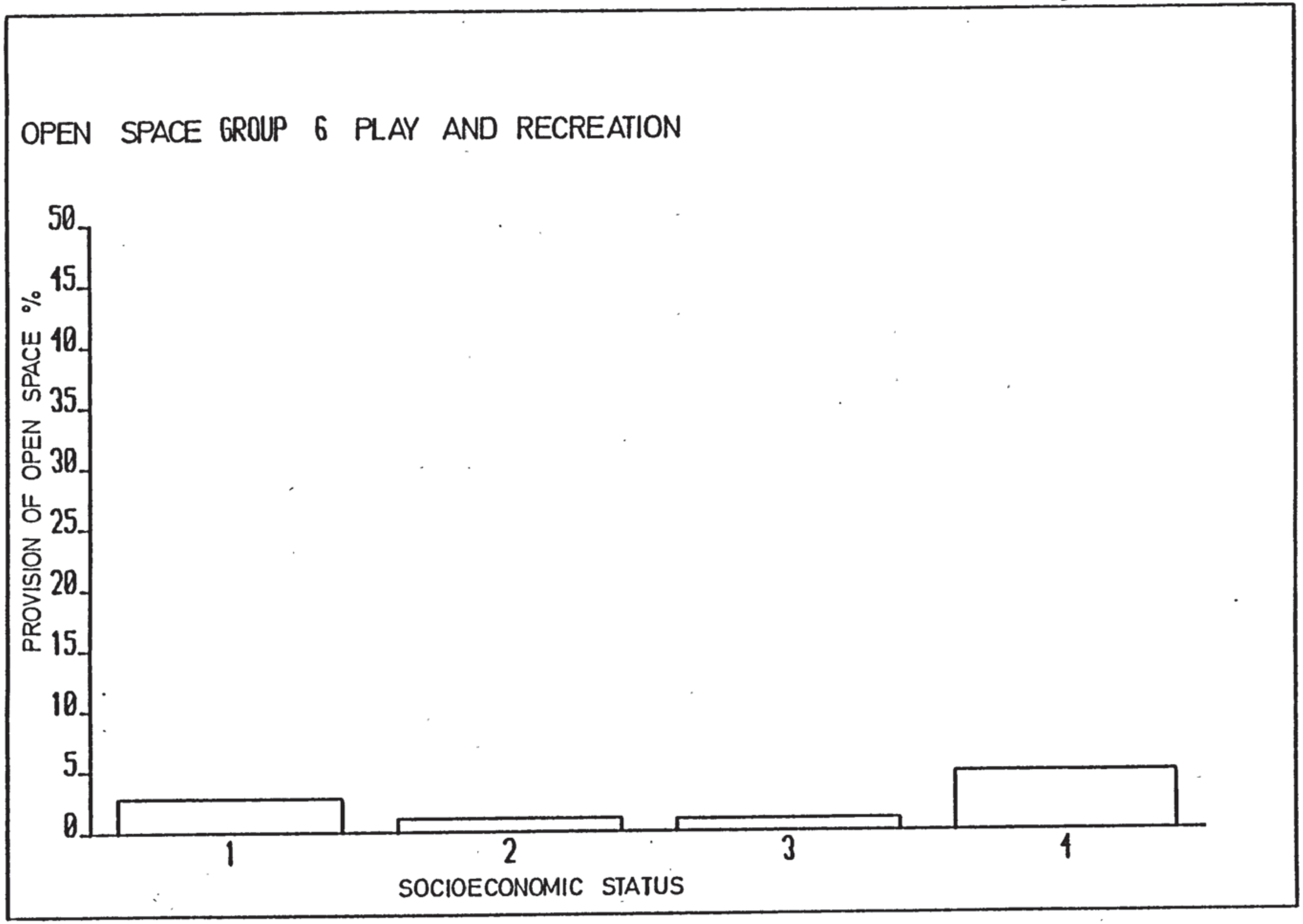

OPEN SPACE GROUP 6 PLAY AND RECREATION
PROVISION OF OPEN SPACE %
0
5
10
15
20
25
30
35
40
45
50
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.10

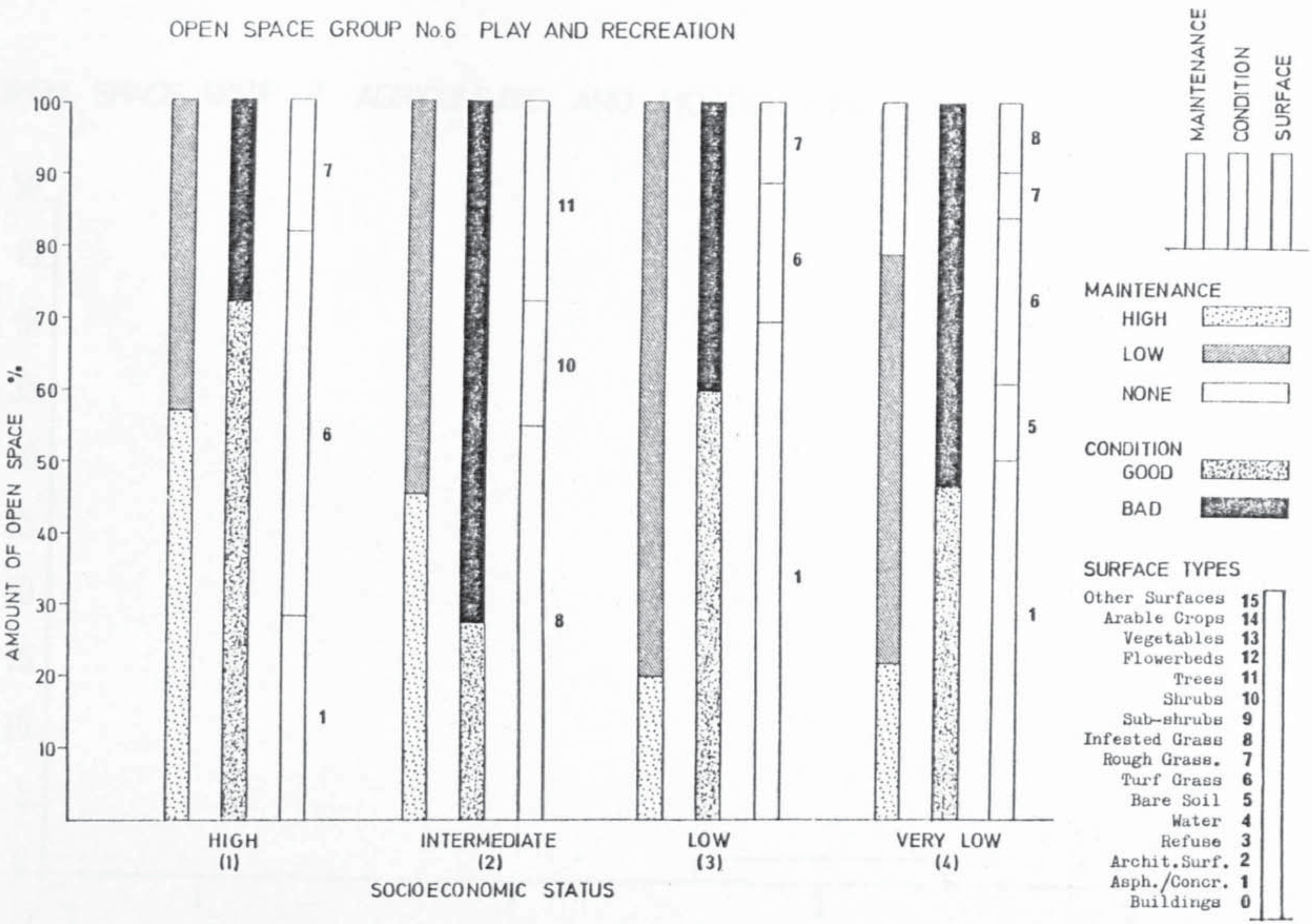

OPEN SPACE GROUP No.6 PLAY AND RECREATION
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
7
6
1
11
10
8
7
6
1
8
7
6
5
1
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.11

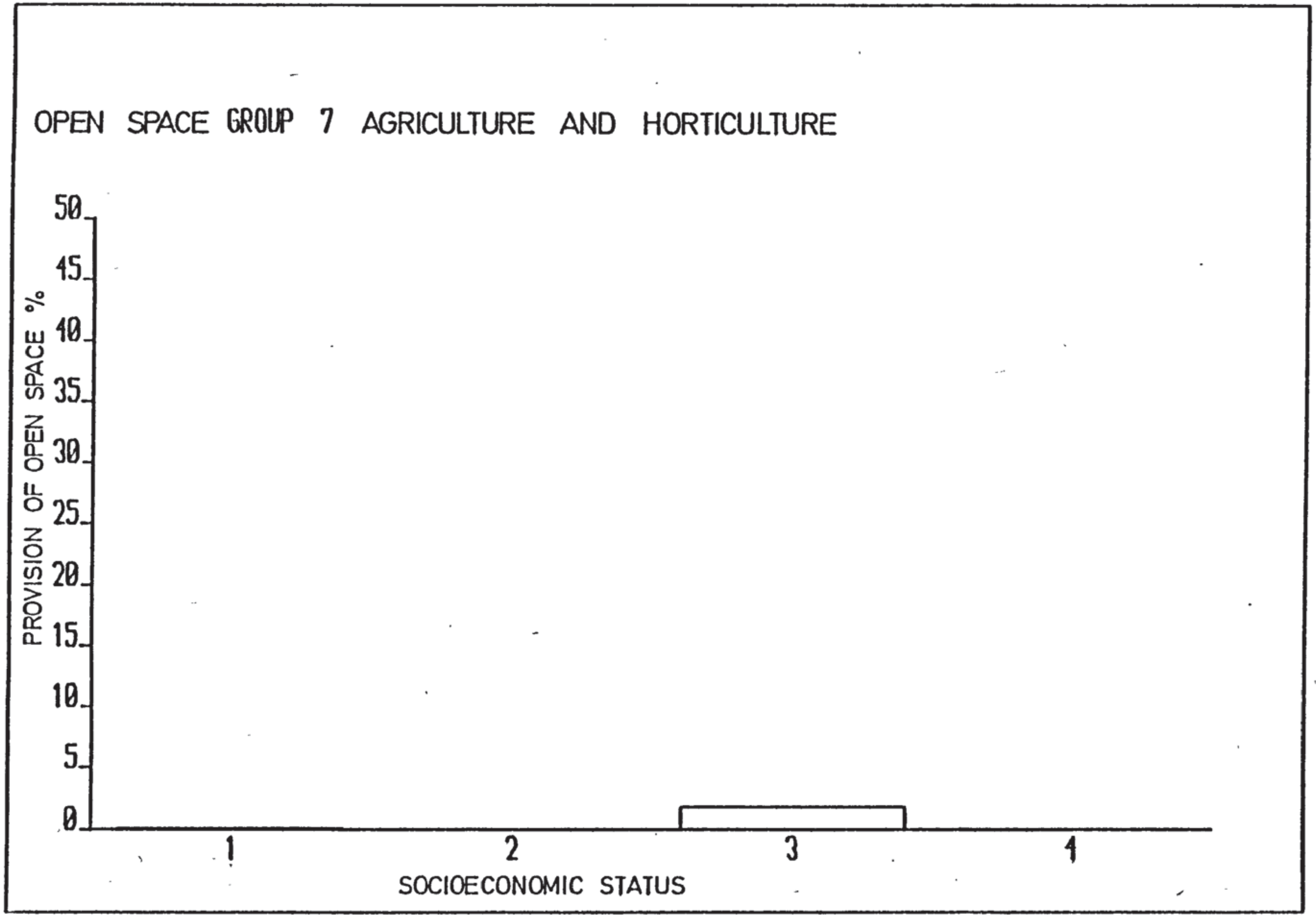
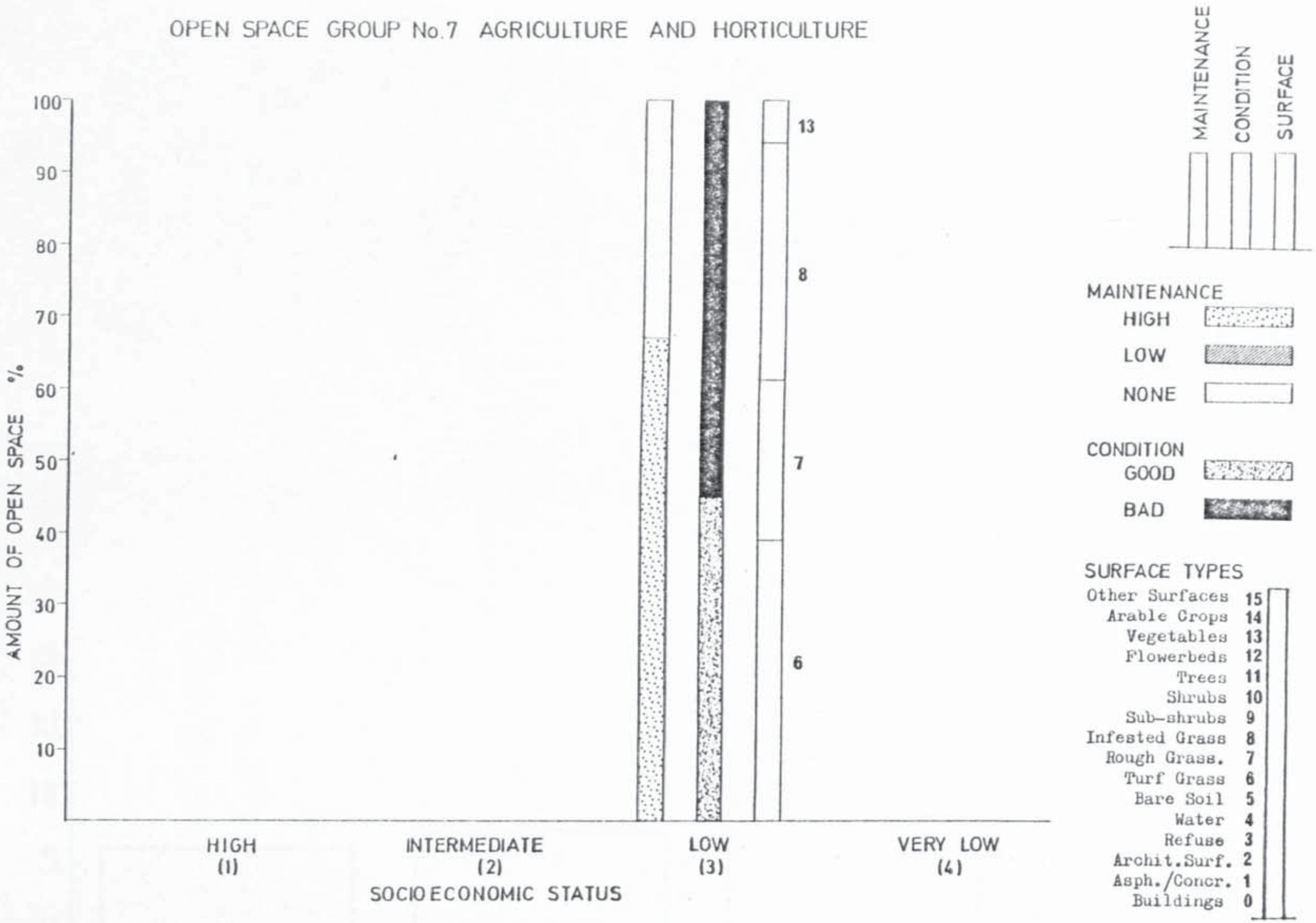

OPEN SPACE GROUP 7 AGRICULTURE AND HORTICULTURE
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.12



OPEN SPACE GROUP No.7 AGRICULTURE AND HORTICULTURE
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
13
8
7
6
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.13

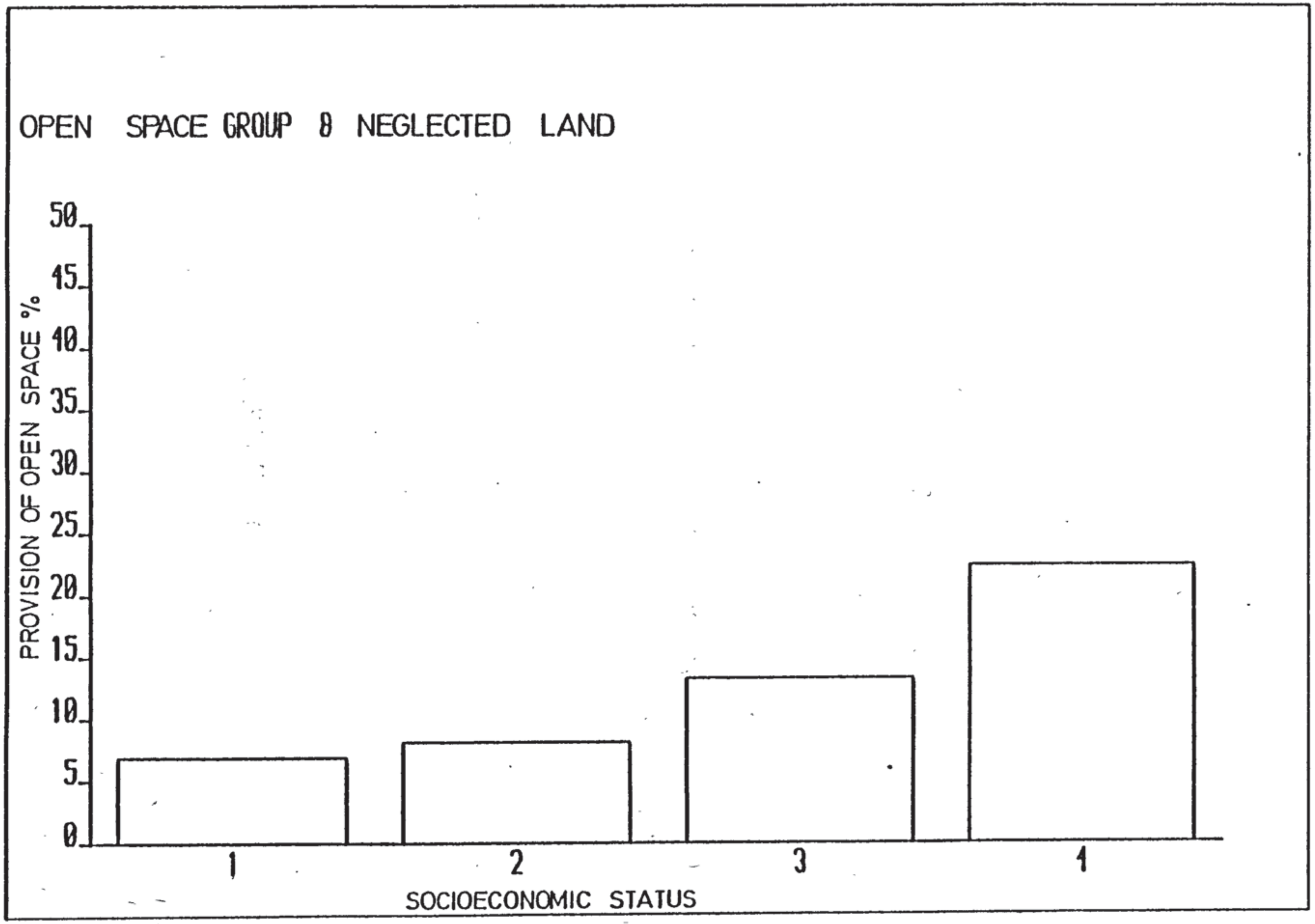

OPEN SPACE GROUP 8 NEGLECTED LAND
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.14

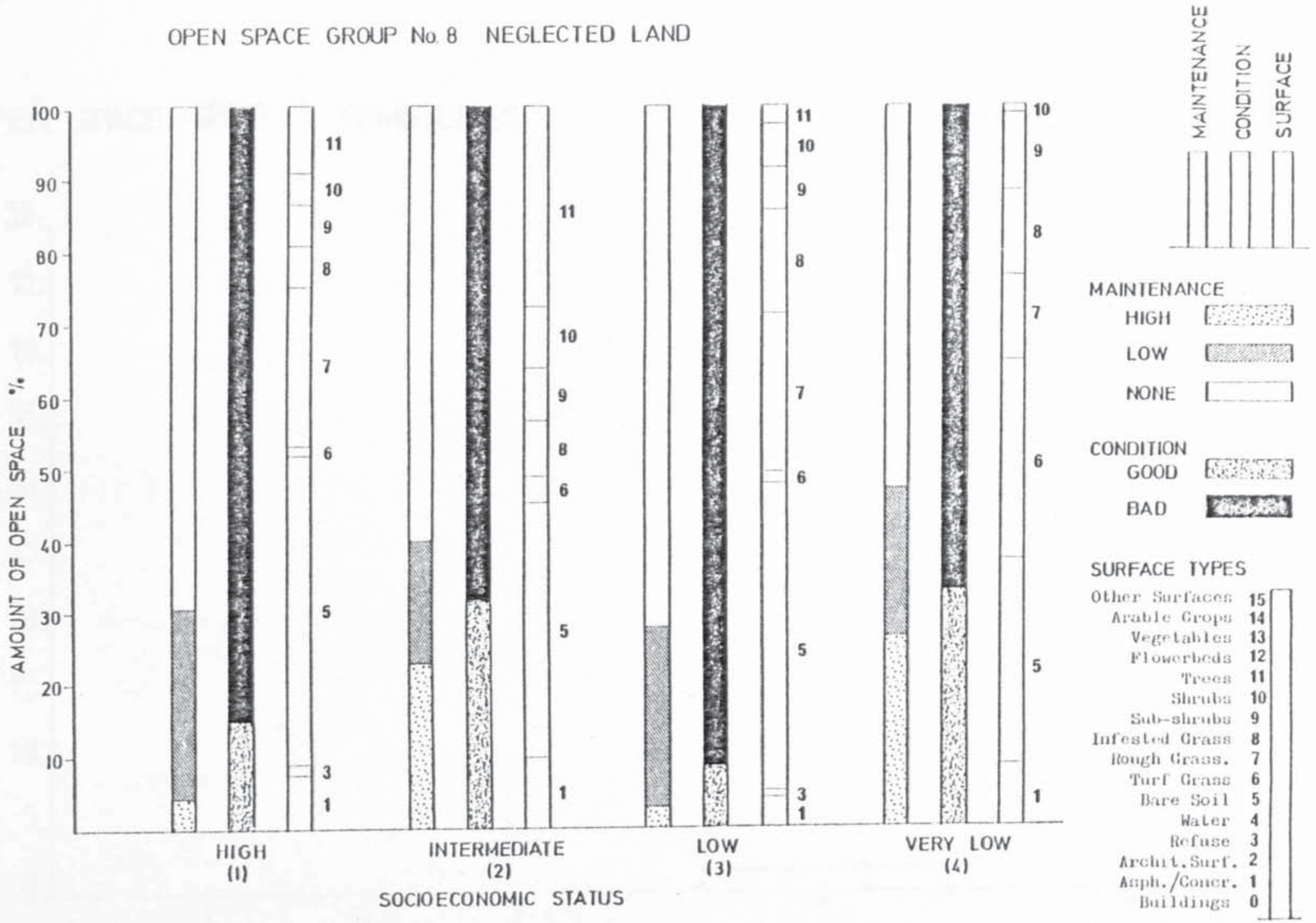

OPEN SPACE GROUP No. 8 NEGLECTED LAND
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.15

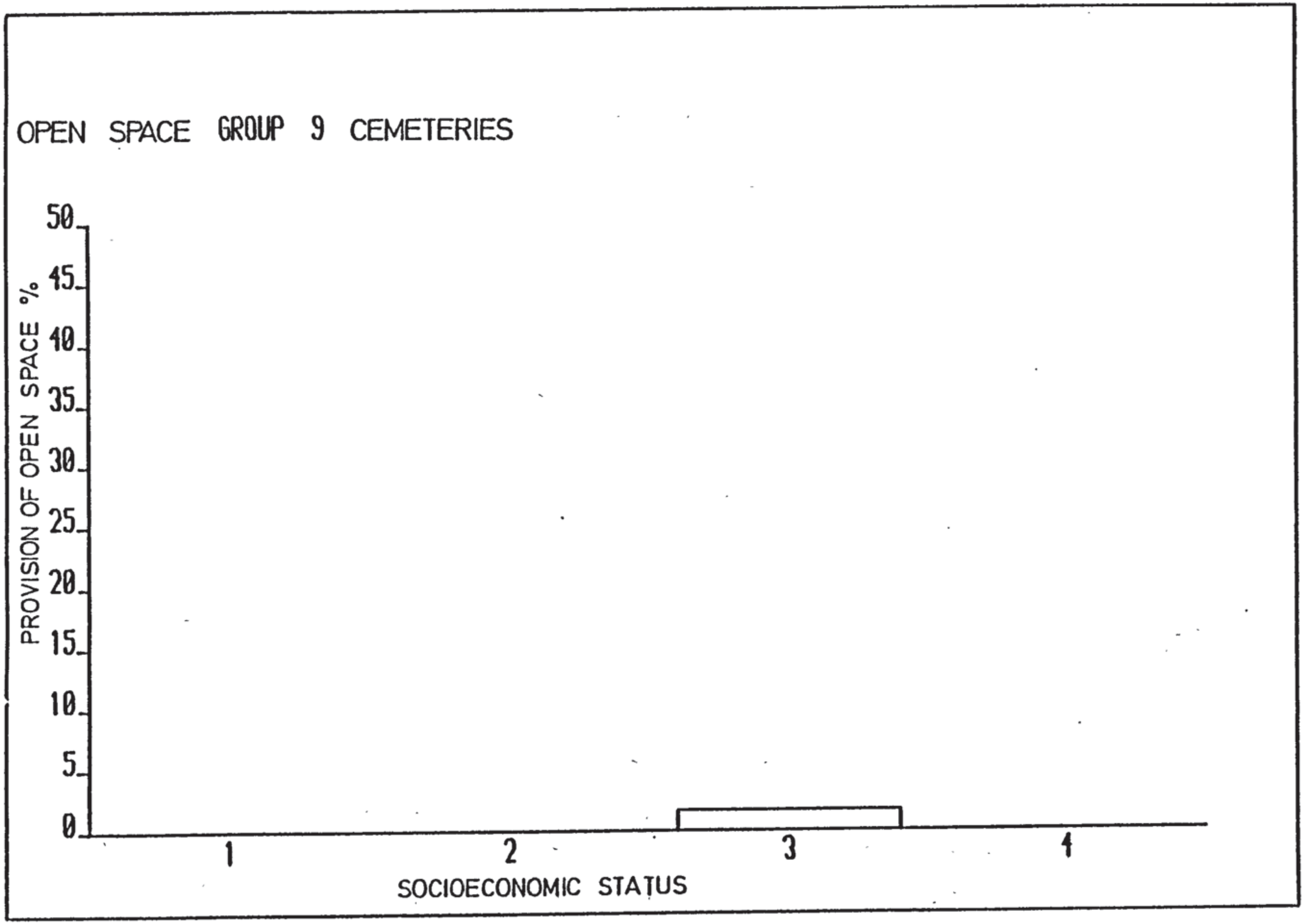

OPEN SPACE GROUP 9 CEMETERIES
PROVISION OF OPEN SPACE %
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
SOCIOECONOMIC STATUS

Figure 8.16

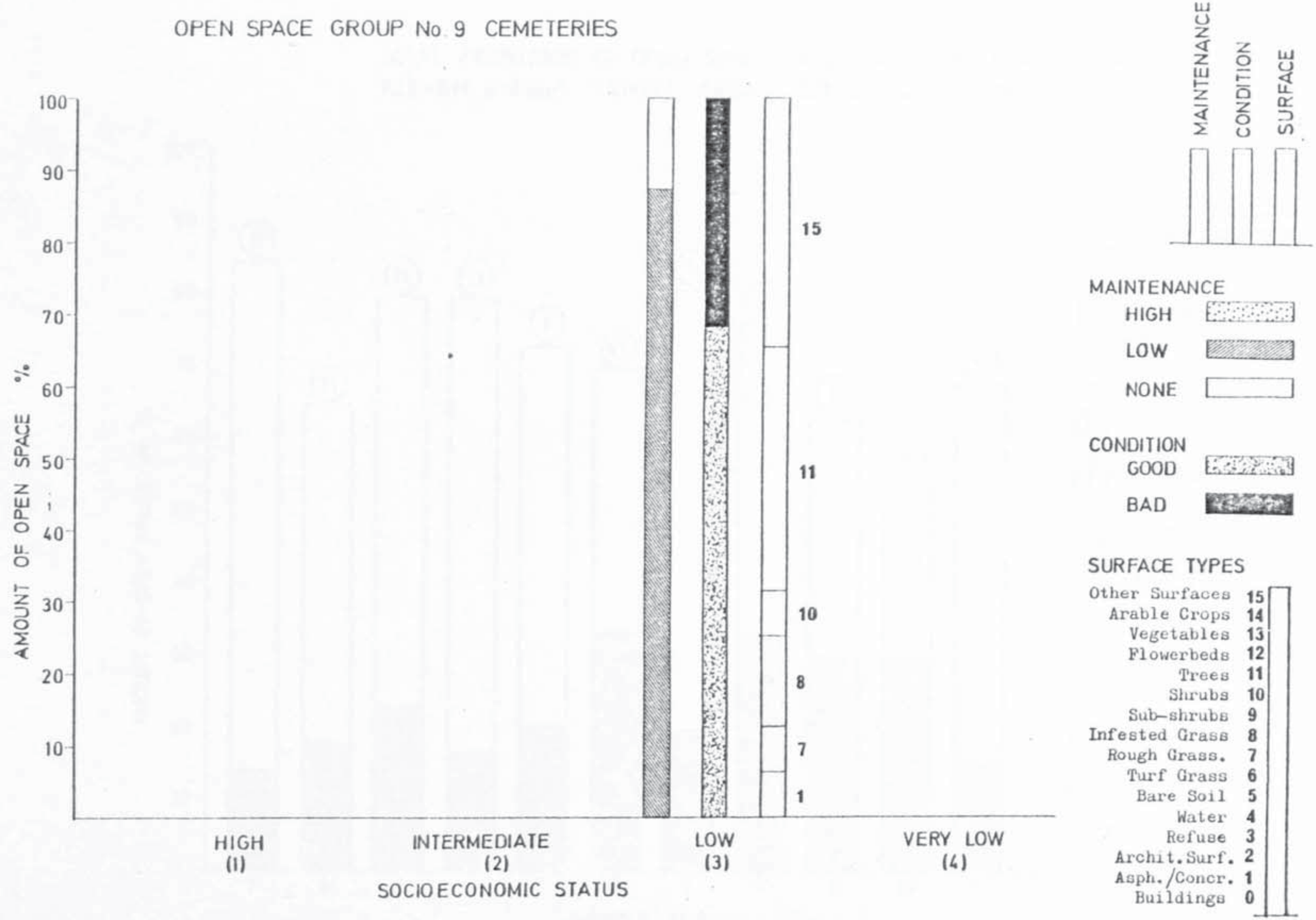

OPEN SPACE GROUP No. 9 CEMETERIES
AMOUNT OF OPEN SPACE %
100
90
80
70
60
50
40
30
20
10
15
11
10
8
7
1
HIGH (1)
INTERMEDIATE (2)
LOW (3)
VERY LOW (4)
SOCIOECONOMIC STATUS
MAINTENANCE
CONDITION
SURFACE
MAINTENANCE
HIGH
LOW
NONE
CONDITION
GOOD
BAD
SURFACE TYPES
Other Surfaces 15
Arable Crops 14
Vegetables 13
Flowerbeds 12
Trees 11
Shrubs 10
Sub-shrubs 9
Infested Grass 8
Rough Grass. 7
Turf Grass 6
Bare Soil 5
Water 4
Refuse 3
Archit.Surf. 2
Asph./Concr. 1
Buildings 0

Figure 8.17

TOTAL PROVISION OF OPEN SPACE AND IT'S CONDITION IN EACH OF THE ELEVEN (1/4 km²) SAMPLE AREAS VERSUS SOCIOECONOMIC STATUS

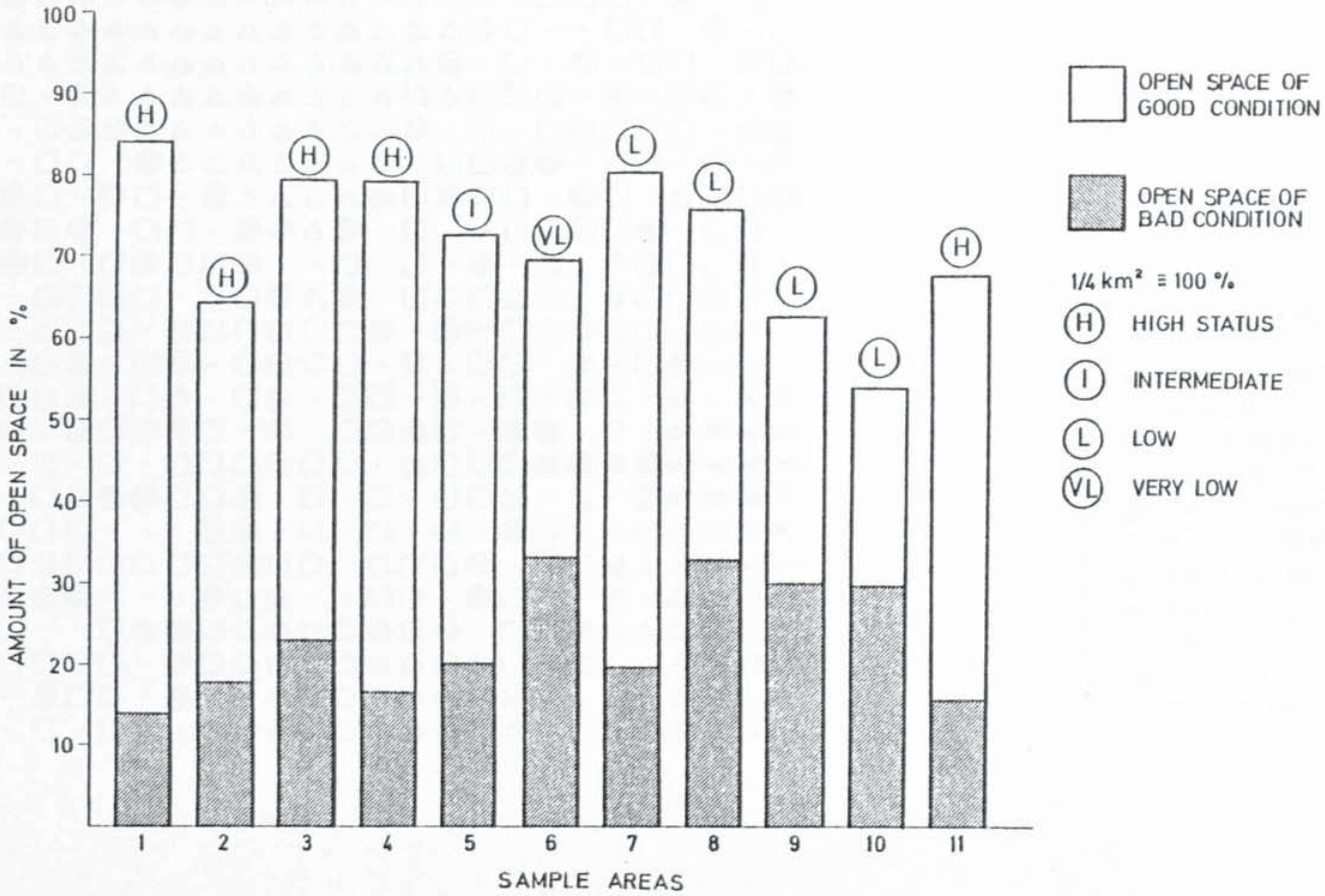


Figure 8.18 CALCOMP DIGITAL MAP SHOWING THE DISTRIBUTION OF OPEN SPACE GROUPS IN SAMPLE AREA NO. 4 (SHERDLEY PARK) - HIGH SOCIOECONOMIC STATUS (CATEGORY 1)

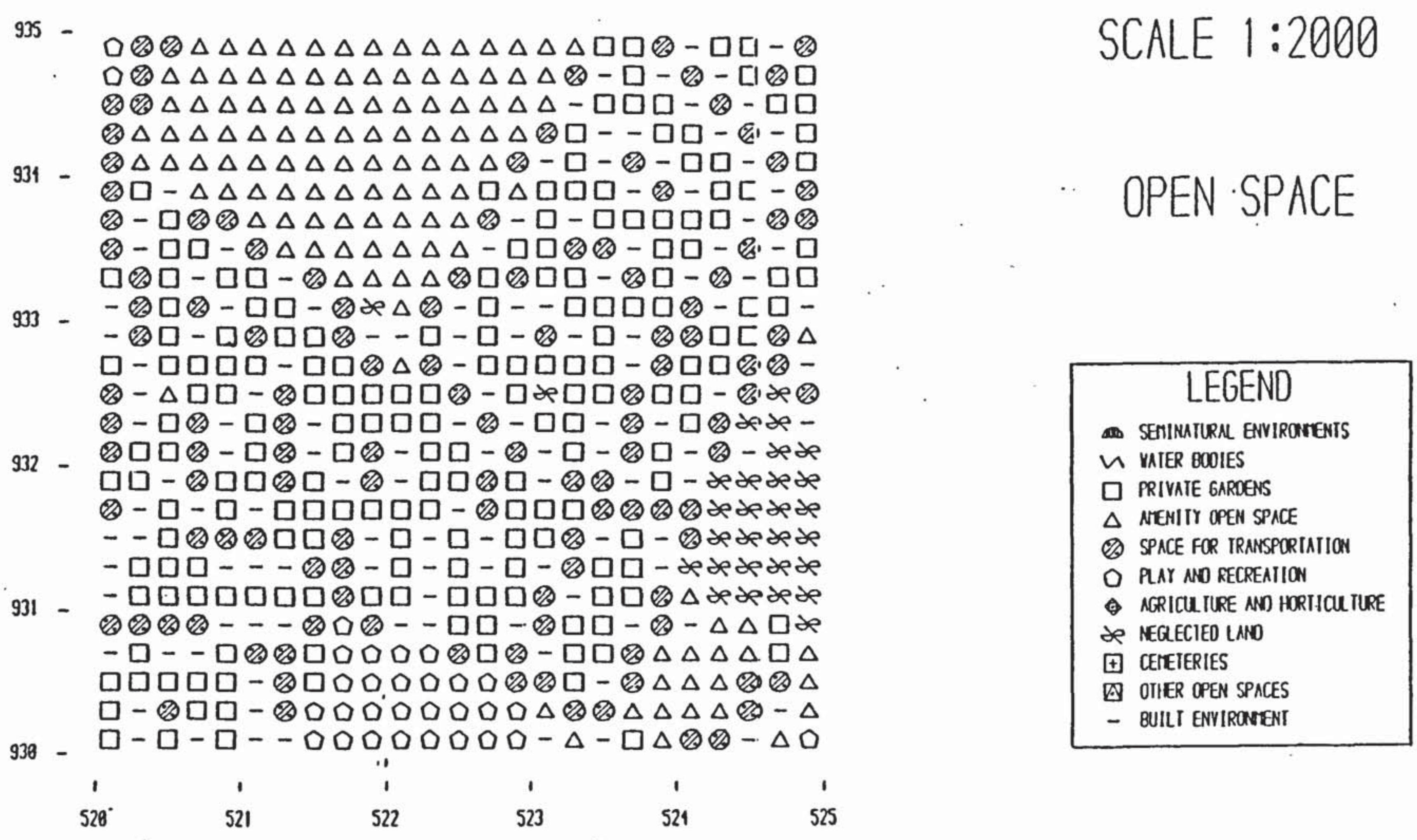


Figure 8.19 CALCOMP DIGITAL MAP SHOWING THE DISTRIBUTION OF OPEN SPACE GROUPS IN SAMPLE AREA NO. 5 (CLAUGHTON) - INTERMEDIATE SOCIOECONOMIC STATUS (CATEGORY 2)

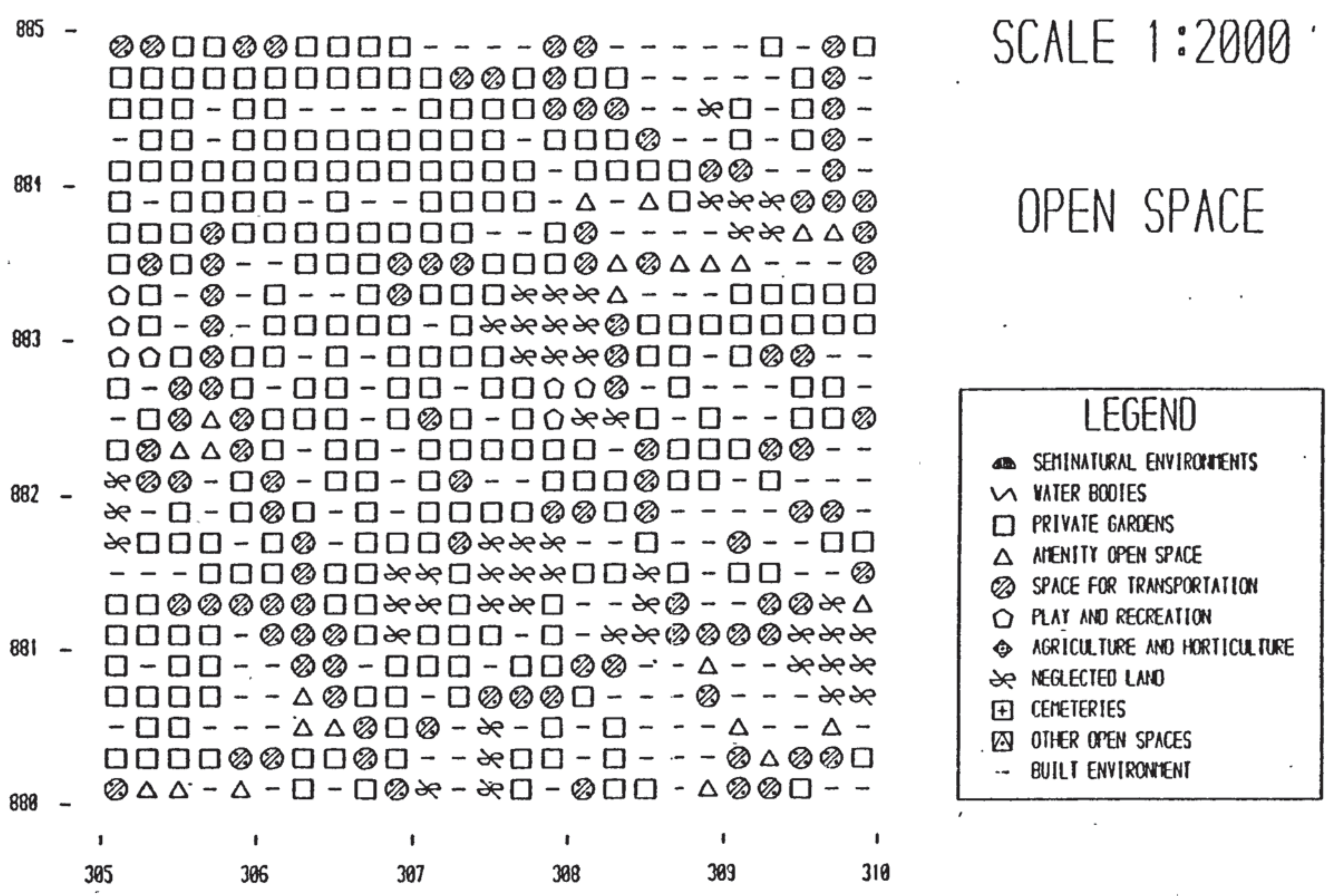


Figure 8.20 CALCOMP DIGITAL MAP SHOWING THE DISTRIBUTION OF OPEN SPACE GROUPS IN SAMPLE AREA NO. 10 (WAVERTREE) - LOW SOCIOECONOMIC STATUS (CATEGORY 3)

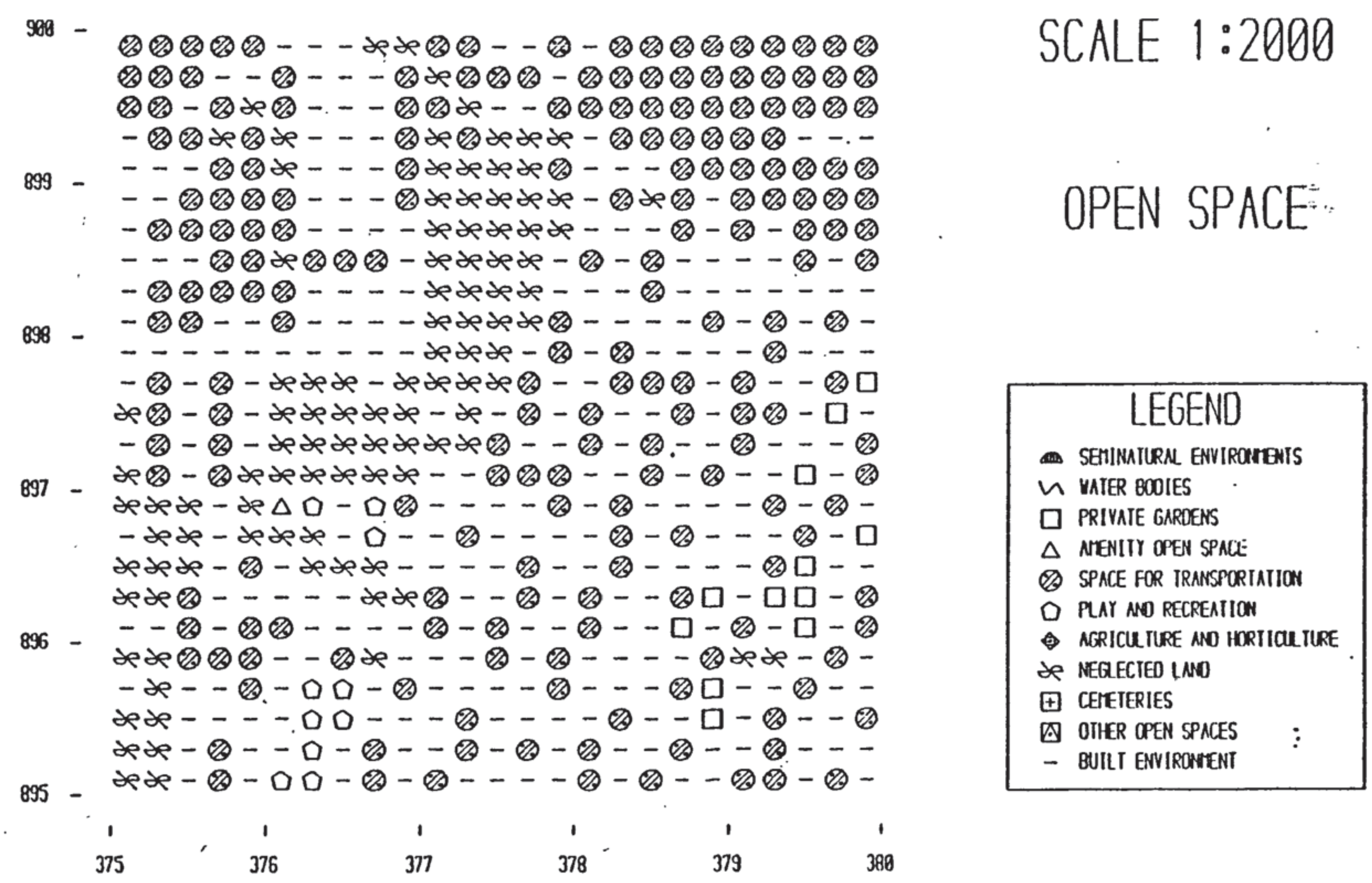


Figure 8.21 CALCOMP DIGITAL MAP SHOWING THE DISTRIBUTION OF OPEN SPACE GROUPS IN SAMPLE AREA NO. 6 (SCOTLAND ROAD) - VERY LOW SOCIOECONOMIC STATUS (CATEGORY 4)

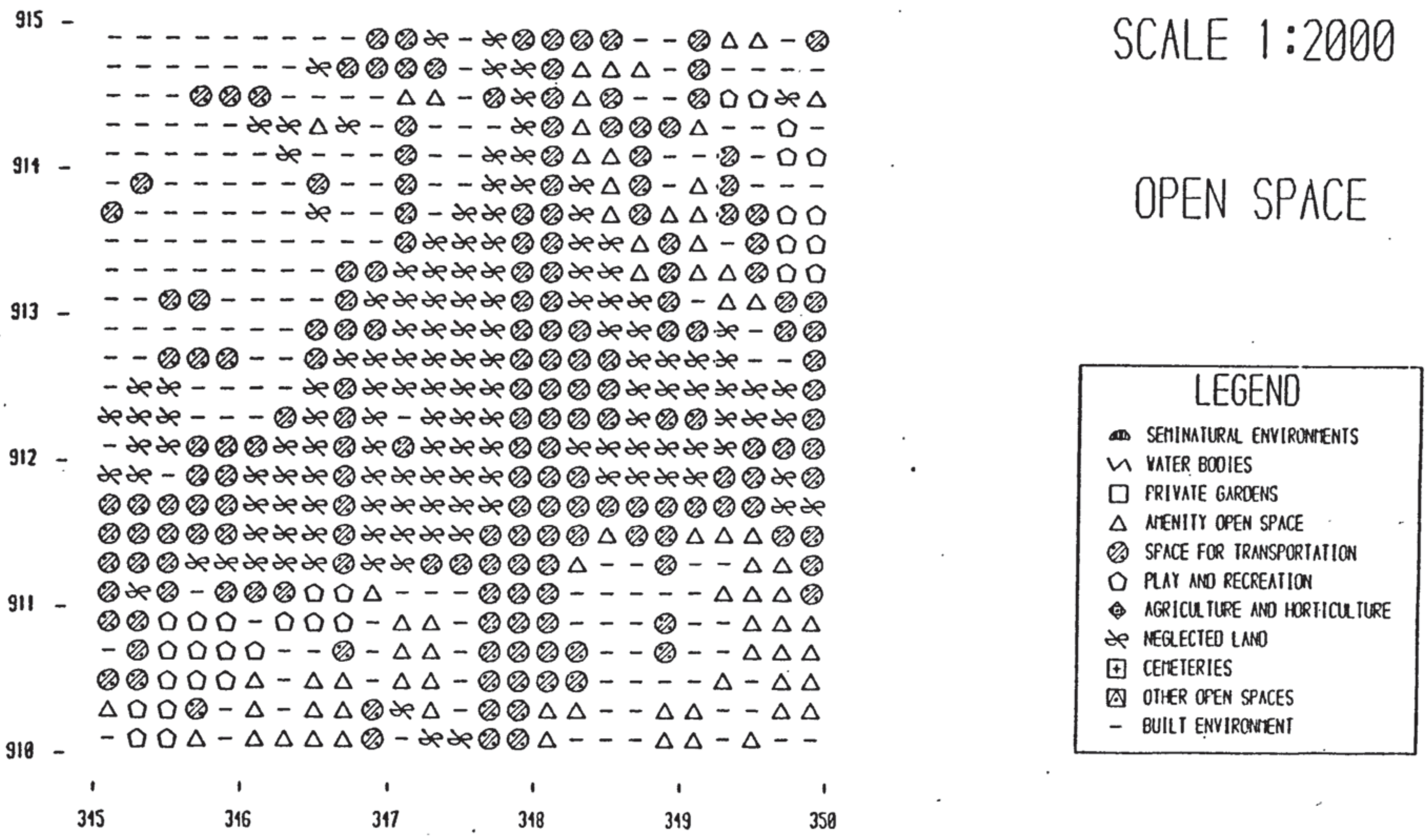


Plate 8.1 COLOUR INFRA-RED AERIAL PHOTOGRAPH OF SAMPLE AREA NO. 4 IN SHERDLEY PARK HIGH SOCIOECONOMIC STATUS (1)

This area belongs to the Family 1 which together with Family 6 form the high status category. It consists of a new estate of good quality semi-detached houses and bungalows. The houses have small gardens. In general, open space is well managed and there is a "near home" park (upper left) for children in the area.

Plate 8.2 COLOUR INFRA-RED AERIAL PHOTOGRAPH OF SAMPLE AREA NO. 5 IN CLAUGHTON INTERMEDIATE SOCIOECONOMIC STATUS (2)

This area belongs to the Family 2 (Rooming Houses) which forms the intermediate social status category. Formerly it was a high quality residential area which now is in decline. A number of cleared sites are visible in this photograph together with some portions of scrubland and there is a large number of mature trees. The population in the area is fairly elderly. Only one third of the houses are in owner occupation.

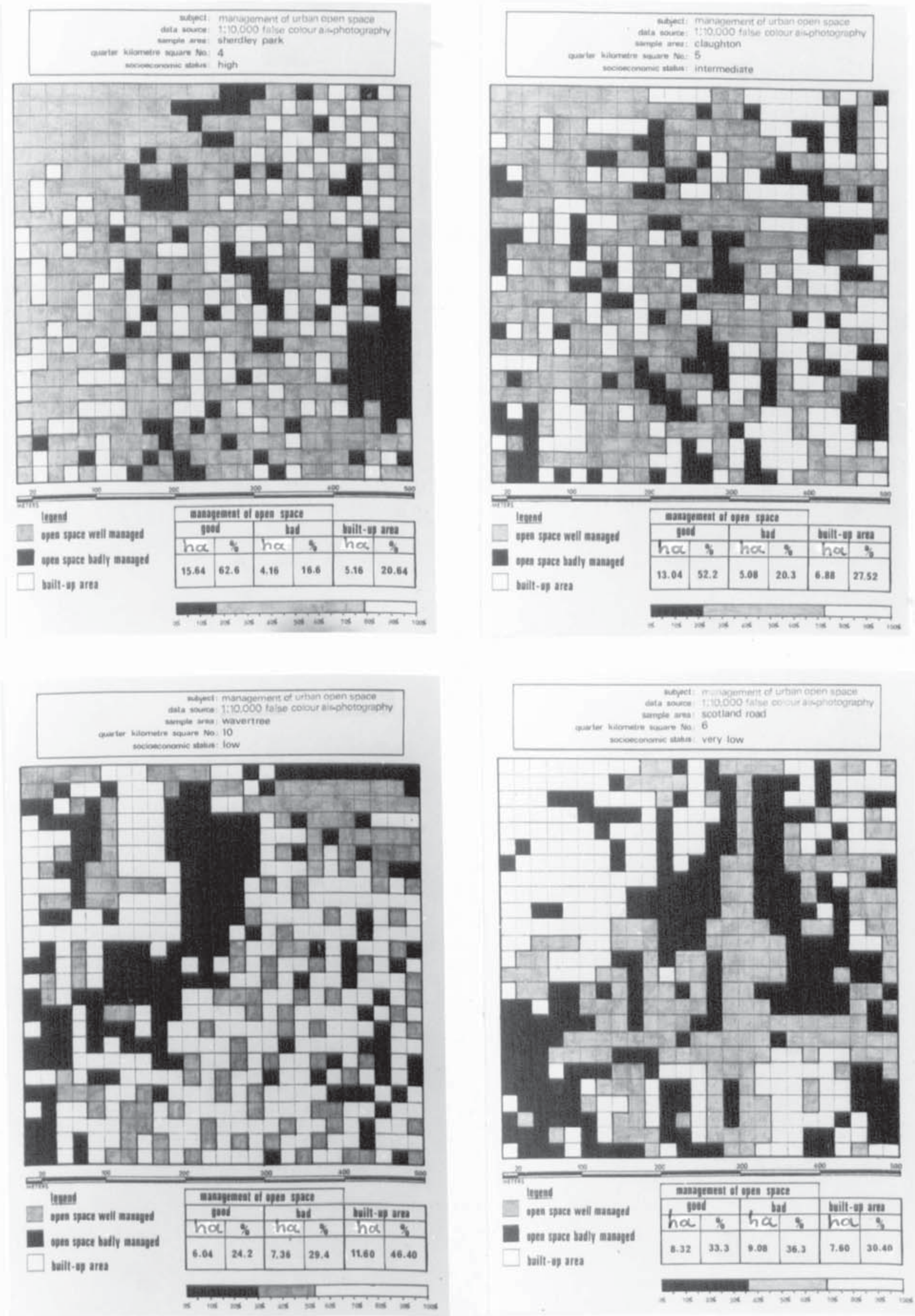
Plate 8.3 COLOUR INFRA-RED AERIAL PHOTOGRAPH OF SAMPLE AREA NO. 10 IN WAVERTREE LOW SOCIOECONOMIC STATUS (3)

This area belongs to the Family 5, which together with the Family 4 form the low status category. It has a rigid linear street pattern, few trees and predominantly terraced houses. A large area of cleared land appearing at the centre of the photograph is not managed at all (bad condition) with litter cover in places. There is a decline in population in the area and the number of children is large.

Plate 8.4 COLOUR INFRA-RED AERIAL PHOTOGRAPH OF SAMPLE AREA NO. 6 IN SCOTLAND ROAD SOCIOECONOMIC STATUS VERY LOW (4)

This area belongs to Family 3 which forms the very low status category. The above area is an inner Council estate and suffers many severe environmental problems. There is a large proportion of cleared land and many of these untidy sites are under treatment by the County Planning Authority which has initiated a revegetation program. The photograph shows that already a high proportion of these open area has been covered with turf grasses and sub-shrubs. There is a large number of 5-14 year old children in the area most of them living in multi-storey blocks of flats.

Plate 8.5 CONDITION OF URBAN OPEN SPACE IN THE FOUR SOCIALLY CONTRASTED SAMPLE AREAS NO. 4, NO. 5, NO. 10 AND NO. 6.



There is an increase in the area of open space in bad condition (shaded with black) from the high status to very low status categories.

CHAPTER 9

GRID CELL DENSITY SAMPLING

9.1 Introduction

The use of a dot grid, or square grid system, is a very effective method of recording data from maps and aerial photographs. From the information it is possible to compile statistical lists and calcomp computer maps of whatever information has been recorded.

A constant problem is presented in carrying out grid surveys: that is to determine the number of observations (or dots) per unit area.

In this survey of open space it was decided to carry out an investigation to identify the density of the grid in relation to the accuracies to be expected in locating and measuring each type of urban open space. One of the eleven sample areas, Prescot, number 7, socio economic class 3 was chosen for this.

Table 9.1 lists the thirty nine types of open space included in the classification, and shows which of these occur in each of the eleven sample areas. The number of different urban land uses found in the eleven sample areas varies from nine to sixteen (Prescot, square no. 7).

9.2 Sampling Procedure

If there is a need to compile a map showing the spatial distribution of the different types of open space, then it is necessary to collect the data, from the aerial photography, on a regular and total grid over the whole area. If, however, only statistical data are required, then not so many points have to be recorded, and these points may be selected on a regular or random basis.

The key issue is to determine the density of the grid points required to obtain the necessary degree of accuracy.

This in turn depends upon the purpose of the survey.

A program was developed which permits a number of different grid (or point) densities to be selected from the original 15 x 15 matrix of 625 points. This program allows the user to select any number of points (less than 625). For this study the following densities of points were recorded:

625, 500, 400, 300, 200, 100 and 50 points per ¼km^2

Table 9.2 lists the results using these grid densities for each of the sixteen different types of open space identified in the survey of area number 7, Prescot. The same program can be used for all eleven of the sample areas, hence all thirty nine categories of open space are included in the print out.

The list shows four sets of data for each type of open space and for each grid density. From the top of each column to the bottom the four numbers indicate the following:

Average area in hectares

Standard deviation of the area in hectares

Average area in percentages

Standard deviation of the area in percentages

The reason these are tabulated as averages is because the computer program took, for each density level, twenty different sets of dots and gave a final figure which was the average of these twenty sets of observations.

9.3 Discussion of the Sampling Results

It can be seen from the computer print out (Table 9.2) that the averages for the area of each type of open space do not alter very much as the density of observations gets smaller, but the standard deviations increase, sometimes quite dramatically. The standard deviation, as the best measure of dispersion, indicates the sort of inaccuracy which would be expected if a particular sample size were used.

The results of the 625 density sample are tabulated down the left hand side of table 9.2 to facilitate comparisons with the results of the other grid density samples.

Table 9.3 lists the percentage errors which can be expected for each of the grid densities tested. This list covers all the sixteen types of open space found in Prescot (sample area number 7).

Each of the eleven sample areas were ¼km^2, i.e. 25 hectares in size, thus open space type number 0, Built up areas, occupied 4.9 ha - nearly 20% of the total sample area.

Assuming it was required to determine to within 10% the areal extent of the built up area (i.e. buildings) then it would be necessary to sample at a density of at least 200 points per ¼km^2.

Open space type 12, Private Gardens, occupies 6.48 ha - just 26% of the total sample area. Built up areas and private gardens are the two most extensive uses and together constitute 11.40 ha, or 45.5% of the urban landscape of the Prescot sample area.

They show close similarity in the way in which the errors of area increase with decreasing density of observations.

The next most extensive areal unit of urban open space is streets. These are subdivided into Type 17, Streets lined with Trees, and Type 18, Streets not lined with Trees. These cover areas of 1.16 ha (4.6%) and 3.08 ha (12%)

respectively, making a total of 4.24 ha, or 17% of the total sample area.

This lack of tree lined streets is very typical of the low quality visual environment found in other socio economic Class 3 areas.

The county planning authority has already expressed considerable interest in this feature because they make annual payments to the District Councils for the maintenance of trees along the highways, and this data gives them some overall idea of the distribution and density of tree lined roads. This has led to further associated work being carried out of a total tree count in all eleven sample areas.

The next most extensive area of open space is Amenity land. This is divided into two groups: number 14, Generally Accessible, 1.16 ha (4.6%) and Limited Access, 2.08 ha (8.3%). It is relevant to note that there is twice as much of the latter which is found in a variety of institutions: hospitals, schools, etc. Less than 5% of the total area of the Prescot sample is generally available and accessible to the resident population as local Amenity Open Space.

In the current fashion of Inner Urban Redevelopment Programmes this lack of Amenity Open Space is very significant, particularly in an area of low socio economic class where the opportunities to travel to more distant amenity areas is very restricted.

Linked to accessible Amenity Open Space is that land devoted to Children's playgrounds, (number 30), which accounts for only 0.08 ha (0.3%) of the total area. As with all the open space types which occupy a very small area, there is a rapid decline in accuracy associated with a decrease in the density of the spot grid observations. As Table 9.3 shows at 50 points per ¼km^2 an error of 250% is to be expected!

It is interesting to note that, in relation to the area of Children's playgrounds, there is twice as much derelict land, and six times as much land devoted to motorways.

The method of selecting at random twenty different sets of each density, and determining an average for each, is evident when comparing Mineral Extraction (Number 35) with Cleared Land (Number 37). Each covers the same area - 0.04 ha - but the errors, expected at various grid densities, do not coincide all the way along the line (Table 9.3). At 50 points per ¼km^2 the error to be expected in Mineral Extraction is 450%, whilst that of Cleared Land goes to infinity!

9.4 Conclusion

The introduction to this chapter refers to the problem of identifying the density of points or squares per unit area required to maintain certain levels of accuracy.

Prescot, sample area number 7, was chosen as the site for this test. Initially a matrix of 25 x 25 points were selected to give a density of 625 points per ¼km^2 (2,500 per km^2). This is a very dense grid and the time taken, and cost involved, for working at this density over areas of county size would be very substantial, and probably not be used operationally. However, for the purpose of the test this dense grid was regarded as the 'truth' and all other sets of data were compared with it.

The areal extent of sixteen land use types were recorded, and the results of the 625 grid survey provide much useful data about the type and extent of the various land uses.

This information provides quantitative data which the urban planner urgently requires.

It was found, not unexpectedly, that in cases where the open space category occupied a large proportion of the sample area there would be only modest changes in the accuracy levels with a decreased density of observation.

It was also found that where a land use type covered only a very small area, then the likely rate of expected error increased quite rapidly. No other general points were evident, but the final table (9.3) should provide useful guidance to urban planners on the relative accuracies which can be expected for each set of density points for each type of open space.

In addition to this, the detailed quantitative information on the extent of the various urban land uses found provides a useful data bank for townscape analysis.

Table 9.1

Quarter Kilometer squares No.:

URBAN OPEN SPACE USE

11	10	9	8	7	6	5	4	3	2	1		URBAN OPEN SPACE UNITS	OPEN SPACE GROUPS
				●				●			01	HEATHLAND	
											02	WOODLAND	
											03	MOSSLAND	
											04	SAND DUNES	SEMI-NATURAL ENVIRONMENTS
											05	BEACHES	
											06	MARSHLAND	
			●								07	STREAMS & RIVERS	
											08	CANALS	WATER BODIES
											09	LAKES & PONDS	
											10	RESERVOIRS	
											11	OCEANS	
●	●	●	●	●		●	●	●	●	●	12	PRIVATE GARDENS	PRIVATE GARDENS
		●					●				13	PARKS	
●		●	●	●	●	●	●	●	●	●	14	AMENITY OPEN SPACE, (general access).	
●	●	●	●	●	●	●	●	●	●	●	15	AMENITY OPEN SPACE, (limited access Institutional etc.)	AMENITY OPEN SPACE
					●			●	●		16	AMENITY OPEN SPACE, (Industrial, Commercial)	
●		●	●	●					●	●	17	STREETS LINED WITH TREES	
●	●	●	●	●	●	●	●	●	●	●	18	STREETS NOT LINED WITH TREES	
	●	●								●	19	RAILWAYS, (Land associated with)	SPACE FOR TRANSPORTATION
			●	●	●		●				20	MOTORWAYS, (Land associated with)	
●	●	●	●	●	●	●	●	●	●		21	OPEN AIR CAR PARKS	
											22	AIRFIELDS	
	●	●	●	●	●		●		●		23	CHILDREN'S PLAYGROUNDS	
						●	●	●	●		24	SPORTFIELDS AND STADIA	
											25	GOLF COURSES	PLAY & RECREATION
●	●				●			●		●	26	EDUCATIONAL PLAYSPACE	
											27	INDUSTRIAL SPORT FACILITIES	
								●			28	OTHER OPEN AIR PLAYSPACES	
								●			29	ALLOTMENT GARDENS	AGRICULTURE & HORTICULTURE
				●							30	AGRICULTURE & HORTICULTURE	
●	●	●		●	●	●	●	●	●		31	INDUSTRIAL/COMMERCIAL OPEN SPACE, ANCILLARY OPEN SPACE(OTHER)	
		●	●							●	32	ROUGH GRASSLAND	
		●	●	●	●	●	●	●			33	SCRUBLAND	
		●		●	●	●	●	●			34	DERELICT LAND	DERELICT & SPOILED LAND
				●	●		●			●	35	MINERAL EXTRACTION	
											36	WASTE DISPOSAL SITES	
●	●	●	●	●	●	●	●	●	●	●	37	CLEARED LAND	
				●							38	CEMETERIES	CEMETERIES
											39	OTHER OPEN SPACES	OTHERS
9	9	14	12	16	13	10	14	15	11	10		total of open space units appearing in each of the 11 squares.	

Table 9.2 GRID DENSITY TEST

SAMPLING OF PRESCOT, SQUARE NO. 7

AV. HA
S.D. HA
AV. PCT
S.D. PCT

UNIT NO	625	500	400	300	200	100	50	
0	4.92	4.92	4.97	4.85	5.04	4.96	4.90	
	0.00	0.16	0.30	0.45	0.49	1.11	1.37	
	19.7	19.7	19.9	19.4	20.2	19.9	19.6	(BUILT ENVIRONMENT)
	0.0	0.6	1.2	1.8	2.0	4.5	5.5	
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(HEATHLAND)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.56	0.56	0.55	0.58	0.54	0.64	0.55	
	0.00	0.08	0.15	0.14	0.16	0.39	0.44	
	2.2	2.2	2.2	2.3	2.2	2.6	2.2	(WOODLAND)
	0.0	0.3	0.6	0.6	0.6	1.6	1.8	
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(MOSSLAND)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(SAND DUNES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(BEACHES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(MARSHLANDS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(STREAMS & RIVERS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(CANALS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(LAKES & PONDS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(RESERVOIRS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(OCEANS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12	6.48	6.49	6.51	6.59	6.44	6.65	6.98	
	0.00	0.23	0.32	0.39	0.60	0.75	1.23	
	25.9	26.0	26.0	26.3	25.8	26.6	27.9	(PRIVATE GARDENS)
	0.0	0.9	1.3	1.5	2.4	3.0	4.9	
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(PARKS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
14	1.16	1.13	1.14	1.17	1.05	1.09	1.30	
	0.00	0.11	0.17	0.25	0.24	0.62	0.89	
	4.6	4.5	4.5	4.7	4.2	4.4	5.2	(AMENITY OPEN SPACE,
	0.0	0.5	0.7	1.0	1.0	2.5	3.5	General access)

Table 9.2 GRID DENSITY TEST

15	2.08	2.06	2.10	2.08	2.04	2.05	2.30	
	0.00	0.11	0.17	0.32	0.38	0.54	0.87	
	8.3	8.2	8.4	8.3	8.2	8.2	9.2	(AMENITY OPEN SPACE,
	0.0	0.4	0.7	1.3	1.5	2.2	3.5	limited access, Institutional etc.)
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(AMENITY OPEN SPACE,
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Industrial, Commercial)
17	1.16	1.19	1.18	1.17	1.25	1.29	1.10	
	0.00	0.11	0.17	0.17	0.32	0.46	0.83	
	4.6	4.8	4.7	4.7	5.0	5.2	4.4	(STREETS LINED WITH TREES)
	0.0	0.5	0.7	0.7	1.3	1.8	3.4	
18	3.08	3.01	3.01	3.06	3.14	3.23	2.80	
	0.00	0.21	0.25	0.28	0.43	0.79	0.89	
	12.3	12.0	12.0	12.2	12.6	12.9	11.2	(STREETS NOT LINED WITH TREES)
	0.0	0.8	1.0	1.1	1.7	3.2	3.5	
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(RAILWAYS, Land associated with)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.48	0.51	0.45	0.48	0.33	0.45	0.45	
	0.00	0.06	0.08	0.10	0.16	0.34	0.35	
	1.9	2.0	1.3	1.9	1.3	1.8	1.8	(MOTORWAYS, Land associated with)
	0.0	0.2	0.3	0.4	0.6	1.4	1.4	
21	0.40	0.39	0.40	0.40	0.44	0.39	0.40	
	0.00	0.05	0.08	0.11	0.17	0.26	0.41	
	1.6	1.6	1.6	1.6	1.7	1.6	1.6	(OPEN AIR CAR PARKS)
	0.0	0.2	0.3	0.5	0.7	1.0	1.6	
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(AIRFIELDS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.08	0.09	0.08	0.06	0.06	0.09	0.10	
	0.00	0.02	0.05	0.05	0.06	0.14	0.20	
	0.3	0.4	0.3	0.2	0.3	0.4	0.4	(CHILDREN'S PLAYGROUNDS)
	0.0	0.1	0.2	0.2	0.3	0.6	0.8	
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(SPORTFIELDS & STADIA)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(GOLF COURSES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(EDUCATIONAL PLAYSPACE)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(INDUSTRIAL SPORT FACILITIES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(OTHER OPEN AIR PLAYSPACES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(ALLOTMENT GARDENS)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	1.84	1.89	1.77	1.74	1.94	1.43	1.75	
	0.00	0.13	0.17	0.27	0.31	0.43	0.96	
	7.4	7.6	7.1	6.9	7.8	5.7	7.0	(AGRICULTURE & HORTICULTURE)
	0.0	0.5	0.7	1.1	1.2	1.7	3.8	
31	0.44	0.44	0.43	0.44	0.43	0.58	0.30	
	0.00	0.08	0.09	0.10	0.21	0.30	0.24	
	1.8	1.8	1.9	1.8	1.7	2.3	1.2	(INDUSTRIAL COMMERCIAL OPEN SPACE,
	0.0	0.3	0.4	0.4	0.9	1.2	1.0	ANCILLARY OPEN SPACE (OTHER))

Table 9.2 GRID DENSITY TEST

32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(ROUGH GRASSLAND)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
33	0.44	0.45	0.43	0.48	0.42	0.44	0.35	
	0.00	0.05	0.10	0.14	0.16	0.30	0.48	
	1.8	1.8	1.7	1.9	1.7	1.7	1.4	(SCRUBLAND)
	0.0	0.2	0.4	0.5	0.7	1.2	1.9	
34	0.16	0.16	0.19	0.18	0.17	0.15	0.23	
	0.00	0.04	0.05	0.06	0.11	0.18	0.37	
	0.6	0.6	0.8	0.7	0.7	0.6	0.9	(DERELICT LAND)
	0.0	0.1	0.2	0.2	0.4	0.7	1.5	
35	0.04	0.04	0.04	0.02	0.05	0.04	0.08	
	0.00	0.02	0.03	0.04	0.06	0.09	0.18	
	0.2	0.2	0.2	0.1	0.2	0.2	0.3	(MINERAL EXTRACTION)
	0.0	0.1	0.1	0.2	0.2	0.4	0.7	
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(WASTE DISPOSAL SITES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
37	0.04	0.05	0.03	0.04	0.03	0.04	0.00	
	0.00	0.01	0.03	0.04	0.05	0.09	0.00	
	0.2	0.2	0.1	0.2	0.1	0.2	0.0	(CLEARED LAND)
	0.0	0.0	0.1	0.2	0.2	0.4	0.0	
38	1.64	1.61	1.63	1.64	1.62	1.51	1.43	
	0.00	0.14	0.16	0.27	0.46	0.59	0.81	
	6.6	6.4	6.7	6.6	6.5	6.1	5.7	(CEMETERIES)
	0.0	0.5	0.6	1.1	1.8	2.4	3.2	
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(OTHER OPEN SPACES)
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Table 9.3 EXPECTED PERCENTAGE ERROR AGAINST GRID CELL DENSITY. SQUARE NO. 7

Grid Cell Density per $\frac{1}{4}km^2$							Open Space Units
625	500	400	300	200	100	50	
-	3.2%	6.0%	9.1%	9.9%	22.5%	27.8%	0. Built up areas
-	14.2%	26.7%	25.0%	28.5%	69.6%	78.5%	2. Woodland
-	3.5%	4.9%	6.0%	9.2%	11.5%	18.9%	12. Private Gardens
-	9.4%	14.6%	21.5%	20.6%	53.4%	76.7%	14. Amenity Open Space (general access)
-	5.2%	8.1%	15.3%	18.2%	25.9%	41.8%	15. Amenity Open Space (limited access)
-	9.4%	14.6%	14.6%	27.5%	39.6%	73.2%	17. Streets lined with trees
-	6.8%	8.1%	9.0%	13.9%	25.6%	28.8%	18. Streets not lined with trees
-	12.5%	16.6%	20.8%	33.3%	70.8%	72.9%	20. Motorways
-	12.5%	20.0%	27.5%	42.5%	65.0%	102.5%	21. Open air car parks
-	25.0%	62.5%	62.5%	75.0%	175.0%	250.0%	23. Children's playgrounds
-	7.0%	9.2%	14.6%	16.8%	23.3%	52.5%	30. Agriculture-Horticulture
-	18.1%	20.4%	22.7%	47.7%	68.1%	54.5%	31. Industrial Commercial (ancillary open spac
-	11.3%	22.7%	31.8%	36.3%	68.1%	109.0%	33. Scrubland
-	25.0%	31.2%	37.5%	68.7%	112.5%	300.0%	34. Derelict Land
-	50.0%	75.0%	100.0%	150.0%	225.0%	450.0%	35. Mineral extraction
-	25.0%	75.0%	100.0%	125.0%	225.0%	-	37. Cleared land
-	8.5%	9.7%	16.4%	28.0%	35.9%	49.3%	38. Cemeteries

CHAPTER 10

CONCLUSIONS

10.1 Conclusions

The fairly recent and very rapid change in government policy - from using agricultural land to build new cities, to that of redeveloping existing cities - created an urgent need to gather data on the land use, structure and environment of existing, well established towns.

One important constituent of this data is urban open space. This type of land can be readily identified, and is likely to be less costly to develop than such areas as declining residential estates or disused industrial sites.

Liaison with the County Planning Authority of Metropolitan Merseyside, confirmed their strong interest in acquiring data relevant to the type and distribution of open space in their county.

Merseyside County Planners had already made quite considerable use of aerial photography. They had commissioned, and used, several sets of black and white photography. With their enthusiasm, and the co-operation of the Department of Environment, London, Merseyside became the first County in the U.K. to obtain total cover of large scale, colour infra-red aerial photography.

This research project was designed to use both black and white, and colour infra-red aerial photography to undertake a three staged study.

Stage 1. To investigate the value of aerial photography as a data source for surveying and mapping open space.

Stage 2. To develop a suitable methodology to enable this work to be carried out, and to test this methodology.

Stage 3. To use the information derived from stage 2 to identify the relationship between the provision of open space and the socioeconomic class of the population.

In the first stage open space was defined and classified. This classification was used when extracting data from the aerial photography. The use of aerial photography proved to be very cost-effective: it was much faster, more accurate and less expensive than alternative methods of data collection, especially field survey methods.

It was shown that where data were required on the type, extent and form of urban open space, then there was little difference in the value of the data source between the black and white and the colour infra-red aerial photography. However, when additional information is required concerning the vegetation cover and condition, then some significant differences do emerge which indicate the advantages of colour infra-red (CIR) photography.

The experience gained in stage 1 led to some changes being made for use in stage 2. The open space classification was modified so that the advantages could be more fully exploited of using CIR photography.

The dot grid was used in stage 1; and that use which lay under the dot was recorded. In stage 2 a square grid was used, and the 'dominant' use of the square was recorded.

It is now realised that the former method has many advantages - including simplicity and speed - and gives a result at least as accurate as the latter method. However the co-operating planning authority specifically requested that the 'dominant use' be used, and this was done in stage 2, but it is not recommended for future work of this kind.

A suite of computer programs was developed to produce calcomp grid maps, and lists of statistics relating to the type, extent, surface cover and condition of urban open space.

The third stage was to illustrate how the methodology and data, derived in the first two stages, could be used as a data input to one aspect of urban planning.

The Merseyside County Planning Authority was interested to discover how the provision of the various types of urban open space, gathered in the air photo based survey, related to the socioeconomic status of the population.

Each of the eleven sample areas in the survey comprised a single socioeconomic class, and these classes were allocated a grade (1-High to 4-Very Low). One problem was that the four classes were not equally represented in the survey area, there being only one sample for each of the categories 2 and 4.

It is strongly recommended that subsequent studies on this topic should include a more equal number of samples from each socioeconomic category.

This comparison identified many interesting and useful relationships, only a relatively few of which are analysed in this thesis.

All the information gathered in this study is being supplied to the Merseyside County Planning Authority, so that they can use and extend it in their urban redevelopment programme.

It is very clear however, from the comparisons that are considered in this thesis, that overall there is a very close relationship between the provision, type and especially the condition of urban open space, and the social status of the population.

An interesting follow up of this initial study would be to carry out a county survey of urban open space; use the results to allocate a socioeconomic status to the population, and compare the results with those enumerated in the Social Area Analysis to determine to what extent open space characteristics can be used to identify socioeconomic status.

The results of this comparison of open space and social status clearly show that, for the end product to be meaningful, it is essential to take into account the type and condition of the surface cover. This requirement establishes the condition that CIR aerial photography must be acquired as the source of data. It would be not only impractical, but virtually impossible to acquire the information from any other source.

The fact that this study was carried out in close co-operation with practising town planners, was a constant reminder that the end product should be not only useful, but also essentially practical.

It is readily appreciated that a proposal that urban areas should be surveyed on a grid at 2,500 points per km^2 would not be regarded as a practical proposition!

Consequently an experiment was carried out to determine the relative accuracies (in areal extent) which could be achieved by grid sampling at a range of different densities - from 625 to 50 points per ¼km^2.

The resulting statistics are tabulated to provide useful guidance which relate the degree of areal accuracy attained for each type of open space unit (in the Prescot sample area) for each density of observation.

That so much data was acquired in such a short space of time by one person, reflects the enormous value of using aerial photography as the data source.

It would have been virtually impossible to have collected this data from any other available source: field work in particular would have been impractical.

It is strongly recommended that aerial photography be acquired at regular intervals (at least every 5 years) for those engaged in the planning and environment disciplines. Such a data source provides the most all embracing, cost effective, land use, land condition, environment data bank, which can satisfy a wide range of needs.

The cost of acquiring aerial photography is relatively little, and can be recouped many times over by utilising the enormous wealth of data they contain.

Such a proposal demands also that planners should either become proficient themselves in air photo interpretation methods, or be able and willing to use experts in other disciplines who could provide such a service.

Although aerial photography is being increasingly used by planners, the review in this thesis reveals that aerial photography is still a very much underutilised source of data for professional planners, especially in the urban field.

Aerial photography provides data for many purposes: this study illustrates one such example.

It is hoped that both the methodology and the results of this research might make a modest and useful contribution to understanding the man/land relationships of urban areas.

Appendix 1.I

TECHNICAL INFORMATION ON AERIAL PHOTOGRAPHS

1.I.1 Scale

The scale of an aerial photograph is determined by two factors: the focal length (f) of the lens, and the flying height above the ground (H_a).

Figure I.1 shows that the scale of the aerial photograph = $\frac{d}{D_2}$ distance on negative / istance on ground

As the triangles df and H_aD_2 are similar then

scale = $\frac{d}{D_2} = \frac{f}{H_a}$

However for an aerial photograph to have a constant scale all over it certain conditions are necessary. These are that the camera should be truly vertical, and the ground quite flat! These conditions are rarely, if ever, met, consequently a single aerial photograph will have variations in its scale which are related to camera tilt and amplitude of ground relief. A single aerial photograph of a mountainous area will exhibit a larger scale for the mountain tops, and a smaller scale for the valley bottoms, relative to all the other areas.

The scale of the photograph is very important as it strongly influences the type of information which can be identified, and the level of detail which can be achieved. Hence the photoscale is strongly and directly related to the purpose for which the survey is to fulfill.

Most aerial photography is taken using a camera lens of 15cm (approximately six inches) focal length. Table I.1 gives some details which relate to cameras of this focal length.

The formulae in figure 1I.2 are approximate values based on a rectangular survey area, having overlaps of 60% forward and 30% sideward, and a photo format of 23cm x 23cm.

The number of photographs covering a unit area will vary as the square of the change of scale e.g. from 1:20,000 to 1:10,000 will increase the scale by two, the area by four, and the number of photographs by four. On the other hand the minimum size site identifiable will increase by four.

1.I.2 Camera Axis.

Aerial photography is classified also on the basis of the way the camera(s) is mounted in the aircraft.

Where the camera axis is pointing directly to the ground i.e. the axis of the camera is vertical, or within 2° of vertical the photographs are described as 'vertical'.

Where the camera axis is tilted off vertical the photography is described as oblique. This is the view obtained by photographing a valley from a nearby summit. The scale of the photo varies rapidly and substantially across a single print.

Oblique photography falls into two calsses: those which contain the horizon - high oblique, and those which do not - low oblique.

Some cameras have several lenses, one vertical, the others oblique. In this case they are referred to as composite photography.

1.I.3 Photomosaics

Mosaics are approximate photo maps consisting of a number of aerial photographs. The geometrical accuracy and the cost of preparation are highly correlated. Uncontrolled mosaics can be made very quickly and easily, while for controlled mosaics more time and skilled operators are needed as well as instruments.

An uncontrolled mosaic is a photo layout in which all (or only the alternate) aerial photographs of a series (block of strips) are laid out, adjusting the aerial photographs so as to obtain the best match of detail. The aerial photographs are fixed in position with tape. A more elaborate method involves cutting the aerial photographs (only the central overlap parts are used for a better match) and mounting them permanently on a base. Badly-flown series or series of mountainous terrain will show a considerable amount of mismatch, but still the general overview of a large area is obtained.

A controlled mosaic is an assembly of similar scale photos. The aerial photographs are enlarged to uniform scale and, if necessary, rectified to correct deviations from the vertical. Mosaics are used if no, or only outdated, maps are available but they will sometimes be more useful than maps, as they are a photo image of the terrain.

1.I.4 Orthophotos

An orthophoto is a photo with the planimetric properties of a topographic map, produced directly on the basis of normal aerial photographs. The photo image will remain but the scale is uniform all over the photo. For buildings, relief displacement will still exist. In a very simple way a grid, text (geographic names) and contour lines (by-product of the process) can be added, the output is then an orthophoto map.

Relative to conventional topographic mapping the production of orthophotos is extremely fast.

The readability of orthophotos and orthophoto maps will be different from topographic line maps: they contain photo information. There are many fields of application for those maps, for example, projects in Urban Planning, Regional Development, Engineering projects, and Soil Mapping. In general they are used for basic mapping and bases for thematic mapping.

1.I.5 Maps and aerial photographs.

The modern topographic map is always based upon photogrammetric procedures. It is possible, however, to use aerial photographs directly as a basis for a sketch map without much equipment or highly trained personnel. The sketch map can be made in a very simple way by tracing on an overlay a selection of terrain features from the aerial photographs. The sketch map can for instance be used for recording interpretation data.

The aerial photograph can also be used to complement a map. Often existing available maps are not up to date or the specific information wanted is not shown. Examples are location of recently built-up areas, new roads, flood damage, exact location and height of buildings, existence and type of vegetation, traffic concentrations, parking lots, unused lots and buildings under construction. For taxation purposes the aerial photographs will often prove to be very useful in recording changes in the real estate data, and property files can be revised as new constructions easily can be detected.

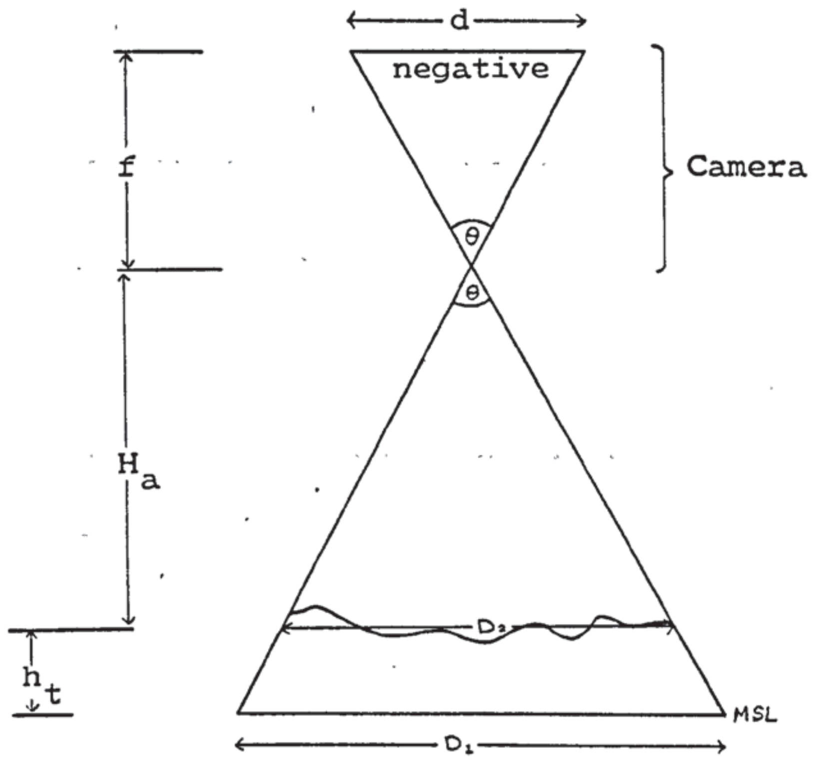
Often the aerial photographs in the form of a single aerial photograph, an enlargement, a mosaic or an orthophoto, can be used with advantage to replace a map. Much time is gained, and moreover, the photoinformation can be used directly.

1.I.6 Equipment

The basic instrument for photo interpretation is the mirror stereoscope which permits a three-dimensional view of the area common to two overlapping aerial photographs. Generally these stereoscopes can be used either without magnification to view the complete stereo model, or with magnification (typically 3x or 8x) for a closer investigation of the detail. Provision must be made to illuminate the aerial photographs. Only in special cases will there not be a serious loss of interpretation quality if the stereo model is not used, therefore the use of a stereoscope with stereo pairs of photos is strongly recommended.

Occasionally, a pocket stereoscope will be adequate but with this instrument a narrow area only can be viewed, and it is not well-adapted to view normal sized photos. Highly recommended is the facility of simultaneous observation by two persons (who can discuss the interpretation and together reach a conclusion) as provided by several instruments such as a pair of Old Delft Scanning Stereoscopes, or the Zeiss-Jena Interpretoscope. The scanning facility and a range of variable magnifications as offered by several stereoscopes will occasionally be very convenient.

Figure 1.I AIR PHOTO SCALE



f = focal length of camera

d = distance on negative

D_1 = Distance on ground at MSL

D_2 = Distance on ground at altitude h_t

H_a = Height of camera above ground h_t above MSL

h_t = height of ground surface above MSL

MSL = Mean Sea Level

Table I.1 RELATIONSHIP BETWEEN SCALE OF AERIAL PHOTOGRAPHY, AREA COVERAGE AND IDENTIFICATION OF OBJECTS, FOR CAMERAS WITH 15cm FOCAL LENGTH LENSES AND 23 x 23cm FORMAT OF THE PICTURE (after ITC-Urban Surveys Compendium, 1974)

Photo scale $I:m_p$	Flight altitude above terrain (Zm)	Side S of terrain square (S)	Terrain area per photo (S^2)	Minimum identification, approximate size of objects	Attainable height accuracy with photogrammetric instruments (contour lines)
1: 2,000	300m	450m	20ha	50cm	± 10cm
1: 5,000	750m	1,125m	125ha	125cm	± 25cm
1:10,000	1,500m	2,250m	500ha	250cm	± 45cm
1:20,000	3,000m	4,500m	$20km^2$	500cm	± 90cm
1:50,000	7,500m	11,250m	$125km^2$	1,250cm	± 230cm

Table I.2 DETERMINATION OF NUMBER OF PHOTOGRAPHS NEEDED TO COVER A GIVEN GROUND AREA COMPLETELY FOR PHOTO-INTERPRETATION OR PHOTOGRAMMETRIC PURPOSES (after ITC-Journal Urban Surveys Compendium, 1974)

$$N = 4 \left(\frac{A}{S^2} \right)$$

or

$$N = \frac{8A \times 10^5}{d^2}$$

where:

N = number of aerial photographs

A = area to be covered in Ha

S^2 = terrain area per photo

d = denominator of representative fraction (scale number)

APPENDIX 1.II PROCESSING AND STORAGE: COLOUR INFRA-RED FILM

1.II.1 Processing Colour Infra-red Photography.

The film is processed directly to a positive on which the images are inverse, rather than complementary in colour, to the effective sensitivity of the layer on which they are recorded. The exposed infra-red sensitive layer forms a cyan positive image, the exposed green sensitive layer a yellow, and the exposed red sensitive layer a magenta image. This creates a false colour transparency of natural objects, in which for instance healthy vegetation, with high infra-red reflectance, appears in a bright magenta colour. Corresponding false colour images for natural targets are as indicated in table 1.II.1.

For interpretation the film may be used directly as a positive transparency, or paper prints can be reproduced via an inter-negative process. One of the advantages of developing the film into a positive print is that the photographs are ready much more quickly, which can be important, especially for interpretation.

A second advantage is that the exposure is not so critical if positives are to be made. So, usable photographs can still be produced under conditions of low light intensity, provided that the development is adjusted accordingly.

One disadvantage is that extra copies on paper or film have to be made by a rather lengthy process and are therefore more expensive than prints made from a negative.

1.II.2 Storage of Colour Infra-red Photographic material

False colour film has been found to be extremely sensitive to the conditions of storage before use, and to the time interval between exposure and development. The films should be kept in deep freeze cabinets at a temperature of about -18°C, and should be acclimatized for some time before use. If possible the film should be exposed completely in one day and developed the next. This means that an effort must be made to take at least 100 shots per flight (Satter, 1973).

Table 1.II.1 CORRESPONDING FALSE COLOUR IMAGES FOR NATURAL TARGETS.

	Reproduction of False Colour Film	
Visual appearance of object	Infrared strongly absorbed	Infrared strongly reflected
Red	Green	Yellow
Green	Blue	Magenta
Blue	Grey-Black	Red
Cyan	Blue	Magenta
Magenta	Green	Yellow
Yellow	Cyan	Grey & Whit
Grey	Cyan	Grey

APPENDIX 1.III BRIEF REVIEW OF CIR PHOTOGRAPHY APPLICATIONS TO AGRICULTURE, FORESTRY, POLLUTION, TERRAIN ANALYSIS AND SOILS.

1.III.1 Agriculture

The following are typical studies in Agricultural applications of CIR photography. Manzer and Cooper (1967) found CIR to be more useful in detecting potato diseases than either panchromatic, colour or black and white infra-red aerial photography. Philpotts and Wallen (1969) found CIR superior to panchromatic and colour films for the detection of diseases in bean crops. The study of Bauer et al (1971) to determine the detectability of the various degrees of corn leaf blight infection, proved that the near-infra-red channels, in this case 800 to 2,500 millimicrons, were of particular value. The early study by Norman and Fritz (1965), concluded that CIR will reveal the presence of sick and declining citrus trees.

At the beginning of the seventies several projects were carried out at the United States Department of Agriculture (USDA) for inspecting by aerial photography fruit and nut trees for disease and insect infestation and much hope has been placed upon CIR to provide this information. Two research projects with significant results carried out by the USDA are those at Weslaco, Texas and Byron, Georgia (see Hart et al, 1968, 1969, 1971) related to the uses of CIR in Entomology. CIR photography can be an aid to livestock inventories as well. Colwell (1968) stated that livestock can be more accurately identified on CIR than on colour aerial photography. Such inventories can be extended to a great variety of wild and domesticated animals.

1.III.2 Forestry.

In the field of forestry and woodland management, information concerning species identification, acreage measurement of each species, cut acreage measurement, tree vigour assessment, tree growth rate, and damage assessment can be provided by CIR films, quickly and relatively inexpensively (Meyer and French (1967) and Heller et al (1959)). For species identification in particular Lauer (1969) has emphasized CIR's distinct advantages in comparison with other film-filter combinations for this purpose; it (1) capitalizes on the multispectral concept through the use of three selective separate emulsion layers, (2) ultilizes near-infra-red reflectance which is an invaluable aid in discriminating between hardwoods and conifers, and (3) minimizes troublesome short wave-length haze interference through the use of a minus-blue filter. He also believed that each species of tree appears to have its own infra-red reflective characteristics.

1.III.3 Water Pollution.

In this field such forms of pollution as algae growth, oil spills and industrial discharges can be detected quite effectively by CIR aerial photography. Although such techniques of remote sensing cannot entirely replace laboratory analysis, they can save both time and money by reducing the amount of necessary field work.

One specific example of CIR's utility has been mentioned by Strandberg (1966). He has found, for instance, that "the trickling filters of some treatment facilities particularly those which are overloaded, reflect a considerable amount of infra-red while trickling filters which are operating more efficiently do not". The increased infra-red reflectance is caused by high flagellate blooms which are initiated by discharges of only partially treated sewage. These microflora flourish in the undegraded organic matter found in the sewage.

The most dramatic type of water pollution in the recent years has been the oil spill. Generally spillages can be detected by most any type of film including CIR. However, since color-infra-red film is so sensitive to sun angle other films have proven more reliable (Aukland and Trexler, 1971).

It is apparent that CIR film has great potential for water quality analysis even though its use presents special problems. Strandberg (1964) has emphasized that the aerial reconnaissance of our nation's water bodies (referring to the United States), will not eliminate the need for established ground methods, but "by augmenting ground methods they can probably save both time and money".

1.III.4 Terrain Analysis and Soils.

Certain aspects of terrain analysis and vegetation analysis can be best carried out with CIR and this has been emphasized by several authors. Wilson (1969) indicated that CIR is the best medium for drainage studies. Strandberg (1969), again, found that CIR is the only type of aerial photography which enables consistent detection of water levels in flooded portions of the Florida Everglades. Anderson (1969) indicated that CIR has been shown to be an effective medium for the study of marshlands. Also Pestrong (1969) referring to marshland environments, emphasized the usefulness of CIR to delineate precisely minor environmental differences within the marshes.

In soil surveys there is a dichotomy of opinion. Wilson

(1969) considers black and white photography to be the best for soil studies; others disagree. Anson (1970), for one, considers CIR to be the best because of greater accuracy in identification and greater speed in interpretation. Kuhl (1970) on the other hand, has taken a somewhat in-between position. He found colour and CIR interpretation to be slightly more accurate than stereo black and white interpretation for predicting drainage and slope. The differences suggest perhaps that for soils studies scale is more important than film type.

APPENDIX 2.I APPLICATIONS OF REMOTE SENSING IN POPULATION ESTIMATION

Wellar (1969), using 1966 Gemini Satellite Imagery (1:900,000 to 1:1,000,000) attempted to predict population in the vicinities of San Antonio and Houston Texas. He utilized Nordbeck's (1965) population estimation formula for American Cities ($A=0.00151\ P^{0.08}, A=aP^{b}$), where A=area in square miles and P=population. The results varied considerably with most areas either significantly overestimated or underestimated. The high degree of cumulative error (37% overestimate) resulting from the application of Nordbeck's formula to the areal measurements derived from the imagery led Wellar to conclude that built-up areal extent and population size were not necessarily closely interrelated.

Holz, Huff and Mayfield's study (1969) centering on forty urban areas in the Tennessee River Valley Region, was an attempt to develop a population estimation technique for use with the Earth Resources Observation System (EROS) programme. The approach was similar to Wellar's in that the basic hypothesis was that "built-up urban areal extent and population size may be functionally related", although they further refined the system and included several central place theory relationships. These included urban size hierarchical relationships and the importance of accessibility, linkages and connectivity of urban population size. In the end they applied a complex regression equation to incorporate these various factors*. In practice this formula proved highly questionable, since most of the 40 test sites were estimated incorrectly, some by a factor of ± 100%. They found that a ratio relationship between the actual censual population and the observed urban signature area often did not correlate and that variation and error tended to be accentuated as actual urban population size increased. Anderson and Anderson (1973) also used built-up area measurement in their attempt to derive population estimates for 23 small Kansas communities. They employed automatic and semi-automatic aerial photointerpretation procedures to supplement human interpretation procedures, unlike the previous studies where only human interpreters were involved. They used 1:20,000 black and white aerial photographs taken in 1966. While the combined error rate for the 23 test sites was only 6.9% (underestimate), errors for individual communities exceeded ± 40% in some cases. Significant problems were experienced in delimiting rural/urban fringe boundaries. Those errors in the end produced unrealistic population size data.

*$P_i = a+b_1L_i+b_2P_j-b_3D_{ij}+b_4A_i$, where P_i= population P or urban area i; L_i= number of direct links L between i and the other urban areas; P_j= the population P of the nearest larger urban area j; D_{ij}= Distance D between urban area i and the nearest larger urban area j; A_i= the observable occupied dwelling area of urban area i; a and b values are local urban area constants.

As a result any population estimation methodology, utilizing total built-up areas as an input, would seem to be of questionable value until such time as an accurate method for delimiting rural/urban boundaries is developed.

A similar problem in the differentiation of the rural/urban transition zone was experienced in a study of communities in the Central Valley of California using ERTS imagery by Estes et al (1973).

Kraus, Senger and Ryerson's approach (1974) was based on the methodology of Collins and El-Beik in which population estimation is based on accurately identifying and measuring areas in different land use and correlating these areal measurements with predetermined average population densities (per unit areas) derived from existing census tract data. Kraus collected land use information from aerial photographs which had been enlarged by 15x (from 1:600,000 of NASA high flight 70 mms panchromatic, red and green bands) to 1:40,000 scale and infra-red 1:120,000 and 1:60,000 flown on April 1971, according to the following land use systems: (R_1): Single family residence, (Rm): Multifamily residence, (Tp): Trailer park residence and (C): All commercial or Industrial uses. Population density related to these uses were obtained from census tract data, the highest density being that of the multifamily residence, followed by the trailer park and single family residence. The commercial area was assumed to have no residents. An accurate and timeless urban population estimate was generated in relating land use information to population density*. This method was applied to four Californian cities having areas of $90km^2$, $75km^2$, $50km^2$ and $20km^2$. The errors encountered in individual cities ranged between 9% (underestimation) and 7% (overestimation), while the composite error for the four cities together was only 5% (underestimation). The advantages of the method were its relative ease and low cost. Thus it is considered to be highly useful for planning and administrative purposes. The disadvantages which could be encountered with respect to this methodology are that the population estimation was done for the whole city as one unit.

In the category of the studies which are characterized as "detailed", the works of Green (1956), Porter (1956), Eyre et al (1970), Hsu (1971) and Dueker and Horton (1971) are included. They utilized low altitude photography as the primary data source. This methodology includes counting individual dwelling units and multiplying this figure by an average per dwelling population density figure extracted from published census tract data. Porter (1956) was the first investigator who actually applied this methodology in Liberia. His basic technique involved

*TOTAL CITY POPULATION P= Area of each land use, its Population Density = $A_{R_1}.D_{R_1} + A_{Rm}.D_{Rm} + A_{R_{TP}}.D_{TP}$, where $A_{R_1}, A_{Rm}, A_{R_{TP}}$ = Areas devoted to each land use type; and D_{R_1}, D_{Rm}, $D_{R_{TP}}$ = characteristic spatial population densities associated with each land use type.

counting individual huts from aerial photographs and multiplying these counts by an occupants-per-hut factor (established by ground observation) to arrive at a population estimate. The results of Porter's study were later verified by a conventional census, although the actual error factor is not known. Hsu's (1971) methodology for the Atlanta, Georgia, area was to estimate urban and rural area populations using housing counts derived from 1:5,000 aerial photographs, U.S.G.S. maps and population census tract data. He used the basic formulae:

$$\text{Population size} = (\text{Number of Houses}) \times (\text{Persons per Household})$$

and

$$\underset{\text{(per unit of measure)}}{\text{Population density}} = \frac{(\text{Persons per Household}) \times (\text{Housing Counts})}{\text{Area}}$$

The results were very impressive with an average random error of $\pm$ 3%. This study together with Kraus, Senger and Ryerson's (1974) and Collins and El-Beik's (1971) are the most accurate studies to date with error rates of $\pm$ 3%, 4%, 5% (underestimation) and 2% (underestimation) respectively.

Dueker and Horton (1971) following a methodology similar to Hsu's in a study of a portion of the Washington D.C. area, which resulted in a 15% underestimation error using high altitude NASA photography of a scale 1:50,000. They identified (and counted) a variety of housing types. Scale of photography and variety of housing types were the two points of difference from Hsu's study.

APPENDIX 2.II APPLICATIONS OF REMOTE SENSING IN ENVIRONMENTAL POLLUTION STUDIES

In the area of atmospheric monitoring, two techniques have been developed for data acquisition and analysis. Veress (1970) in his study using colour films with a polaroid filter used aerial photographs taken of a polluted air mass. Then the polluted air mass was mapped as an overlay to the USGA topographic map. Information included the horizontal extent of the air mass as well as the elevation of the smoke above sea level. Quantitative measurements were derived using a microdensitometer which scanned the photo through the image of the polluted air layer and the neighbouring ground. A second technique, developed by Barringer et al (1968), made use of the characteristic optical absorption exhibited by virtually all gases. Nitrogen and sulphur dioxides which absorb in the ultraviolet and visible spectra, can be sensed remotely using natural daylight as the illumination source.

In the area of water quality a number of studies (Strandberg 1969, Scherz 1972, and others) have been carried out and emphasize the capability of remote sensing techniques for providing necessary data. Strandberg (1969) indicated that colour and false colour aerial photographs can frequently be used and provide information about the location and extent of effluent discharges into a water body. Furthermore, where the effluent is responsible for excessive algae growth, detection is made relatively easy through the use of colour infra-red films. This film can also detect the presence of large quantities of sediment which may have been washed into streams or other water bodies from the surrounding, unprotected landscape.

APPENDIX 2.III

APPLICATIONS OF REMOTE SENSING IN JAPAN AND THE THIRD WORLD

Some remarkable work has already been carried out in Japan involving an estimation of population density in Tokyo districts by using the multispectral characteristics of urbanized areas, low populated areas such as forests and crop fields, and non-populated areas such as seas, lakes or mountains, in the two dimensional signature space of MSS 5* and MSS 7*, (Murai, 1974). The accuracy of the estimated density was approximately 90%, in spite of the existence of misregistration and low resolution. Misregistered points and misresolved points near boundaries of water bodies have been eliminated in the study. Murai concluded that estimation of population density from ERTS (LANDSAT) data of Tokyo will provide useful information for urban planning or regional development between censuses of the population taken every five years in Japan. Population density can be estimated with high accuracy from ERTS-1 data, acquired in the season when trees and crops are in good vigour because highly populated areas consisting of concrete, asphalt and roof, and low populated areas with a large area of trees or crops make different decision regions in the two signatures of MSS 5 and MSS 7.

In the field of Urban Climate, Tsuchiya (1974) of the Meteorological Research Institute of Tokyo used thermal infra-red remote sensing methods to determine patterns of air circulation which cause a very complicated flow of polluted air, resulting in several densely polluted spots

*MSS 5: Multispectral scanner, Band 5, Wavelength 600-700 nanometers (Lower red)

MSS 7: Multispectral scanner, Band 7, Wavelength 800-1100 nanometers (Near Infra-red) in the suburban area. He made a series of observations in 1971 and 1972 and found that open spaces, such as different types of woodlands and water bodies inside the urban area, have the lowest temperature during the summer, with the urban areas with dense buildings and highways being hotter than the suburban areas. The survey revealed that the highest temperature was in the factory area of downtown Tokyo. The study was supplemented by ground surveys and temperature differences have been recorded and analysed. Tsuchiya concluded that thermal imagery is relevant to several aspects of thermometric monitoring but does not indicate absolutely accurate temperatures.

The fact that cooling effects are reduced closer to banks of rivers, big green areas and natural forests, illustrates the environmental conservation effect of such spaces on urban atmospheric thermal pollution.

Information provided by the UNESCO centre (ITC) in Netherlands makes clear that the collection of data by means of aerial photography is practised in many cities in the Third World. These applications refer to ad hoc surveys, for example the detection of squatter settlements (Seoul, Korea), valuation of property, (Gizeh, Egypt), evaluation of site capacity and general land use maps (Constantine, Algeria), the estimation of the actual and expected number of inhabitants and percentage of built up areas (Nezahual-coyotl, Mexico), traffic studies (Mexico city, Mexico), selection and delineation of sample areas for socioeconomic household interviews, and transportation surveys (Jeddah, Saudi-Arabia).

Lack of population and housing information is a particular handicap in the rapidly urbanising areas of developing countries. Even the results of decennial censuses are of only limited value in cases where a population growth of fifty per cent between censuses may be considered normal, and examples of over a hundred per cent are not out of the question (Masser, 1974). In such circumstances it is necessary to explore survey methods suitable for updating census material. In these countries there is also a need for short term forecasting methods based on the extrapolation of trends derived from sequential data on population and housing. The idea of using aerial photographs for this purpose is not new, as we have seen, but the yield of methodological publications in this field is extremely meagre (Kraus et al, 1974). For these countries aerial photographs seem to be the only solution to overcome such major urban problems as land use management and population estimation caused by rapid urbanization.

APPENDIX 5.I

COMPUTER PROGRAMMES USED IN
THE COMPARISON OF BLACK AND
WHITE AND COLOUR INFRA-RED
AERIAL PHOTOGRAPHS.

```
      INTEGER DATABW(25,100),TITLE(10),TYPEBW(1),DATAIR(25,100),
     1 TYPEIR(1),IX(100),IY(100),IXIR(100),IYIR(100),DATAT(25,100),
     2 IDIF(25,100),NDIF(4),NAMDIF(4,4),LEGSYM(2),LTB(4,2)
      REAL AUBW(99),PCUBW(99),AGBW(20),PCGBW(20),AVL .(4),PCVBW(4)
      REAL AUIR(99),PCUIR(99),AGIR(20),PCGIR(20),AVIR(4),PCVIR(4)
      REAL AREAU(99),PCU(99),AREAG(20),PCG(20),AREAV(4),PCV(4)
      COMMON /UNITS/ IGRP(99),IVEG(99),NAMU(15,99),NAMGRP(10,20),
     1 NAMV(10,4),NG
      DATA LEGSYM/1,90/
      DATA LTB/4HIN C,4HIR, ,4HOUT ,4HB+W ,
     1          4HIN B,4H+W, ,4HOUT ,4HCIR /
      DATA NAMDIF/4HBOUN,4HDARI,4HES  ,4H    ,
     1             4HHOUS,4HES/G,4HARDE,4HNS  ,
     2             4HWITH,4HIN G,4HROUP,4HS   ,
     3             4HBETW,4HEEN ,4HGROU,4HPS  /
      CALL SETUP(S)
      CALL INPUT(1,DATABW,IX,IY,NC,IOX,IOY,IDX,IDY,TYPEBW,ICL,TITLE,NT)
      CALL INPUT(3,DATAT,IXIR,IYIR,NCIR,IOXIR,IOYIR,IDXIR,IDYIR,
     1 TYPEIR,ICLIR,TITLE,NT)
      IF  (IOX.NE.IOXIR.OR.IOY.NE.IOYIR.OR.ICL.NE.ICLIR
     2 .OR.IDX.NE.IDXIR.OR.IDY.NE.IDYIR.OR.NC.NE.NCIR)
     1 CALL ERSTOP(32HINCONSISTENT CONTROL INFORMATION ,32)
      MU=1
      DO 20 IBW=1,NC
      JX=IX(IBW)
      JY=IY(IBW)
      DO 21 IIR=MU,NC
      IF(JX.NE.IXIR(IIR).OR.JY.NE.IYIR(IIR)) GO TO 21
      DO 22 J=1,25
      DATAIR(J,IBW)=DATAT(J,IIR)
   22 CONTINUE
      IF(IIR.EQ.MU) MU=MU+1
      GO TO 20
   21 CONTINUE
      CALL ERSTOP(12HCARD MISSING ,12)
   20 CONTINUE
      CALL TOTALS(DATABW,NC,AUBW,PCUBW,AGBW,PCGBW,AOSBW,PCOSBW,ATBW,
     1 AVBW,PCVBW)
      CALL TOTALS(DATAIR,NC,AUIR,PCUIR,AGIR,PCGIR,AOSIR,PCOSIR,ATIR,
     1 AVIR,PCVIR)
      WRITE(6,2) TITLE,ICL,TYPEBW,TYPEIR
    2 FORMAT(1X,10A4/8H CLUSTER,I3,3X,14HDIFFERENCES    ,A3,3H - ,A3///
     1 28H AREA(SQ.KM.)  PERCENT  UNIT //)
      DO 30 I=1,99
      AREAU(I)=AUBW(I)-AUIR(I)
      PCU(I)=PCUBW(I)-PCUIR(I)
   30 CONTINUE
      DO 31 I=1,NG
      AREAG(I)=AGBW(I)-AGIR(I)
      PCG(I)=PCGBW(I)-PCGIR(I)
   31 CONTINUE
      DO 32 I=1,4
      AREAV(I)=AVBW(I)-AVIR(I)
      PCV(I)=PCVBW(I)-PCVIR(I)
   32 CONTINUE
      AREAOS=AOSBW-AOSIR
      PCOS=PCOSBW-PCOSIR
      AREAT=ATBW-ATIR
      PCT=100.0*AREAT/ATIR
      CALL PRNTOT(AREAU,PCU,AREAG,PCG,AREAOS,PCOS,AREAT,PCT,AREAV,PCV)
      NP=INT(25.0*ATIR+0.5)
      DO 40 I=1,NC
      DO 40 J=1,25
      IDIF(J,I)=0
      IUBW=DATABW(J,I)
      IUIR=DATAIR(J,I)
      IF(IUBW.EQ.IUIR) GO TO 40
      IF(IUBW.EQ.0.OR.IUIR.EQ.0) GO TO 41
      IF(IUBW.EQ.99.AND.IGRP(IUIR).EQ.1) GO TO 42
      IF(IUIR.EQ.99.AND.IGRP(IUBW).EQ.1) GO TO 42
      IF(IGRP(IUBW).EQ.IGRP(IUIR)) GO TO 43
      IDIF(J,I)=4
      GO TO 40
   41 IDIF(J,I)=1
      GO TO 40
```

```
42 IDIF(J,I)=2
   GO TO 40
43 IDIF(J,I)=3
40 CONTINUE
   DO 50 JDIF=1,4
   NDIF(JDIF)=0
   WRITE(6,1) (NAMDIF(I,JDIF),I=1,4),TYPEBW,TYPEIR
 1 FORMAT(15H1DIFFERENCES -  ,4A4//10H GRID REF. ,2(2X,A3)//)
   DO 51 I=1,NC
   DO 51 J=1,25
   IF(IDIF(J,I).NE.JDIF) GO TO 51
   NDIF(JDIF)=NDIF(JDIF)+1
   JJ=(J-1)/5
   JX=(IX(I)-JJ)*10+2*J-1
   JY=10*IY(I)-2*JJ+9
   WRITE(6,9) JX,JY,DATABW(J,I),DATAIR(J,I)
 9 FORMAT(1X,2I4,1X,2I5)
51 CONTINUE
   WRITE(6,3) NDIF(JDIF),NP
 3 FORMAT(//1X,I4,32H SUCH DIFFERENCES IN A TOTAL OF ,I4,7H POINTS )
50 CONTINUE
   CALL OPENGINOGP
   CALL LAYOUT(IOX,IOY,IDX,IDY,TITLE,NT,ICL,
  1 20HBOUNDARY DIFFERENCES ,20,2,4)
   CALL LEGEND(LEGSYM,2,LTB,4)
   CALL SHIFT2(40.0,40.0)
   DO 10 I=1,NC
   DO 10 J=1,25
   IF(IDIF(J,I).NE.1) GO TO 10
   ISYM=1
   IF(DATAIR(J,I).EQ.0) ISYM=90
   JJ=(J-1)/5
   JX=(IX(I)-IOX-JJ)*5+J
   JY=(IY(I)-IOY)*5+5-JJ
   CALL MAPSYM(ISYM,10.0*FLOAT(JX),10.0*FLOAT(JY))
10 CONTINUE
   CALL LAYOUT(IOX,IOY,IDX,IDY,TITLE,NT,ICL,
  1 16HREAL DIFFERENCES,16,2,4)
   CALL LEGEND(LEGSYM,2,NAMDIF(1,3),4)
   CALL SHIFT2(40.0,40.0)
   DO 11 I=1,NC
   DO 11 J=1,25
   IF(IDIF(J,I).LT.3) GO TO 11
   ISYM=1
   IF(IDIF(J,I).EQ.4) ISYM=90
   JJ=(J-1)/5
   JX=(IX(I)-IOX-JJ)*5+J
   JY=(IY(I)-IOY)*5+5-JJ
   CALL MAPSYM(ISYM,10.0*FLOAT(JX),10.0*FLOAT(JY))
11 CONTINUE
   CALL DEVEND
   STOP
   END
```

```
      SUBROUTINE LAYOUT(IOX,IOY,IDX,IDY,TITLE,NT,ICL,SUBTIT,NS,
     1 NLL,NWL)
      INTEGER TITLE(10),SUBTIT(5)
      REAL LBH,LBW
      COMMON /POSITN/ XCTC,YBTC,LBW,LBH
      DATA STDCHH,STDCHW/3.0,3.0/
      IF(NLL.GT.5.OR.NWL.GT.4) CALL ERSTOP(14HLEGEND TOO BIG ,14)
      ILBW=12*NWL+35
      LBW=FLOAT(ILBW)
      TITW=15.0*FLOAT(NT)*STDCHW/STDCHH
      TCW=AMAX0(8*NS,90,ILBW)
      FRW=AMAX1(TCW+FLOAT(50*(IDX+1)+90),TITW+60.0)
      SMW=FRW-90.0-TCW
      LBH=10.0*FLOAT(NLL)+25.0
      IF(NLL.EQ.0) LBH=0.0
      SMH=AMAX1(FLOAT(50*(IDY+1)),40.0*STDCHH/STDCHW+LBH)
      FRH=SMH+110.0
      CALL PICCLE
      CALL DEVPAP(FRW,FRH,1)
      CALL TRANSF(2)
      CALL FRAME(FRW,FRH)
      CALL CHASWI(1)
      CALL SCALE(3.0/STDCHW)
      CALL COORDS(IOX,IOY,IDX,IDY)
      CALL MOVTO2(0.5*(FRW-TITW),SMH+75.0)
      CALL SCALE(15.0/STDCHH)
      NWT=NT/4
      CALL CHAARR(TITLE,NWT,4)
      NLT=NT-4*NWT
      IF(NLT.NE.0) CALL CHAARR(TITLE(NWT+1),1,NLT)
      CALL TRANSF(2)
      XCTC=SMW+70.0+0.5*TCW
      YBTC=LBH+50.0
      YSTC=SMH+50.0-YBTC
      CALL MOVTO2(XCTC-40.0,0.833*YSTC+YBTC)
      CALL SCALE(8.0/STDCHW)
      CALL CHAHOL(9HCLUSTER*.)
      CALL CHAINT(ICL,3)
      CALL TRANSF(0)
      CALL MOVTO2(XCTC-FLOAT(4*NS),0.5*YSTC+YBTC)
      CALL TRANSF(1)
      NWS=NS/4
      CALL CHAARR(SUBTIT,NWS,4)
      NLS=NS-4*NWS
      IF(NLS.NE.0) CALL CHAARR(SUBTIT(NWS+1),1,NLS)
      CALL TRANSF(0)
      CALL MOVTO2(XCTC-48.0,0.167*YSTC+YBTC)
      CALL TRANSF(1)
      CALL CHAHOL(9HSCALE 1*.)
      CALL CHAASC(50)
      CALL CHAHOL(6H2000*.)
      CALL TRANSF(2)
      RETURN
      END
```

```
      SUBROUTINE LEGEND(LEGSYM,NLL,LEGTXT,NWL)
      INTEGER LEGTXT(NWL,NLL),LEGSYM(NLL)
      REAL LBW,LBH
      COMMON /POSITN/ XCTC,YBTC,LBW,LBH
      DATA STDCHH,STDCHW/3.0,3.0/
      CALL MOVTO2(XCTC-18.0,YBTC-14.0)
      CALL SCALE(6.0/STDCHW)
      CALL CHAHOL(8HLEGEND*.)
      CALL TRANSF(2)
      CALL SCALE(3.0/STDCHH)
      XBLS=XCTC-0.5*LBW+10.0
      YBLS=YBTC-20.0
      XBLT=XBLS+15.0
      YBLT=YBLS+3.0
      DO 2 I=1,NLL
      CALL TRANSF(0)
      YD=10.0*FLOAT(I)
      CALL MAPSYM(LEGSYM(I),XBLS,YBLS-YD)
      CALL MOVTO2(XBLT,YBLT-YD)
      CALL TRANSF(1)
      CALL CHAARR(LEGTXT(1,I),NWL,4)
    2 CONTINUE
      CALL TRANSF(2)
      CALL SHIFT2(XBLS-10.0,50.0)
      CALL FRAME(LBW,LBH)
      CALL TRANSF(2)
      RETURN
      END



      SUBROUTINE PRNTOT(AREAU,PCU,AREAG,PCG,AREAOS,PCOS,
     1 AREAT,PCT,AREAV,PCV)
      REAL AREAU(99),PCU(99),AREAG(20),PCG(20),AREAV(4),PCV(4)
      COMMON /UNITS/ IGRP(99),IVEG(99),NAMU(15,99),NAMGRP(10,20),
     1 NAMV(10,4),NG
      LG=NG-1
      DO 20 IG=1,LG
      DO 21 IU=1,99
      IF(IGRP(IU).NE.IG) GO TO 21
      WRITE(6,3) AREAU(IU),PCU(IU),IU,(NAMU(I,IU),I=1,15)
    3 FORMAT(2F11.2,I5,3X,15A4)
   21 CONTINUE
      WRITE(6,4)
    4 FORMAT(23H ---------------------- )
      WRITE(6,1) AREAG(IG),PCG(IG),(NAMGRP(I,IG),I=1,10)
    1 FORMAT(2F11.2,8X,10A4)
      WRITE(6,4)
      WRITE(6,7)
   20 CONTINUE
      WRITE(6,6)
    6 FORMAT(23H ====================== )
      WRITE(6,5) AREAOS,PCOS
    5 FORMAT(2F11.2,8X,16HTOTAL OPEN SPACE )
      WRITE(6,6)
      WRITE(6,7)
    7 FORMAT(//)
      DO 22 IU=1,99
      IF(IGRP(IU).NE.NG) GO TO 22
      WRITE(6,3) AREAU(IU),PCU(IU),IU,(NAMU(I,IU),I=1,15)
   22 CONTINUE
      WRITE(6,4)
      WRITE(6,1) AREAG(NG),PCG(NG),(NAMGRP(I,NG),I=1,10)
      WRITE(6,4)
      WRITE(6,7)
      WRITE(6,6)
      WRITE(6,8) AREAT,PCT
    8 FORMAT(2F11.2,8X,10HTOTAL AREA )
      WRITE(6,6)
      WRITE(6,7)
      DO 23 IV=1,4
      WRITE(6,1) AREAV(IV),PCV(IV),(NAMV(I,IV),I=1,10)
   23 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPUT(ICH,DATA,IX,IY,NC,IOX,IOY,IDX,IDY,
     1 TYPE,ICL,TITLE,NT)
      INTEGER DATA(25,100),TITLE(10),TYPE(1),IX(100),IY(100)
      COMMON /UNITS/ IGRP(99),IVEG(99),NAMU(15,99),NAMGRP(10,20),
     1 NAMU(10,4),NG
      NC=1
      READ(ICH,1) IOX,IOY,TYPE,ICL,NT,TITLE
    1 FORMAT(2I3,1X,A4,I2,1X,I2,1X,10A4)
   11 READ(ICH,2) IX(NC),IY(NC),(DATA(I,NC),I=1,25)
    2 FORMAT(26I3,I2)
      IF(IX(NC).LT.0) GO TO 20
      JX=IX(NC)
      JY=IY(NC)
      JDX=JX-IOX
      IF(JDX.LT.0) JDX=JDX+1000
      IF(IDX.LT.JDX) IDX=JDX
      JDY=JY-IOY
      IF(JDY.LT.0) JDY=JDY+1000
      IF(IDY.LT.JDY) IDY=JDY
      LC=NC-1
      IF(LC.EQ.0) GO TO 31
      DO 30 IC=1,LC
      IF(IX(IC).EQ.JX.AND.IY(IC).EQ.JY)
     1 CALL ERSTOP(13HDATA REPEATED ,13)
   30 CONTINUE
   31 DO 10 I=1,25
      IT=DATA(I,NC)
      IF(IT.EQ.0) GO TO 10
      IF(IGRP(IT).NE.0) GO TO 10
      WRITE(2,3) IT,JX,JY
    3 FORMAT(14H INVALID UNIT ,I2,17H FOUND IN SQUARE  ,2I3)
   10 CONTINUE
      NC=NC+1
      IF(NC.LE.100) GO TO 11
      READ(ICH,2) IE
      IF(IE.GE.0) CALL ERSTOP(13HTOO MUCH DATA ,13)
   20 NC=NC-1
      RETURN
      END
```

```
      SUBROUTINE ERSTOP(MESS,NC)
      REAL MESS(1)
      NW=(NC+7)/8
      WRITE(2,1) (MESS(I),I=1,NW)
    1 FORMAT(///23H ***** ERROR STOP ***** //1X,15A8)
      STOP 77
      END
```

```
      SUBROUTINE SETUP(ICH)
      COMMON /SYMBLS/ INDEX(99),INSTR(500),DX(500),DY(500)
      COMMON /UNITS/ IGRP(99),IVEG(99),NAMU(15,99),NAMGRP(10,20),
     1 NAMV(10,4),NG
      DO 20 I=1,99
      IGRP(I)=0
      IVEG(I)=0
   20 INDEX(I)=0
      READ(ICH,9) NG
    9 FORMAT(I2)
      IF(NG.GT.20) CALL ERSTOP(15HTOO MANY GROUPS,15)
      DO 30 I=1,NG
      READ(ICH,3) IG,(NAMGRP(J,I),J=1,10)
    3 FORMAT(I2,1X,10A4)
      IF(IG.NE.I) CALL ERSTOP(19HGROUPS OUT OF ORDER ,19)
   30 CONTINUE
      DO 32 IV=1,4
      READ(ICH,5) (NAMV(I,IV),I=1,10)
    5 FORMAT(10A4)
   32 CONTINUE
      READ(ICH,9) NU
      DO 31 IK=1,NU
      READ(ICH,4) IU,IGRP(IU),IVEG(IU),(NAMU(I,IU),I=1,15)
    4 FORMAT(I2,1X,I2,1X,I1,1X,15A4)
      IF(IGRP(IU).GT.NG.OR.IGRP(IU).LE.0)
     1 CALL ERSTOP(13HINVALID GROUP ,13)
      IF(IVEG(IU).GT.4) CALL ERSTOP(16HINVALID VEG.CODE ,16)
   31 CONTINUE
      ICOUNT=1
   10 READ(ICH,1) ISYM,NSTEP
    1 FORMAT(2I2)
      IF(ISYM.EQ.0) RETURN
      IF(INDEX(ISYM).NE.0) CALL ERSTOP(16HSYMBOL REDEFINED,16)
      INDEX(ISYM)=ICOUNT
      LP=ICOUNT+NSTEP-1
      IF(LP.GT.499) CALL ERSTOP(21HSYMBOL TABLE OVERFLOW,21)
      READ(ICH,2) (INSTR(I),DX(I),DY(I),I=ICOUNT,LP)
    2 FORMAT(5(I5,2F5.0))
      ICOUNT=LP+1
      INSTR(ICOUNT)=0
      ICOUNT=ICOUNT+1
      GO TO 10
      END



      SUBROUTINE MAPSYM(ISYM,X,Y)
      COMMON /SYMBLS/ INDEX(99),INSTR(500),DX(500),DY(500)
      CALL MOVTO2(X,Y)
      IF(ISYM.EQ.0) RETURN
      IF(ISYM.LT.0.OR.ISYM.GT.99) CALL ERSTOP(16HUNDEFINED SYMBOL ,16)
      ISTORE=0
      ILOC=INDEX(ISYM)
      IF(ILOC.LE.0) CALL ERSTOP(16HUNDEFINED SYMBOL ,16)
      GO TO 11
   10 ILOC=ILOC+1
   11 I=INSTR(ILOC)
      IF(I) 20,30,40
   40 IF(I.GT.4) CALL ERSTOP(19HINVALID SYMBOL CODE,19)
      GO TO (41,42,43,44), I
   41 CALL MOVBY2(DX(ILOC),DY(ILOC))
      GO TO 10
   42 CALL LINBY2(DX(ILOC),DY(ILOC))
      GO TO 10
   43 CALL ARCBY2(DX(ILOC),0.0,DY(ILOC),0.0,0)
      GO TO 10
   44 CALL ARCBY2(DX(ILOC),0.0,DY(ILOC),0.0,1)
      GO TO 10
   20 ISTORE=ILOC
      ILOC=INDEX(-I)
      GO TO 11
   30 IF(ISTORE.EQ.0) RETURN
      ILOC=ISTORE
      ISTORE=0
      GO TO 10
      END
```

```
      SUBROUTINE FRAME(DX,DY)
      CALL MOVTO2(1.0,1.0)
      DDX=DX-2.0
      DDY=DY-2.0
      CALL LINBY2(DDX,0.0)
      CALL LINBY2(0.0,DDY)
      CALL LINBY2(-DDX,0.0)
      CALL LINBY2(0.0,-DDY)
      RETURN
      END
```

```
      SUBROUTINE COORDS(IOX,IOY,IDX,IDY)
      IX=IOX-1
      IY=IOY-1
      NX=IDX+2
      NY=IDY+2
      MX=NX+1
      MY=NY+1
      DO 10 I=1,NX
      CALL TRANSF(0)
      CALL MOVTO2(50.0*FLOAT(I)-7.5,25.0)
      CALL TRANSF(1)
      CALL CHAINT(IX+I,4)
   10 CONTINUE
      CALL TRANSF(0)
      DO 11 I=1,NX
      CALL MOVTO2(50.0*FLOAT(MX-I),40.0)
      CALL LINBY2(0.0,-3.0)
   11 CONTINUE
      DO 20 I=1,NY
      CALL MOVTO2(10.0,50.0*FLOAT(I)-1.6)
      CALL TRANSF(1)
      CALL CHAINT(IY+I,4)
      CALL TRANSF(0)
   20 CONTINUE
      DO 21 I=1,NY
      CALL MOVTO2(40.0,50.0*FLOAT(MY-I))
      CALL LINBY2(-3.0,0.0)
   21 CONTINUE
      CALL TRANSF(2)
      RETURN
      END
```

```
      SUBROUTINE TOTALS(DATA,NC,AREAU,PCU,AREAG,PCG,AREAOS,PCOS,
     1 AREAT,AREAV,PCV)
      INTEGER DATA(2500)
      REAL AREAU(99),PCU(99),AREAG(20),PCG(20),AREAV(4),PCV(4)
      COMMON /UNITS/ IGRP(99),IVEG(99),NAMU(15,99),NAMGRP(10,20),
     1 NAMV(10,4),NG
      AREAT=0.0
      AREAOS=0.0
      DO 80 I=1,99
   80 AREAU(I)=0.0
      DO 81 I=1,20
   81 AREAG(I)=0.0
      DO 82 I=1,4
   82 AREAV(I)=0.0
      NP=NC*25
      DO 10 I=1,NP
      IU=DATA(I)
      IF(IU.EQ.0) GO TO 10
      AREAT=AREAT+0.04
      AREAU(IU)=AREAU(IU)+0.04
      J=IGRP(IU)
      AREAG(J)=AREAG(J)+0.04
      IF(J.NE.NG) AREAOS=AREAOS+0.04
      J=IVEG(IU)
      IF(J.NE.0) AREAV(J)=AREAV(J)+0.04
   10 CONTINUE
      DO 20 I=1,99
   20 PCU(I)=100.0*AREAU(I)/AREAT
      DO 21 I=1,20
   21 PCG(I)=100.0*AREAG(I)/AREAT
      PCOS=100.0*AREAOS/AREAT
      DO 22 I=1,4
   22 PCV(I)=100.0*AREAV(I)/AREAT
      RETURN
      END
```

```
      INTEGER DATA(25,100),TITLE(10),TYPE(4),IX(100),IY(100)
      REAL AREAU(99),PCU(99),AREAG(20),PCG(20),AREAV(4),PCV(4)
      DATA TYPE/4H****,4HPHOT,4HOGRA,3HPHY/
      CALL SETUP(5)
      CALL RLEASE(5)
      CALL INPUT(1,DATA,IX,IY,NC,IOX,IOY,IDX,IDY,TYPE,ICL,TITLE,NT)
      CALL RLEASE(1)
      CALL TOTALS(DATA,NC,AREAU,PCU,AREAG,PCG,AREAOS,PCOS,AREAT,
     1 AREAV,PCV)
      WRITE(6,2) TITLE,ICL,TYPE
    2 FORMAT(1X,10A4/8H CLUSTER,I3,3X,3A4,A3///
     1 28H AREA(SQ.KM.)  PERCENT  UNIT //)
      CALL PRNTOT(AREAU,PCU,AREAG,PCG,AREAOS,PCOS,AREAT,100.0,
     1 AREAV,PCV)
      CALL OPENGINOGP
      CALL LAYOUT(IOX,IOY,IDX,IDY,TITLE,NT,ICL,TYPE,15,0,0)
      CALL SHIFT2(40.0,40.0)
      DO 10 I=1,NC
      DO 10 J=1,25
      JJ=(J-1)/5
      JX=(IX(I)-IOX-JJ)*5+J
      JY=(IY(I)-IOY)*5+5-JJ
      CALL MAPSYM(DATA(J,I),10.0*FLOAT(JX),10.0*FLOAT(JY))
   10 CONTINUE
      CALL DEVEND
      STOP
      END
```

APPENDIX 5.II

COMPUTER TABLES PRODUCED FOR THE COMPARISON OF BLACK AND WHITE WITH COLOUR INFRA-RED PHOTOGRAPHY.

Tables

TABLE 5.II.1

PHOTOINTERPRETATION OF BLACK AND WHITE AERIAL PHOTOGRAPHS - STATISTICS

E.D. 68 / 1046
CLUSTER 5 D+U PHOTOGRAPHY

AREA (HA)	PERCENT	UNIT	
0,00	0.00	1	PRIVATE GARDENS - UNVEGETATED
1,12	4.91	2	PRIVATE GARDENS - SELF-MAINTAINED VEGETATION
2,28	10.00	3	PRIVATE GARDENS - MANAGED VEGETATION
0,76	3.33	4	PRIVATE GARDENS - POORLY MAINTAINED VEGETATION
4,16	18.25		PRIVATE GARDENS
0,00	0.00	6	PARKS - UNVEGETATED
0,00	0.00	7	PARKS - SELF-MAINTAINED VEGETATION
0,00	0.00	8	PARKS - MANAGED VEGETATION
0,00	0.00	9	PARKS - POORLY MAINTAINED VEGETATION
0,00	0.00	10	AMENITY OPEN SPACE - UNVEGETATED
0,32	1.40	11	AMENITY OPEN SPACE - SELF-MAINTAINED VEGETATION
0,00	0.00	12	AMENITY OPEN SPACE - MANAGED VEGETATION
0,00	0.00	13	AMENITY OPEN SPACE - POORLY MAINTAINED VEGETATION
0,32	1.40		PUBLIC GARDENS
0,80	3.51	15	STREETS LINED WITH TREES
0,80	3.51		LANDSCAPED OPEN SPACE FOR CIRCULATION
0,00	0.00	19	CHILDREN'S PLAYGROUNDS - UNVEGETATED
0,00	0.00	20	CHILDREN'S PLAYGROUNDS - SELF-MAINTAINED VEGETATION
0,00	0.00	21	CHILDREN'S PLAYGROUNDS - MANAGED VEGETATION
0,00	0.00	22	CHILDREN'S PLAYGROUNDS - POORLY MAINTAINED VEGETATION
0,48	2.11	23	PLAYFIELDS - UNVEGETATED
4,16	18.25	24	PLAYFIELDS - SELF-MAINTAINED VEGETATION
2,20	9.65	25	PLAYFIELDS - MANAGED VEGETATION
0,20	0.88	26	PLAYFIELDS - POORLY MAINTAINED VEGETATION
0,00	0.00	27	GOLF COURSES - UNVEGETATED
0,00	0.00	28	GOLF COURSES - SELF-MAINTAINED VEGETATION
0,00	0.00	29	GOLF COURSES - MANAGED VEGETATION
0,00	0.00	30	GOLF COURSES - POORLY MAINTAINED VEGETATION
0,20	0.88	31	EDUCATIONAL PLAY SPACES - UNVEGETATED
0,52	2.28	32	EDUCATIONAL PLAY SPACES - SELF-MAINTAINED VEGETATION
0,28	1.23	33	EDUCATIONAL PLAY SPACES - MANAGED VEGETATION
0,00	0.00	34	EDUCATIONAL PLAY SPACES - POORLY MAINTAINED VEGETATION
0,00	0.00	35	OTHER RECREATIONAL SPACE
8,04	35.26		PLAYSPACE, RECREATION, SPORTS
0,04	0.18	37	WOODLAND OR CLUMPS OF TREES - HEALTHY
0,00	0.00	38	WOODLAND OR CLUMPS OF TREES - DAMAGED
0,00	0.00	40	WOODLAND - UNVEGETATED AREAS
0,04	0.18		WOODLAND
0,08	0.35	41	ALLOTMENTS - AUXILIARY AND UNUSED SPACE
0,76	3.33	42	ALLOTMENTS - IN USE
0,52	2.28	43	ALLOTMENTS - NOT IN USE
1,36	5.96		ALLOTMENT GARDENS

0,00	0,00	46	AGRICULTURAL GRASSLAND AND FALLOW
0,04	0,18	47	AGRICULTURAL CROPLAND, HORTICULTURE, ORCHARDS
0,04	0,18		AGRICULTURE
0,00	0,00	48	ESTABLISHED HEATH
0,00	0,00	50	SHRUBS - HEALTHY
0,00	0,00	52	SHRUBS - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	54	SCRUB - HEALTHY
0,00	0,00	55	SCRUB - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	56	MOSSLAND
0,00	0,00	57	SAND DUNES
0,00	0,00	60	MARSHLAND
0,00	0,00		UNDISTURBED OPEN SITES
0,00	0,00	58	DERELICT AND SPOILED LAND - UNVEGETATED AREAS
0,00	0,00	59	DERELICT AND SPOILED LAND - VEGETATION WELL ESTABLISHED
0,00	0,00	60	DERELICT AND SPOILED LAND - VEGETATION NOT WELL ESTABLISHED
0,00	0,00	61	DERELICT AND SPOILED LAND - SCATTERED VEGETATION
0,00	0,00		DERELICT AND SPOILED LAND
0,08	0,35	62	NEGLECTED WASTE LAND - NO VEGETATION
2,44	10,70	63	NEGLECTED WASTE LAND - VEGETATION WELL ESTABLISHED
1,12	4,91	64	NEGLECTED WASTE LAND - VEGETATION NOT WELL ESTABLISHED
0,56	2,46	65	NEGLECTED WASTE LAND - SCATTERED VEGETATION
4,20	18,42		NEGLECTED WASTE LAND
0,00	0,00	68	OPEN WATER (RIVERS, CANALS, LAKES - NOT RESERVOIRS ETC.)
0,00	0,00		WATER BODIES
0,00	0,00	70	CEMETERIES
0,00	0,00		CEMETERIES
0,32	1,40	71	OTHER OPEN SPACE
0,32	1,40		OTHER OPEN SPACES
19,28	84,56		TOTAL OPEN SPACE
3,52	15,44	00	OTHER LAND USES
3,52	15,44		OTHER LAND USES (NOT OPEN SPACE)
22,80	100,00		TOTAL AREA
0,84	3,68		TOTAL UNVEGETATED OPEN SPACE
10,20	44,74		TOTAL SELF-MAINTAINED VEGETATION
5,60	24,56		TOTAL MANAGED VEGETATION
1,52	6,67		TOTAL POORLY MAINTAINED VEGETATION

TABLE 5.II.2

PHOTOINTERPRETATION OF COLOUR INFRA-RED AERIAL PHOTOGRAPHS - STATISTICS.

E.D. 68 / 1046
CLUSTER 5 CIR PHOTOGRAPHY

AREA(HA)	PERCENT	UNIT	
0,36	1,59	1	PRIVATE GARDENS - UNVEGETATED
1,32	5,82	2	PRIVATE GARDENS - SELF-MAINTAINED VEGETATION
2,48	10,93	3	PRIVATE GARDENS - MANAGED VEGETATION
0,68	3,00	4	PRIVATE GARDENS - POORLY MAINTAINED VEGETATION
4,84	21,34		PRIVATE GARDENS
0,00	0,00	6	PARKS - UNVEGETATED
0,00	0,00	7	PARKS - SELF-MAINTAINED VEGETATION
0,00	0,00	8	PARKS - MANAGED VEGETATION
0,00	0,00	9	PARKS - POORLY MAINTAINED VEGETATION
0,00	0,00	10	AMENITY OPEN SPACE - UNVEGETATED
0,08	0,35	11	AMENITY OPEN SPACE - SELF-MAINTAINED VEGETATION
0,16	0,71	12	AMENITY OPEN SPACE - MANAGED VEGETATION
0,04	0,18	13	AMENITY OPEN SPACE - POORLY MAINTAINED VEGETATION
0,28	1,23		PUBLIC GARDENS
0,88	3,88	15	STREETS LINED WITH TREES
0,88	3,88		LANDSCAPED OPEN SPACE FOR CIRCULATION
0,00	0,00	19	CHILDREN'S PLAYGROUNDS - UNVEGETATED
0,00	0,00	20	CHILDREN'S PLAYGROUNDS - SELF-MAINTAINED VEGETATION
0,00	0,00	21	CHILDREN'S PLAYGROUNDS - MANAGED VEGETATION
0,00	0,00	22	CHILDREN'S PLAYGROUNDS - POORLY MAINTAINED VEGETATION
0,68	3,00	23	PLAYFIELDS - UNVEGETATED
0,72	3,17	24	PLAYFIELDS - SELF-MAINTAINED VEGETATION
3,88	17,11	25	PLAYFIELDS - MANAGED VEGETATION
1,52	6,70	26	PLAYFIELDS - POORLY MAINTAINED VEGETATION
0,00	0,00	27	GOLF COURSES - UNVEGETATED
0,00	0,00	28	GOLF COURSES - SELF-MAINTAINED VEGETATION
0,00	0,00	29	GOLF COURSES - MANAGED VEGETATION
0,00	0,00	30	GOLF COURSES - POORLY MAINTAINED VEGETATION
0,20	0,88	31	EDUCATIONAL PLAY SPACES - UNVEGETATED
0,04	0,18	32	EDUCATIONAL PLAY SPACES - SELF-MAINTAINED VEGETATION
0,48	2,12	33	EDUCATIONAL PLAY SPACES - MANAGED VEGETATION
0,24	1,06	34	EDUCATIONAL PLAY SPACES - POORLY MAINTAINED VEGETATION
0,00	0,00	35	OTHER RECREATIONAL SPACE
7,76	34,22		PLAYSPACE, RECREATION, SPORTS
0,00	0,00	37	WOODLAND OR CLUMPS OF TREES - HEALTHY
0,00	0,00	38	WOODLAND OR CLUMPS OF TREES - DAMAGED
0,00	0,00	40	WOODLAND - UNVEGETATED AREAS
0,00	0,00		WOODLAND
0,12	0,53	41	ALLOTMENTS - AUXILIARY AND UNUSED SPACE
0,80	3,53	42	ALLOTMENTS - IN USE
0,32	1,41	43	ALLOTMENTS - NOT IN USE
1,24	5,47		ALLOTMENT GARDENS
0,00	0,00	46	AGRICULTURAL GRASSLAND AND FALLOW
0,12	0,53	47	AGRICULTURAL CROPLAND, HORTICULTURE, ORCHARDS
0,12	0,53		AGRICULTURE

0,00	0,00	43	ESTABLISHED HEATH
0,00	0,00	50	SHRUBS - HEALTHY
0,00	0,00	52	SHRUBS - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	54	SCRUB - HEALTHY
0,00	0,00	55	SCRUB - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	56	MOSSLAND
0,00	0,00	57	SAND DUNES
0,00	0,00	59	MARSHLAND
0,00	0,00		UNDISTURBED OPEN SITES
0,00	0,00	58	DERELICT AND SPOILED LAND - UNVEGETATED AREAS
0,00	0,00	59	DERELICT AND SPOILED LAND - VEGETATION WELL ESTABLISHED
0,00	0,00	60	DERELICT AND SPOILED LAND - VEGETATION NOT WELL ESTABLISHED
0,00	0,00	61	DERELICT AND SPOILED LAND - SCATTERED VEGETATION
0,00	0,00		DERELICT AND SPOILED LAND
0,08	0,35	62	NEGLECTED WASTE LAND - NO VEGETATION
1,60	7,05	63	NEGLECTED WASTE LAND - VEGETATION WELL ESTABLISHED
1,08	4,76	64	NEGLECTED WASTE LAND - VEGETATION NOT WELL ESTABLISHED
0,88	3,88	65	NEGLECTED WASTE LAND - SCATTERED VEGETATION
3,64	16,05		NEGLECTED WASTE LAND
0,00	0,00	68	OPEN WATER (RIVERS, CANALS, LAKES - NOT RESERVOIRS ETC.)
0,00	0,00		WATER BODIES
0,00	0,00	70	CEMETERIES
0,00	0,00		CEMETERIES
0,40	1,76	71	OTHER OPEN SPACE
0,40	1,76		OTHER OPEN SPACES
19,16	84,48		TOTAL OPEN SPACE
3,52	15,52	99	OTHER LAND USES
3,52	15,52		OTHER LAND USES (NOT OPEN SPACE)
22,68	100,00		TOTAL AREA
1,44	6,35		TOTAL UNVEGETATED OPEN SPACE
5,10	22,75		TOTAL SELF-MAINTAINED VEGETATION
7,92	34,92		TOTAL MANAGED VEGETATION
3,36	14,81		TOTAL POORLY MAINTAINED VEGETATION

TABLE 5.II.3

AREA DIFFERENCES BETWEEN THE
TWO SETS OF PHOTOGRAPHS AND
DIFFERENCES IN DECISION MAKING
DURING PHOTOINTERPRETATION.

E.D. 68 / 1046
CLUSTER 5 DIFFERENCES B+W - CIR

AREA (HA)	PERCENT	UNIT	
-0,36	-1,59	1	PRIVATE GARDENS - UNVEGETATED
-0,20	-0,91	2	PRIVATE GARDENS - SELF-MAINTAINED VEGETATION
-0,20	-0,93	3	PRIVATE GARDENS - MANAGED VEGETATION
0,08	0,34	4	PRIVATE GARDENS - POORLY MAINTAINED VEGETATION
-0,68	-3,09		PRIVATE GARDENS
0,00	0,00	6	PARKS - UNVEGETATED
0,00	0,00	7	PARKS - SELF-MAINTAINED VEGETATION
0,00	0,00	8	PARKS - MANAGED VEGETATION
0,00	0,00	9	PARKS - POORLY MAINTAINED VEGETATION
0,00	0,00	10	AMENITY OPEN SPACE - UNVEGETATED
0,24	1,05	11	AMENITY OPEN SPACE - SELF-MAINTAINED VEGETATION
-0,16	-0,71	12	AMENITY OPEN SPACE - MANAGED VEGETATION
-0,04	-0,18	13	AMENITY OPEN SPACE - POORLY MAINTAINED VEGETATION
0,04	0,17		PUBLIC GARDENS
-0,08	-0,37	15	STREETS LINED WITH TREES
-0,08	-0,37		LANDSCAPED OPEN SPACE FOR CIRCULATION
0,00	0,00	19	CHILDREN'S PLAYGROUNDS - UNVEGETATED
0,00	0,00	20	CHILDREN'S PLAYGROUNDS - SELF-MAINTAINED VEGETATION
0,00	0,00	21	CHILDREN'S PLAYGROUNDS - MANAGED VEGETATION
0,00	0,00	22	CHILDREN'S PLAYGROUNDS - POORLY MAINTAINED VEGETATION
-0,20	-0,89	23	PLAYFIELDS - UNVEGETATED
3,44	15,07	24	PLAYFIELDS - SELF-MAINTAINED VEGETATION
-1,68	-7,46	25	PLAYFIELDS - MANAGED VEGETATION
-1,32	-5,82	26	PLAYFIELDS - POORLY MAINTAINED VEGETATION
0,00	0,00	27	GOLF COURSES - UNVEGETATED
0,00	0,00	28	GOLF COURSES - SELF-MAINTAINED VEGETATION
0,00	0,00	29	GOLF COURSES - MANAGED VEGETATION
0,00	0,00	30	GOLF COURSES - POORLY MAINTAINED VEGETATION
0,00	-0,00	31	EDUCATIONAL PLAY SPACES - UNVEGETATED
0,48	2,10	32	EDUCATIONAL PLAY SPACES - SELF-MAINTAINED VEGETATION
-0,20	-0,89	33	EDUCATIONAL PLAY SPACES - MANAGED VEGETATION
-0,24	-1,06	34	EDUCATIONAL PLAY SPACES - POORLY MAINTAINED VEGETATION
0,00	0,00	35	OTHER RECREATIONAL SPACE
0,28	1,05		PLAYSPACE, RECREATION, SPORTS
0,04	0,18	37	WOODLAND OR CLUMPS OF TREES - HEALTHY
0,00	0,00	38	WOODLAND OR CLUMPS OF TREES - DAMAGED
0,00	0,00	40	WOODLAND - UNVEGETATED AREAS
0,04	0,18		WOODLAND
-0,04	-0,18	41	ALLOTMENTS - AUXILIARY AND UNUSED SPACE
-0,04	-0,19	42	ALLOTMENTS - IN USE
0,20	0,87	43	ALLOTMENTS - NOT IN USE
0,12	0,50		ALLOTMENT GARDENS

0,00	0,00	46	AGRICULTURAL GRASSLAND AND FALLOW
-0,08	-0.35	47	AGRICULTURAL CROPLAND, HORTICULTURE, ORCHARDS
-0,08	-0,35		AGRICULTURE
0,00	0,00	48	ESTABLISHED HEATH
0,00	0,00	50	SHRUBS - HEALTHY
0,00	0,00	52	SHRUBS - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	54	SCRUB - HEALTHY
0,00	0,00	55	SCRUB - DAMAGED OR DEFICIENT FOLIAGE
0,00	0,00	56	MOSSLAND
0,00	0,00	57	SAND DUNES
0,00	0,00	69	MARSHLAND
0,00	0,00		UNDISTURBED OPEN SITES
0,00	0,00	58	DERELICT AND SPOILED LAND - UNVEGETATED AREAS
0,00	0,00	59	DERELICT AND SPOILED LAND - VEGETATION WELL ESTABLISHED
0,00	0,00	60	DERELICT AND SPOILED LAND - VEGETATION NOT WELL ESTABLISHED
0,00	0,00	61	DERELICT AND SPOILED LAND - SCATTERED VEGETATION
0,00	0,00		DERELICT AND SPOILED LAND
0,00	-0,00	62	NEGLECTED WASTE LAND - NO VEGETATION
0,84	3.65	63	NEGLECTED WASTE LAND - VEGETATION WELL ESTABLISHED
0,04	0.15	64	NEGLECTED WASTE LAND - VEGETATION NOT WELL ESTABLISHED
-0.32	-1.42	65	NEGLECTED WASTE LAND - SCATTERED VEGETATION
0,56	2.37		NEGLECTED WASTE LAND
0,00	0,00	68	OPEN WATER (RIVERS, CANALS, LAKES - NOT RESERVOIRS ETC.)
0,00	0,00		WATER BODIES
0,00	0,00	70	CEMETERIES
0,00	0,00		CEMETERIES
-0,08	-0.36	71	OTHER OPEN SPACE
-0,08	-0.36		OTHER OPEN SPACES
0,12	0,08		TOTAL OPEN SPACE
0,00	-0,08	99	OTHER LAND USES
0,00	-0,08		OTHER LAND USES (NOT OPEN SPACE).
0,12	0,53		TOTAL AREA
-0,60	-2,66		TOTAL UNVEGETATED OPEN SPACE
5,04	21,99		TOTAL SELF-MAINTAINED VEGETATION
-2,32	-10.36		TOTAL MANAGED VEGETATION
-1,84	-8.15		TOTAL POORLY-MAINTAINED VEGETATION

DIFFERENCES - WITHIN GROUPS

GRID REF.	B+W	CIR
26238781	99	2
26258781	2	99
26278781	2	99
26198775	3	99
26158773	3	99
26258775	99	4
26278775	99	2
26258773	99	3
26298771	3	99
26018765	99	4
26298769	99	1
26378767	99	3
26338763	99	3
25958759	99	1
25958757	3	99
25978757	4	99
25998757	99	3
25998755	4	99
25978753	99	3
25998753	99	1
25978751	99	3
25998751	99	1
26018757	99	2
26018755	4	99
25958743	2	99
25938741	99	2
25958741	3	99
26438749	3	99
26458745	3	99
26458743	99	3
25938739	99	4
25958737	99	1
26058733	4	99
26078731	99	3
26098731	3	99
26158733	2	99
26198733	2	99
26118731	3	99
26258733	99	3
26278733	99	3
26338735	3	99
26378735	99	4
26318733	99	3
26418737	2	99
26438737	2	99
26418735	3	99
26278785	3	2
26358783	63	64
26318781	63	65
26338781	63	64
26098771	2	3
26198779	2	3
26198773	4	3
26218777	3	4
26238771	2	4
26318777	2	3
26338775	3	4
26318773	2	3
26338773	2	3
26378773	2	3
26358771	3	2
26398771	2	1
25998761	3	4
26098767	2	3
26058765	4	2
26098765	3	4
26018763	3	1
26038763	4	3
26018761	3	2
26038761	3	2
26118769	3	2
26138769	24	26
26178769	24	26
26198769	24	25
26158767	24	23
26178767	24	25
26198767	24	25
26118765	24	23
26138765	24	25
26158765	24	26
26338751	24	26
26358751	24	25
26378751	24	25
26418757	63	64
26438755	64	63
26418753	64	65
26438753	64	63
26458753	65	63
25958749	63	65
25998747	64	63
25938745	3	2
25958745	3	2
25998745	64	63
25998743	63	65
26058749	33	32
26098749	43	42
26058747	32	33
26078747	32	33
26098747	42	43
26018745	64	63
26038745	32	31
26078745	32	33
26018743	64	63
26038743	63	64
26058743	33	34
26078743	32	33
26098743	32	33
26038741	64	65
26058741	33	31
26078741	32	33
26098741	32	34
26118749	42	41
26138749	43	42
26178749	25	24
26198749	24	25
26118747	42	43
26158747	43	42
26158745	43	42
26118743	32	34
26158743	42	43
26118741	32	33
26178741	43	42
26198741	43	42
26218749	24	25
26238749	25	26
26258749	24	26
26298749	24	25
26218747	24	25
26238747	25	26
26278747	25	26
26218745	24	25
26258745	25	26
26278745	24	26
26298745	24	25
26218743	24	25
26258743	24	25
26278743	25	24
26298743	24	25
26218741	23	24
26238741	24	25
26278741	26	25
26298741	26	25
26318749	24	25
26338749	25	26
26358749	24	25
26398749	24	25
26318747	24	25
26358747	24	25
26398747	25	26
26318745	26	25
26358745	25	26
26378745	26	25
26398745	24	25
26338743	24	26
26378743	25	26
26398743	24	25
26318741	25	26
26338741	25	26
26358741	25	26
26378741	24	25
26398741	24	25
26418745	24	25
26418743	24	25
26438743	2	3
26418741	24	25
25978739	4	3
25998739	64	63
26178765	24	26
26198765	24	26
26138763	24	25
26158763	24	26
26178763	24	23
26198763	24	25
26118761	24	26
26138761	24	25
26158761	24	25
26198761	25	26
26218769	3	4
26258769	64	63
26218767	63	65
26298767	64	63
26218765	25	24
26238765	64	65
26278765	64	65
26278763	64	65
26298763	64	65
26218761	25	26
26258761	65	64
26278761	63	64
26338769	3	1
26398769	3	2
26338767	4	2
26358765	4	3
26398765	65	63
26318763	4	3
26378763	63	64
26318761	24	25
26338761	65	64
26378761	65	64
26398761	65	64
26418763	64	65
26418761	64	65
25938751	65	63
26038759	63	64
26078759	63	64
26038757	63	65
26058757	62	64
26078757	63	64
26038755	3	2
26058755	63	64
26038753	3	2
26018751	3	2
26038751	32	33
26058751	32	34
26138759	24	23
26158759	24	25
26198759	25	26
26138757	24	23
26158757	24	23
26178757	24	25
26118755	23	25
26158755	24	25
26198755	24	25
26138753	24	23
26158753	24	26
26178753	24	25
26158751	24	25
26198751	24	25
26238759	25	26
26298759	25	26
26258757	25	24
26298757	24	25
26278755	25	26
26218753	25	26
26298753	24	26
26218751	24	26
26238751	25	26
26258751	24	25
26298751	24	25
26318759	24	25
26358759	63	64
26398759	63	64
26318757	24	25
26338757	24	25
26358757	63	64
26378757	63	64
26338755	24	25
26358755	24	26
26378755	63	64
26398755	63	64
26318753	24	26
26338753	24	26
26358753	24	25
26318751	25	26
25998737	63	65
26038737	64	63
26058737	63	65
26078735	11	12
26078733	2	3
26198739	43	42
26158737	11	12
26178737	43	41
26138735	11	13
26158735	11	12
26118733	3	2
26138733	4	2
26218739	43	42
26238739	24	25
26298739	24	25
26238737	24	23
26258737	24	25
26278737	23	24
26298737	24	25
26218735	2	3
26298731	11	12
26338739	24	25
26358739	24	25
26398739	24	25
26318737	24	25
26338737	24	25
26358737	24	25
26318735	4	2
26398735	2	3
26418739	24	25
26438739	24	25

285 SUCH DIFFERENCES

IN A TOTAL OF 570 POIN

DIFFERENCES - BOUNDARIES

GRID REF.	B+W	CIR
26378785	63	0
25918745	99	0
25918743	0	99
25938737	0	99
26478739	99	0
26478737	3	0
26438735	99	0

7 SUCH DIFFERENCES IN A TOTAL OF 570 POINTS

DIFFERENCES - BETWEEN GROUPS

GRID REF.	B+W	CIR
26298787	71	15
26298785	63	1
26118773	2	15
26298779	47	3
26218773	15	3
26318779	63	47
26338779	63	47
26358779	63	3
26338777	63	47
26358777	63	3
26378775	37	3
25958761	99	15
26038765	63	99
26058763	15	2
26058761	99	71
26078761	24	99
26138767	24	2
26238769	63	3
26378769	11	99
26398767	65	4
26378765	65	4
25938755	4	71
25958755	64	3
25938753	64	71
26018759	63	4
26078755	41	62
26058753	42	15
26138751	24	43
26378759	63	99
26378753	63	25
26418751	63	99
26438751	63	99
25978749	99	63
25978747	99	63
25978745	99	65
25978743	4	63
25978741	63	2
26018749	32	99
26078749	42	34
26198743	24	43
26138741	42	34
26058739	31	63
26098739	71	99
26098735	99	11
26118739	31	99
26198737	43	65
26118735	11	71
26178735	64	2
26218737	64	24
26258735	24	2
26278735	24	3
26298733	24	2
26378737	24	3

53 SUCH DIFFERENCES IN A TOTAL OF 570 POINTS

APPENDIX 6.I

PERFORMANCE OF THE SEVEN MERSEYSIDE FAMILIES ON EACH OF THE FORTY GROUPING CRITERIA

(The score for each family is expressed as a percentage of the mean score for the county)

	Family						
	1a	1b	2	3	4	5	6
Professional/managerial SEGs	199	201	93	21	38	44	204
Non-manual SEGs	150	136	127	50	71	73	140
Skilled manual SEGs	75	92	89	71	117	115	67
Semi-skilled SEGs	57	47	110	136	128	125	70
Unskilled SEG	29	16	80	314	136	134	45
Male unemployment	46	28	141	245	139	101	71
Male sickness	55	29	146	268	116	118	92
HNC or degree	211	217	135	12	28	30	198
Cars per person	156	179	84	18	63	71	139
Owner occupation	178	212	78	6	24	92	127
Council housing	15	14	22	241	231	38	8
Privately rented unfurnished	94	34	200	42	24	236	165
Privately rented furnished	105	32	810	36	17	61	503
One or two room dwellings	52	17	562	198	93	52	345
Seven or more room dwellings	225	87	192	24	42	50	210
Overcrowding over 1.5 pp/room	17	13	180	442	160	63	56
Underoccupancy under 0.5 pp/room	145	91	93	60	69	111	141
Shared dwellings	111	12	666	62	32	67	558
No inside wc	30	12	61	47	43	328	29
Students	137	111	162	56	91	63	103
Married women activity rate	92	106	104	102	104	99	84
Employment in manufacturing/mining	69	100	80	90	117	117	49
Employment in services, dist'n, govt.	130	109	116	95	82	83	155
Work trip on foot	69	52	100	190	94	146	137
Work trip by bus	69	51	112	136	134	105	33
Work trip by car	143	186	81	19	70	71	120
2 adults, five dependent children	46	43	67	249	177	58	27
Single non pensioner household	96	57	316	130	69	109	178
Five year migrant households	93	130	129	90	102	78	144
New Commonwealth born	107	29	230	194	84	117	55
Aged 0-4	79	131	99	98	96	114	58
Aged 5-14	84	110	76	117	120	88	57
Aged 15-24	84	77	135	116	116	95	78
Aged 25-44	96	146	97	88	90	99	75
Aged 45-64	114	75	94	96	97	104	118
Aged 65+	137	53	109	87	77	110	234
Marriage rate	100	121	87	81	96	101	89
Rooms/person*	122	100	101	71	88	106	119
Household size*	92	105	81	111	111	95	81
Dwelling size*	120	105	80	88	100	102	80

*Estimates

APPENDIX 6.II

DETAILED INTERPRETATION OF EACH OF THE SEVEN FAMILIES.

Areas of established high status, (1a), (22% of county), are found in an intermediate ring between the inner areas of the conurbation and the recent post war peripheral growth. This type is found in areas which developed rapidly during the inter-war period and comprises large amounts of fairly large semi-detached dwellings, built at low densities. Some areas of rather older housing at higher densities are included, dating perhaps to the Edwardian period. The three largest concentrations are found in south Liverpool (Childwall, Aigburth, Allerton, Church and Woolton wards), in Wallasey and in Crosby. There is also a substantial amount of this type of housing in parts of West Wirral and in Southport. The type is significantly absent in the Knowsley and St. Helens districts and appears infrequently in those parts of the outer conurbation where development is recent, such as Aintree/Maghull and Bebington.

Areas of modern high status development, (1b), (12% of county), are found mostly on the periphery of the county. These areas have poor accessibility and high dependence on private transport and attract mostly young families to houses both more modern but less spacious and built to a higher residential density than the type of area designed for inter-war high status groups. The type is conspicuously infrequent in Liverpool but is most extensive in St. Helens district, especially in commuting centres such as Ashton South, Billinge, Rainford and Rainhill. Other areas with large amounts of this type are Aintree/Maghull and Formby. Southport consists mostly of older established high status areas except on the extreme northern and southern peripheries. In the Wirral, this type is extensive in Eastham and in parts of Bebington, in Irby and Pensby and in the Upton-Oxton-Moreton area. The type is not found significantly in Hoylake/West Kirby or in Wallasey.

The rooming house area, (2) (5% of county) is characterised by dwellings constructed for an earlier generation of high status families. Typical of this type of area are very large houses, often semi-detached villas with more than two storeys, which are now too large for single family occupation. Many of these have been converted to flatlets or bedsits attractive to students, other young and elderly single persons, immigrants or others with few well-developed family or community ties. Others have been converted into hotels and boarding houses, hostels and residential homes for old people. Because such areas were often originally built to very high environmental standards and in attractive parts of the conurbation, they also tend to accommodate a residual high status population.

The largest single concentration of this type is to be found in South Liverpool stretching from Granby/Abercromby to Princes and Sefton Parks. It is also found around Newsham Park and around Stanley Park, extensively in Claughton and Grange wards in Birkenhead, in New Brighton and in central Southport. All of these areas represent areas of pre-1914 high status. It is significant how closely associated this type is with the distribution of Victorian parks. This family is entirely absent from the Knowsley and St. Helens districts.

Inner/deprived council estates, (3), (4% of county), are closely associated with accessibility to dock employment. The largest concentration is in inner Liverpool, corresponding approximately to the limits of areas of redevelopment, as distinct from greenfield council housing, and stretching from St. James ward along the dockfront to Sandhills and Vauxhall wards. A smaller concentration is found close to the docks in Central Bootle. Other enumeration districts belonging to this type are found in St. James ward in Birkenhead, in Christchurch ward in Crosby and in Princess ward in Huyton. This type of environment is distinguished from outer council estates by its especially low social status and by its much worse performance on most measures of deprivation such as overcrowding, car ownership, unemployment, social class and large families. These are areas of very serious poverty, poor educational attainment, and lack of skills, often dependent on declining employment sectors and tending to accommodate either problem families or those unable for financial or other reasons to gain access to the more desirable estates on the metropolitan periphery.

Outer council estates, (4), (33% of county) are the most extensive of the seven families and are characterised by areas almost exclusively owned by the local authority. These areas are often found in the outer parts of the county and hence experience problems of accessibility to shopping, employment and recreation, though amenities and local environmental standards are high. This type of environment is characterised by large families and by a large proportion of children in the population, especially those of school age. Knowsley is the district with the largest proportion of this type and there are significant concentrations in outer Liverpool at Speke, Childwall Valley and in the Norris Green/Dovecot area. In the Wirral the type is most strongly represented in the mid-Wirral area, including much of Oxton, Upton and Moreton wards. St. Helens has rather less of this type than might be expected from its socioeconomic profile, and in Sefton the type occurs significantly only in the outer parts of the old Bootle CB.

Areas of <u>older terraced housing</u>, (5), (22% of county), are found mostly in the inner and older parts of the county but not in the very centre where the quality of older housing has resulted in the replacement of older terraces with publicly owned housing. This type of development consists of dwellings, many with four rooms, some with a back addition and bay window, arranged in terraced streets separated by narrow back alleys. These areas contain a significant number of owner occupiers, many of them young married couples with pre-school age children, as well as the majority of unfurnished private tenants. Besides young families, there is often a substantial concentration of elderly persons, many of them living at very low room densities although overall housing densities are higher for this type than for any other. The district with largest concentrations of this type of housing is St. Helens where it comprises the bulk of the inner areas as well as the core of smaller industrial settlements such as Haydock and Newton-le-Willows. The type is also extensive in an arc stretching from Dingle ward in Liverpool through Picton, Tuebrook, Anfield and Westminster wards to Stanley and Linacre in Bootle and Christchurch in Crosby. Within this arc lie areas of inner council estates, currently extending outwards rapidly. The outer margins of this type merge into the older terraced parts of family no. 1, characterised by better amenities and more extensive owner occupation. On the Wirral, this type is extensive in the lower and older parts of Birkenhead and in the Seacombe district of Wallasey. The type also occurs extensively in the old port settlements of Port Sunlight and Garston (Liverpool) and in Prescot.

Retirement areas, (6), (2% of county), form the smallest of the seven families and can in many ways be considered a variant on the established high status family. The family is almost entirely restricted to two areas, Southport and Hoylake/West Kirby, which function as regional retirement centres as well as local commuter areas. Within both areas the type is found close to the seafront, enumeration districts belonging to established high status areas tend to lie further and recent high status estates furthest inland.

APPENDIX 6.III

DETAILED DESCRIPTION OF THE CHARACTERISTICS OF THE TWENTY SEVEN P.R.A.G. CLUSTERS.

SOCIAL AREA ANALYSIS

Characteristics of P.R.A.G. Clusters

Family 1a - Established High Status (22% of County)

Cluster One (Very high Status)

Clusters one and two form the highest status part of the county. This cluster experiences all the features of high status, especially those variables which relate to a small minority of the population, such as workers with HNC or degree and households with two or more cars.

Cluster Two (Top areas)

This cluster forms the "best" part of the county. Two thirds of households belong to the professional/managerial grouping, a third of workers have HNC or degree and a third of all households own two or more cars. All but 10% of households are owner-occupiers.

Cluster Three (Edwardian terraces)

This cluster is differentiated from the family as a whole by its lower socioeconomic status. The housing is somewhat earlier than that of the other high status clusters, is built to higher densities and often has a small residue of privately rented accommodation. On measures of deprivation, such as sickness, unemployment or overcrowding, this cluster does not differ significantly from the family as a whole.

Cluster Four (Inter-war semis)

This cluster is differentiated from the family as a whole by its lower socioeconomic status. It differs from cluster three in being further from the city centre, semi-detached housing being more modern than terraced. Many of the original settlers in this type of area are now reaching retirement and there is, as yet, little sign of the inflow of younger families which is observed in cluster three.

Family 1b - Modern Peripheral Estates (12% of county)

Cluster Five (modern peripheral estates)

This cluster forms the outermost edge of the high status areas. It contains mostly post-war owner-occupied estates and differs from the family as a whole by an above-average household size, resulting from the large proportion of households with dependent children.

Family 2 - Rooming House (5% of county)

Cluster Six (high status rooming house)

This cluster consists of those parts of the rooming house family which have the highest socioeconomic status. Features of this cluster are the relative absence of shared dwellings, the relatively low incidence of serious over-crowding and the large proportion of elderly persons in the population.

Cluster Seven (intensive sub-division)

This cluster acts as a buffer between the high status rooming house cluster (cluster six) and the rooming house clusters which experience acute social stress (clusters 8 and 10). This type of area contains an exceptionally high proportion of single non-pensioner households and of one and two room dwellings. A large proportion of the sub-divided properties are inhabited by young, transient, single people, such as students.

Cluster eight (Abercrombie/Princes Avenue)

This cluster comprises a very small proportion of the county and locationally is highly concentrated along Princes Avenue and Upper Parliament Street. Although the socioeconomic profile of the cluster is not significantly below that of the county, the cluster experiences some of the most acute concentrations of overcrowding, sickness and unemployment. Another striking feature of the cluster is the very high concentration of New Commonwealth immigrants. The problems of this type of area stem from its function as a residual housing area for a transient population.

Cluster nine (moderate sub-division)

This cluster appears to comprise areas where the process of sub-division is less advanced or areas containing pockets of larger sub-divided housing intermingled with smaller terraced housing. It is distinguished from the rooming house family as a whole by having lower concentrations of distinctive rooming house features. Thus the average dwelling size is larger, there are fewer small dwellings and young single people, less privately rented furnished accommodation and fewer shared dwellings.

Cluster Ten (Granby)

Like cluster eight, this cluster tends to experience rates of social deprivation much higher than might be expected from their socioeconomic profiles. The cluster is centred on the Granby ward and much of the area consists of small terraced houses. Despite the large amount of shared accommodation and the large proportions of single non-pensioner households, residential mobility in this type of area is much lower than in the rest of the rooming house family. The cluster has a very high incidence of children in care, illegitimacy, delinquency and low reading ability.

Family 3 - Inner Estates (4% of county)

<u>Cluster eleven (unstable inner estates)</u>

This type of inner council estate is differentiated from the remainder of the family by its high concentration of deprived groups and its tendency towards family instability. The cluster has high rates of sickness, over-crowding and unemployment. It also has very many more New Commonwealth immigrants and single parent families. Cluster eleven appears to experience the problems of both the inner rooming house area and of the inner area council estates.

<u>Cluster twelve (dockers' estates)</u>

This cluster consists almost exclusively of council housing, much of it dating from the inter-war period. Compared with the other inner area council estates, cluster twelve has lower status, having the lowest car and house ownership in the county, the fewest workers with educational qualifications and the highest proportions of semi-skilled and unskilled households. However, despite the low socio-economic profile of this type of area, it is by no means the part of the county with the most serious housing problems or lack of social cohesion.

Cluster thirteen (other inner estates)

This is a relatively small cluster which contains a number of recent council developments on the edge of the inner council estates family. The cluster can be differentiated from the family as a whole by its somewhat higher socioeconomic status. It contains particularly few one, two and three bedroom dwellings and suffers from high levels of sickness and unemployment.

Family 4 - Outer Estates (33% of county)

Cluster fourteen (small flats for the elderly)

This cluster consists mostly of relatively new council developments, often in the form of tower blocks and containing small dwellings and concentrations of small, often elderly households. The socioeconomic profile of this cluster is lower than that of the family as a whole and it has the largest proportion of unskilled workers and unemployed workers in the family. There is a somewhat higher proportion of New Commonwealth born residents than in the outer estates as a whole.

Cluster fifteen (areas of mixed tenure 1)

This cluster is very small and contains many areas with owner-occupied as well as council housing. This type of area displays a number of the features of the high status family with its larger than average share of non-manual workers, a fairly elderly age structure and relatively few unskilled, sick or unemployed workers.

Cluster sixteen (areas of mixed tenure 2)

This cluster is another small one of mixed tenure with owner-occupiers and council tenants being equally divided. The only feature on which the cluster can be differentiated from the family as a whole is by its very large proportion of skilled manual heads of household.

Cluster seventeen (older high quality estates)

This cluster comprises mostly low density, semi-detached council housing dating from the 1930's and the immediate post-war period. With the exception of clusters 15 and 16 this cluster has the highest status and fewest deprivations of all council housing estates. It contains a relatively small proportion of sick, unemployed or unskilled workers and its lower than average level of car ownership may be accounted for by its elderly age structure.

Cluster eighteen (post-war estates)

Cluster eighteen is in many ways the most deprived of the outer council estates, since it contains a very large proportion of unskilled workers, the largest proportion of seriously over-crowded households and households lacking the use of a car and of unemployed men. Other significant features are the very large numbers of very large families, the very high proportions of school age children and the high dependence on public transport for the journey to work.

Cluster nineteen (early post-war estates)

Cluster nineteen, like cluster eighteen, consists exclusively of post-war council developments on the periphery of the county. This is another cluster which experiences serious problems, the performance on welfare indicators being less favourable than on the outer council estates as a whole, though in general somewhat more favourable than in cluster eighteen.

Cluster twenty (new estates)

The variable which most strongly differentiates both cluster twenty and twenty-one from the rest of the family is the high number of five year migrants. Another striking feature of this type of area is the high proportion of population in the pre-school age group. The lack of serious over-crowding in cluster twenty reflects the fact that the fit between households and dwellings tends to be more efficient just after a population has moved into a new area.

Cluster twenty-one (large family estates)

Like cluster twenty, cluster twenty-one is concentrated on the extreme periphery of the county. Like cluster twenty it is differentiated from the family as a whole by extremely high rates of residential mobility. The distinguishing features of this cluster relate to age structure and household composition. Cluster twenty-one has a larger share of very large families and also more children of school age.

Family 5 - Older Terrace (22% of county)

Cluster twenty-one (good quality terraces)

This cluster is to some extent transitional between areas of Victorian terraced housing and the high status owner-occupied family. The socioeconomic profile of the cluster is similar to the county mean. The most over-represented socioeconomic groups are skilled and semi-skilled manual workers. This type of area performs more favourably than the county as a whole on almost all measures of welfare.

Cluster twenty-three (intermediate quality terraces)

In terms of social character this cluster deviates only marginally from the pattern of the family as a whole. There are only two features which differentiate this type of area from the rest of the family. The socioeconomic profile has a rather larger concentration of skilled manual heads of household and fewer unskilled, and both sickness and unemployment are below the family average.

Cluster twenty-four (poor quality terraces)

Clusters twenty-four and twenty-five contain much of the least adequate of the older housing stock which is not in multi-occupation. The two clusters can be distinguished by their differential accessibility to local manufacturing employment opportunities, cluster twenty-four having a more balanced employment structure. The cluster can be distinguished from the family as a whole by its very high proportion of pre-school children and by the high proportion of privately rented unfurnished accommodation. Although housing in this type of area is particularly susceptible to the lack of household amenities, the evidence suggests that this type of housing area performs a valuable role by giving young couples access to cheap owner-occupied housing.

Cluster twenty-five (low status terraces)

This type of area occurs in parts of the county which have been traditional centres of industrial activity. The cluster is differentiated from the family as a whole by its lower socioeconomic status and poorer housing conditions. The high accessibility to employment is reflected in high activity rates among married women and by low rates of male unemployment, especially in relation to sickness and the proportion of unskilled workers.

Family 6 - Elderly (2% of county)

Cluster twenty-six (owner-occupied retirement)

Cluster twenty-six and twenty-seven are almost entirely restricted to two areas, Southport and Hoylake/West Kirby which function as regional retirement centres as well as local commuter areas. Cluster twenty-six may be distinguished by its high level of owner-occupation. It consists mostly of semi-detached houses and bungalows favoured by the elderly.

Cluster twenty-seven (sub-division/retirement)

This type of area may be distinguished by its high proportion of privately rented furnished accommodation and by a significant percentage of shared dwellings and amenities. The high proportion of one and two roomed dwellings reflects a high rate of dwelling sub-divisions.

APPENDIX 7.I

COMPUTER PROGRAMMES USED IN THE PRODUCTION OF STATISTICS AND MAPS REFERRING TO THE ELEVEN SAMPLE AREAS.

```
      MASTER STATS
      INTEGER TITLE(20),IUSE(25),ISUR(25),IMAINT(25),IMAN(25),ICLASS(11)
      REAL TAB1(15,39),TAB2(15,39,2),TAB3(15,39,3),CTAB1(15,39,2),
     1 CTAB2(15,39,2,2),CTAB3(15,39,3,2),CMULT(2),CBILT(2)
      DATA ICLASS/4*1,2*0,4*2,1/
      DATA CTAB1,CTAB2,CTAB3/7020*0.0/,CMULT/0.2,0.25/,CBILT/2*0.0/
      DO 100 ISQ=1,11
C     LOOP FOR DATA ON EACH 500M SQUARE
      DO 20 I=1,15
      DO 20 J=1,39
      TAB1(I,J)=0.0
      DO 21 K=1,2
      TAB2(I,J,K)=0.0
   21 CONTINUE
      DO 22 K=1,3
      TAB3(I,J,K)=0.0
   22 CONTINUE
   20 CONTINUE
      BILTUP=0.0
      READ(5,1) TITLE
    1 FORMAT(20A4)
      DO 10 I=1,25
C     READ DATA ON EACH 100M SQUARE
      READ(5,2) (IUSE(J),ISUR(J),IMAINT(J),IMAN(J),J=1,25)
    2 FORMAT(2(6X,10(1X,2I2,2I1)/),6X,5(1X,2I2,2I1))
      DO 11 J=1,25
C     CHECK FOR DATA ERRORS AND INCREMENT TABLES
      JUSE=IUSE(J)
      IF(JUSE.EQ.0) GO TO 12
      IF(JUSE.LT.0.OR.JUSE.GT.39) GO TO 13
      JSUR=ISUR(J)
      IF(JSUR.LE.0.OR.JSUR.GT.15) GO TO 13
      JMAINT=IMAINT(J)
      IF(JMAINT.GT.3.OR.JMAINT.EQ.0) GO TO 13
      JMAN=IMAN(J)
      IF(JMAN.GT.2.OR.JMAN.EQ.0) GO TO 13
      TAB1(JSUR,JUSE)=TAB1(JSUR,JUSE)+0.04
      TAB2(JSUR,JUSE,JMAN)=TAB2(JSUR,JUSE,JMAN)+0.04
      TAB3(JSUR,JUSE,JMAINT)=TAB3(JSUR,JUSE,JMAINT)+0.04
      GO TO 11
   12 BILTUP=BILTUP+0.04
      GO TO 11
   13 WRITE(6,3) I,J
    3 FORMAT('INVALID DATA IN BLOCK ',I2,' UNIT ',I2)
   11 CONTINUE
   10 CONTINUE
C     ADD TO TOTAL FOR S.E. CLASS IF NECESSARY
      JCLASS=ICLASS(ISQ)
      IF(JCLASS.EQ.0) GO TO 40
      DO 30 I=1,15
      DO 30 J=1,39
      CTAB1(I,J,JCLASS)=CTAB1(I,J,JCLASS)+TAB1(I,J)*CMULT(JCLASS)
      DO 31 K=1,2
      CTAB2(I,J,K,JCLASS)=CTAB2(I,J,K,JCLASS)+TAB2(I,J,K)*CMULT(JCLASS)
   31 CONTINUE
      DO 32 K=1,3
      CTAB3(I,J,K,JCLASS)=CTAB3(I,J,K,JCLASS)+TAB3(I,J,K)*CMULT(JCLASS)
   32 CONTINUE
   30 CONTINUE
      CBILT(JCLASS)=CBILT(JCLASS)+BILTUP*CMULT(JCLASS)
      GO TO 41
   40 WRITE(7,7)    ISQ,TAB1
    7 FORMAT(I5,39(/15F5.2))
   41 CALL PRINT(TAB1,TAB2,TAB3,BILTUP,TITLE)
  100 CONTINUE
      DO 200 IG=1,2
      READ(5,1) TITLE
      WRITE(7,7) IG,((CTAB1(I,J,IG),I=1,15),J=1,39)
      CALL PRINT(CTAB1(1,1,IG),CTAB2(1,1,1,IG),CTAB3(1,1,1,IG),
     1 CBILT(IG),TITLE)
  200 CONTINUE
      STOP
      END
```

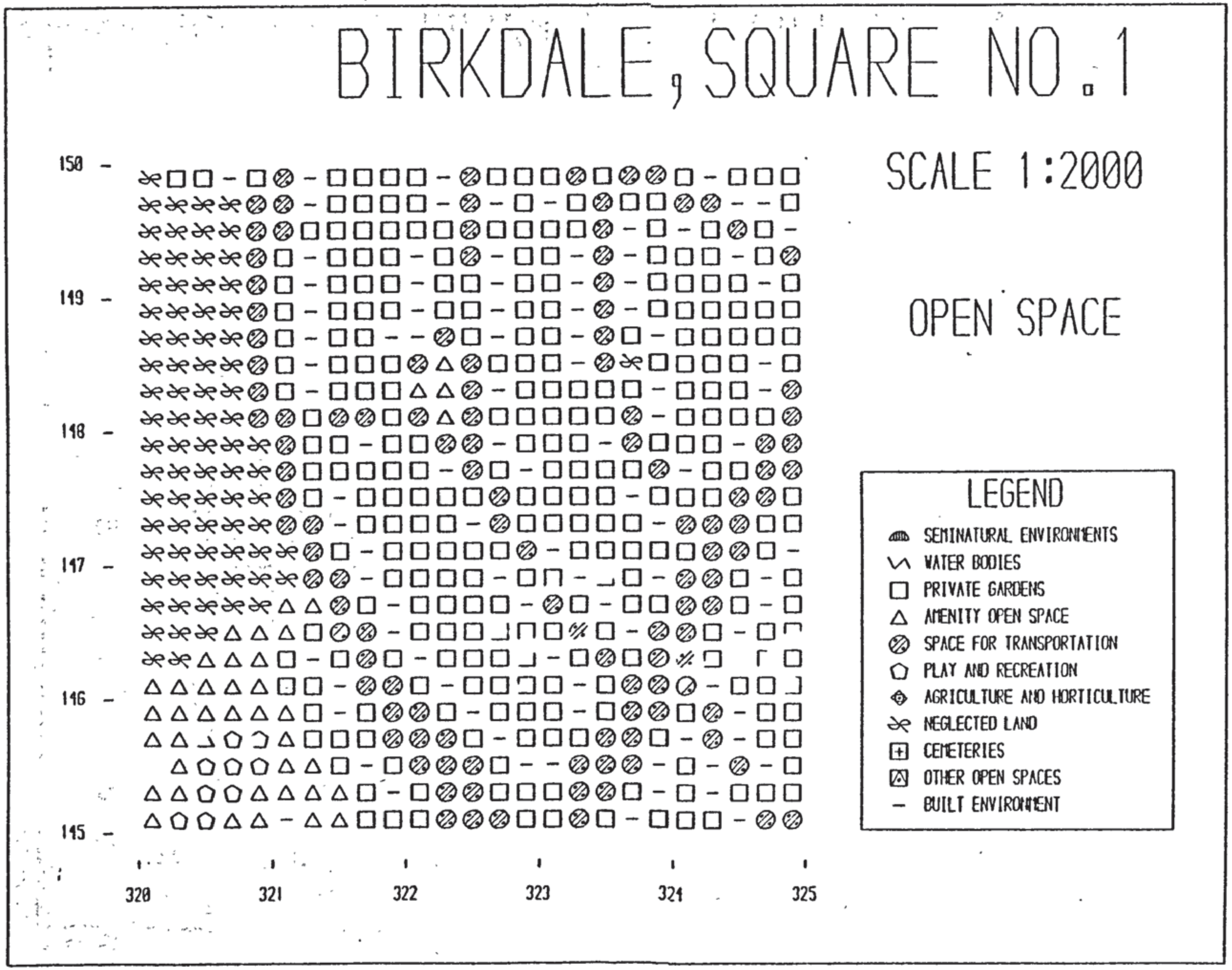
```
      SUBROUTINE PRINT(TAB1,TAB2,TAB3,BILTUP,TITLE)
      INTEGER TITLE(20),MANTXT(2),MNTTXT(3)
      REAL TAB1(15,39),TAB2(15,39,2),TAB3(15,39,3)
      DATA MANTXT/'GOOD','BAD'/,MNTTXT/'HIGH','LOW','NON'/
    1 FORMAT('1',20A4///)
      WRITE(6,1) TITLE
      WRITE(6,2)
    2 FORMAT('PROVISION OF OPEN SPACE'///)
      CALL PRNTAB(TAB1)
      PCB=4.0*BILTUP
      WRITE(6,3) BILTUP,PCB
    3 FORMAT(///'BUILT AREA - ',F5.2,' HA  ',F6.2,'%')
      DO 10 I=1,2
      WRITE(6,1) TITLE
      WRITE(6,4) MANTXT(I)
    4 FORMAT(' MANAGEMENT OF OPEN SPACE - ',A4,' MANAGEMENT'///)
      CALL PRNTAB(TAB2(1,1,I))
   10 CONTINUE
      DO 20 I=1,3
      WRITE(6,1) TITLE
      WRITE(6,5) MNTTXT(I)
    5 FORMAT(' MAINTENANCE OF OPEN SPACE - ',A4,' MAINTENANCE'///)
      CALL PRNTAB(TAB3(1,1,I))
   20 CONTINUE
      RETURN
      END
```

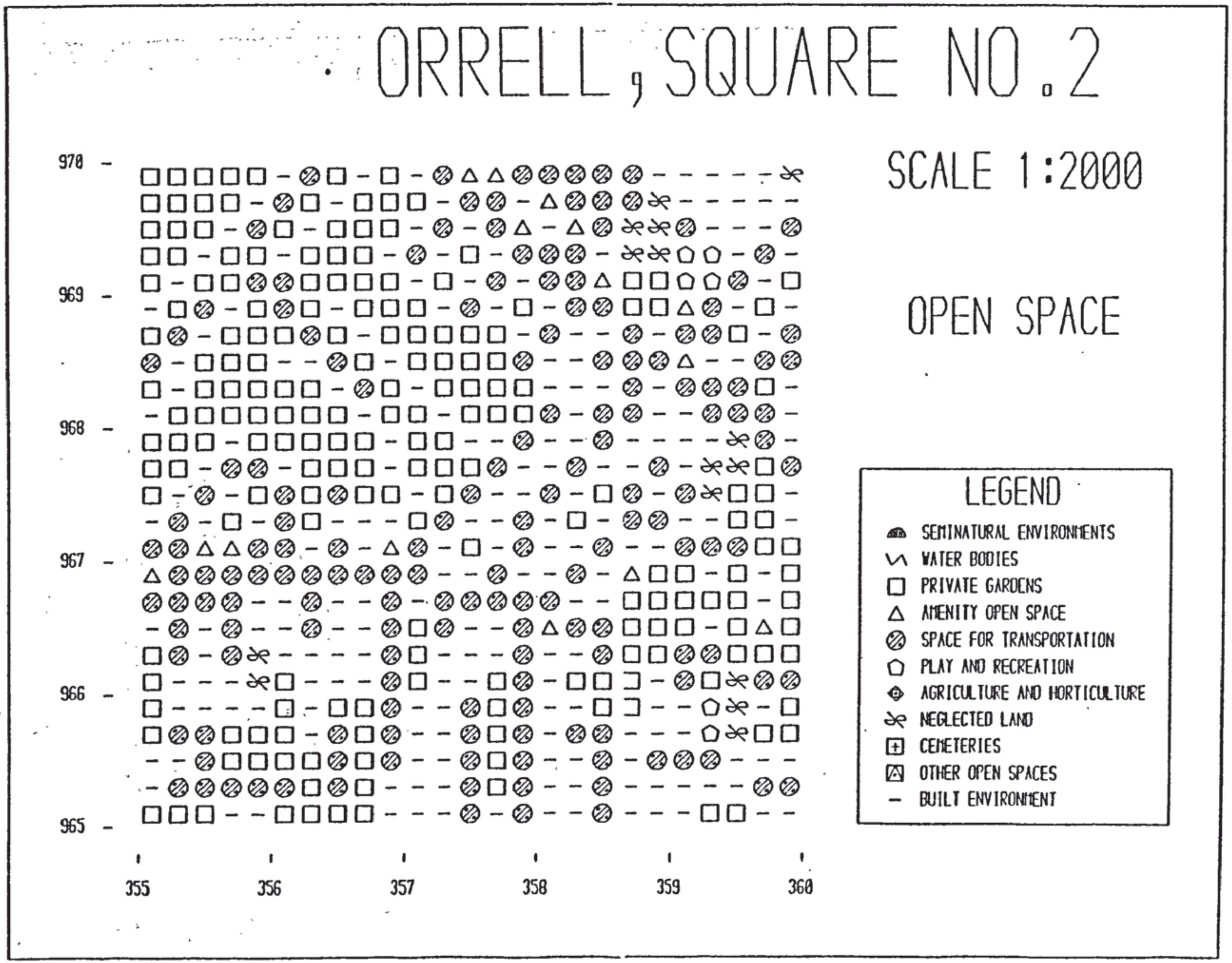
```
      MASTER MAPROG
      INTEGER TITLE(20),DATA(25,25),IX(25),IY(25),ISYM(40),LEGSYM(11),
     1 LEGTXT(7,11)
      COMMON /POSITN/ XCTC,YBTC,WLB,HLB
      DATA ISYM/99,6*57,5*66,1,4*10,6*15,6*23,2*47,7*55,70,71/
      DATA STDCHH,STDCHW/3.0,3.0/
      CALL SETUP(5)
      READ(1,9) (LEGSYM(I),(LEGTXT(J,I),J=1,7),I=1,11)
    9 FORMAT(I2,1X,7A4)
      READ(1,1) TITLE
    1 FORMAT(20A4)
      DO 12 I=1,25
      READ(1,2) IY(I),IX(I),(DATA(J,I),J=1,25)
    2 FORMAT(2I3,1X,10(I2,5X)/  2X,10(5X,I2) /2X,5(5X,I2))
      DO 11 J=1,25
      DATA(J,I)=DATA(J,I)+1
      IF(DATA(J,I).LT.1.OR.DATA(J,I).GT.40) DATA(J,I)=1
   11 CONTINUE
   12 CONTINUE
      IOX=IX(1)
      IOY=IY(1)
      DO 15 I=2,25
      IF(IOX.GT.IX(I)) IOX=IX(I)
      IF(IOY.GT.IY(I)) IOY=IY(I)
   15 CONTINUE
      IDX=4
      IDY=4
      DO 16 I=1,80
      NT=81-I
      J=1
      CALL COMP(J,TITLE(1),NT,' ',1)
      IF (J.NE.1) GO TO 17
   16 CONTINUE
      NT=1
   17 CALL OPENGINOGP
      WLB=120.0
      TITW=15.0*FLOAT(NT)*STDCHW/STDCHH
      FRW=AMAX1(WLB+FLOAT(50*(IDX+1)+90),TITW+60.0)
      SMW=FRW-90.0-WLB
      HLB=135.0
      SMH=AMAX1(FLOAT(50*(IDY+1)),40.0*STDCHH/STDCHW+     HLB)
      FRH=SMH+110.0
      CALL PICCLE
      CALL DEVPAP(FRW,FRH,1)
      CALL TRANSF(2)
      CALL FRAME(FRW,FRH)
      CALL CHASWI(1)
      CALL SCALE(3.0/STDCHW)
      CALL COORDS(IOX,IOY,IDX,IDY)
      CALL MOVTO2(0.5*(FRW-TITW),SMH+75.0)
      CALL SCALE(15.0/STDCHH)
      NWT=NT/4
      CALL CHARR(TITLE,NWT,4)
      NLT=NT-4*NWT
      IF(NLT.NE.0) CALL CHARR(TITLE(NWT+1),1,NLT)
      CALL TRANSF(2)
      XCTC=SMW+70.0+0.5*  WLB
      YBTC=HLB+50.0
      YOTC=SMH+40.0
      CALL MOVTO2(XCTC-46.0,YOTC)
      CALL SCALE(6.0/STDCHW)
      CALL CHAHOL(5HSCALE 1*.)
      CALL CHAASC(58)
      CALL CHAHOL(6H2000*.)
      CALL TRANSF(0)
      CALL MOVTO2(XCTC-46.0,YOTC-55.0)
      CALL TRANSF(1)
      CALL CHAHOL(13H OPEN SPACE*.)
      CALL TRANSF(2)
      CALL LEGEND(LEGSYM,11,LEGTXT,7)
      CALL SHIFT2(40.0,40.0)
      DO 20 I=1,25
      DO 20 J=1,25
      JJ=(J-1)/5
      JX=(IX(I)-IOX-JJ)*5+J
```

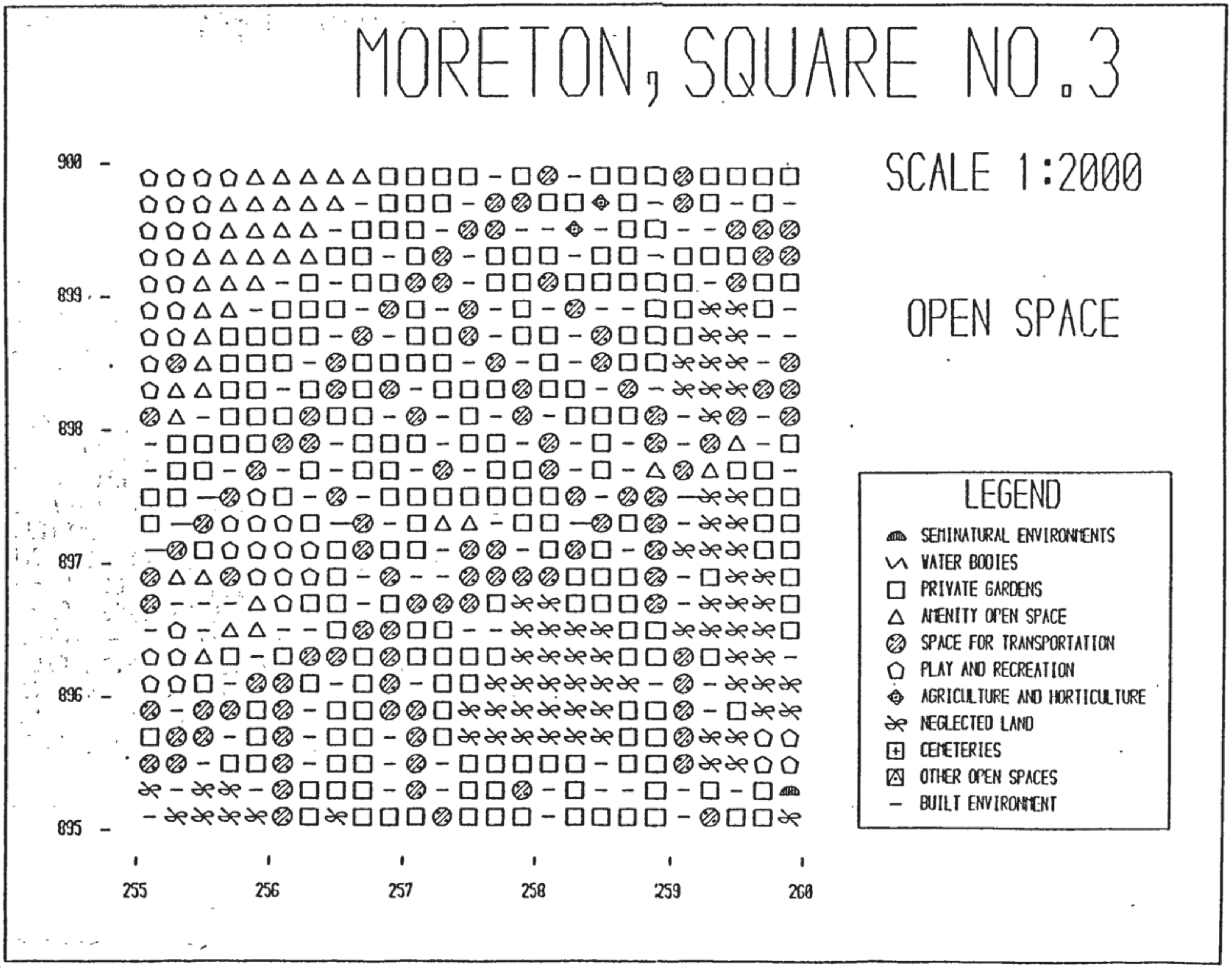
```
      JY=(IY(I)-IOY)*5+5-JJ
      CALL MAPSYM(ISYM(DATA(J,I)),10.0*FLOAT(JX),10.0*FLOAT(JY))
   20 CONTINUE
      CALL DEVEND
      STOP
      END
```

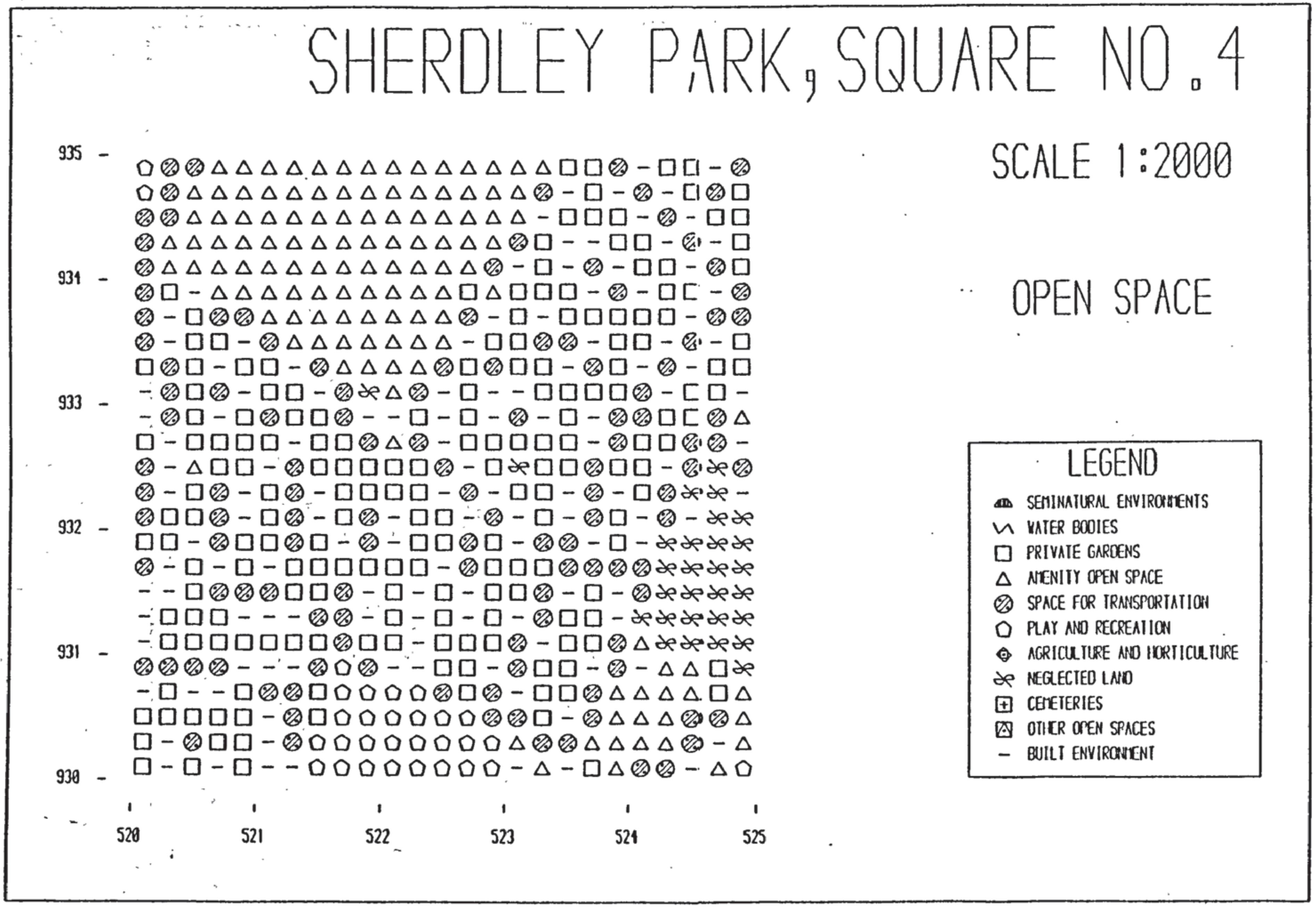
APPENDIX 7.II

A SET OF CALCOMP MAPS SHOWING OPEN SPACE DISTRIBUTION AT GROUP LEVEL IN THE ELEVEN SAMPLE AREAS.

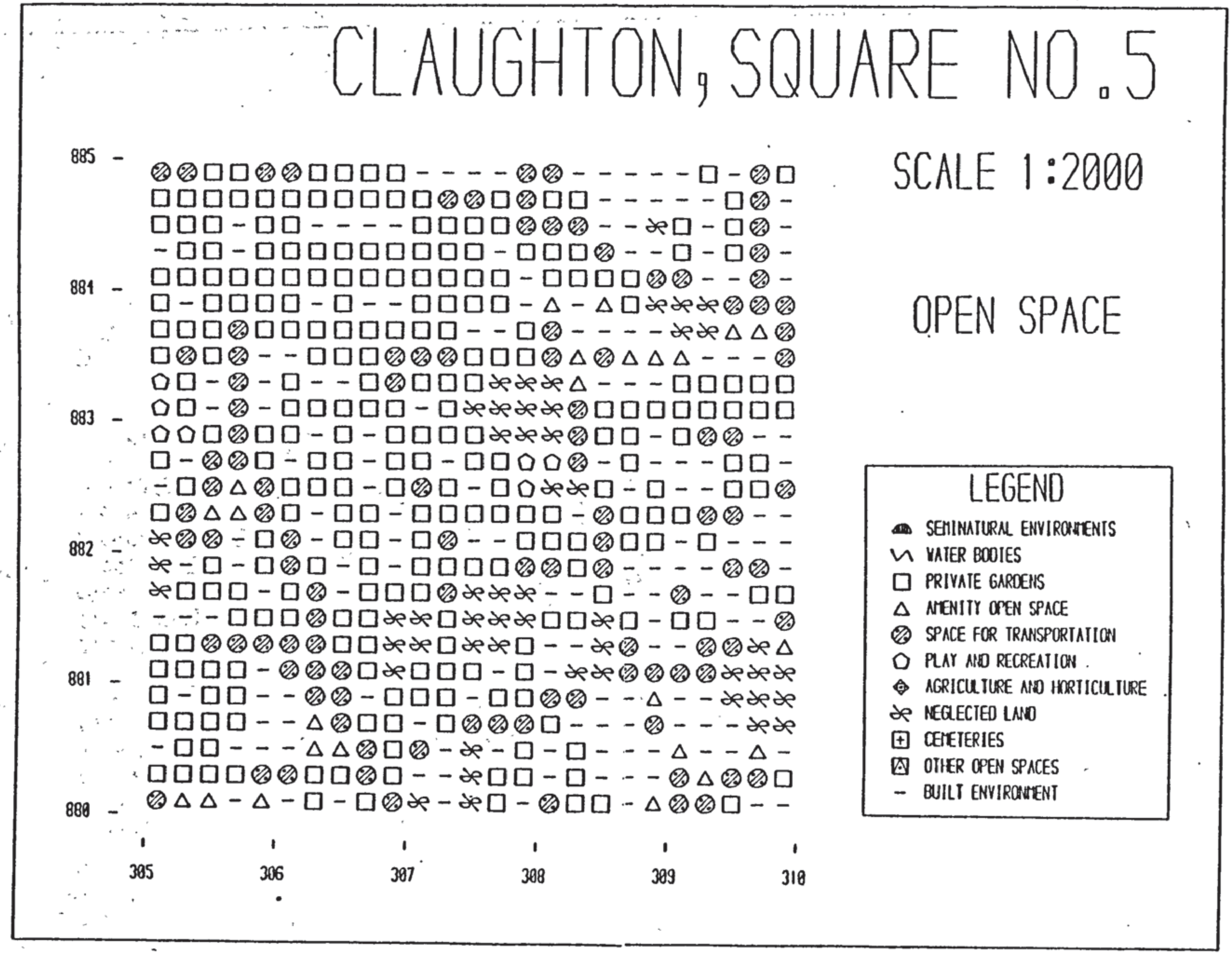

BIRKDALE, SQUARE NO. 1
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
150
149
148
147
146
145
320
321
322
323
324
325

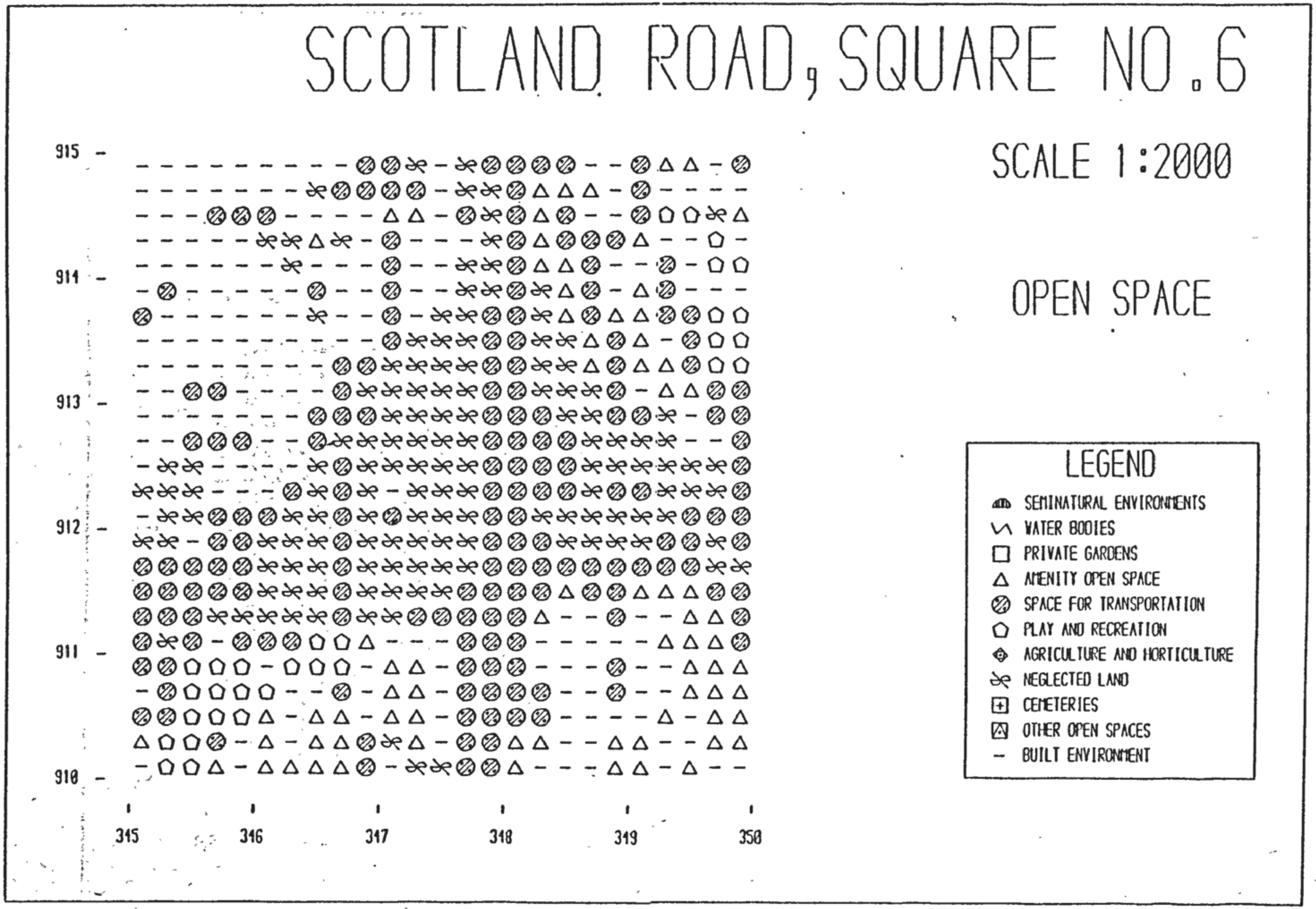

ORRELL, SQUARE NO. 2
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
970
969
968
967
966
965
355
356
357
358
359
360

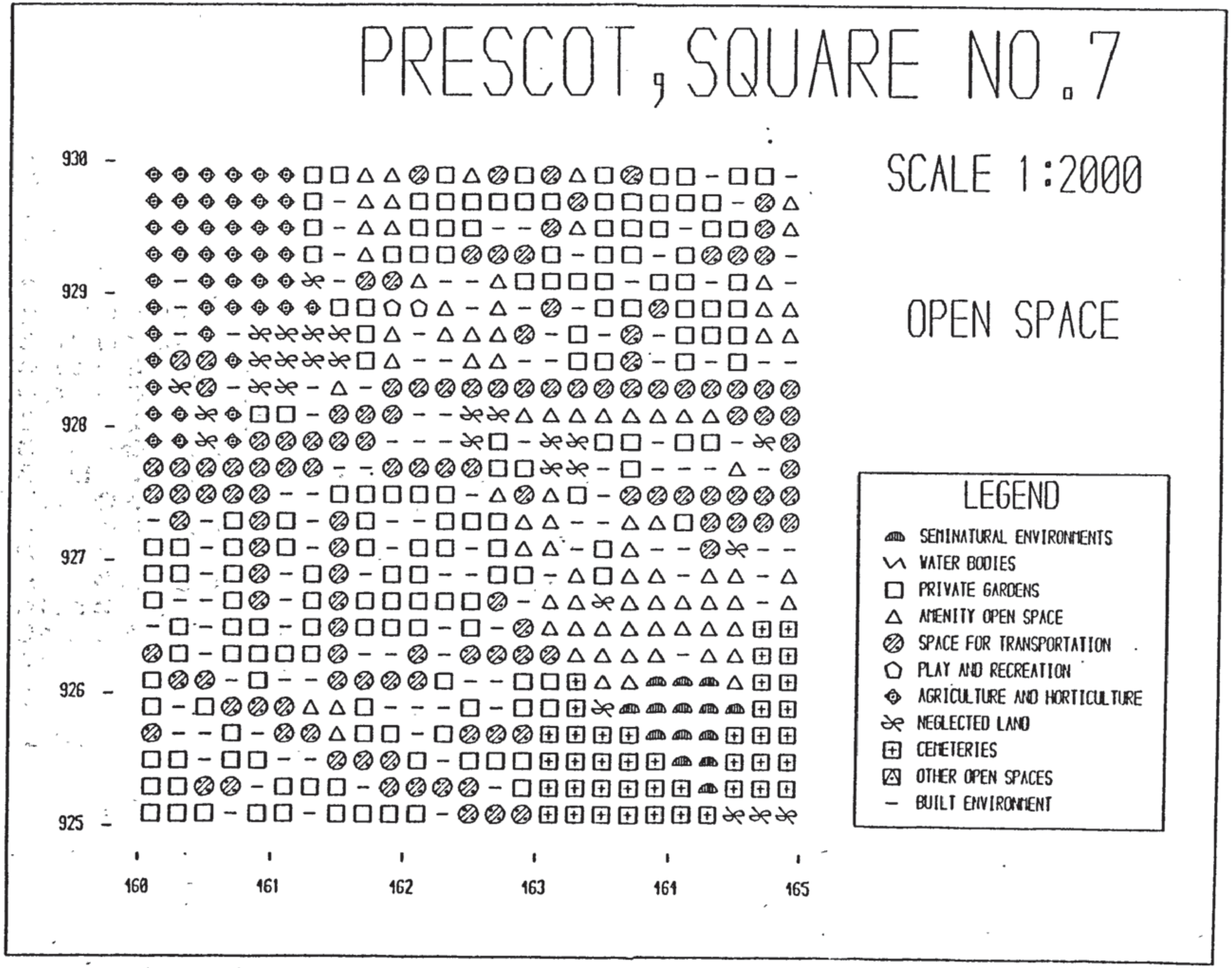

MORETON, SQUARE NO.3
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
900
899
898
897
896
895
255
256
257
258
259
260



SHERDLEY PARK, SQUARE NO. 4
SCALE 1:2000
OPEN SPACE
935
934
933
932
931
930
520
521
522
523
524
525
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT


CLAUGHTON, SQUARE NO.5
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
885
884
883
882
881
880
305
306
307
308
309
310

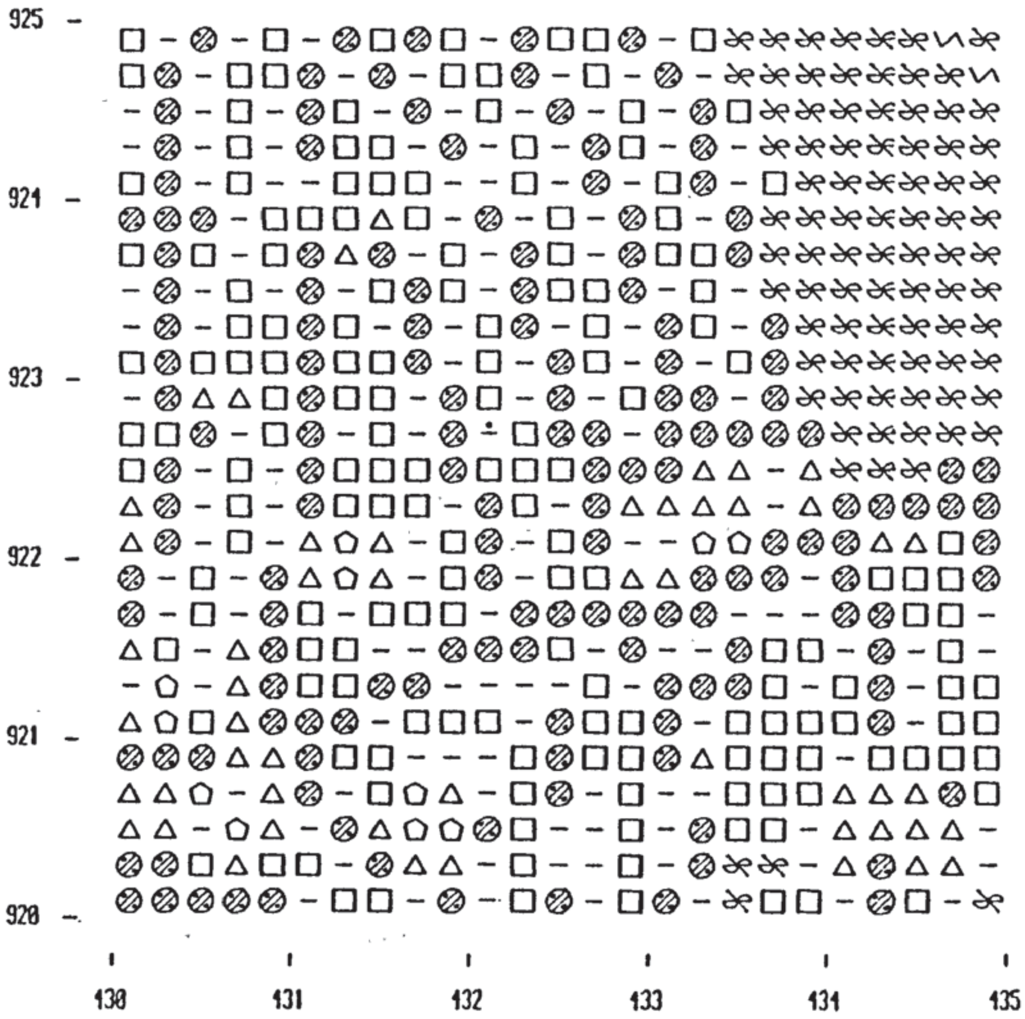

SCOTLAND ROAD, SQUARE NO.6
SCALE 1:2000
OPEN SPACE
915
914
913
912
911
910
315
316
317
318
319
350
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT


PRESCOT, SQUARE NO.7
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
930
929
928
927
926
925
160
161
162
163
164
165

WOOLFALL HEATH, SQUARE NO.8

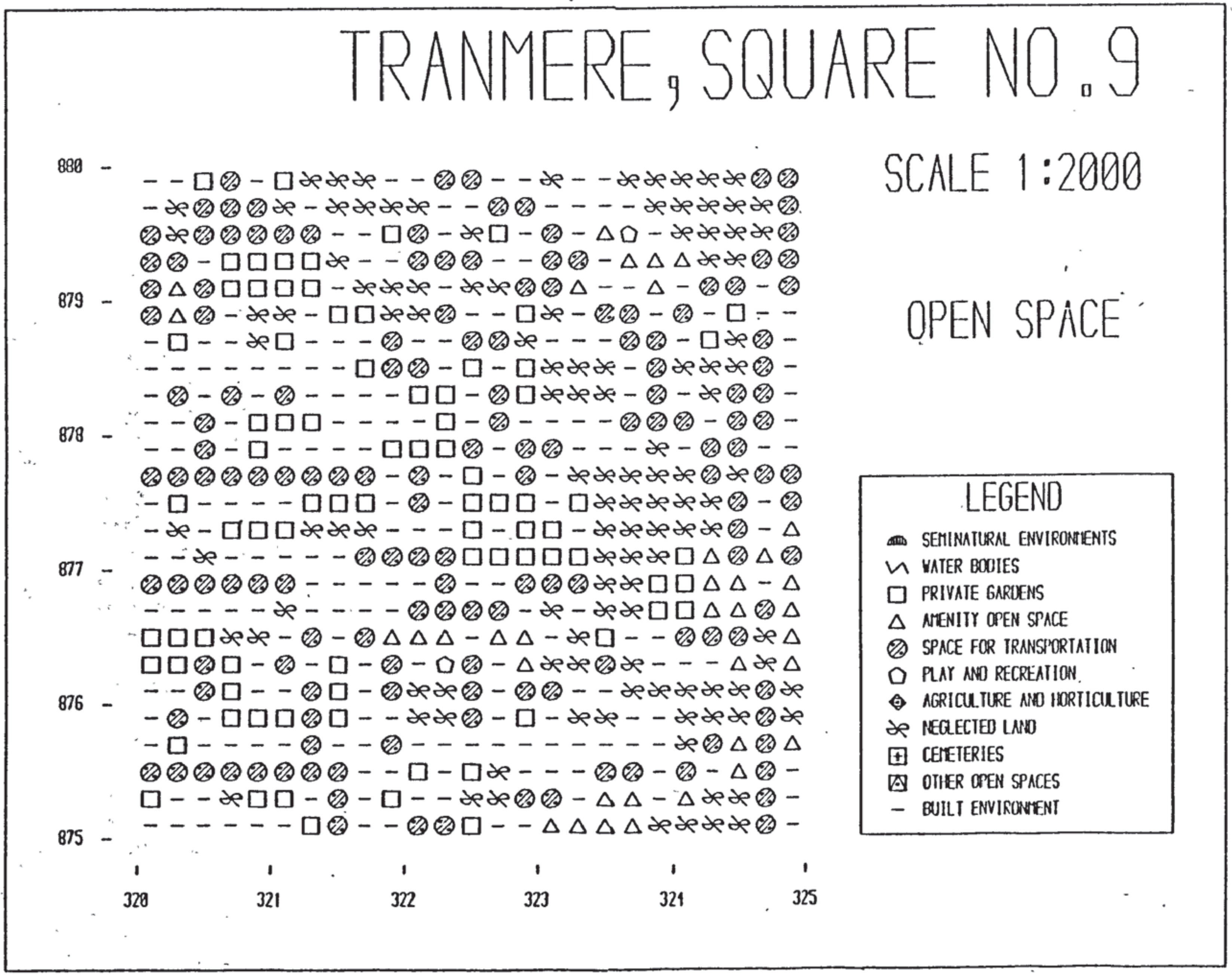
SCALE 1:2000

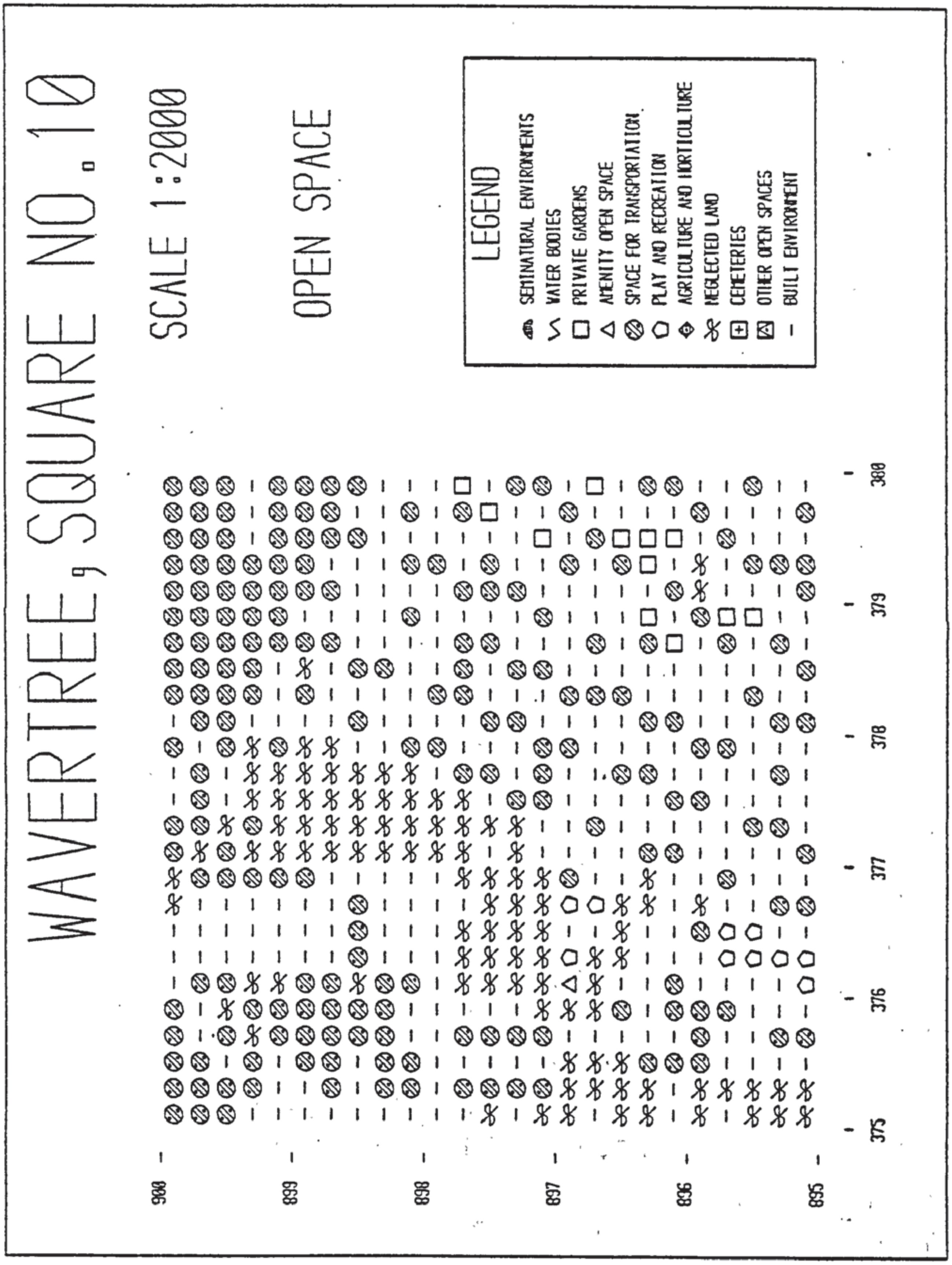
OPEN SPACE

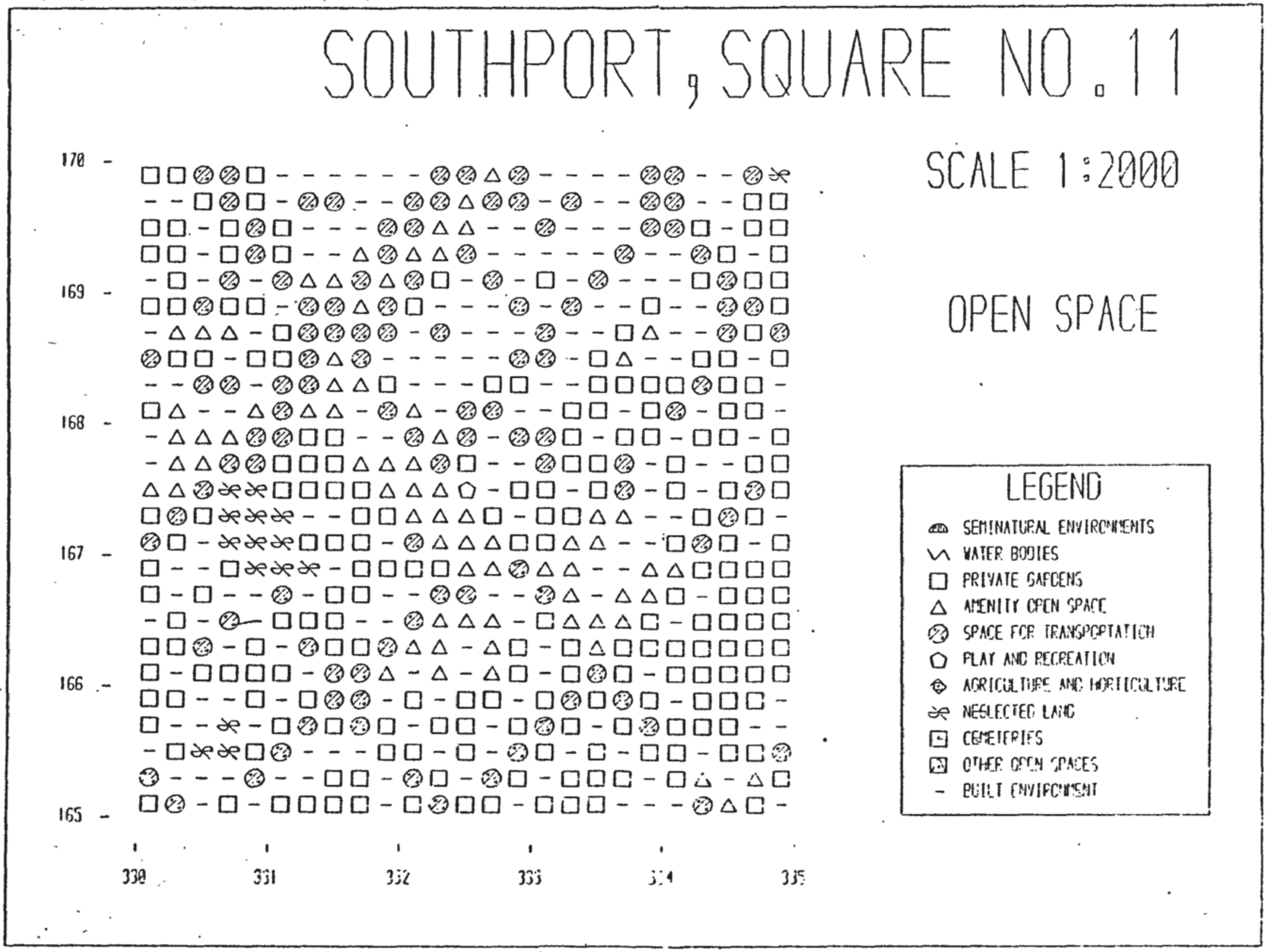


LEGEND

- SEMINATURAL ENVIRONMENTS
- WATER BODIES
- PRIVATE GARDENS
- AMENITY OPEN SPACE
- SPACE FOR TRANSPORTATION
- PLAY AND RECREATION
- AGRICULTURE AND HORTICULTURE
- NEGLECTED LAND
- CEMETERIES
- OTHER OPEN SPACES
- BUILT ENVIRONMENT


TRANMERE, SQUARE NO. 9
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
880
879
878
877
876
875
320
321
322
323
324
325

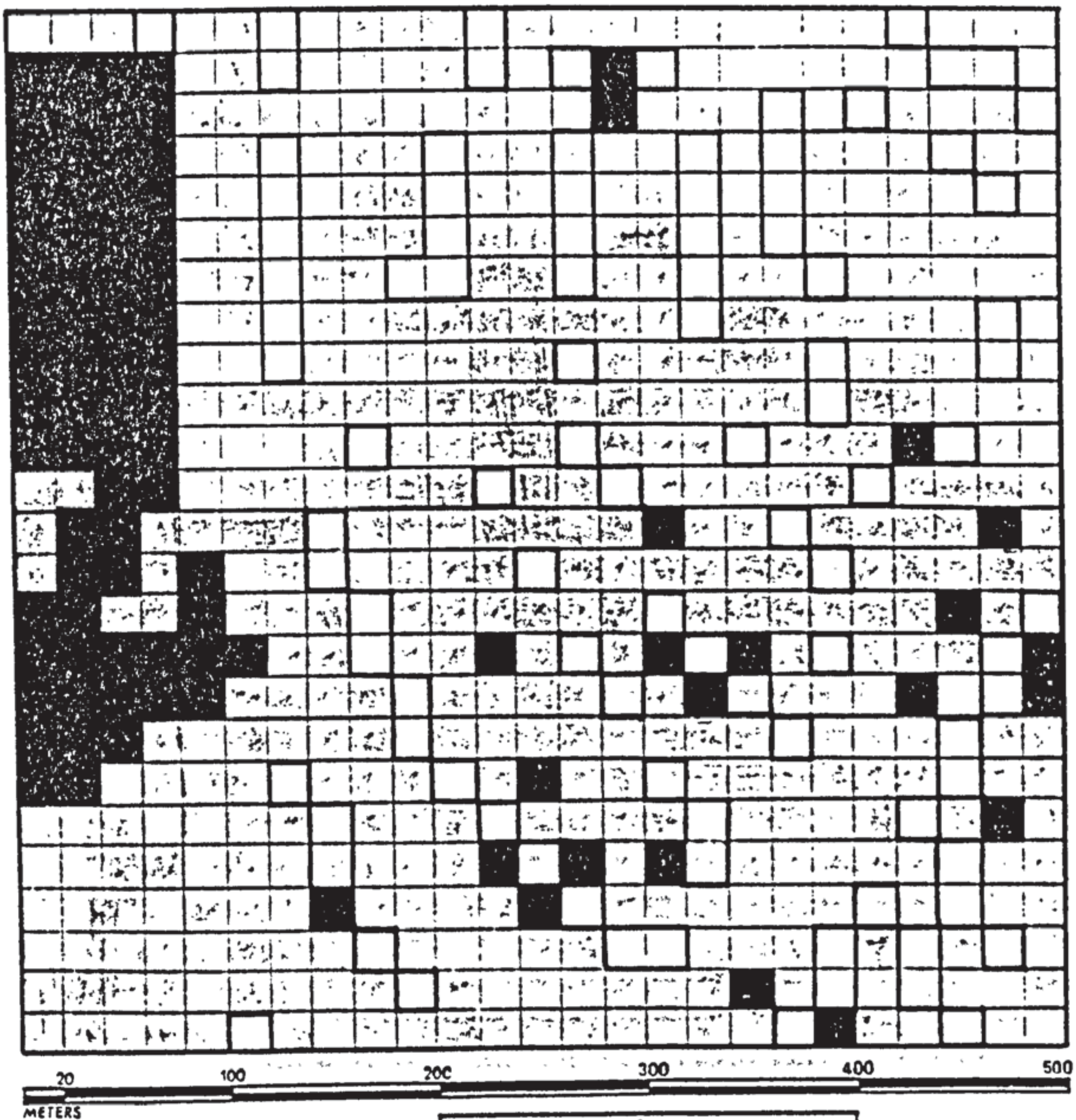

WAVERTREE, SQUARE NO.10
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
900
899
898
897
896
895
375
376
377
378
379
380


SOUTHPORT, SQUARE NO. 11
SCALE 1:2000
OPEN SPACE
LEGEND
SEMINATURAL ENVIRONMENTS
WATER BODIES
PRIVATE GARDENS
AMENITY OPEN SPACE
SPACE FOR TRANSPORTATION
PLAY AND RECREATION
AGRICULTURE AND HORTICULTURE
NEGLECTED LAND
CEMETERIES
OTHER OPEN SPACES
BUILT ENVIRONMENT
170
169
168
167
166
165
330
331
332
333
334
335

APPENDIX 7.III

A SET OF MANUALLY PRODUCED MAPS SHOWING OPEN SPACE CONDITION IN THE ELEVEN SAMPLE AREAS

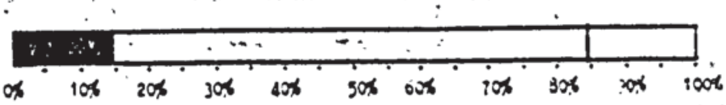
subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: birkdale
quarter kilometre square No.: 1
socioeconomic status: high



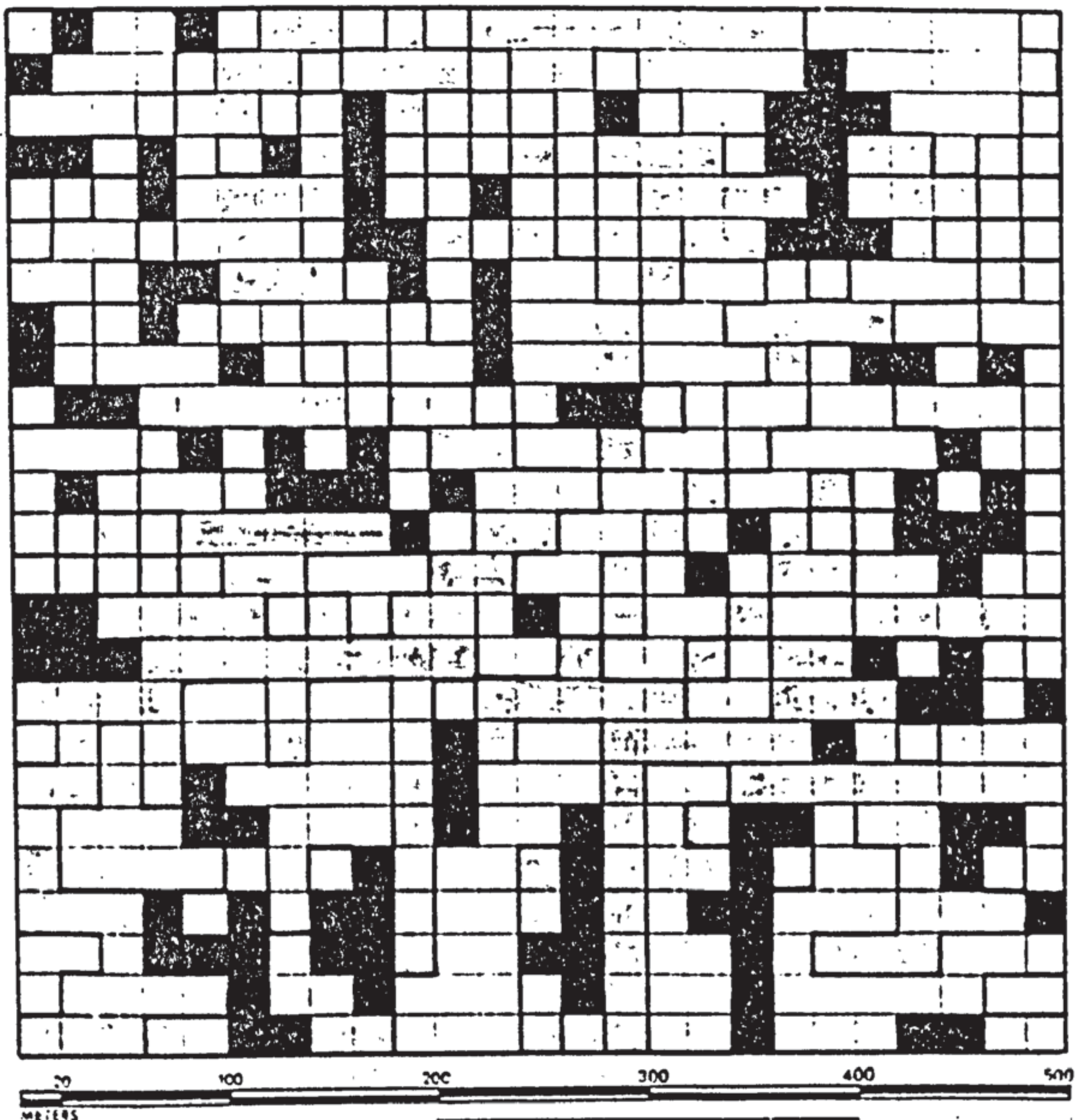
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
17.48	69.9	3.60	14.4	3.92	15.68



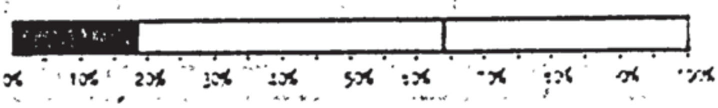
subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: orrell
quarter kilometre square No.: 2
socioeconomic status: high



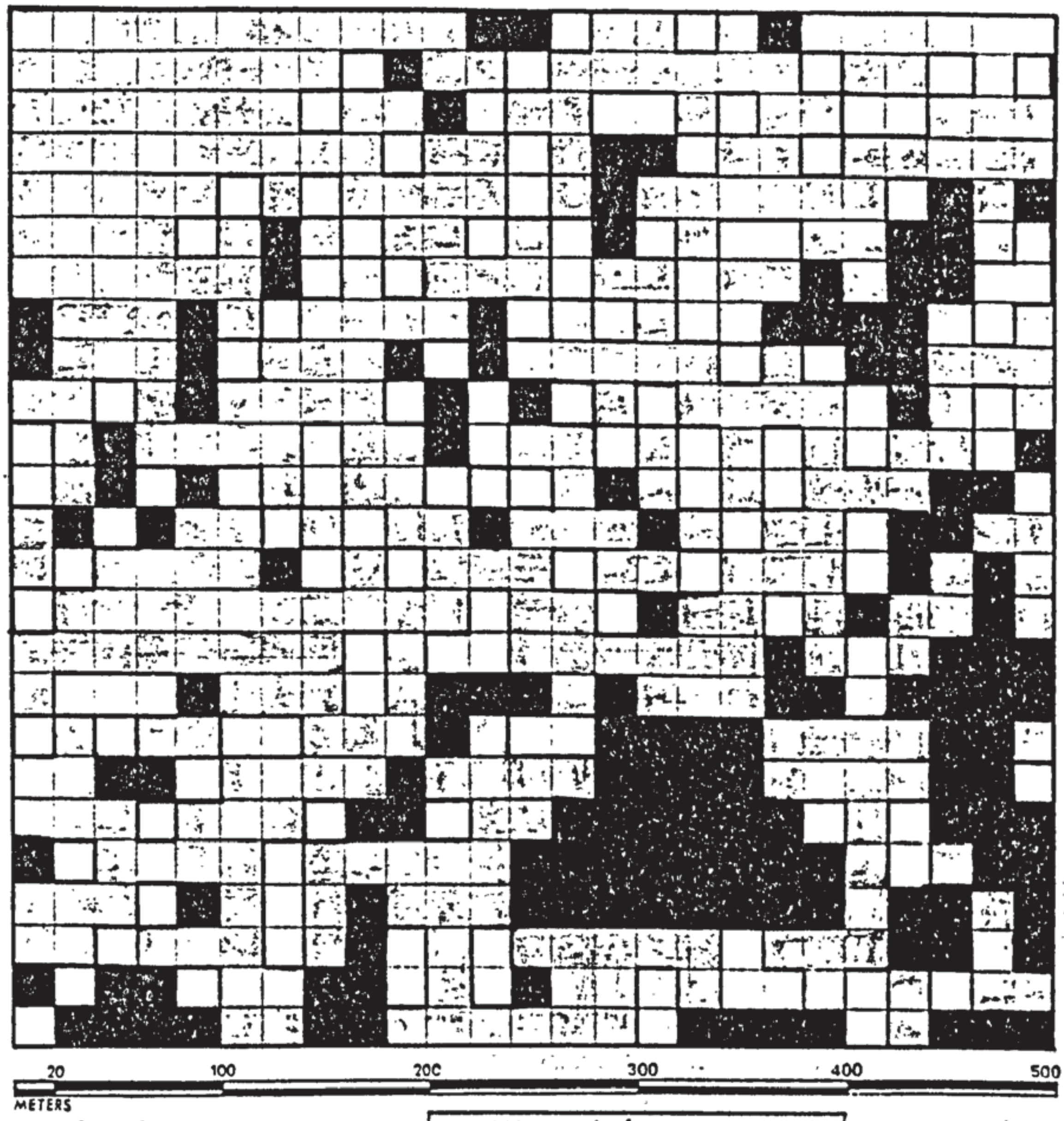
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
11.68	46.7	4.44	17.8	8.84	35.36



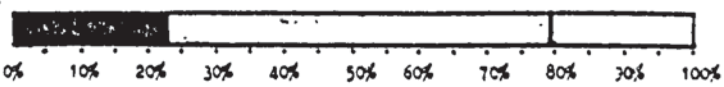
subject:	management of urban open space
data source:	1:10,000 false colour air-photography
sample area:	moreton
quarter kilometre square No.:	3
socioeconomic status:	high



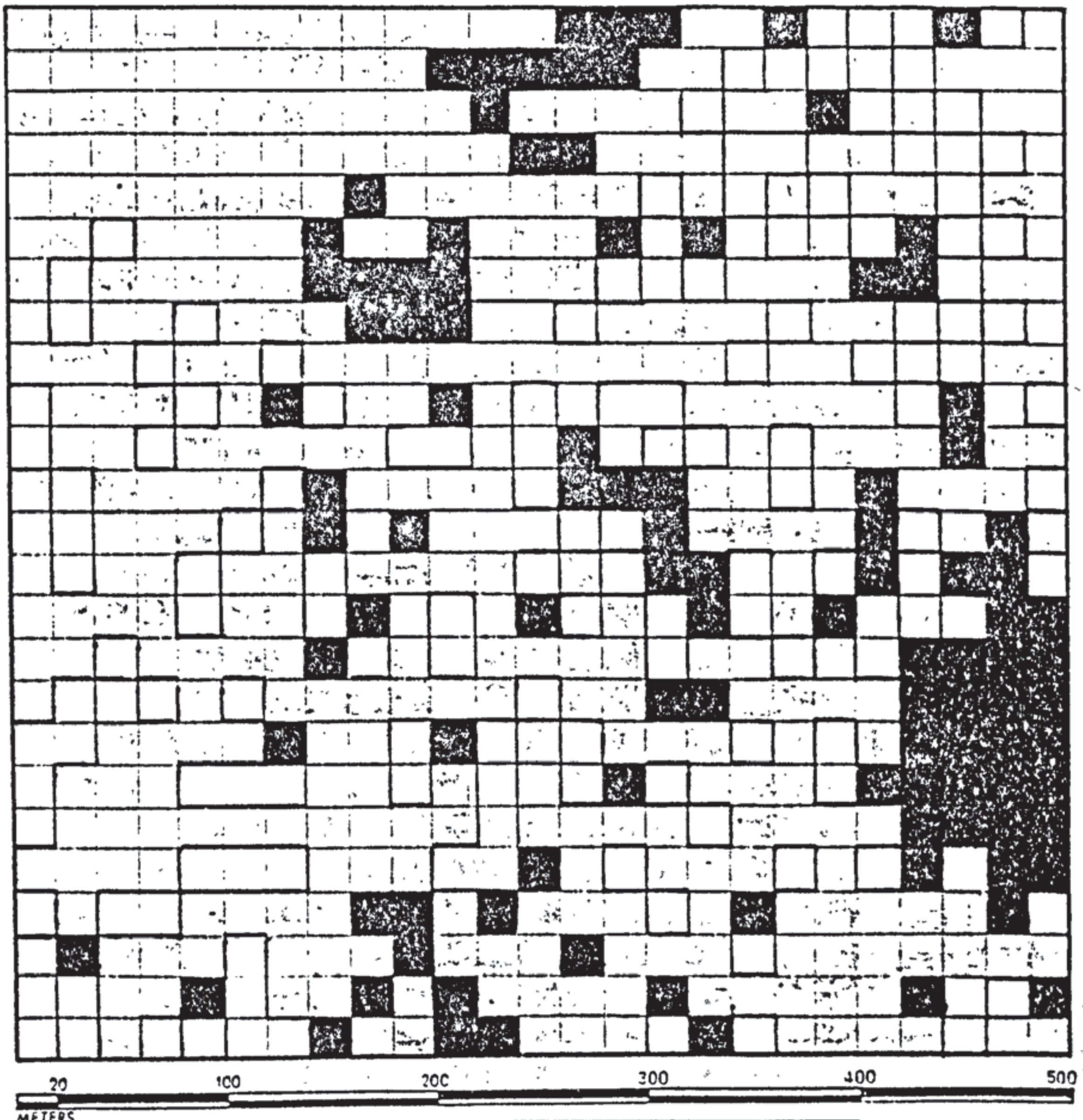
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
14.08	56.3	5.76	23.0	5.16	20.64



subject:	management of urban open space
data source:	1:10,000 false colour air-photography
sample area:	sherdley park
quarter kilometre square No.:	4
socioeconomic status:	high



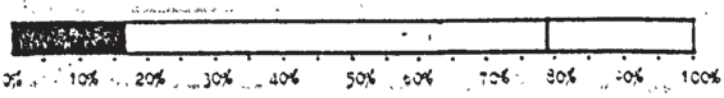
legend

open space well managed

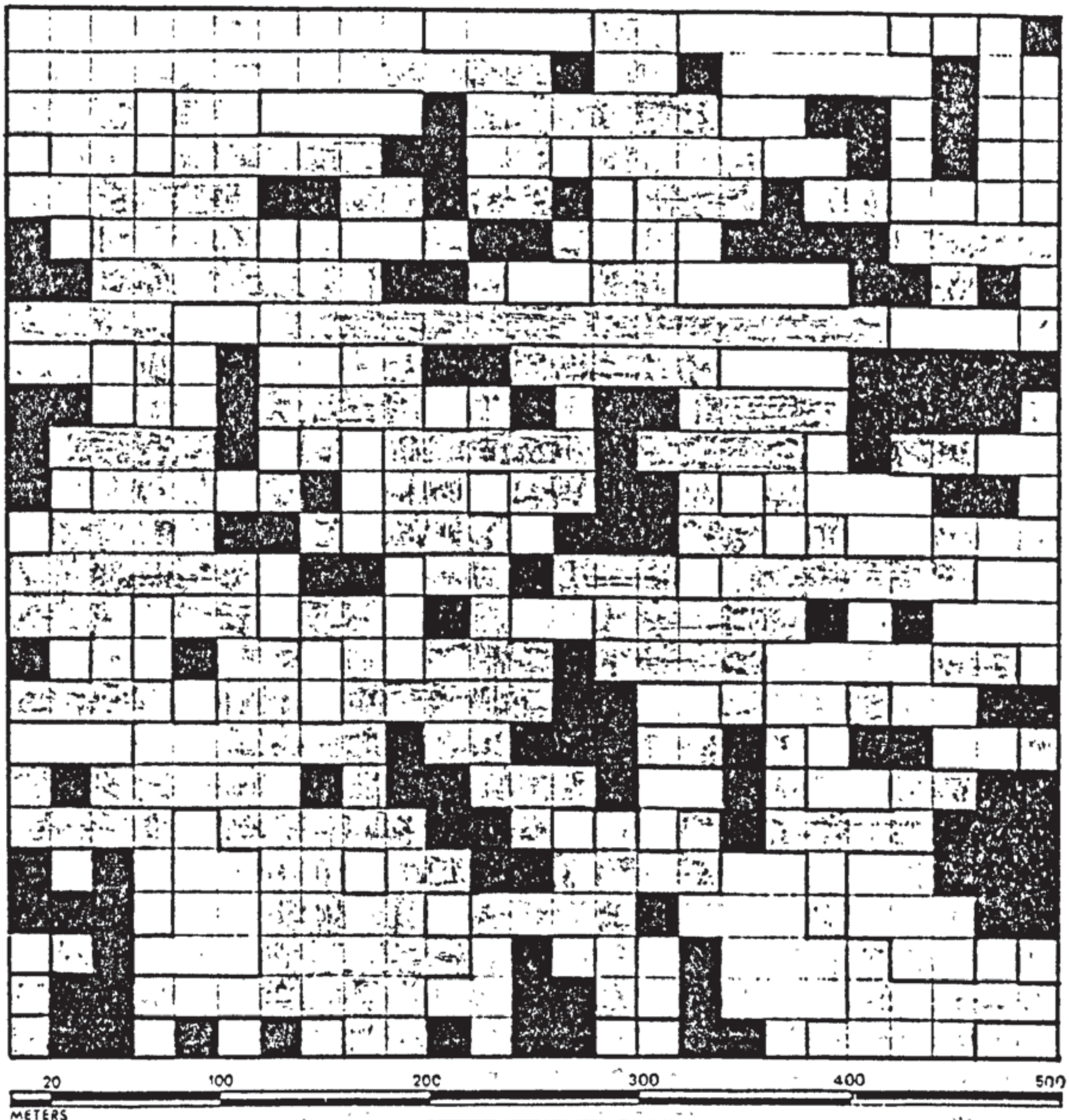
open space badly managed

built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
15.64	62.6	4.16	16.6	5.16	20.64



subject:	management of urban open space
data source:	1:10,000 false colour air-photography
sample area:	claughton
quarter kilometre square No.:	5
socioeconomic status:	intermediate



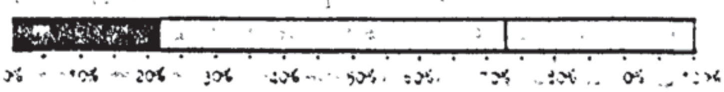
legend

open space well managed

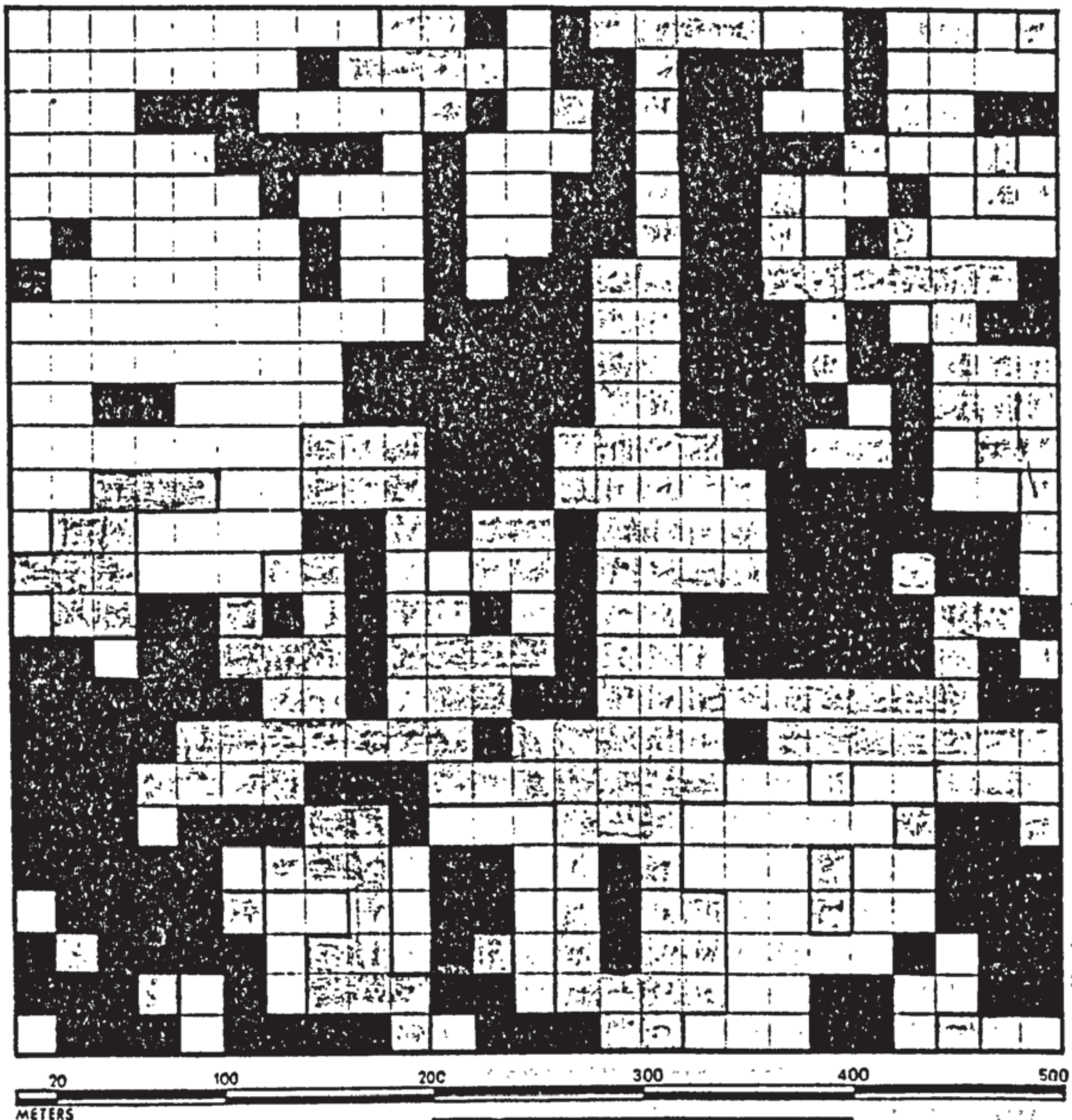
open space badly managed

built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
13.04	52.2	5.08	20.3	6.88	27.52



subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: scotland road
quarter kilometre square No.: 6
socioeconomic status: very low



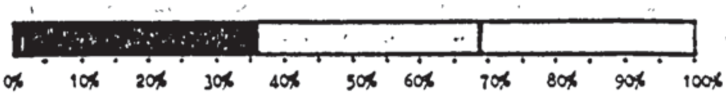
legend

open space well managed

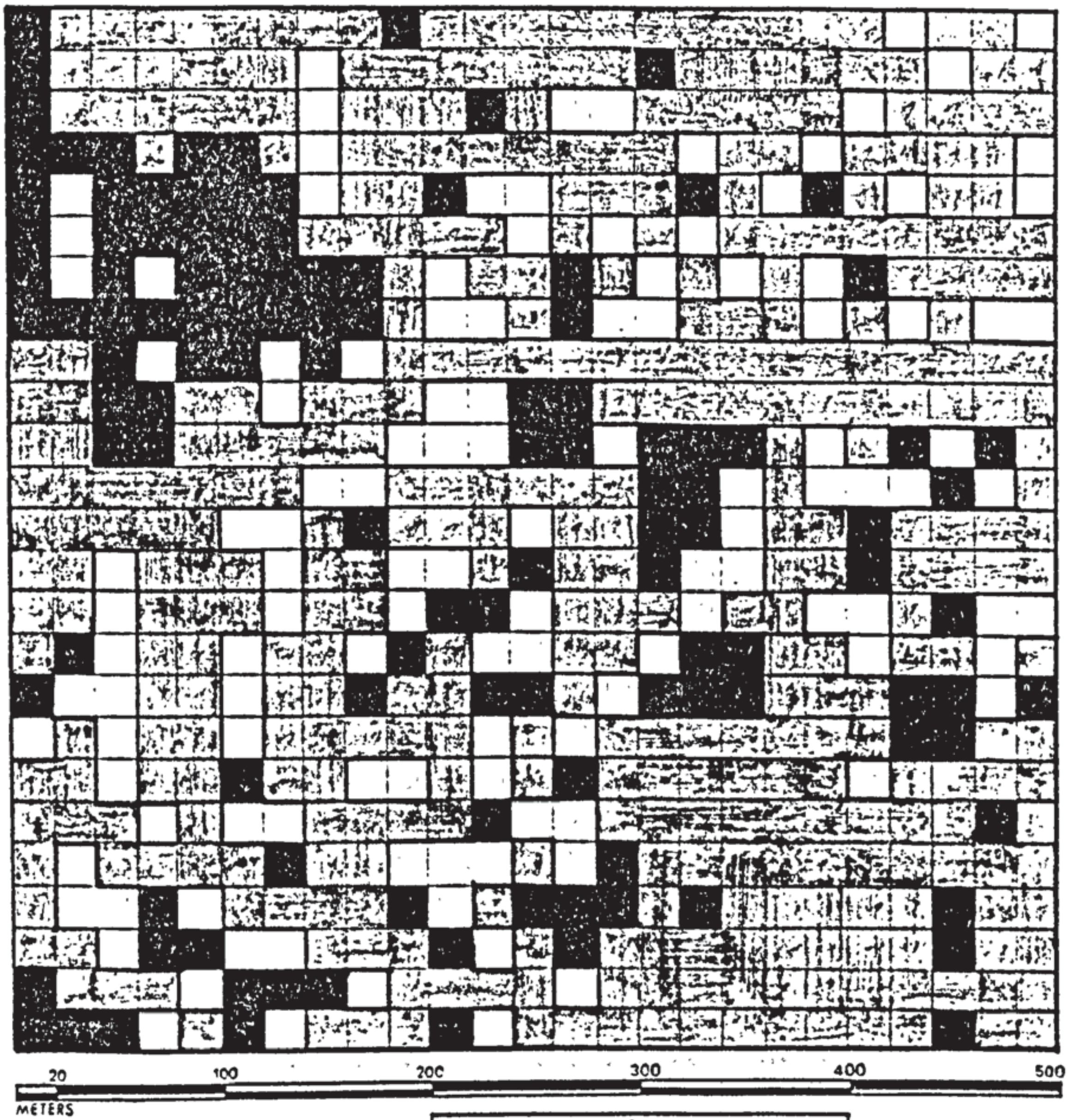
open space badly managed

built-up area

management of open space				built-up area	
good		bad			
ha	%	ha	%	ha	%
8.32	33.3	9.08	36.3	7.60	30.40



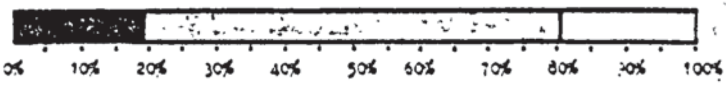
subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: prescot
quarter kilometre square No.: 7
socioeconomic status: low



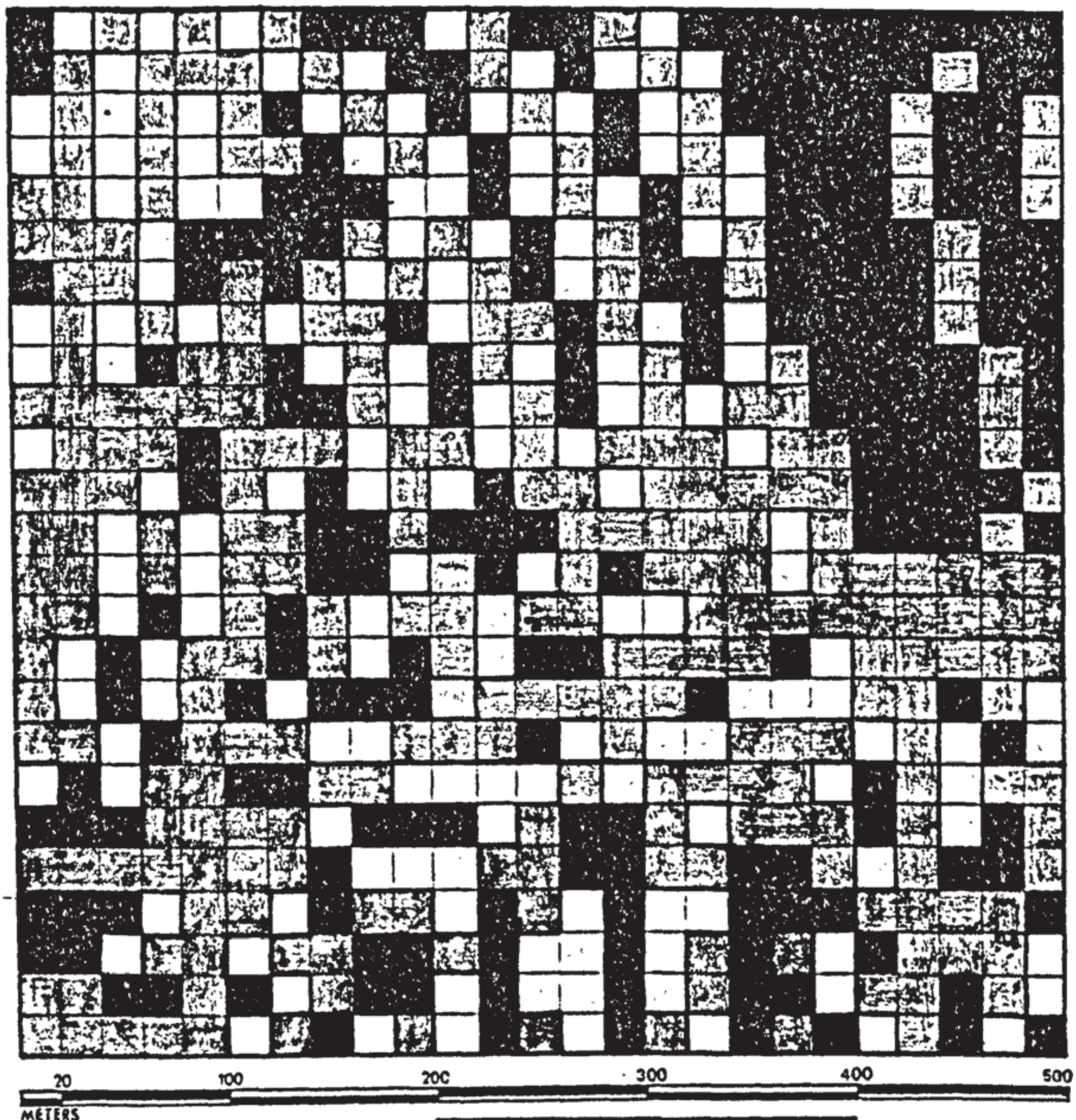
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
15.32	61.3	4.76	19.0	4.92	19.68



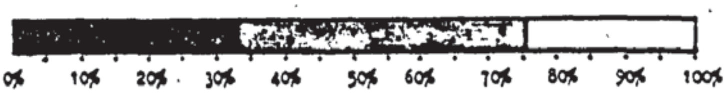
subject:	management of urban open space
data source:	1:10,000 false colour air-photography
sample area:	woolfall heath
quarter kilometre square No.:	8
socioeconomic status:	low



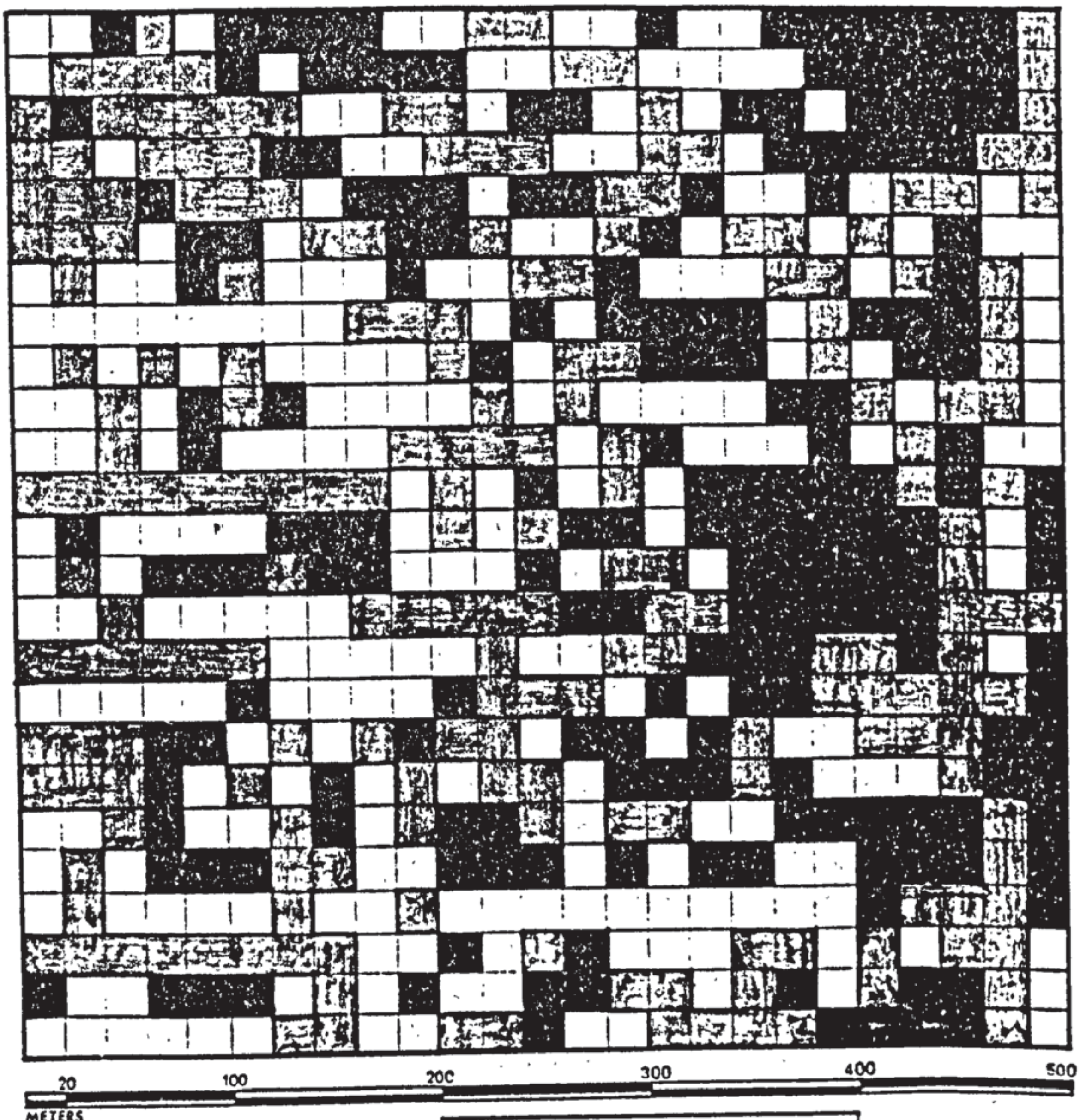
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
10.72	42.9	8.20	32.8	6.08	24.32



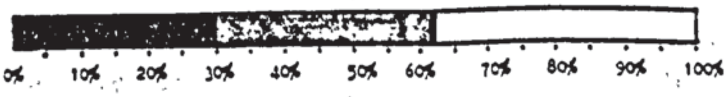
subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: tranmere
quarter kilometre square No.: 9
socioeconomic status: low



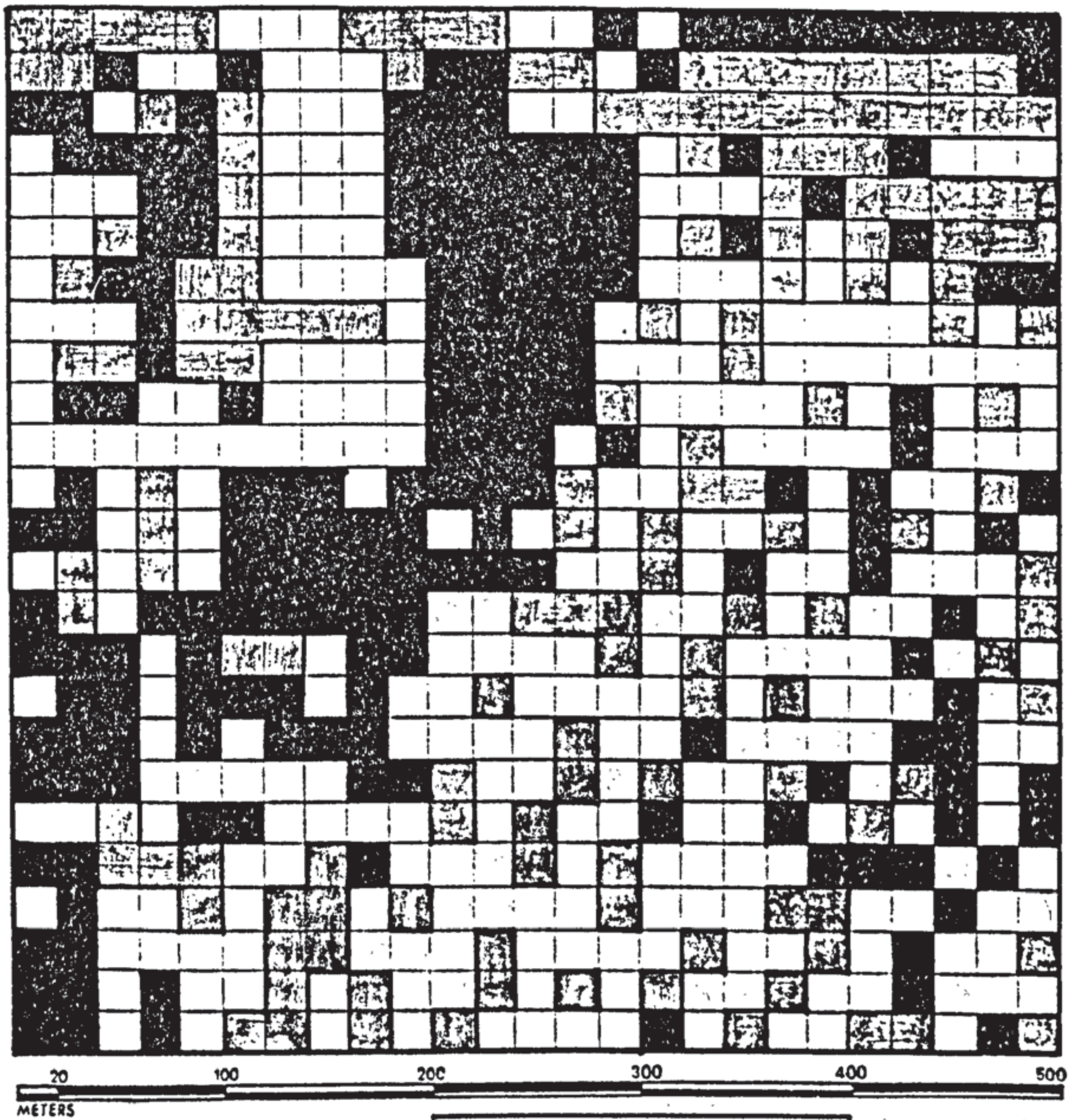
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
8.24	33.0	7.48	29.9	9.24	36.96



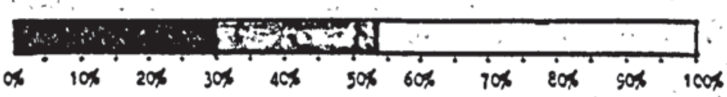
subject: management of urban open space
data source: 1:10,000 false colour air-photography
sample area: wavertree
quarter kilometre square No.: 10
socioeconomic status: low



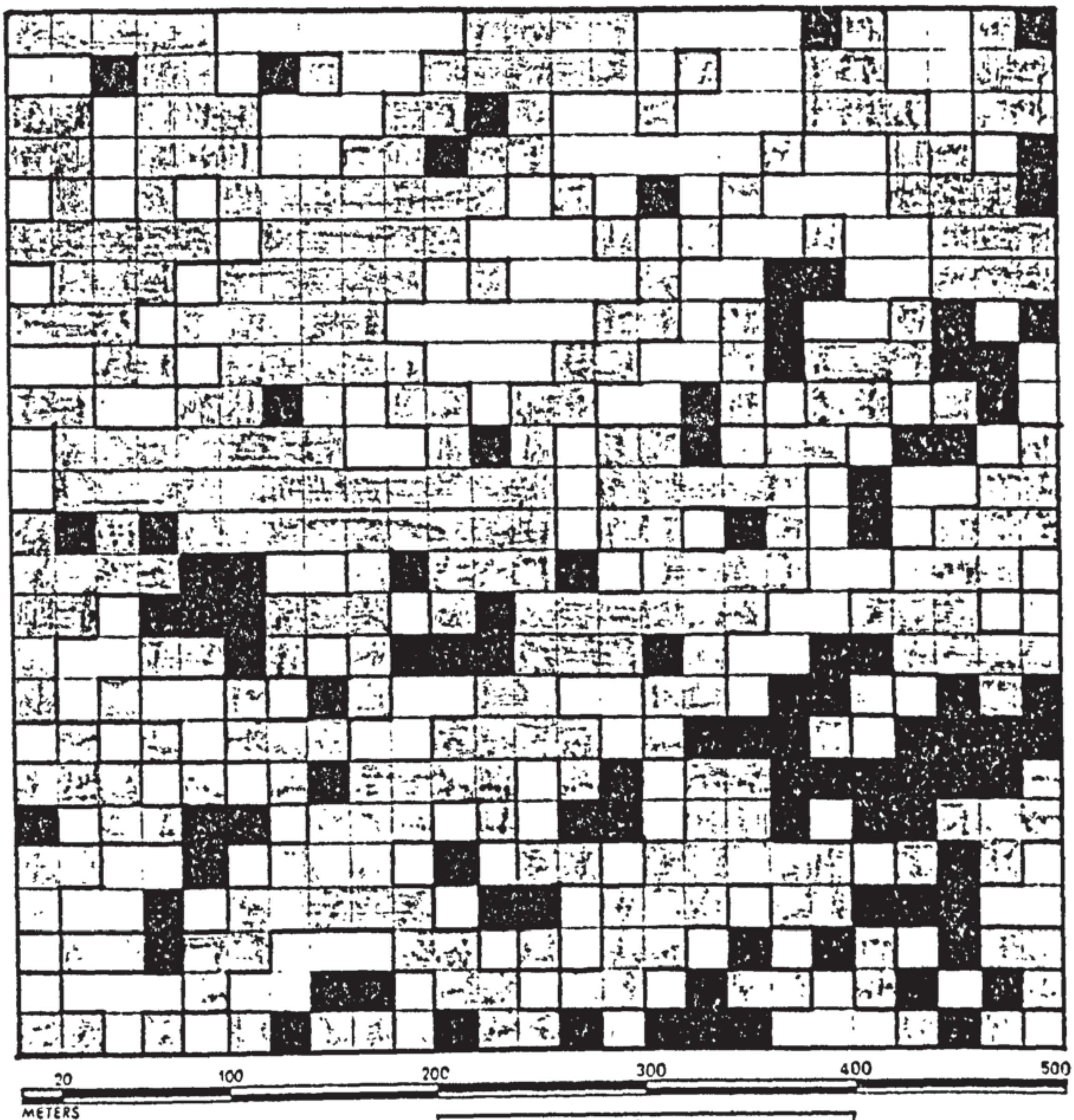
legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
ha	%	ha	%	ha	%
6.04	24.2	7.36	29.4	11.60	46.40



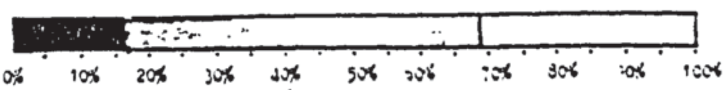
subject: management of urban open space
data source: 1:10,000 false colour aerial photography
sample area: southport
quarter kilometre square No.: 11
socioeconomic status: high



legend

- open space well managed
- open space badly managed
- built-up area

management of open space					
good		bad		built-up area	
has	%	has	%	has	%
13.00	52.0	3.92	15.7	8.08	32.32



APPENDIX 8.I

COMPUTER PROGRAMME DEVELOPED
TO PRODUCE HISTOGRAMS
SHOWING PROVISION OF OPEN
SPACE GROUPS VERSUS
SOCIOECONOMIC STATUS

```
      MASTER HISTO
      REAL HIST(4,10),TAB(585)
      INTEGER KG(4),LG(10),MG(10)
      DATA LG/  1, 91,166,161,241,331,421,451,556,571/
      DATA MG/ 90,153,160,240,330,420,450,555,570,585/
      DATA KG/1,5,2,6/
      DO 10 ICOUNT=1,4
      READ(5,7) IG,TAB
    7 FORMAT(I5,39(/15F5.2))
      DO 11 JG=1,4
      IF(IG.EQ.KG(JG)) GO TO 12
   11 CONTINUE
      CALL ERSTOP('PROGRAM ERROR 1',15)
   12 DO 13 IG=1,10
      L=LG(IG)
      M=MG(IG)
      TOT=0.0
      DO 14 I=L,M
      TOT=TOT+TAB(I)
   14 CONTINUE
      HIST(JG,IG)=4.0*TOT
   13 CONTINUE
   10 CONTINUE
      CALL OPENGINOGP
      CALL ERRMAX(1)
      CALL DEVPAP(297.0,210.0,1)
      DO 20 IG=1,10
      IF(IG.NE.1) CALL PICCLE
      CALL FRAME(297.0,210.0)
      CALL MOVTO2(50.0,180.0)
      CALL CHAHOL('GROUP *.')
      CALL CHAINT(IG,2)
      CALL AXIPOS(1,20.0,20.0,255.0,1)
      CALL AXIPOS(1,20.0,20.0,140.0,2)
      CALL AXISCA(5,4,0.0,0.8,1)
      CALL AXISCA(3,10,0.0,50.0,2)
      CALL AXIDRA(0,1,1)
      CALL AXIDRA(-1,-1,2)
      CALL GRAHIS(HIST(1,IG),4,0.5)
   20 CONTINUE
      CALL DEVEND
      STOP
      END
```

APPENDIX 9.I

COMPUTER PROGRAMME
DEVELOPED FOR THE GRID
CELL DENSITY EXPERIMENT

```
      MASTER SAMP2
      INTEGER TITLE(20),IUSE(625),ISEL(625),NSAMP(15)
      REAL TOT1(15,40),TOT2(15,40),SAMPL(40)
      DATA TOT1,TOT2/1200*0.0/
      READ(5,1) TITLE
    1 FORMAT(20A4)
      DO 13 I=1,625,25
      READ(5,2) (IUSE(I+J-1),J=1,25)
    2 FORMAT(2(4X,10(3X,I2,2X)/),4X,5(3X,I2,2X))
   13 CONTINUE
      NSAMP(1)=625
      READ(5,3) (NSAMP(I),I=2,15)
    3 FORMAT(14I5)
      DO 15 I=1,625
      J=IUSE(I)+1
      TOT1(1,J)=TOT1(1,J)+0.04
   15 CONTINUE
      DO 20 ISAMP=2,15
      N=NSAMP(ISAMP)
      IF(N.EQ.0) GO TO 40
      STEP=25.0/FLOAT(N)
      DO 21 IREPT=1,20
      DO 22 I=1,40
      SAMPL(I)=0.0
   22 CONTINUE
      CALL SAMPLE(N,625,ISEL)
      DO 25 I=1,625
      IF(ISEL(I).EQ.0) GO TO 25
      J=IUSE(I)+1
      SAMPL(J)=SAMPL(J)+STEP
   25 CONTINUE
      DO 27 I=1,40
      TOT1(ISAMP,I)=TOT1(ISAMP,I)+SAMPL(I)
      TOT2(ISAMP,I)=TOT2(ISAMP,I)+SAMPL(I)**2
   27 CONTINUE
   21 CONTINUE
   20 CONTINUE
      ISAMP=16
   40 NCOLS=ISAMP-1
      WRITE(6,4) TITLE,(NSAMP(I),I=1,NCOLS)
    4 FORMAT(13H1SAMPLING OF ,20A4/ 58H0AV.  HA/54 S.D. HA/54 AV.  PCT/
     1 54 S.D. PCT  / 5H0UNIT / 2X,2HN0,3X,15I6/)
      DO 41 I=2,NCOLS
      DO 41 J=1,40
      TOT1(I,J)=0.05*TOT1(I,J)
      TOT2(I,J)=SQRT(0.05*TOT2(I,J)-TOT1(I,J)**2)
   41 CONTINUE
      DO 42 J=1,40
      JJ=J-1
      WRITE(6,5) JJ,(TOT1(I,J),I=1,NCOLS)
    5 FORMAT(1H0,I3,4X,15F6.2)
      WRITE(6,6) (TOT2(I,J),I=1,NCOLS)
    6 FORMAT(8X,15F6.2)
      DO 43 I=1,NCOLS
      TOT1(I,J)=4.0*TOT1(I,J)
      TOT2(I,J)=4.0*TOT2(I,J)
   43 CONTINUE
      WRITE(6,7) (TOT1(I,J),I=1,NCOLS)
      WRITE(6,7) (TOT2(I,J),I=1,NCOLS)
    7 FORMAT(8X,15F6.1)
   42 CONTINUE
      STOP
      END
```

```
      SUBROUTINE SAMPLE(NS,MAX,IS)
      DIMENSION IS(MAX),CRAND(4001),KRAND(4000)
      INTEGER G05AZF
      DATA MAXSET/0/
      IF(MAX.EQ.MAXSET) GO TO 5
      IF(MAX.GT.4000) STOP 'TOO BIG'
      MAXM1=MAX-1
      CALL G05ATF(1,MAX,MAXM1,CRAND,KRAND,MAX+1,MAX)
      MAXSET=MAX
    5 IF(NS.GT.MAX) STOP 'OVERSIZE SAMPLE'
      IF(NS.GT.MAX/2)          GO TO 6
      MAJOR=0
      NP=NS
      GO TO 7
    6 MAJOR=1
      NP=MAX-NS
    7 MINOR=1-MAJOR
      DO 1 I=1,MAX
      IS(I)=MAJOR
    1 CONTINUE
      DO 2 I=1,NP
    3 J=G05AZF(MAXM1,CRAND,KRAND,MAX)
      IF(IS(J).NE.MAJOR) GO TO 3
      IS(J)=MINOR
    2 CONTINUE
      RETURN
      END
```

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