THE APPLICATIONS OF AERIAL PHOTOGRAPHY, PHOTOGRAMMETRY AND PHOTO-INTERPRETATION IN THE PLANNING PROCESS.

Submitted by

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Frontispiece: High oblique of Cape Town supplied by Terence McNally, Cape Town.

Abstract

To date aerial photography and associated photogrammetric and photo-interpretation techniques have played but a limited role in the planning process. In this study their dual role (i) as a base medium and (ii) as a source of data is investigated bearing in mind the requirements of planning data and certain inherent defects of conventional maps in the planning process. Having considered certain pertinent technical aspects of aerial photography and associated techniques, especially modern developments such as orthophotos, use of multi-emulsion photography, automated data extraction and automated data processing techniques, the application of these techniques is discussed in greater detail in respect of the dual role mentioned earlier. Aerial photographs are shown to be of considerable value to the planner as an analytic tool and a powerful source of data when dealing with such topics as feasibility studies, land use, resource surveys, urban and regional research and analysis, urban history, urban and rural administration, site evaluation, transportation and other branches of engineering, urban sociology and economics, as well as urban aesthetics. Aerial photographic data adequately meets the data requirements of the planning process and furthermore lends itself to modern automatic data processing methods. The modern improved forms of photography, i.e. photomaps, orthophotos, etc. have definite advantages over conventional maps insofar as a base medium in planning is concerned, and the wider use of aerial photographs and products is anticipated when planners become more aware of their universal application and versatility.

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1. INTRODUCTION

Urban and Regional Planning may be defined as an overall sphere of activity, to which numerous disciplines make their contributions towards the creation of an improved, comprehensive environment in which people can work, live and play. The emphasis is on people - planning is primarily for people. Implicit in planning is the decision-making process and this in turn is dependent on data - complete, accurate and valid - data about people and their environment, which furthermore satisfies the inter-disciplinary requirements of the planning process. Another important characteristic is the dynamic nature of the planning process, - the society's characteristics, its aims and its physical environment are constantly changing over time. Consequently information concerning that society rapidly becomes obsolete and requires revision or renewal. In addition to data, the planner requires a base on which to measure, experiment with and display the spatial characteristics and proposals of his plan. Generally topographic and other maps and plans have served in the past as the base material with varying measures of success. However, as a source of data in the planning process, such maps and plans have certain inherent limitations. In this study, the overall advantages of the aerial photograph plus the techniques of photogrammetry and photo-interpretation, will therefore be examined with respect to two distinct applications in the planning process:

(i) as a base material in lieu of or complementary to maps and plans;

(ii) as a source of data for decision-making, prediction and research in the numerous social and technological disciplines comprising urban and regional planning.

Comparatively little attention has been given in planning literature to the applications of aerial photography, either as a data source or base material and consequently many planners are unaware of the advantages of aerial photography in the planning process. A diligent search reveals that such references as are found tend to stress the principles of photogrammetry and photo-interpretation rather than the applications. For instance, M.C. Branch's "Aerial Photography in Urban Planning and Research" (3) devotes the major content to an explanation of techniques rather than applications. Part I consists of a comprehensive analysis of the use of aerial photography in planning, including future possibilities. Part II has as its objective the dissemination of the specialist knowledge concerning aerial photography, photogrammetry and photo-interpretation. Although published in 1948, Part II is still of considerable value to planners in that it covers, without great technical detail, the background knowledge necessary for intelligent use of aerial photography. However technical advancement has been rapid and twenty years later techniques, methods and products have improved beyond recognition. Orthophotos have become technically possible, the photo-interpretation and data-extraction process has been improved by the introduction of electronic methods, automatic stereoplotting of maps is an accomplished (although expensive !) procedure and generally "the state of the art" is such that much more elaborate use can be made by planners today, and the applications of Part I, although still valid, have been supplemented by many exciting possibilities resulting from new technologies.

In a recent issue of the Town Planning Review, M.G. Burry (6) in a paper based on his thesis for the Diploma in Town and Country Planning at Birmingham describes in considerable detail the principal methods of using aerial photographs, discussing their application to planning practice in rather general terms. While a review of the theoretical principles associated with aerial photography, photogrammetry and photo-interpretation is essential for a proper comprehension of specialised applications, an endeavour will be made in this study to concentrate on the applications of and benefits to be derived from aerial photographs in the field of urban and regional planning. Approaching the subject from a combined knowledge of the disciplines of photogrammetry and planning, will, it is hoped, bring some fruitful results to both disciplines.

The lack of attention given by planners is forcefully stated by Jeanne Davis in introducing the handbook (4) - "The remarkable versatility of the aerial photograph as a planning tool needs more widespread recognition by planners." One possible explanation for this apparent shortcoming is the fact that the more specialised applications have quite naturally been discussed in photogrammetric literature, which would seldom be freely available to planners. This is perhaps inevitable in such a widely dispersed interdisciplinary field as planning, but its inevitability does not make it a necessity. For example problems of traffic engineering of import to planners are freely discussed in both planning and engineering literature and there seems no valid reason why planning and applications of aerial photography might not be similarly handled.

Perhaps the best treatment of the topic is that appearing in the chapter of the American Manual of Photo Interpretation (1) dealing with Urban Area Analysis, but modern development has made even this recent publication outdated in certain respects. The intention of the International Institute for Aerial Survey and Earth Sciences to commence a diploma course as from 1969 devoted to the use of aerial photography in urban area studies will doubtless encourage greater interest and research by planners to the application of aerial photography in their discipline.

It must be recognised that the aerial photograph cannot be regarded simply a variant of the topographical map to be used purely as a base. There is the subtle difference that the aerial photograph presents each and every piece of data of interest to the planner in its TOTAL environment, whereas a map or plan can at best only present it in its PARTIAL environment. This concept will be expanded in the main text.

In examining the dual use of aerial photography as a base material and a data source, a necessary prerequisite is a consideration of the role, characteristics and origin of data in the planning process, the nature and function of maps, plans and photographs together with the specific requirements of this material in planning and the pertinent technical aspects of aerial photography, photogrammetry and photo-interpretation. No attempt is made to present these technical aspects in other than broad detail, being rather a statement of possibilities of the methods, than a detailed technical treatment. Thereafter the applications and potential of aerial photography and its associated processes will be examined in greater detail, bearing in mind such parameters as cost, accuracy and expediency in certain planning activities.

The field is inevitably wide, covering as it does most of the disciplines in planning, and quite clearly the testing of the reported and proposed applications in the field would be beyond the scope of this thesis. It is impossible, for instance, to acquire suitable aerial photography locally without considerable expense; field investigations would again require considerable time and expense to test all hypotheses locally, but many have been tested experimentally and are used elsewhere. It is hoped to follow up certain proposed applications at a later date in a more detailed investigation, when adequate funds and time are available.

One object of the dissertation is, in stressing the usefulness of modern aerial photography and subsequent process, to convince planners and students of the benefits and advantages that can accrue in practice with its use, and thereby stimulate further new applications. A second related objective is to complete a comprehensive review of all the newer applications and possibilities in the contributing disciplines. Such a document is so far as can be ascertained not available under one cover. All available sources of information have been consulted, as will be evident from the bibliography, in an endeavour to get as wide a coverage as possible and some interesting usages have come to light.

For convenience diagrams, photographs, etc., have been inserted as Appendices with appropriate references in the main text.

2. DATA AND THE PLANNING PROCESS

The Planning Process can be divided into six definite stages :

(i) The Statement and Definition of the Problem.

(ii) The Collection of all Data that bears on the Problem.

(iii) The Analysis of the Data.

(iv) The Synthesis of Alternative Solutions arising from the Analysis.

(v) The Evaluation of these Alternatives.

(vi) The Statement of the Final Proposal or Plan.

2.1 Relationship between the Six Stages of Planning

From a closer examination of the six stages, it is immediately apparent that stage (ii) - the collection of data - will have a fundamental bearing on all subsequent stages. Information is basic to theorising, decision-making and subsequent action, and the accuracy and comprehensiveness of the basic data collected at the survey stage, virtually affects the decision-making process and the ultimate product of that process, the PLAN. Notwithstanding the work done by Wald and others in the field of decision theory, there is no fundamental scientific law at present which can nationalise decision making, and hence precisely define the nature of data required. Existing decision theory can best be described as the application of formalised common sense to the available data concerning the problem. Prediction or decision-making about the future depends on present and past data together with a measure of intuition on the part of the planner. It is impossible to predict any event with absolute certainty, since such events are for instance to the whims and vagaries of human nature, unpredictable political trends, etc. Rationalised decision-making may well come in future when every possible unknown, which could have a direct or indirect bearing on the subject may be isolated, quantified and applied to a complex mathematical model to yield a correct decision on the basis of the data supplied. Clearly inaccurate, incorrect, outdated information will adversely affect stage (iii) rendering the subsequent stages of the process invalid. This vital dependence of planning and decision-making on accurate data is stressed most forcefully in Sir Patrick Geddes' philosophy - "Survey before Plan".

The six stage scheme would appear to imply a rigid chronological relationship. This is not the case - planning is never a finite act - it is a continuous dynamic process. The planning process and the plan are under constant revision due to the feedback of new data, which may either reinforce or alter the original decisions. Blackham (7) writes, "The plan initiates a course of action which produces events experienced by the agent, in the light of which he modifies the plan so that in a sequence of phases the plan is continuously initiating action or being modified by the results of action." This modification may well result in an new set of goals culminating in an entirely new plan during this process of review and appraisal. To detect the events referred to above sequential (ideally continuous) surveys and data collections are desirable.

2.2 Some Essential Characteristics of Planning Data

Data are defined in the Shorter Oxford Dictionary as the plural of datum - a thing given or granted, something known or assumed as a fact and made the basis of reasoning or calculation. In the sociological context, data are more specifically defined as selected and processed facts arising from the observation of phenomena. Observation may be made directly, indirectly or from various documentary sources (which could include photography).

(i) The data is defined by the assumptions and definitions made in the first stage - the statement of the problem. It is apparent that all data which may pertain to the problem either directly, indirectly or even intuitively must be collected.

(ii) The data should be accurate and correct. Data whose accuracy cannot be precisely guaranteed, but can nevertheless be shown by some other reasoning to have a reasonably high level of confidence is still of considerable value in the planning process, where 100% accurate data is often the exception rather than the rule. A distinction must be made here between accuracy and validity. Data may only be accurate to a rounded-off figure; e.g. inventory and census data can seldom be accepted as correct to the last digit but nevertheless is completely valid. On the other hand data may be 100% accurate, and yet have little validity in the particular context in which it is used.

(iii) Data collection is generally correlated with one point or narrowly defined period in time. Although field surveys generally take some time to complete, the data derived from them is generally assumed to refer to some definite point in time. The phenomena with which planning is concerned are seldom static and may vary considerably with the passage of time. Ideally all data used in the decision-making process should refer to the same point in time. In this way the maximum correlation between data derived from the numerous phenomena of interest to the planner will be attained. As a corollary to this condition the availability of data at numerous points of time from the past to the present would be especially valuable to indicate sequential trends of development.

(iv) Data should be comparable for the purposes of comparative studies. For optimum comparability, data must be correlated in the dimensions of time and area. Here equivalent rather than absolute time is envisaged, i.e. the epochs when two urban areas were at similar stages of development, for instance. Data should also be specifically applicable to the unit size adopted for the study area. Often available data refers to larger or smaller unit areas and correlation and comparison is at best a matter of "guesstimation".

(v) Planning requires a comprehensive evaluation of data rather than piecemeal acquisition and digestion of data resulting from numerous minor and uncorrelated studies.

Furthermore it is highly desirable that it be capable of rapid manipulation - it should be easily assimilable, readily accessible and capable of projection into the future. Numerical or coded data fulfils these requirements admirably. To optimise the planning process, it is essential that the planner be continuously aware of the current situation, increasing or decreasing the scope of his data gathering as occasion demands and employing "the feedback" process to modify and improve the plan.

(vi) Since a diversity of disciplines contribute to the planning activity, the data required is likewise widely diverse, e.g. economic, cultural, sociological, historical, demographic, climatic, cadastral, statistical, geographical, geological, etc.

2.3 Origin and Handling of Data

Data may originate from the following three sources :

(i) Official statistical data such as census reports, year books, etc. Such sources are general and intended for purposes other than planning. Furthermore they may or may not present the data in the specific form that the planner requires for his particular purpose.

(ii) The specific research survey; land use studies, resource surveys, origin and destination surveys, market surveys, opinion surveys, employment studies, etc. These surveys are conducted by each particular discipline operating in the framework of the planning activity for its own specific needs rather than as part of a comprehensive data collection procedure.

(iii) Indirect sources such as aerial and terrestrial photography, sociological phenomena, intuitive assessments of urban areas, etc.

Comprehensive acquisition of data depends on all these sources being fully exploited and correlated. Systematic handling, storage and use of data is important as there is always the inherent danger of swamping the available facilities with a mass of data. L.S. Jay (83) states the problem succintly as follows, "The first step is collecting the information - it then has to be stored somewhere. Information is of little use unless it is used - a process which means retrieving it from storage and then interpreting and analysing it as well. Collectively these steps are referred to as "data-processing"." The methods adopted for processing the data after collection naturally exert a radical influence on the method of acquisition. Most methods of "data capturing" in use today are oriented towards the use of digital computers in data processing and here again data in a numerical or coded form is desirable.

3. THE CHARACTERISTICS AND SUITABILITY OF MAPS, PLANS AND PHOTOGRAPHS AS A TOOL IN PLANNING

Maps, plans and other graphic representations (including photographs) of the features on the earth's surface serve the primary purpose of enabling man to cope with his environment. They are an important tool of the planner with two distinct functions (i) to provide data of use to the planner, and (ii) to provide a base for the analysis of the data, the synthesis and evaluation of proposals, and for the presentation of proposals in their spatial context.

Maps are representations of portions of the earth's surface delineating those features as may be desired according to a definite scale and projection. Various categories of maps of application in planning are:

Topographic maps, compiled from an original survey and depicting all natural and artificial features (including relief) which can reasonably be shown at the selected scale. A planimetric map is a topographical map from which relief information has been omitted.

Atlas maps which generally represent large regions, countries and continents on a small scale.

Special maps which include thematic, administrative, political, geological, pedological, cadastral, nautical, road and tourist maps. Thematic maps do not have to be drawn true to scale, e.g. population density maps, street directories, etc.

Plans can be regarded as orthographic representations of small portions of the earth's surface whose curvature is neglected and which have been prepared for a specific purpose generally at a large scale. An implied difference between a plan and a map is that the latter apart from its geometrical value, should endeavour to present in as artistic a manner as possible a picture of the earth's surface. The graphical depiction of features demands symbolisation and the impossibility of reproducing graphically all features at correct scale results in a selection of features and the consequent generalisation of the map. This generalisation takes the form of omission of detail considered irrelevant or insignificant, the smoothing of curves and the exaggeration and distortion of the selected features. The selected data is improved in that it is interpreted, named and quantified, its usefulness thereby being greatly enhanced.

At first sight the conventional maps and plans showing improved selected data in its precise location according to a rigid specification would appear to satisfy fully the multi-disciplinary needs of the planner, yet closer examination shows this is not so. Although many parts of the world have not as yet been mapped accurately, mapping cover of a sort does exist in most developed and developing countries, but the range of scales and variety of data presented is wholly inadequate to meet the planner's need. For instance, a planning project on metropolitan scale would require large, medium and small scale maps as well as a host of special maps depicting such diverse factors as population, land value, geology, climate, cadaster, etc., etc. Map specifications seldom cater for one particular class of user and constitute a compromise between the very conflicting requirements of many disciplines. The selection, exaggeration and generalisation of detail which is correlated to the scale of the map, weaken its application still further and the very attributes of conventional maps in fact detract from its final usefulness. T.J. Blachut (8) writes "Paradoxically, some of the characteristics that constitute the main attractiveness of the conventional map are, at the same time, its serious limitations and drawbacks. The symbols, that unequivocally define the details, cannot depict the individual characteristics of the represented features. Trees, buildings, bridges, etc. are portrayed by identical symbols for each kind of detail irrespective of their actual appearance; small and large trees are represented by the same symbols and the ground outline of a one-storey house may be identical to that of a skyscraper. Thus this method is unsatisfactory for depicting landscapes, morphological forms, vegetation, man-made objects and other features of human activity, or specific changes produced by the ever active forces of nature, because the conventional map is a static picture of an abstract of the earth's surface rather than its actual dynamic presentation." It will be noted that these defects apply particularly to environmental features of major concern to the planner. Other limitations of conventional maps arise from the fact that as development of an area proceeds larger scale maps are required, demanding more intensive and time-consuming preparation, secondly the existing maps become outdated more rapidly, thirdly the very expensive cost structure of mapping procedures inhibits its wider use and application and finally some maps - for instance - cadastral maps depict features which are not on the ground.

Maps and plans therefore only partially meet the planner's demand, and the more complex the planning process becomes the less likelihood exists of existing topographical and special maps meeting his exacting demands regarding base material and data. It is presumed that seldom, if ever, will the planning activity command sufficient financial resources to frame a complete series of maps and plans de novo to a specification that is unique to the problem in hand.

Aerial photographs on the other hand can record every feature on the earth's surface (within the limits imposed by photographic resolution and scale) to any desired scale. Furthermore the aerial photograph presents each piece of detail in its total environment, whereas the map or plan presents it in its partial environment, by the very nature of the cartographic process. Consequently considerably more data can be gleaned by inferential and intuitive processes from aerial photographs than from maps and plans. A typical example will illustrate this concept of the use of total and partial environment in data gathering. A large scale aerial photograph of a residential area will show a particular house in a particular block

- further examination will indicate a tiled roof, carport, swimming bath, three large trees, an area of lawn and much other micro-detail. The map or plan at identical scale (if available) will show certain detail as required by specification, but the total environment as manifest by the totality of all detail can never be depicted on a map. From the infinite number of seemingly unimportant details comprising the total environment, it is possible to determine with reasonable certainty sociological, demographic, economic and other invisible data so fundamental to planning.

The photograph has its limitations as a map - distortions, variable scale, no processed information, etc., but as will be shown in the next chapter, these defects can be eliminated or minimised by relatively inexpensive techniques, without radically disturbing the total detail. Further improvements to photographs result photomaps and similar productions discussed in 4.1.3.

4. TECHNICAL ASPECTS OF AERIAL PHOTOGRAPHY, STEREOSCOPY, PHOTOGRAMMETRY AND PHOTO-INTERPRETATION

4.1.1 Aerial Photography

Although photography of reasonable quality could be exposed with any high-quality camera, it is normal practice to use a specialised camera - the aerial survey camera - to expose successive photographs at short, regular intervals from an aircraft moving at speed along a flight-line to afford stereoscopic coverage. Ideally the camera axis should be in a near-vertical position and the air-base joining successive camera stations should be horizontal. Single exposures are seldom required owing to their limited use in interpretation and photogrammetric procedures, although oblique photographs, where the camera axis deviates considerably from the vertical do have some application in the planning process. To overcome the problems caused by low contrast of terrain features, atmospheric haze, necessity for high resolution, the precision of production of central perspective views, moving camera platform and so provide a satisfactory record of features on the earth's surface, demands highly specialised photographic materials, equipment and techniques. Typical modern aerial survey cameras have formats of either 7"x7" or 9"x9", focal lengths varying from 3½" to 8 " and angular fields of view varying from 70° to 120°. The coverage of the earth's surface is thus a function of the angular field. Military reconnaissance cameras are usually of narrower angular field and longer focal length to afford exceptional resolution of detail in a concentrated area. The scale at which images of features on the earth's surface are reproduced on the film is primarily a function of the focal length and the flying height above the earth's surface. At the present date, flying heights may vary from about 500 ft. to the altitude of an earth satellite.

It is important to note that when an aerial photograph is exposed, the rays of light from object to image point all pass through the lens centre and the resulting photograph is therefore a perspective projection and not an orthogonal projection. Hence an aerial photograph at best only approximates to a map in the case where the camera axis is vertical and the terrain flattish. Since scale is a function of the height of the aircraft above the terrain, (which is subject to greater or lesser variations in height) the scale at which images are produced on the photograph varies with the altitude of the corresponding terrain objects. In other words the scale of a photograph is not constant - this variation of scale gives rise to the so-called phenomenon of height distortion - the distortion of images from their plan position due to the height of the object. The image of a tall chimney for instance appears as a line and not a point. Height distortion is nil at the nadir point directly below the lens centre and increases to a maximum at the edge of the photograph. It is a function therefor of the radial distance from the centre and the height of the object point above a datum. (See Appendix A).

When the camera axis is tilted off the vertical, further distortions in image positions occur. These are referred to as tilt distortions. They are radial from a point known as the iso-centre and are functions of the amount of angular tilt, distance from the isocentre and the scale of the photograph. In a near-vertical photograph the iso-centre, nadir point and physical centre of the photograph are assumed coincident. Notwithstanding these apparent defects, a near-vertical photograph of flattish terrain (e.g. Cape Flats) will approximate closely to a true scale map.

Various emulsions may be used for the photography provided they have high speed, good colour sensitivity and high resolving power. These emulsions are effective in various spectral ranges and are of considerable value in interpretation techniques. Orthochromatic emulsion is sensitive to the blue-green radiation, while panchromatic gives uniform sensitivity over the whole spectrum. The resulting images appear in an infinite tonal gradation from white to black depending inter alia on the colour of the object photographed, its reflectance and other similar properties. These tonal differences should preferably be emphasised by using a high contrast emulsion. A large proportion of the ultra violet light from the sun is scattered by moisture and dust in the atmosphere. This light is very actinic photographically and must be filtered from the emulsion to avoid fogging. To increase the data-extraction possibilities, emulsions sensitive to infra-red radiation outside the visible spectrum are used with considerable success. Infra-red film is able to penetrate atmospheric haze, while the fact that the reflection qualities of infra-red rays vary considerably for different objects, especially water features and vegetation, considerably facilitates the photo-interpretation procedure. Since radiation at a longer wave length is used, a specially designed lens must be used in the camera. Finally colour film is finding increasing application in both the photogrammetric and photo-interpretation processes. As with general usage, both colour reversal and colour negative material is available. Colour negative material is favoured rather than reversal film for the following reasons :

(i) Printing from a negative is easier and superior;
(ii) Colour negatives can be used for production of black and white prints as well as colour prints;
(iii) Colour negatives are more tolerant of physical conditions.

Finally a new material - false colour reversal film - has been developed, whose three emulsion layers are sensitive to green, red and infra-red radiation. When processed to a positive, the green sensitive layer yields a yellow image, the red layer a magenta image while the infra-red yields a blue image. This combination gives a false colour rendition for most natural objects. The specific applications of infra-red colour and false colour photography in photo-interpretation are more fully dealt with in 4.3.2. All the emulsions and emulsion bases used for aerial photography are extremely stable and linear resolution of images to a few microns in the scale of the negative is possible.

The processing of aerial photographic materials follows standard practice, but meticulous care is taken to avoid any distortion of the film. The following variants may be produced from the aerial negative :

(i) Contact positive prints made by direct printing from the negative in the conventional manner.

(ii) Contact prints prepared using electronic scanning techniques. In this method the negative is systematically scanned electronically and the exposure controlled by the density of the negative, resulting in a print which is of uniform density and reduced overall contrast, making fine detail readily visible and minimising halation effects. (See Appendix B).

(iii) Contact diapositives (transparent positives) on film or glass made by (i) or (ii) above for use in stereoplotting equipment. Certain stereoplotters require reduced-scale diapositives.

(iv) Enlarged or reduced-scale prints made by optical projection from the negative. The grain of the film will allow reasonable enlargement by a factor of about x 15, but generally the available equipment and paper sizes restrict this factor to about x 6. Enlargements are particularly useful in clarifying fine detail.

(v) Colour diapositives, prints or enlargements where the appropriate material was used.

The planning and actual flying of photography is beyond the scope of this dissertation, but it must be emphasised that the scale of the photography must be tailored to fit the task for which the photography is intended. For example, the extraction of data in an intensely developed urban area would require much larger scale photography than a regional project. Photography is generally flown in a systematic pattern of parallel strips to ensure a block of photography giving a complete stereoscopic coverage of the area. The required scale of the photography determines the flying height above mean terrain height and this in turn determines the distance between successive exposures along a strip as well as the distance between successive strips. The photography is exposed with the camera axis as near vertical as possible, unless oblique photography is desired, in which case the camera axis is deliberately inclined from the vertical. High obliques are those containing an image of the horizon. Oblique photography is generally used in limited specialised applications such as the presentation of proposals, and the detection of information in disciplines such as archaeology and geology. Measuring and interpretation of oblique photography is more difficult than with the conventional near vertical photography. The airborne camera is generally conveyed in a specially adapted conventional aircraft, but today both helicopters and earth satellites have been used with successful results for specialised photography.

4.1.2 Improved Aerial Photography : Rectification, Orthophotos and Mosaics

To render aerial photography more valuable it can be improved in various ways. Firstly the distortions in the image positions due to any tilt of the camera axis can be removed to a degree that is dependent on the flatness of the terrain. Where the terrain is flattish it is possible to rectify a tilted photograph to yield an equivalent vertical photograph at a fixed scale. This process of rectification can be undertaken mathematically, photographically or graphically, with the practical emphasis on the latter two methods. In the photographic method the tilted photograph is transformed using a general projective conversion in a rectifying camera or rectifier, while instruments of the camera lucida or sketchmaster type are used for graphical transformation. It must be reiterated that the end product is an equivalent vertical photograph with the inherent defects of height distortion still present - however these are minimal in flattish terrain and in this case a rectified photograph corresponds closely to a map insofar as positional accuracy of detail is concerned. Since development generally takes place in flattish terrain, the rectified photograph can be of considerable value to the planner. It can be prepared in a fraction of the time and at a fraction of the cost that is necessary for the production of a planimetric map, and furthermore it retains the total environment of the photograph.

To eliminate the displacements in image positions due to height distortion (or in other words prepare a photograph which is at constant scale irrespective of the height of the terrain object points) a differential rectification process is resorted to, whereby the central perspective of the aerial photograph is converted to an equivalent orthogonal projection. The procedure is a complex one, demanding expensive equipment and a precise knowledge of terrain heights, involving a reprojection of the aerial negative at scales varying with the changes in terrain elevation, and yielding a typical photographic print known as an orthophoto. The process lends itself to automatic contouring with the production of a contoured orthophoto as the end product. The orthophoto possesses all the metric characteristics of a conventional map, while retaining the wealth of detail in an aerial photograph. The number and size of details depicted on the orthophoto depend on the scale of the original negative and the reproduction efficiency of the orthophoto technique. By eliminating the inherent inaccuracy of the conventional aerial photograph insofar as its use as a base for precise measurement is concerned, the orthophoto can be regarded as a perfect map substitute. The orthophoto satisfies the growing demand for immediate up-to-date information regarding features on the earth's surface and as such will be extremely valuable in the planning process.

Where the area of interest exceeds that which can be conveniently covered by one photograph, at the scale desired, a photomosaic can be prepared. A mosaic can be defined as an assemblage of near-vertical aerial photographs whose edges have been cut and matched to form a composite photographic representation of an area. The uncontrolled mosaic is the simplest and cheapest to prepare, being simply a "best fit" technique. Such a mosaic is invaluable in the initial stages of any planning project, where planimetric accuracy is often of minor concern, compared to the amount of information that can be presented at little more than the basic cost of photography. The individual photographs can be rectified and scaled to ensure better internal matching of detail and finally the whole mosaic can be tied to ground control yielding a controlled mosaic or photoplan which again in flat terrain approximates reasonably closely to a map. The mosaic provides a detailed overview of large areas of the earth's surface, in which detail is presented to a fair degree of planimetric accuracy. Since it covers a much larger area than the single photograph, regional trends and patterns are often evident, which escape notice on single prints. It has the obvious disadvantage that it cannot be subjected to stereoscopic examination. (See Appendices C and D).

4.1.3 <u>Photomaps</u>

Orthophotos, rectified photographs and mosaics can be further improved to yield photomaps, orthophotomaps, pictomaps and similar products. Relief information in the form of contour lines and spot elevations, names, boundaries, road classifications, etc., may be added using cartographic symbolisation for clarification and augmentation of data to improve the usefulness of the map. Obviously the amount of symbolisation should be controlled so as to retain the benefits of the photomap insofar as cost structure, speed of preparation and preservation of photographic detail are concerned. The annotation of names is regarded as essential plus the highlighting of features that may be obscured by vegetation. Urban areas are particularly suitable for large scale orthophotomapping, since the photographic images have sufficient resolution to permit the interpretation of the features with little or no field work. It is generally agreed that the photomap (or orthophotomap) is superior to the conventional map in the depiction of drainage patterns, vegetation (especially lone trees and shrubs), cultivated areas, and urban areas. All features are shown to scale and the exaggerations and generalisations of the conventional map are absent. (See Appendix E). A variant of the photomap is the three-dimensional map - here the photomap is printed on a plastic base which is then stamped out by an appropriate die giving a map in three dimensions. This has gained popularity for military use but its cost is, for obvious reasons, prohibitive.

A pictomap is a processed photomap, where photographic images have been converted into colours and symbols, using three tonal separations plus added data such as names, etc. At large scales the shadows of photomap features assist in their delineation and lend a three dimensional effect to such features as buildings and trees. The process is complicated and its cost, rather than its suitability, would mitigate against its wide application in planning.

4.2 Principles of Photogrammetry including Stereoscopic Viewing and Measurement

Photogrammetry may be defined as the science of measurement from photography, its main function being to reconstruct a precisely geometrically similar model of an object appearing on two photographs which have been exposed from two different aspects. The reconstructed model may then be accurately measured in three dimensions. In topographic mapping a model is formed of portions of the earth's surface at varying scales - subsequent measurement of this model yields precise planimetric and relief information regarding features on the earth's surface which appear as images on aerial photographs. The model is an abstract one and may be formed in various ways. Basic to photogrammetry is the concept of stereoscopic vision. In viewing a normal scene, three dimensional perception results from a combination of binocular and monocular clues, which the brain converts to a fused image in three dimensions. The binocular clues include the physiological phenomena of the simultaneous convergence and accomodation of the eyes on to an object but the most important clue is binocular parallax. Parallax may be generally defined as the apparent displacement of the position of any object referred to a fixed reference point caused by a shift in the point of observation. In natural stereoscopic vision, parallaxes in the image positions on the retina of each eye result from the separation of the left and right eyes. Monocular clues such as perspective, texture gradient, shadows, etc. assist the binocular clues to give a strong sense of stereoscopic vision. The parallaxes must always be parallel to the eyebase.

Natural stereoscopic vision may be replaced by artificial stereoscopic vision, where two photographs taken from each end of a base replace the normal view seen by each eye. Certain essential conditions must be complied with :

(i) Each eye receives its appropriate image.
(ii) The parallaxes of corresponding image points must lie on lines parallel to the eyebase.
(iii) The images must be approximately the same scale.

It is apparent that a pair of overlapping aerial photographs taken from each end of an airbase of a common area of terrain will satisfy the requirements of stereoscopic vision, providing each eye receives the correct perspective view. To achieve this the stereoscope was devised to present the left hand photograph to the left eye and vica versa. Setting the aerial photographs under the stereoscope, so that condition (ii) above is complied with, at the correct distance apart, results in a three dimensional view of a portion of the terrain. It must be noted that the depth impression is greatly magnified, due to the increased base distance, compared with the natural eyebase. Further magnification can be achieved with the use of magnifying oculars which can increase the angular relationships of the images by factors varying from x 3 to x 8, resulting in a final magnification of the stereoscopic effect which may reach x 50,000. Stereoscopic examination of the visual model formed by viewing the area common to two overlapping aerial photographs, yields unlimited precise information in the third dimension, which is so essential to photo-interpretation and data-extraction. The systematic formation of stereoscopic models is ensured by regulating the frequency of each photograph along the strip so that a common overlap of ±60% is achieved.

The parallaxes of corresponding image points may be measured stereoscopically to a high degree of precision using the stereometer or parallax bar. The distance between a pair of identical dots may be varied so that their parallaxes coincide with those of corresponding image points, in which case the dots appear to fuse in contact with the point on the stereomodel. Reducing the distance between the marks, yields a stereoscopic impression of a single fused dot floating above the model, while increasing the distance beyond apparent contact results in the dots breaking apart. Due to the considerable magnification in depth impression of the stereomodel, the contact position may be observed with considerable accuracy. Since the differences in elevation between two terrain points are a function of the differences in parallax between the images of the corresponding points on the aerial photograph, the focal length of the aerial camera and the flying height above ground, it is a simple matter to "measure" differences in height, using comparatively simple equipment to a degree of accuracy which may approach ±0.05% of the flying height, e.g. if the flying height is 1500/15000 ft., heights of points on the terrain could be measured to about 0.75/7.5 ft.

Extending this principle, stereo-plotting machines have been devised which form true-to-scale, three-dimensional models from a pair of overlapping photographs or diapositives, yield orthographic projections and measure the heights of the features on the models as a fused pair of measuring marks apparently maintain contact with the model. The orthographic projections are plotted in the form of, and to specifications applicable to, conventional maps and plans. Scales of production vary from about 1/1000 or larger to 1/250,000. The mechanical and optical precision of stereoplotting equipment is of an extremely high order to obtain values of position and height compatible with those obtained by conventional ground survey methods. Accuracies equivalent to a few microns in the scale of the negative are possible.

Modern developments include the application of computer technology and the automation of both the photogrammetric and cartographic procedures. Completely automatic position determination from aerial photography is already an accomplished fact and attempts are now being made to automate the cartographic process (9). Stereophotogrammetric techniques are not confined to topographic and other mapping operations, but can be applied in any field where photographic images can be measured and interpreted to obtain the size, shape, position or any other characteristic of physical features or objects.

4.3 Principles of Photo-Interpretation and Data-Extraction using Aerial Photography

4.3.1 Photo-Interpretation

Photo-interpretation is the act of examining photographic images of objects for the purpose of precisely identifying objects, judging their significance in relation to the environment and finally extracting data of either a quantitative or qualitative nature (or both). In a general sense any person looking at a photograph is practising photo-interpretation albeit at a low level. Images are recognised, their significance evaluated and possibly a quantitive or qualitative analysis made. Typical examples would be photographs appearing in the press and magazines. The ability to recognise images and make deductions, etc. regarding those images is closely correlated with the background knowledge and education possessed by the observer - for instance, an X-ray photograph of the body is generally incomprehensible to any but the trained practitioner. The background knowledge includes generalised, specialist as well as localised knowledge. The interpretative process may be carried on at various levels from the simplest (so-called photo-reading, i.e. detection, recognition and identification) to the most complex (photo-analysis and interpretation) depending on the nature and quality of the photographic material, the variety and applicability of equipment and techniques used, additional reference material and the individual skill and experience of the interpreter. The data-extraction stage follows from the highest level of photo-interpretation, where the analytical and deductive procedures are combined with photogrammetric and statistical techniques to yield quantitative and qualitative data to which further inferential techniques can now be applied. At the photo-reading stage objects may be recognised and identified to a fair degree of precision by the following image characteristics :

(i) Shape relates to the general form or outline of an object. The three-dimensial shape as observed stereoscopically is a most valuable element in photo-interpretation.

(ii) Size. The approximate scale of a photograph is either known or can be determined very simply, giving the absolute sizes of all features. Both absolute and relative sizes are vital factors in the interpretation process, and this element must often be considered simultaneously with shape.

(iii) Pattern which is defined as the spatial arrangement of features. Many natural and artificial objects exhibit a characteristic pattern (e.g. drainage pattern, street layout) especially in a regional context, hence permitting delineation of specific regions, areas and zones. Artificial patterns particularly are related to the operational characteristics of the system, e.g. railways have large radius curves, gentle gradients and few intersections, roads have sharper bends, steeper grades and many intersections.

(iv) Shadows. These assist in depth perception, render both profile and plan views (e.g. bridge), increase size of object raising it above the threshold of visibility, yield information for estimation of height and may help in recognition of texture. They do, however, obliterate certain detail. In urban planning 30° shadows are of considerable assistance in detecting invisible vertical features such as pylons, poles, etc. as well as information regarding heights and facades of buildings.

(v) Tone (or more specifically grey tones), while being an important element in the interpretation process, is most difficult to use in that it is caused by both terrain and other influences. Terrain factors include the physical surface of the earth - rocks, soil, vegetation, cover, etc. and the moisture or organic nature of soils, etc. Extraneous factors include the photographic process and photographic materials used, meteorological and climatological factors, etc. Strong tonal contrasts between various terrain factors assist considerably in the delineation of boundaries.

(vi) Texture is defined as tonal repetitions within an image. It can be considered as a pattern of tone as opposed to (iii) above which is a pattern of shapes. Texture is, like tone, affected by extraneous factors but nevertheless is a most useful element in interpreting agricultural and similar landscapes.

(vii) Site, locality and environment of an object are often helpful clues in identifying certain objects. Another factor is association, e.g. derricks, tanks, etc. would be associated with oilfields.

(viii) Date and Time of Photography can often provide invaluable additional information to the interpreter.

(ix) Colour. This element gives rise to the infinite variation of tonal contrast discussed in 4.1 when orthochromatic and panchromatic films are used. The use of colour, infra-red and false colour photography will be discussed later in 4.3.2.

A sine qua non of the interpretation process is the visibility of images on the photograph and this is dependent firstly on certain inherent characteristics of the objects themselves, such as shape, size and orientation, which are usually beyond human control, the acuity of the observer and finally the kind, scale and quality of the photography which can be controlled by the interpreter. The scale element is particularly important in that it must be large enough to ensure that the dimensions of images lie above the limit of recognition. The quality must be such that the photography have sufficient tonal contrast, sharpness and stereoscopic parallax. Sharpness depends on the movements of the object (e.g. motor vehicle), the movement of the aerial camera and the film process. Stereoscopic parallax as stated in 4.2 is a function of many variables; heights of object and aircraft above object, length and direction of airbase and the focal length of the camera. For these reasons special photography is often flown specifically for interpretation purposes, rather than topographic mapping. In South Africa, unfortunately, most aerial photography is multi-purpose and must meet the divergent needs of topographic mapping, (super wide field and as small a scale as is compatible with the theoretical photogrammetric accuracy and map specifications) and general photo-reading and interpretation purposes (large scale, detailed resolution, precise tonal variations, etc., which are generally associated with the narrower field angles and longer focal lengths.)

As an additional aid, photo-interpretation keys may be used. These are collections of reference material to facilitate the rapid and accurate identification of objects from their photographic images. The key consists of standard photographic illustrations of known objects for direct comparative purposes, together with a verbal description of systematic recognition features. More elaborate are the so-called dichotomous keys in which a series of yes/no decisions are made. Provided each decision is correctly made, the end result should be a correct identification of the particular photographic image. To date some 400 standard keys pertaining to the various disciplines have been prepared in the U.S.A. Keys, however, take considerable time and effort to prepare and are seldom foolproof, since the evaluation of the significance of objects in their total environment still requires considerable subjective analysis by a skilled interpreter and it follows that such an interpreter operates most effectively within the field of his particular discipline, using all the related background knowledge. The interpretative process is a systematic build-up of observation, deduction (aided by measurement and other techniques and above all logical thinking), until all the pieces of evidence converge to the correct or very nearly correct solution. Ideally the process should follow that of scientific method, i.e. observation, classification, generalisation, framing initial hypotheses, verification and elimination of certian hypotheses, and final confirmation of hypothesis, i.e. positive identification and interpretation of the aerial photographic images.

4.3.2 Special Photography and Instrumentation in Photo-Interpretation

Infra-red photography shows considerable advantages over panchromatic emulsions in certain branches of photo-interpretation - it enables clear distinctions to be made between deciduous and coniferous trees, water areas are clearly defined, soil moisture content is apparent (refer Appendix F) and there is improved penetration of atmospheric haze leading to improved image visibility. In the military sphere it is useful for detecting camouflage. Roads appear with greater clarity, the distinction between paved and gravel roads is greater, and generally tonal contrast is greater on infra-red photography. It also has important applications in geology and allied disciplines such as pedology, etc.

In monochrome photography, interpretation depends to a considerable degree on the distinct tonal separations between the various "grey" tones that constitute the photograph. The introduction of colour adds another dimension and replaces the "grey" tones by an infinite number of colours and shades. Further it introduces an element of reality, in that the images are closer to what those viewed under natural conditions of vision and more subtle data is discernible. The task of the photo interpreter is made easier and furthermore colour photography can provide more significant information than black and white photography.

Certain types of information, not readily discernible on either monochrome or natural colour photography becomes apparent when false colour emulsion is used. Trees may appear as magenta, yellow, or purple depending on species and their condition, i.e. healthy or diseased. Drainage patterns showing water features as blue contrast vividly with magenta or green of the terrain, and like infra-red emulsion attempts at camouflage are instantly apparent (see Appendix G).

A stereoscope and stereometer are essential for all photo-interpretation purposes to permit the use of the third dimension. Other elementary equipment includes the so-called "grey-scales" for measuring the density of photographic images. Limited use has also been made of direct optical projection stereoplotters to reconstruct precise spatial models of a strip of photographs and subject the whole strip to an interpretation process simultaneously (52). A newly developed stereoscope, designed by Eranti, (10) also permits the continuous stereoscopic observation of a strip of photography. In an endeavour to eliminate the human element considerable research is at present proceeding to devise instrumentation to measure accurately such parameters as tonal contrast, image density, etc. thereby increasing the precision of interpretation, as well as the amount and reliability of extracted data. Colwell (11) has studied the use of spectrophotometers and spectrometric analysis to measure the spectral reflectance of rocks, soils and other features on the earth's surface so as to predict accurately the tonal contrasts that would be obtained with various film filter combinations. In this way the optimum film-filter combination can be selected to yield maximum contrasts and hence increase interpretability and data extraction. Chevallier (12) has investigated the use of optical filtration of coherent light, as emitted by a laser, in the interpretation process and has undertaken certain experimental work in the field of oceanography, city planning and archaeology. By studying the trace of a filtered aerial photograph, much statistical information is obtained about features which tend to exhibit a pattern of regularity, e.g. houses in a built up area and waves on the sea (refer Appendix H).

The human eye is limited in its ability to detect minor changes in the density of photographic images and hence micro-densitometers have been used to scan the variations in optical density across a linear portion of a photograph at much greater sensitivity than human capability and present the data in digital form to a computer for analysis. Pearse (13) describes an instrument known as the isodensitracer which accurately measures optical densities and then plots the densities on a map of the area (see Appendix I). In common with other disciplines, applications of automation are being examined in photo-interpretation to cope with the problems occasioned by the repetitive photographic coverage needed to keep pace with development. Sequential aerial photography is a powerful tool of analysis for the photo-interpreter enabling him to detect and predict trends and movements, disclose intentions and record changes (see Appendix J). Gribben (14) proposes the use of comparative sequential orthophotography and the subtractive logic of the automated image correlator or an automatic stereo-plotting machine to yield a final orthophotograph on which only the changed information appears. This can immediately be processed and analysised by the interpreter, without him having to search for, plot and examine all significant changes. DiPentima (15) and Sharp (9) discuss the current trends in automating photogrammetric and photo-interpretation methods, including the new opto-electronic methods, viz. lasers, holography, optical data processing and other methods still in the experimental stage. Parameters such as the size, shape, shadows, texture, pattern and position of images (in three dimensions) have all been determined automatically to date. Hawkins and Munsey (16) describe the automatic detection of motor vehicles on aerial photographs primarily through their shape. Basically a shape index is determined (expressed by the square of the perimeter divided by the area) and this is characteristic for types of images. Rosenfeld (17) has used ultra-high resolution scanning and digital coding to yield a quantitative measure of the texture of the photographic image of a wheatfield. Pattern recognition is simply an extension of shape detection.

4.3.3 Data-Extraction

Provided the interpretative process has been systematically carried out, commencing with a general over-view of the area and then considering the more detailed functions of images and their significance in their environmental context, considerable data is immediately available in respect of all image features that have been correctly identified. For the purposes of this study it is proposed to call this data, which has been derived by positive identification, PRIMARY DATA. Inferential and other techniques can then be applied to this primary data to yield SECONDARY DATA.

Primary data would include all positively identified features on the earth's surface of either natural or cultural (man-made) origin. No attempt is made here to compile a complete catalogue of such features but sufficient will be listed to indicate the wide possibilities.

Natural features: Mountains, plains, rivers, lakes, coastline, nature of terrain surface, natural vegetation, and under water detail.

Cultural features: The results of agricultural operations including afforestation, orchards, vineyards, row and cover crops; extractive industries, including mines, quarries, oilfields, forestry; gross urban land use, residential, industrial, commercial and recreational; communications and transportation systems, airports, harbours, highways, railways, canals, power-lines, radio-stations and even pipe-lines.

With an increase in the scale of photography there is a corresponding increase in the grade of data available. For instance a large-scale photograph of an urban area permits the differentiation of motor vehicles and the detailed analysis of buildings, (refer Appendix K). Once the primary data is available it can be measured and quantified, e.g. number of houses in block, roof area of each house, etc., etc. More elaborate measuring techniques involving sequential photography (which may be exposed at units of time varying from seconds to years apart) will yield accurate measurements of rate and change of rate, e.g. speed and acceleration of motor vehicles, rate of urbanisation and its annual change, etc. In 4.3.2 the use of instrumentation equipment to aid the interpretation problem was described. Although the equipment is at first sight able to undertake much of work of the interpreter, even in the sphere of elementary decision-making, nevertheless the final interpretation, data-extraction and subjective analysis remains the task of the human interpreter. At present the machine and the human are complementary in the data-extraction process, but it can be expected that automated assistance in data-extraction will become more and more effective in future. Automatic change detection as envisaged will be a particularly powerful tool in data-extraction for the planner.

The secondary data can be derived using tested inferential techniques from the primary data. This secondary data is of necessity at a lower level of confidence than the primary, but it is nevertheless of great value especially in the planning process, where the acquisition of identical data by alternative means is often impractical or impossible. Firstly, after the interpretation process there will be certain visible features on the photographs that cannot be identified with complete certainty. However, by inference their identification can be made with reasonable certainty and the resultant data treated with certain reservations. The greatest source of information is the <u>invisible data</u> that can be gleaned from correct identification and measurement of visible features followed by systematic inferential and statistical treatment. Conclusions are drawn on the principle of probabilities. Having correctly identified certain basic features or types of features, their areal and other contexts are then considered. Several hypotheses may suggest themselves but critical analysis usually shows that only one is acceptable. Having tested such a statement on several occasions in the field, correlations of reasonable reliability can be established. A typical example will best illustrate this process. Having postulated and proved that certain sociological phenomena show a definite correlation with physical and spatial characteristics in urban areas, Green and Monier (18) related these known correlation characteristics to positively identified physical structure on aerial photography to yield sociological data of considerable significance and value. The fund of secondary data available using these inferential techniques is virtually unlimited - this fact was stressed by E.A. Gutkind (20) in 1952 - "the aerial photograph is more than a visual supplement to bolster knowledge acquired elsewhere, it is in itself a fundamental source of data and knowledge."

A third type of secondary data would be that collected intuitively - those impressions which have been mentally extracted from a photograph without applying conscious inferential or measuring techniques. Although not quantifiable, such intuitive data is nevertheless valid. For instance data regarding aesthetic impressions of areas cannot be precisely measured, but it could well exercise profound influence on the decision-making process and the physical planning of an area.

An important consideration in data-extraction is the time reference point of the photographic data. The aerial photograph is a complete visual record analogous to the field records of any specific research or data survey. The latter type surveys will of necessity extend over a considerable period of time - months or maybe years. The "collection" of the basic photographic data is virtually instantaneous since a single stereopair of aerial photographs can be exposed in a minute or so, while a complete block of photographs, such as might be required in a regional project could be exposed in a matter of hours. For all practical purposes, the primary and secondary data derived from photographs can be considered as referring to one point in time. This fact is extremely valuable in view of the rapid rate of urbanisation and development - aerial photography can yield trend data over extremely short periods of time.

5. APPLICATION OF AERIAL PHOTOGRAPHY AND ALLIED PROCEDURES IN PLANNING

As mentioned in the introduction there are two distinct usages of aerial photography and the procedures allied thereto in the planning process;

(i) the provision of a base medium in lieu of or complementary to conventional maps or plans;

(ii) a source of data in the many contributing disciplines.

5.1 Aerial Photography as a Base Medium

Maps or similar graphic presentations are necessary in planning to record and summarise data descriptive of the urban environment, to measure physical quantities such as distance, area, height, volume, etc., to experiment with and investigate the spatial characteristics of alternative proposals and finally to display proposals contained in the final plan, which may include a land use plan, zoning plan, or may form part of the master plan, town planning scheme, etc. Chapin (5) - "planning analyses call for a variety of maps which not only provide a basic description of the physical layout of the urban area and its physiographic features but provide a base for plotting and analysing information assembled in surveys." Aerial photographs, coupled with stereophotogrammetric methods, are today universally used in the compilation of topographic and other maps, which are the end product of a field survey procedure. Such maps are then used by the planner as a base medium. As has been discussed in 3, maps and plans only partially meet the planners' need both as a base medium and as a source of data. This statement is especially valid in urban and peri-urban areas, and is also governed by the map series available in the particular country. South Africa's national map series includes 1/50,000, 1/250,000 and smaller scale topographical and topo-cadastral maps. The various cities do endeavour to carry out a large-scale mapping programme - e.g. Cape Town 1/480 series - but battle against the rapidly increasing rate of urbanisation to provide up to date large-scale plan and mapping cover so vital to urban planning. At the present rate of urbanisation, maps covering metropolitan, urban and peri-urban areas become obsolete within a matter of a year or so. Cape Town is now using photogrammetric procedures to undertake de novo mapping and revision in its large scale series (21). There is a complete lack of suitable mapping cover in South Africa in the medium scale range (1/2,500 - 1/25,000), which is the range within which the urban planner operates. Various compilation maps are available in respect of cadastral and other data, but their accuracy cannot be guaranteed. Plans for specific engineering works are available, but have limited application. Chapin (5) recommends two series of planning base maps, - the general purpose map (wallmap) at between 1/2,500 and 1/30,000 depending on the size of the urban sphere of interest, and the detailed planning base map at scales from 1/1000 to 1/2500. The latter would be used as a base medium for land use, space use, use of water areas, blighted areas, land value, aesthetic and similar studies in planning.

To provide basic material at the scales 1/1000 to 1/30,000 where none exists the following alternative procedures could be resorted to

(i) complete photogrammetric survey plus cartographic production of a line map;

(ii) preparation of an orthophotomap;

(iii) preparation of a photomap from a controlled mosaic, or even a controlled mosaic without further embellishment.

The first possibility would be the optimum - it could be compiled to a specification laid down by the planning agency but it would be extremely expensive and time-consuming in preparation. In a rapidly developing urban area, portions might well be obsolete before final printing. The use of an orthophotomap (see 4.1.3) overcomes the time factor, but it is still a relatively expensive process, its costs per unit area being somewhere between conventional mapping and the photomaps prepared by similar procedures (controlled mosaics or rectified photographs). Such photomaps combine the advantages of speed and low cost in preparation, and should in many cases provide sufficient accuracy and certainly adequate information for a general base map. There is little doubt that the costs of orthophotos and orthophotomaps will decrease with continued application and greater automation, in which case they will provide the ideal base map material for urban planning. In a paper presented at the 1965 Conference de Photogrammetric Urbaine, Blachut (22) discusses the application of orthophotomapping in urban regions, mentioning its immediate application in the production of medium (1/10,000 - 1/25,000) scale maps, in those countries lacking an organised large scale survey and mapping of urban areas. At very large scales (1/500 - 1/1000) urban areas present certain technical problems. to orthophoto procedures in the differential projection of tall buildings, etc., and they will have less application there. However the CBD and other areas characterised by tall buildings are not subject to such rapid changes as the urban perimeter and may not require such frequent mapping. Photomaps (or controlled mosaics) can be used as is, or alternatively line maps prepared by tracing the information directly off them, together with any additional detail it is desired to add from other sources. The latter procedure will, of course, negate some of the advantages of a photomap, such as the preservation of photographic detail and the presentation of the total environment to the planner. Because of their low cost it would not be impractical to prepare a new photomap series every couple of years or so thereby overcoming the problem of obsolescence. Scales are variable and would be controlled by the detail it is desired to present. As stated above, at very large scales the aerial photograph does present certain difficulties in mapping urban areas - detail is obscured by overhanging roofs, balconies, etc., buildings create dead ground and shadows, etc., but these difficulties can be minimised by suitable photography and in any event are outweighed by the economy, speed and expediency of photomaps.

The problem of mapping the urban area has been the subject of considerable research in France where the Centre de Recherche d'Urbanisme has devoted considerable attention to the many problems that rapidly increasing urbanism has created in photogrammetric mapping; the impact of the dynamic nature of urbanisation on city plans, the various uses to which the plans are put, the varying accuracies and specifications demanded, organisational problems and the use of numerical photogrammetry.

If de novo mapping is undertaken consideration should be given to the related problem of data storage and presentation. The feasibility of linking mapping systems based on aerial photography to computers, resulting in new methods of data presentation other than by conventional line maps is currently being investigated and it can be expected that these techniques will have great application in planning, where vast quantities of data have to be spatially correlated. Nowicki (23) envisages the ultimate in map production as the numeric map - the production of qualitative and quantitative data in digital form only, from aerial photography. The numeric map could be used to generate conventional maps, or as a basis for detailed design and planning of any proposals that pertain to features on the surface of the earth. The concept of the Digital Terrain Model discussed more fully in 5.2.6.1 embodies certain of these principles.

The presentation of proposals is an important part of the planning process, either at the evaluation stage of alternative proposals or in the statement of the final proposal. Appraisal of planning proposals involves their reference to administrative officials, and the general public. It is highly desirable that the public especially participate in the planning of their future environment, apart from their rights as taxpayers in the expenditure of public moneys. It is essential therefore that all planning proposals be presented in as detailed and comprehensible form as possible to all who have to examine, comment on and approve the proposals. Experience has shown that whereas the non-technical and lay user has considerable difficulty in deciphering and understanding technical maps and plans with their inevitable symbolisation and in visualising the third dimension, the same individual can comprehend photographs and models with ease. Aerial photography therefore provides a most suitable base for the presentation of certain spatial proposals, either by simply draughting the proposals over the photograph or by more elaborate methods such as double photography, photo-montage, or half-tone suppression of unwanted detail and consequent accentuation of new proposals, resulting in the preparation of a "faked" photograph, which is a combination of the existing environment and proposed changes. The photographic method is most valuable when considering aesthetic considerations (see Appendix L). Models of various forms are also most valuable for the appraisal of proposals, and the plastic 3D maps mentioned in 4.1.3 have a certain limited application. In addition the wealth of features available on an aerial photograph gives the model-maker the necessary pictorial information with little effort. Oblique aerial photographs often are useful in presenting proposals and information but have limited value in data-extraction and measuring procedures and are seldom available from official agencies. In South Africa all oblique photography is undertaken by press and similar photographic agencies. Oblique aerial photographs are most suitable for showing to their best advantage not only individual houses and estates, but also the greater environment of towns and cities (see frontispiece). They also provide a graphic record of progress on engineering and architectural construction projects. The "public relations" use of aerial photography extends to the educational process. Branch (3) - "It is in this respect especially that larger scale photographs are effective in the classroom as a means of depicting the city as a reality of many parts - their value for illustrative purposes in urban geography, land economics, urban sociology, housing or various aspects of design and public administration needs no elaboration."

5.2 Aerial Photography as a Source of Data in Planning

The principles governing the extraction of primary and secondary data in the photo-interpretation process have been discussed in 4.3. These principles can be applied in the numerous disciplines and sub-disciplines that comprise the planning process. For convenience the applications will be dealt with under the following headings:

General Feasibility Studies; Land Use and Natural Resource Surveys, including Census and Inventory Surveys; Urban and Regional Research and Analysis; Urban History and Archaeology; Urban and Rural Administration; Site Evaluation including Geologic and Climatic Factors; Engineering, including Transportation and Hydrology; Sociology; Urban and Regional Economics; Aesthetics.

Inevitably the various fields overlap to a certain extent.

5.2.1 General Feasibility Studies

Aerial photography can in most planning studies provide sufficient data at little or no extra effort to enable studies of the general feasibility of any planning project to be undertaken, i.e. a pre-planning study whereby an initial appraisal can be obtained with little expenditure in time, cost and effort of existing conditions and any significant trends. If the project appears realistic, practical and worthwhile, the data gleaned from this quick pre-planning study can operate as the initial feedback in the process and clearly will improve the statement and definition of the plan and problem as well as the planning of more detailed surveys. Rapid extraction of primary data only, will yield the solution of the feasibility problem in most of the disciplines contributing to the planning process, since they all require to a greater or lesser degree, quantitative and qualitative information regarding the human environment. At the feasibility stage the actual accuracy of this information is of lesser concern than its relevancy and considerable inaccuracies can be tolerated without adversely affecting the feasibility. A rather extreme but simple example in site evaluation will illustrate this concept. Is it feasible to consider an area of land as being suitable for a specific purpose - a new town? Quick examination of available photography can yield data regarding slopes, drainage, access and other essential parameters in a matter of hours - possibly quicker than an inspection in situ - if the data reveals that a portion is marshy and the remainder rocky and broken, difficult of access and the whole area generally unsuitable for development from many points of view, it matters little whether maximum slopes are 10° or 12°, whether the area is 5 sq. miles or 5.5 sq. miles, etc. Such inaccuracies are tolerable when the actual feasibility and initiation of the planning process is being considered. (The data required in the actual process must of course be of much greater precision). Considerable economies have resulted in that the setting-up of an elaborate planning organisation is unnecessary at this stage. The feasibility studies can be handled by a compact organisation with great efficiency provided aerial photography is available.

5.2.2.1 <u>Land Use and Natural Resource Surveys</u>

A primary requirement for the planned development of any area, be it urban or rural in character, large or small, is up to date knowledge of the present usage of the land within that area. "The complex intricate pattern of land use or non-use is the result of the action and interaction of many factors: some physical, such as elevation, slope, drainage, soil, rainfall and temperature; others historical such as ownership and tenure; others more purely economic such as working costs and agricultural prices. But whatever the reason for the present complex pattern, it is from this and upon this that any planning for the future must start. The land is not a blank sheet of paper to be planned de novo." (24) The importance of accurate and comprehensive land use data is undeniable and the aerial photograph has proved itself to be ideal in supplying this data, in that predominant land uses may be identified, classified, measured and delineated. The extracted data may then be transferred to a base medium, which may well be a photomap since high positional accuracy is not required. The land use study may be undertaken on whatever scale is necessary ranging from the broad study of regions and macro-areas down to the detailed study of micro-areas such as neighbourhoods and blocks. The survey can be related to time available, financial considerations and local conditions merely by varying the scale of the aerial photography. For a broad study on a regional basis no field control (other than the personal knowledge of the photo-interpreter) would be necessary, provided good quality photographs at a scale between 1/30,000 and 1/70,000 were available. The following broad categories of land use could be accurately determined from primary data:

(1) Settlement and Industrial Land; (2) Tree Crops (orchards, plantations, etc.); (3) Other Agricultural Land; (4) Grazing Land; (5) Woodland and Forest; (6) Marsh and Swamp Land; (7) Unused Land.

This broad survey immediately provides an inventory of agricultural and other areas, clearly indicating those which require more detailed investigation and assists planned regional development to proceed on a complete knowledge of existing conditions. Sridas (25) reports that the cost of a land use survey in Ceylon undertaken by photo-interpretation techniques was one-third of that of a similar survey using conventional methods! Increasing the scale of the photography to the 1/10,000 - 1/20,000 range and applying the more elaborate techniques discussed in 4.3, such as the use of different photographic emulsions and advanced data extraction methods, detailed land use surveys are possible, particularly of urban areas. Coupled with land use surveys are the land potential and natural resource surveys, since the planner requires not only complete knowledge of the usage of the land but also its capabilities. Factors such as gradient, nature of surface and sub-surface, elevation, aspect, climate and drainage control the most efficient use of the land as far as agricultural and other development is concerned. Further natural, cultural and economic factors influence the best use of the land in the most general context, (land being one of the limited productive resources of concern to the economist) - communications, urban concentrations, natural resources, etc.

These are possibly of more interest to the economic geographer, but are of more than passing interest to the planner. The assessment of natural resources such as forests, agricultural land, mineral deposits, water supplies, etc. can be facilitated by means of aerial photography. For instance, in forestry data regarding tree distribution, timber volumes and afforested areas can be assembled rapidly at a fraction of the cost of a ground survey. Ideally geological, pedological, ecological, hydrological and topographical surveys, all based on aerial photography should be integrated in a comprehensive study of the natural environment and its resources, prior to planned development.

For land use and land potential surveys required for planning on an urban and metropolitan scale, primary and secondary data extracted from aerial photography exposed at scales between 1/5,000 and 1/15,000 is adequate to identify the major categories of existing land use classification systems, except perhaps for certain processing, distribution and service activities. In certain categories such as communications, it will be possible to classify the more detailed "second or third digit" sub-categories with 100% precision, e.g. railroads, highways, etc. Referring to the various systems enumerated in Chapin (5) p. 278 et seq., it has been estimated that 60% of the 67 "two-digit" land use categories can be identified with certainty and quantified using data extraction techniques. In central urban areas the accent is on space use rather than land use and here the aerial photograph has limitations, but it can be used as a base medium for an "inspection" or "inspection-interview" survey. More specific applications in urban land use analysis will be discussed in 5.2.3.1.

Considerable use has been made in South Africa for regional land studies - refer Board (26) and associated literature. No publications could be traced concerning the application of photography in more detailed land use studies on the metropolitan and urban scale in South Africa, but there is little doubt that the planning branches of the larger local authorities and provincial administrations do utilise aerial photography for this purpose. In France Cazabat (27) has prepared special thematic maps at 1/10,000 from aerial photography to ensure best use of rural and peri-urban land by the Real-Estate Improvement and Rural Construction Companies.

Changes in land usage in an areal and/or time context resulting from a conversion from rural to urban use, for example, are very simply detected by means of sequential aerial photography exposed at identical scales. Automated techniques in change detection discussed in 4.3.2 will have wide application in this field. Since the standard classification systems use digital coding, automatic data processing systems are ideal for handling land use data from photography since the location of each use can be defined by numerical co-ordinates obtained either by stereophotogrammetric techniques, if high precision is desired, or by scaling off the simpler photomaps where lesser precision is tolerable. Automatic plotting machines can then prepare the land use plans, with no further human effort. A similar concept - the Digital Terrain Model - is currently being used in engineering planning; see 5.2.6.1.

5.2.2.2 Census and Inventory Surveys

Aerial photographs have proved most useful in undertaking census surveys of human and animal populations as well as a general inventory of any particular feature whose image is identifiable on the photograph. In a doctoral thesis J.N. Scheepers (28) used more than 13,000 aerial photographs to count the number of dwellings. He then used density values correlated with land usage and established the most accurate population pattern of the Transvaal yet determined. His globular totals corresponded closely with official census data and the micro-distribution of population was more meaningful than that which could be ascertained from counts within administrative units. The method of counting dwelling-units and then allocating persons to each, bearing in mind such factors as residential locality, population group, family size, etc. has proved most successful in rapidly determining reliable demographic data of specific areas whose boundaries do not coincide with those used in census surveys.

Wild life census operations have been successfully undertaken using suitable scale photography - the census of seals and seabirds on the islands off the South African coast - counts of reindeer in Norway - are typical examples. Here the count is digital and not inferential. Totals of inanimate objects within specific areas are also facilitated e.g. the number of houses, parked cars, etc., can be accurately assessed, provided they can be identified. Care must therefore be taken when planning the photography to ensure that all objects of which a census is to be made are above the limit of photographic recognition.

5.2.3.1 Urban Research and Analysis

Urbanisation is complex phenomenon which dominates the contemporary scene and whose contributory causes are not wholly understood. There is no comprehensive theory underlying the process of urbanisation, which can give a universal explanation to urban problems throughout the world, and which can explain in detail man's interaction with the environment and as such serve as a basis for prediction. Space is recognised as an essential parameter in defining this environmental interaction and thus in many urban ecological studies the twin spatial characteristics - form and structure - play a dominant role. Urban morphology - the dissection of the city into functional units - is defined by Vance as "a study of the operating forces that cause land uses to associate or dis-associate with one another" thereby implying a synonymity between land use and activity systems. Catherine Wurster defines form as (i) the physical pattern of land use, (ii) population distribution, and (iii) service networks, while structure is defined as the spatial organisation of human activities and inter-relationships. In studying urban morphology, spatial data and characteristics of the physical and human environment are essential. As has been demonstrated, aerial photography is ideally suited for the acquisition of any data that is distributed spatially over the earth's surface.

In studies of spatial phenomena the starting point is a definition of the areal extent of the study, i.e. the delimitation of boundaries. This has proved to be an extremely difficult problem; a region may have many boundaries, geographical, political, administrative, climatic, etc.; an urban area has no distinct boundary, suburbs and neighbourhood areas, market areas, traffic catchment areas, all require a different approach in delimitation. In many cases boundaries are zonal rather than linear and various techniques have been proposed for the delimitation of boundaries. Gibbs (29) suggests a "walk-around" method or alternatively the use of aerial photographs. "A picture taken over the centre of an urban area at an altitude sufficient to provide a wide view of the surrounding territory reveals in a most dramatic fashion the physical reality of its boundaries. Although the technical complexity and expenses entailed may often preclude the use of aerial photography, it warrants consideration as providing what is perhaps a superior means of delimitation." His objection to aerial photography on the grounds of technical complexity and expense is hardly valid when it is borne in mind that most urban areas in South Africa and elsewhere are at least covered with reasonably modern medium scale photography, which is available at reasonable cost and suitable for delimitation of boundaries. Where the extent of the urban and peri-urban area is such that a single photograph will not provide coverage at the scale required, a mosaic can provide the coverage. The advantage of the aerial photograph or mosaic is firstly that it provides an overview of the whole area - the general form and structure becomes evident on inspection since certain patterns caused by breaks in building type, homogeneous land use, transportation routes, natural features, as well as other elements such as texture, etc. discussed in 4.3.1, indicate boundaries that in many instances will not be readily apparent from an inspection on the ground - a good example of not being able to see the wood for the trees! Secondly the time involved in a ground inspection would preclude this method on economic grounds alone.

Many of the basic problems in urban planning - traffic and residential congestion, urban sprawl, urban blight to name but a few - are intimately bound up with the spatial structure and distribution of physical units within the urban area. Obviously aerial photography can provide the necessary data to isolate and describe location patterns, but what is of greater importance to the researcher is the correlation between the location patterns and other variables such as population size, density, areal extent and spatial shape. The data regarding location patterns, density, areal extent and spatial shape can be easily extracted from the photography, which also facilitates the comprehension of the interactions between the units. An invaluable reference in this topic is the chapter dealing with Urban Area Analysis in the Manual of Photo Interpretation (1), and this section is therefore confined to more specific applications than those dealt with in this publication.

Gibbs (29) stresses the importance of spatial shapes in relation to urban growth, planning and technological developments in transportation. He proposes techniques to measure the spatial form of urban units and sub-units. The mathematical description of space presupposes the existence of boundaries to these units and as has been shown above boundary determination is best achieved with aerial photography. The distribution and spatial structure of the residential, commercial, industrial and recreational sub-areas can be determined from aerial photography since it involves data on land use boundaries as well as socio-economic data.

The CBD is the predominant sub-area of the urban scene and considerable attention has been devoted to its delimitation - refer Murphy and Vance (30), Davies (31), et al. Detailed techniques have been devised to have universal application, using variables such as space devoted to central business usage, vertical height, land values, pedestrian and traffic counts, employment figures, etc., etc. In many of these techniques appropriate aerial photography can provide the requisite data. The CBD is the focus of the city's vehicular and pedestrian movement and both pedestrian and traffic counts could be made on properly timed large scale aerial photographs, exposed possibly from a series of helicopters stationed at strategic points over the C.B.D. and fringe. The vertical component has particular significance in both the CBD and high density residential areas. The CBD is characterised by the tallest buildings in the urban area and the application of stereo-photogrammetric principles yields the vertical heights of buildings, relief and urban profiles and other information in the third dimension. The existence of barriers to CBD expansion and their effects are readily apparent on examination of the urban profile - see Davies (31) and Beavon (32). Another application of this technique coupled with the input of secondary data could lead to an approximate yet extremely rapid delimitation of the CBD especially of smaller urban areas. It is accepted that precise usage of floor space cannot be determined with certainty, but a composite analysis of photographic data concerning vehicular and pedestrian congestion, urban profiles, the spatial location of buildings, size of city blocks, transport, etc. might well serve to delimit the CBD in a first stage analysis of an urban area. It is hoped to test this concept in selected South African urban areas at a later stage when suitable large scale photography is available. It is understood Kelland (33) has used aerial photography to identify, delimit and compare three CBD's in the U.S.A. but unfortunately no details are available as the work has not been published.

The vertical component also has a certain significance in the CBD fringe area where high rise residential blocks are encountered. Basic to the triple concept of the CBD according to Mallows and Beinart (34) - hard core, periphery and frame - is the vertical component on the premise that movement, use and value affect the degree of vertical development and hence the physical form of the city. A comparative study of the spatial structure of a CBD in terms of all three dimensions, which can be determined stereophotogrammetrically at various points in time, correlated with relevant economic and demographic data, might well throw some new light on CBD change and development, and prove to be a rewarding topic of research.

An interesting application of photographic data is reported by Falkner (35). Using sequential photography exposed at intervals of two to three years over what was previously a semi-rural area but currently undergoing urbanisation, the short term land use changes were determined. These showed a strong correlation with enrolment figures in school districts, thereby enabling future predictions to be made with more certainty and facilitating future planning. Wagner (36) has successfully analysed sequential aerial photographs to measure land use conversions within three mile radii from highway interchanges, which provide the only access to free and toll roads.

Further applications of primary and secondary photographic data relevant to the analysis of urban areas are the following :

(i) Assessment of land use intensity, housing density, layout, etc.

(ii) Location of retail nodes other than CBDs. Suburban shopping centres for instance can be recognised by their location in relation to transport routes and localised congestion of vehicular and pedestrian movement.

(iii) Correlation of building heights and land values.

(iv) Classification of urban land use - residential, commercial and industrial.

(v) The availability of urban amenities and facilities including the relationship of built-up areas and open space. Any tendency towards over - or underplanning of open space will be evident. The use of colour photography is especially valuable here.

(vi) Classification of building types. The phenomenon of height distortion greatly assists identification especially of structures away from the nadir point of the photograph - see 4.1, since a side view is obtained thereby indicating style, number of floors, windows, condition, etc. (see Appendix K) Lack of balconies would indicate commercial buildings. The adequacy of light and ventilation provision can be tested by shadow analysis. In many instances data concerning types of materials used in building construction is also available.

(vii) Movement patterns of pedestrian and vehicular traffic.

(viii) Blighted areas - here again colour photography is invaluable - the building colours (roofs, walls, etc.) are dull, little vegetation is evident, etc.

(ix) Determination of indices such as roof cover, site coverage, bulk, building orientation, etc.

(x) Analysis of environmental characteristics as suggested by Verschoyle (37), including the evaluation of homogeneous, non-homogeneous and neglected residential areas, conservation and open areas as well as nodes, edges, landmarks and other parameters contributing to the perspective environment.

Depending on the purpose, the scale of photography for urban area analysis should be between 1/1500 if it is desired to identify objects such as pedestrians, to about 1/3,000 where the identification of buildings, vehicles, etc. is required.

The optical filtration of aerial photographs (12) provides the urban analyst with an invaluable diagnostic tool - see 4.3.2 and Appendix H. Different residential zones have certain general characteristics such as density, mean size of buildings, number and size of service roads and other factors which can be expressed in terms of a spatial frequency. Accurate data concerning the general orientation axes of the urban area, the spatial variation between buildings, mean building size, and building density have been measured automatically using this technique and the results are very promising for the urban analyst.

5.2.3.2 Regional Research and Analysis

Much of what has been said about urban areas is equally applicable to regions - the difficulty of delimiting regions and their components, the significance of land use within the region, etc. Definitions of a region vary - a portion of the earth's surface that can be treated as a unit for any purpose, any area which has a meaningful problem, etc. - but implicit to all in the planning context is the fact that all regions have a fundamental resource base. This may be labour, capital and entrepreneurial skill in the metropolitan region, or natural resources - water, mineral, climatic - in rural regions. Regions are usually large and complex and consequently regional data is likewise complex and of vast proportions. The co-ordination of this data is the responsibility of the regional scientist, but unless the data is relevant and adequate, all his models will be of little avail in regional analysis. Teams of specialists using aerial photographs in combination with minimal field observations are able to acquire the data required in the regional approach to the problem, both economically and expeditously. The delineation of regions can best be made with the aid of aerial photographs, while aerial photography is indispensable in such essential studies as broad land use, communications and natural resources surveys. Generally the photography for such purposes would be of the order of 1/30,000 to 1/50,000 or even smaller, but with the advent of small scale high resolution satellite photography the urban and regional planner, and the regional geographer have been given a powerful new tool. The reduction of scale for regional photography in fact automatically achieves the generalisation needed on the regional scale by omitting insignificant detail and only presenting that which is significant on the broader scale. The functional ties and interdependence between metropolis and hinterland, can be easily reconstructed at this scale by the photo-interpretation process. Colwell (38) in discussing the numerous applications of satellite photography specifically cites the example of urban area analysis. "Urban planners wishing to study the regional settings of cities can use satellite photography to better advantage than photomosaics made from large scale photography. Problems of suburban development with the attendant competition between residential, industrial and agricultural forms of land use can better be studied with the aid of satellite photography - as can the effects of proposed highways and airports."

To analyse the potential of a region Marinet (39) considers the following inventories essential - developed land, vegetation including afforestation, mineral resources, water resources, population and communication routes, coupled with studies of the geology, topography and climate. Aerial photographic data of primary and secondary order will provide adequate information for these inventories and studies. As more detailed studies are required, larger scale photography should be used. Wilmet (40) in a study of economic regions in underdeveloped countries found aerial photographs indispensable, since the portrayal of the economic infrastructure was inadequate on the available mapping cover. At the University of North Carolina, photo-interpretation has been successfully used in a study of a regional network of cities (19).

The provision of recreational, tourist and conservation facilities is primarily a regional responsibility and here again aerial photography is invaluable. Oblique aerial photographs of the shore-lines of bodies of water such as the sea, lakes, lagoons and rivers gives the planner an excellent insight into the development of their potential as holiday and recreational resorts. Bokos (41) in conducting surveys for the development of tourism in Greece writes, "Geomorphology, climatology, geological and soil texture, hydrological patterns of the area, with the demographic, anthropogeographic, aesthetic, social, archaeological, folkloric and historical data which photo-interpretation will supply from a full map of qualitative information, which is a fundamental presupposition for a rational touristic policy." The selection and delimitation of suitable terrain for conservation areas such as national parks, wild life reserves for both flora and fauna, as well as the development of regional recreational facilities, wilderness areas, caravan parks, etc. can also be undertaken with aerial photography.

5.2.4 Urban and Rural Administration

The legal system of land tenure often impinges on the planning process and at times can influence proposals quite drastically especially insofar as property acquisition, expropriation, servitudes, etc., are concerned. An unsatisfactory cadastral system could, for example, delay the implementation of redevelopment schemes for a long period if uncertainties in determining the boundaries or ownership of affected properties occur. Since stereophotogrammetric methods yield numerical position data to a high degree of accuracy, there is a tendency to use this numerical data for the legal registration of land in lieu of data obtained using the classical methods of ground survey. Naturally the use of photogrammetric techniques is dependent on the cadaster of the particular country and the size of the land units. Much of the cadastral survey in European countries today results from the large scale re-allotment of land as part of their post-war development schemes and photogrammetry is being extensively employed. In underdeveloped countries where no proper registration system previously existed, a preliminary system based on aerial photography, mosaics or photomaps has proved satisfactory. The boundaries are annotated after the photography or preferably the beacons are marked prior to photography. A valuable record is immediately available, whose precision can be increased at a later date when land values have appreciated. It is important to keep the costs of a cadastral survey commensurate with the general economic value of the land and its use - by applying photography and photogrammetry the costs of providing a land register, albeit somewhat crude, are a fraction of those incurred using rigorous survey methods. Typical examples of these applications are found in East Africa, where the land registration system in the African small holding areas is based on aerial photographs, in Mexico (42) where aerial mosaics provided the base material, and in Rhodesia, (whose cadastral system is virtually identical to that of South Africa) where photogrammetric determination of beacon and boundary positions has been advocated for the survey of holdings in African areas (43). In South Africa existing legislation only permits the determination of irregular curvilinear boundaries by photogrammetric methods, but experimental work has been undertaken in the Bantu areas in the determination of numerical boundaries (44).

The valuation process is vital to the local authority in that it determines the tax base, which is the prime source of revenue. The administrator of a valuation department is plagued by problems of out of date valuations, caused by changes in land use, development or blight, depreciating currencies and other factors. A combination of aerial photography and field inspections offers a practical solution to the problem, especially if automatic data processing methods are incorporated. Tomlinson (45) has used aerial photography in carrying out the valuation of rural properties in the East London Divisional Council area with considerable success. "By combining the examination of aerial photographs with physical inspection on the ground a far more reliable and more accurate amount of data can be collected than was possible with the cursory methods that were used in the past." King (46) describes a typical American example of tax assessment using aerial photography. An interesting result of this tax-survey was the stimulation of aerial photography as a tool in other municipal fields of administration.

Sequential photography at a large scale offers an economic and foolproof method of detection of infringements to such local regulations as affect land, buildings and their use, eg. departures from zoning plan, excessive bulk, unauthorised structures, etc. Helsinki has used sequential large scale photography exposed at six monthly intervals to detect unauthorised erection or modification of buildings. Attempts at camouflaging the unauthorised structures and tax evasions were rapidly detected, much to the owner's discomfiture. As a general reconnaissance tool aerial photographic cover is invaluable to urban authorities

- it provides a quick assessment of any situation, assists the technical branch with the preparation of estimates, especially regarding the acquisition of property and the estimation of public utility services required, as well as the presentation of proposals to the executive branch and it affords the planning branch a check on their executed work. Raw aerial photographs or photomaps are ideal for these purposes and further applications may be found in the preparation of voter's rolls, the delimitation of wards and other local government boundaries, preliminary investigations regarding slum clearance and urban renewal, all of which operations require reasonably accurate data of the type that can be extracted from aerial photographic cover.

5.2.5 Urban History and Archaeology

The urban areas of today have developed in many cases on the sites of original settlements and the historical variable has consequently shaped the urban environment as we know it today. In the words of Mumford (47), "If we would lay a new foundation for urban life, we must understand the historic nature of the city - in our attempt to achieve a better insight into the present state of the city we must peer over the edge of the historic horizon, to detect the dim traces of still earlier structures and more primitive functions." The aerial photograph has in recent years proved itself an admirable tool in investigating the urban area as a product of the past, as well as ensuring the preservation of historic sites for posterity. In his book (48) St Joseph covers the general applications of aerial photography in archaeology, history and planning, while more detailed techniques using photography for archaeological and historical research are fully described in (1) and will not be detailed here, but the amount and variety of accurate data that has been assembled by these methods - e.g. precise details of Roman centuriation patterns laid out more than 2,000 years ago - has proved invaluable in urban research.

Very recent methods include the application of optical filtration for the detection and measurement of spatial pattern - for example Chevallier's work on the analysis of Roman cadastral patterns (centuriation) in Italy and Tunisia (12). Adamesteanu (49) and Schiemdt (50) describe the work done in Italy and the Ancient Greek colonies using both panchromatic and colour film. Apart from preparing an inventory of areas of historical interest, the aerial photography has been used to survey historical sites lying either below the surface of the ground or the sea. Both near-vertical and oblique photography was used. Clues such as crop and soil-markings resulting from soil changes due to sub-surface structures, etc., shadows and other effects of the micro-relief and unexplained changes in colour rendition are used to discover, survey and obtain precise data regarding earlier urbanisations and settlements. In Japan Nishio (51) has detected and recorded ancient remains using similar techniques prior to the expansion of modern urban areas, thereby ensuring their preservation.

The advent of satellite photographs promises to increase the application of the method in that high altitude photography may increase visibility of underwater sites and further the large area coverage may facilitate the positioning of both underwater sites and those in featureless desert regions.

Although not strictly within the scope of this study, terrestrial photography (exposed from camera stations on the ground) has proved most useful in the recording and precise survey of all structures of an historical nature, thereby ensuring their preservation. Vintage aerial photography - the first aerial photograph of an urban area was exposed in 1858 of a portion of Paris, and shortly thereafter Boston was photographed from a balloon at an altitude of 1,200 ft - can provide important historical details from bygone years which are not readily available to the urban researcher.

5.2.6.1 <u>General Engineering</u>

As is to be expected the applications of aerial photography, photogrammetry and photo-interpretation in engineering are extremely widespread. For convenience they will be considered under three headings : General, Hydrological and Transportation. Factors such as route location and design and data acquisition will be considered under the heading of General rather than Transportation which will consider specific problems in Transportation Planning. The evaluation of site characteristics will be considered separately under 5.2.7, since this aspect is not confined purely to engineering applications.

The implementation of any engineering project implies (i) an alteration to the environment and (ii) the culmination of a planning process. For the latter accurate data concerning the surface, sub-surface and atmosphere within or contiguous to the area of interest of the project is essential. Large scale maps, plans and profiles prepared by stereophotogrammetric methods can supply the precise positional and relief data concerning physical features, both artificial and natural, on the surface of the earth, which is required for the evaluation, prèliminary and final design, cost studies, construction and administration of the project, be it a reservoir, road, harbour, irrigation scheme, etc. Accurate measurements of length, area and volume are possible. Aerial photography and improved products such as mosaics and photomaps plus stereophotogrammetric procedures are ideal for pre-planning feasibility studies of engineering projects as well as route and site location studies, directed towards the selection of the optimal route or site for a particular project - be it an industrial township, a water scheme, a residential subdivision, a railway line, etc. The methods are obvious and well documented and it would be inappropriate to detail them in this work other than to emphasise the variety and comprehensive nature of the data that the engineer can glean from suitable aerial photography in his search for the best solution - data covering such as aspects as demand for project, costs, land use, sub-soil details, etc., etc.

In Sweden (52) the lack of suitable large scale mapping has been overcome by undertaking location studies and preliminary design, directly on stereomodels formed on a double direct optical projection stereoplotter. The location studies broadly determine extent of the selected area which is then rephotographed at a larger scale yielding models at 1/4,000 which is suitable for preliminary design purposes. Brunnthaler (53) recommends the use of large scale contoured orthophotographs for many engineering purposes rather than conventional line-maps in view of the additional data available.

The application of computer technology has brought about a new development in engineering planning in recent years which promises to have a much wider application in the other planning disciplines and in fact the broader planning process. This is the concept of the Digital Terrain Model, originally developed in 1957 by Miller at M.I.T., improved versions of which are now being used in many countries (54). In this model the terrain surface is represented by a systematic pattern (which may be varied at will to suit particular conditions) of points, whose three dimensional co-ordinates are measured stereophotogrammetrically, recorded on paper tape and stored in a computer. Sufficient significant points are measured so that by automatic interpolation an accurate representation of the terrain can be reconstructed in the abstract by the computer. The principal application to date has been the design of routes for proposed communication systems such as roads, railways, pipelines, powerlines, etc., where computer logic has been applied to determing the optimum design of the route, subject to specified design criteria, avoidance of certain areas (which can be specified by co-ordinates), land values, operating costs, etc. Having determined the optimum design, the computer and associated computer graphic system will then produce the design data necessary for construction - the centre line plans, route plans, longitudinal and cross sections, mass diagrams and perspectives.

The concept of the Digital Terrain Model can be extended to cope with many of the data processing problems encountered in planning. Instead of being relevant only in the engineering context, provided the data is spatially distributed, any data, be it demographic, land valuation, land use, socio-economic or what have you, is suitable for processing using this technique. As in engineering it may well then be possible to use the computer in a preliminary décision-making process. It will be appreciated that the aerial photograph is an essential component in the process; firstly stereophotogrammetric techniques permit of accurate numerical position determination, at a speed and cost commensurate with the subsequent design process, and secondly photo-interpretation procedures permit the economic collection of much of the spatial data required in planning. Presentation of proposals will be expedited using one of the many computergraphic (or automated plotting and drawing) systems in operation today. Intriguing possibilities are the application of the concept to gravity and other mathematical models. With the information supplied by automated change detection systems to rationalise predicted trends and future projections. The "Geographic Information System" developed in 1967 for the Canadian Land Inventory stores data obtained from aerial photographs, field work and other sources on magnetic tape. The conversion of map to digital data is achieved through optical scanning and a variety of automatic methods are available for retrieving and analysing the data.

In coastal and harbour engineering studies, analyses of waves, direction of currents, marine effluent disposal, underwater topography and charting, beach profiles and limits of high water are some of the many applications of aerial photography. Infra-red, false colour and true colour photography have been successfully used especially in tropical waters for under-water surveys, pollution investigations (with or without appropriate dyes) and other oceanographic studies such as tidal, current measurement, coastal subsidence and charting (55).

In structural engineering Ibukiyama (56) has successfully used aerial photography to assess the live load characteristics of long span bridges under actual traffic conditions. Other engineering applications include the use of photographic data to locate and map sources of suitable road-building material (57), the isolation of terrain unsuitable for construction purposes, e.g. soft subsoil or susceptible to landslides, and precise surveys of land subsidence.

5.2.6.2 Hydrological Engineering

The planning, development and conservation of water supplies is vital for the continued existence of man, whether in an urban or rural environment. Because of increasing competition for water by the rapidly expanding population, the planning engineer must often solve hydrological problems with a minimum of data - to obtain complete data would take too long. Aerial photography has proved to be a valuable tool in the solution of many hydrological problems. Clearly a combination of photographic and other data can supply all the necessary information regarding drainage basins, catchment areas, surface water features, magnitude of surface water flow and runoff, proposed dam sites, flood prevention, etc. In conjunction with geologic photo-interpretation, data regarding subterranean water, nature of soils, possible sediment yield of basin and probable chemical content of water may be readily obtained; geomorphologic studies yield drainage pattern analysis data; snow volumes are easily measured using aerial surface area determinations coupled with ground sampling of depths (58); emulsions other than panchromatic yield valuable information concerning silt deposition at river mouths, swampy and marshy areas and micro-drainage systems (see Appendix F). The whole field of application of aerial primary and secondary data to hydrological problems is fully dealt with by Lohman and Robinove (59).

Of particular interest to the urban planner is the question of urban and industrial waste and effluent disposal and the consequent pollution and contamination of rivers. Urban areas use surface water both as a source of water and a low-cost carrier for the disposal of waste products which can be conveniently removed in suspension or solution. Strandberg (60) deals with the problem of wastes originating from all forms of land use including residential, industrial, commercial, agricultural, transportation, recreation and natural. For instance urban land drainage would contain significant amounts of oil, asphalt waste, detergents, etc., as well as sewage in either raw or treated form, while agricultural land has been found to contain heavy concentrations of silt from lack of soil conservation practice and chemicals resulting from pesticides and fertilisers. Recreational usage of water areas, (as evidenced by concentrations of small boats) leads to contamination by outboard motors, fish wastes, etc. Oil slicks show up better on oblique photography due to change in reflectance. Raw sewage low in dissolved oxygen is often evident where it enters a stream which has an adequate supply of dissolved oxygen. Underwater sewage outfalls can be detected by the presence of sea-birds and other side effects. Pearse (13) has used the Isodensitracer to map the dispersion of effluent from a sewage treatment plant on entering a river (see Appendix I). False colour film, by differentiating between healthy and unhealthy vegetation can also provide considerable information regarding the effects of pollution.

5.2.6.3 Transportation Engineering

Transportation engineering is inextricably bound up with urban planning - the communications system of the urban area is closely related to land use and land use planning; transportation is a function of land use and vica versa; land use generates movement - movement of people on foot, by car, public transport and even air. Transportation facilities become the dominant factor in the development of an urban area or a region; the land potential is dictated by transportation routes, they may act as a catalyst to stimulate development - for example nodal development at intersections of transport arteries - on the other hand new transportation routes may bisect and destroy existing functional units. The urban transportation system focusses on the CBD and has a major effect on its continued viability, and transportation and spatial location are interdependent in the economic sphere. Guttenberg (61) postulated that the transportation system holds the key to the way in which growth proceeds. The Chicago Area Transportation Study (62) for example clearly portrays the intimate relationship between travel, transportation facilities and land use, and indicates how these parameters determined the planning of future facilities in the area of concern. Present transportation technology is overwhelmingly oriented towards the motor vehicle and therefore the study of transportation engineering is likewise oriented to road transport, although the study of all movement, whether of goods or persons, by foot, road, rail, air, sea or any other system is in fact the concern of the transportation planner.

"Expertly interpreted air photographs, mainly enlarged verticals have the unique advantage of revealing how people move about a landscape or townscape, whether on foot or on wheels - the planner will be given a clue to the pedestrian system - its linear forms will tend to be slightly wavy, non-geometrical, hugging all external angles, with a variety of radials from fixed points and a general absence of parallel lines. Motor vehicle patterns are quite different. Left free, as on a beach or at a race meeting, vehicles will trace interlocking regular arcs in turning, but will head pretty straight from point to point. The engineer knows this, and provides for the vehicles' special characteristics with more science than he uses in providing for pedestrians. But even here pretty patterns and symmetry are liable to override functionalism as one can see by observing in air photographs the actual tracks worn by vehicles in passing through a roundabout. One can also learn a great deal about the details of infestation of a town centre by parked cars from a vertical photograph which shows up every ingenious hideout," (48) (see Appendix K). Although panchromatic photography is adequate for the detection of movement patterns, colour photography enhances and emphasises these.

Turpin (63) analyses in detail the numerous applications of the aerial photograph as a tool in collecting data for the projection of future transportation networks, in assessing existing and earlier conditions and in determining primary and secondary data in respect of geographic features; land use and land value; traffic patterns including composition of streams, types of vehicle, driving habits, directional characteristics, density, headway, congestion, flow, accident and potential accident patterns, parking facilities and characteristics, effect of off-street parking on traffic flow, pedestrian movement where the pavements are open and unobstructed by canopies, information regarding roads including surface, adjacent occupancy and use of contiguous land; availability of land for future expansion and development of transportation systems. "Inadequate methods of data collection and utilisation are luxuries that the transportation planner cannot afford - the employment of an economical, comprehensive and accurate method such as photo-grammetry and photo-interpretation provides is fast becoming a necessity." (63)

The advantage of photographically recording traffic characteristics such as flow, etc. is that vehicles can be "frozen" in position and time enabling more accurate counts with less likelihood of duplication than with terrestrial counts. The idea has been mooted of using marked vehicles to join arterial traffic flows and thereby obtain approximate origin and destination data - the driver would endeavour to remain with the main flow until it reaches its dispersion point near the CBD. Agreement between traffic flows based on laborious ground counts and those based on photographic data has been shown in Canada to be of the order of 7%, while other advantages in favour of counts from the air were lower cost, a permanent instantaneous record and no disruption of traffic. (6) Obviously the smaller the urban area, the more suitable it will be for aerial traffic analysis, although with ingenuity there is no reason why it should not be applied to the larger connurbations.

In France, Dubuisson (64) has determined spot speeds, accelerations and decelerations of vehicles along such busy streets as the Champs D'Elysees and analysed the operation of that classic rotary around the Arc D'Triomphe and states quite categorically that the data obtained by aerial analysis is more meaningful and varied in nature than that obtained by conventional traffic surveys. Using photographs exposed at 1/15,000 with an 80% longitudinal overlap at intervals of 7 seconds, he was able to identify individual vehicles on enlargements at 1/1,000 on five successive photographs, i.e. five positions of the vehicle were known as well as the instants at which it occupied those positions. With this information five parameters defining traffic flow could be determined - deviations from mean speed and mean speed capacity of a lane, accelerations and decelerations as well the number of variations from acceleration to deceleration and vica versa.

In America Taylor (65) has recently used photogrammetric procedures to obtain accurate spacing and velocity data on platoons of vehicles proceeding along a highway. The photogrammetric techniques formulated and tested in this study provided accurate traffic flow data continuous in both time and space. The method involved sequential photography, at a scale of 1/12,000, exposed at one second intervals with a 70 mm. camera mounted in a helicopter, of traffic surrounding a test car. The study yielded spacing and velocities. Such data is basic in investigations of traffic platoon characteristics, traffic volume-speed-density relations, speed distributions, lane changing as well as passing and following manoeuvres. Simultaneous ground study and recording of vehicles over a section of highway is well nigh impossible. Other advantages of the aerial method are : Drivers are not influenced as they are unaware their behaviour is being observed and measured; a permanent visual record of traffic behaviour is available; location of analysis sites can be selected from air enabling interesting situations to be diagnosed as and when they occur without having to establish ground recording systems.

Other possible applications include bypass studies of the CBD, interrelation between parking facilities and walking distance in the CBD, traffic control, road classification - trucks and busses would only use roads suited to their operational characteristics. Terrestrial photogrammetric procedures are commonly used in the analysis of traffic accidents for court purposes in Switzerland and elsewhere. Considerable time is saved in recording evidence and high accuracies are possible in determining vehicle positions, skid marks, (which can be accentuated prior to photography) and other points of evidence.

5.2.7 Site Evaluation Including Geologic, Climatic and Other Characteristics

In planning an area for development an essential prerequisite is a detailed knowledge of the physiographic and topographic characteristics of the area. Among the most important characteristics necessary to complete the environmental picture are: the surface and sub-surface geology, landform and pedology - low density development may only be suitable if the sub-surface is unsuitable for carrying large structures, clays and sandy soils have their advantages and disadvantages as regards urban, residential and industrial development; disposal of wastes and contamination of underground water, sources of construction material, influence of landform and topography on site accessibility; drainage - the drainage and micro-drainage of the area, land subject to flooding; relief and micro-relief, slope areas, orientation of slopes; climate and micro-climate, prevailing winds, rainfall, sunshine, air pollution, smog; existing development, and statement of land use, depressed or derelict areas (old mine workings, slums, etc., etc.) undeveloped areas; aesthetic character of area.

The topography is best surveyed using stereo-photogrammetric techniques and aerial photography can supply accurate data, together with brief on site inspections, in respect of all the other site characteristics except rainfall. Anschutz and Stallard (66) confirm the role of aerial photographic site evaluation in the methodical and orderly growth of urban areas - "Nearly all facets of a land evaluation project can be investigated by photo-interpretation procedures - sufficient data with good accuracy can be expected and appropriate decisions can be made from this data. Field work may not be eliminated, but it can be substantially reduced. The primary role of field work is generally not to gather information but rather to check the data obtained from photo-analysis and possibly extend such data."

Cazabat (67) has used stereophotogrammetry and photo-interpretation to prepare medium scale maps of slope areas classifying slopes at 5% intervals from 0% to 45% and above. There is no reason why this technique should not be extended to larger scales or the orientation of slopes included with especial reference to north or semi-north facing slopes. Nakano (68) has used aerial photographic analysis to discover "soft-ground" conditions in Japan in regional development projects. "Soft-ground" includes areas subject to earthquake and flooding and must obviously be avoided in any development project. This soft-ground is characterised by high moisture content and consists of silt, organic materials such as peat bogs, clay or marsh-land. Kasamatsu (69) has accurately determined wind velocities and directions using synchronous stereo-photographs of smoke trails emitted from aircraft and rockets at various altitudes.

The use of special emulsion photography - infra-red, colour and false colour - is invaluable in the field of site evaluation. The effect of water and soil moisture on infra-red emulsions has been discussed earlier and is illustrated in Appendix F. Kalensky (70) has investigated the relation between soil moisture and soil colour in localised areas and by means of local correlation curves, developed a technique for the quantitative determination of soil moisture.

5.2.8 <u>Sociology</u>

Urban sociology studies people, their characteristics, and social organisation, with the emphasis continually on the ecological approach, which recognises (i) the influence which the natural environment exerts on man's social life and (ii) the reverse influence of man on his environment. The spatial distribution of social units is affected, inter alia, by the physical environment and also by social interaction - social norms have an impact on social groupings. Evidence of this is provided by the familiar process of concentration, centralisation and decentralisation, segregation, invasion and succession, leading to clearly defined areas known as Natural Areas to the sociologist. These areas "are the results of a natural process rather than the products of a deliberate plan" (71). They adjoin but do not merge and do not always have clearly defined physical boundaries.

Since sociology deals with people, subtle methods of investigation are necessary to get the correct answer and the aerial photograph being a "view from above" has proved itself invaluable as a source of sociological data and an analytical tool of the spatial environment of society. De Haas (72) examines the work of Gutkind, Chombart de Lauwe, Burger, Green and Monier in detail. Chombart de Lauwe (73) recognised the aerial photograph as a primary source of data and in a later publication (74) prepared a manual for the application of aerial photography to the social sciences, dealing with social space and various "sub-spaces". Following on from de Lauwe, Burger (75) emphasised the ability of recognising the natural areas by their influence on land use, layout, environment, etc. (see Appendix M).

Perhaps the greatest contribution in photo-sociology has been made in the U.S.A. by Green and Monier (18 et al) who used secondary photographic data to determine the urban social and demographic structure. Green proceeded from the assumption that such physical phenomena as the zonal location of an area, its description in terms of internal and adjacent land use, the prevalence of single family homes, and the density of housing expressed in average numbers of dwellings per block are of wide sociological significance. He showed that these parameters, spatial and quantitative data in respect of which could accurately be obtained from aerial photography, showed systematic correlations to many sociological characteristics inherent in an urban area. For instance in one city, Birmingham, significant between-zone differences were found in average monthly rentals, educational status and adult crime rates, which were also correlated to the prevalence of single-family residences, and other structural types. Having tested the correlations, these structural types were used in a scale of residential desirability as a reliable model of prediction in the socio-economic patterns of urban areas. In this manner primary and secondary photographic data may be translated into information pertaining to urban social structure including rankings of sub areas, and social and non-material information derived from the physical form and material structure of the urban area.

Silberman (76) discusses three applications of "sociogrammetry"; "to supply general social and economic statistics, cross-checked with ground social surveys and nationally or regionally collected annual or census statistics; a basis of planning; the evaluation of policy and the effectiveness of any constructive activity." Mambower and Donoghue (77) have investigated photographically-derived data to study the problem of urban poverty. The results indicate that it is possible to use such data to, "delimit urban residential areas that exhibit poverty characteristics in a more precise manner than urban studies based on census data alone; provide both qualitative and quantitative descriptions of these areas either from the photography alone or in conjunction with sample ground surveys; identify physical changes to areas of the city to initiate the deletion or collection of information pertaining to that area; support the analysis of proposed action programmes by portraying the spatial relationships of these residential areas to other functions of the city (e.g. recreation, schools, transportation, industry)". Nine cities were investigated and residential areas that exhibited characteristics associated with poverty were delineated. Sequential photography yielded quantitative and qualitative descriptions of these areas and the changes in the areas. Strong correlation between urban poverty and residential areas near the CBD, industrial and transportation zones was confirmed. Other useful references in sociological applications include Witenstein (78) and MacFadden (79).

5.2.9 Regional and Urban Economics

Economic factors force society into a spatial framework - space becomes an essential component in locating future economic activity. The planner must be continually aware of the market mechanism and its influence on the allocation of space, of the spatial distribution of economic resources, of the effect of site characteristics and accessibility, and of the spatial distribution of density. On the national and regional scale, economic planning requires spatial data in respect of natural resources, industry, agriculture, cadastral and administrative boundaries, demography, etc. so that the full potential may be realised. Photomaps have proved adequate for determining economic data in its spatial context where high accuracy positional data is of lesser importance than a complete inventory. Typical examples are the Economic Map of Sweden, 1/10,000 (80) and the 1/5,000 Fiscal, Economic and Legal Survey of El Salvador (81).

Among the analytical tools used by the regional planner and regional scientist, the gravity model and its various modifications have been of great use in determining both present and future potential. On the regional, metropolitan and urban scales the spatial data necessary to set up the gravity model can readily be obtained from mosaics or photomaps whose scale can be varied according to the unit being examined. With spatial data, plus other secondary data regarding population distribution, accessibility, etc., readily available, the application of gravity models on a micro-scale becomes a practical possibility - e.g. in assessing the potential of shopping centres, retail nodes and even "corner-shop" sites in various locations. Irrespective of whatever method of analysis is used, large-scale aerial photography and photomaps are currently being successfully used in many market-research projects, as well as for investigations into hierarchy of business centres and the pattern of tertiary activity. It is possible to extract considerable quantities of secondary data by correlating residential types with income levels, demographic and other socio-economic data. The method is being used by planning consultants in Cape Town, to cite an example, as follows. A detailed examination of residential properties and particularly their outbuildings on large scale photography gives information regarding homogeneous areas, type of house, area of site, number and possibly type of cars and servants. From this the capital investment in a property may be deduced, which can then be correlated with probable income. Using Bureau of Statistics Income Allocation Data, probable purchasing power in respect of various commodities can be allocated at the finest grain possible, the individual property, at a cost of about one-third that of other less detailed methods. The delimitation of market areas using for instance the micro-analysis method is simplified considerably and the location of access routes and competitors immediately apparent. Furthermore the socio-economic pattern is continually changing and to provide the up-to-date data so necessary to the urban economist, sequential aerial photography is the most expeditious and economical method.

5.2.10 Aesthetics

"Along with the more utilitarian features of urban land, land use planning is also concerned with the perceptual aspects of the urban environment, its aesthetic qualities, and the preservation and development of natural features in a manner calculated to enhance these qualities for the enjoyment of city residents." (5) Williams (82) recognises 6 general types of urban site forms, any of which may be subject to modification by additional natural features such as bodies of water, as well as five further parameters defining man-made features: viz. urban texture, green areas, circulation facilities, paved open spaces and individually significant architectural masses. Aerial photographic data can be of great use in surveying and assessing these aesthetic characteristics, indeed it is difficult to see how it could be done otherwise, apart from repeated visual surveys of which no complete record can be made. Apart from analysing existing urban areas, an aesthetic appraisal can be made of areas earmarked for future development, using existing natural features such as woodland, hedges and windbreaks to segregate and screen industrial areas, and analysing the existing landscape with colour photography. A further application in aesthetic analysis is the assessment of whether the environment will be improved or otherwise, as discussed in 5.1 and illustrated in Appendix L, by examining a graphical presentation of the proposed development photographically imposed on the existing environment.

6. SUMMARY AND CONCLUSIONS

A thorough perusal of planning literature discloses that planners have made rather limited use of aerial photography and allied techniques to date, and as a consequence the full potential of its application has not been realised. The aerial photograph is in fact a most versatile tool for the planner and should not be regarded merely as another graphic presentation of the features on the surface of the earth. The photograph presents each feature in its total environment, whereas the conventional map by virtue of the selection and generalisation of the cartographic process, is only able to present the partial environment. As St Joseph (48) so succintly expresses it, the aerial photograph gives the planner "synoptic vision - a unified study of the impress of human settlement and cultivation of the earth's surface."

An examination of the data required in the planning process indicates that among its most important attributes are validity, comparability in both time and areal contexts (both absolute and relative versions of these parameters apply), completeness (although precise numerical values are not always necessary), and the ability to express it in coded form suitable for automatic data processing techniques. By virtue of the dynamic nature of the planning process and the constant feedback of newly acquired information, data collection tends to become a continuing process rather than a single finite act.

Although conventional maps and plans may appear adequate for planning purposes, they have definite inherent limitations in the planning discipline, both as a base medium and a source of data, due to the selection and generalisation of the cartographic process. New techniques in the photographic and photogrammetric process such as orthophotos, rectification, photomaps, etc. have resulted in converting the aerial photograph with its disadvantages of variable scale due to tilts and terrain heights and lack of processed information into an admirable base medium, with these disadvantages eliminated and with the added advantage of presenting the total environment to the user. These photomapping processes are not as time consuming nor as expensive as the cartographic process, and hence provide the ideal solution to the rapid obsolescence of cartographic products in urban areas, by eliminating much of the delay incurred in map production. Their accuracy is adequate for the base maps required by the planner, who does not require the high positional accuracy demanded by most map specifications, but is more interested in complete environmental data. Scale variation is simple and the degree of generalisation demanded by the size of unit is achieved photographically; detail which is too fine grained to be of interest to the planner may be submerged or eliminated either during photography by varying the flying height or by photographic reduction at a later stage. The planner could also prepare with whatever draughting resources he commands, such specific maps and plans from the photomap material as required, quickly and economically. The cost structure of photographs (see Appendix N) is such that revision and up-dating of base material and the acquisition of new data should be within the ability of most private and public planning organisations.

Recent developments in the field of photo-interpretation including new and improved photographic emulsions, instrumentation and automation, plus direct extraction of primary data followed by inferential extraction of secondary data, make the aerial photograph an impressive source of data, which satisfies the exacting requirements of data in planning as stated in 2. Apart from always giving an initial evaluation of any given situation and permitting the feasibility of any projected development to be rapidly and adequately assessed, photographic data is an instant record of all the natural and artificial features on the earth's surface comprising the visible environment and can be adapted to any unit size from the smallest block and neighbourhood to the largest region. Aerial photographic data collection is generally the cheapest method in terms of unit area, while the information is available at short notice with little effort and is readily adapted to modern automatic data processing methods. Sequential photography coupled with modern change detection methods accurately measures land use conversions and permits accurate projections and predictions of future trends, as well as keeping the data current with the continuing planning process. Finally photographically-extracted data complies with the requirements emphasised by Geddes - planning must be founded on data concerning folk, work and place with the stress on the interrelationship and interdependence of these factors.

The modern conurbation is such a complex phenomenon that it cannot possibly be analysed in terms of single disciplines. Aerial photographic data is eminently suitable for analyses across the boundaries of the activities that contribute to the whole field of urban analysis. Tested fields of application include land use and resource surveys, urban and regional research and analysis, urban history and archaeology, urban and rural administration, site evaluation, transportation and other branches of engineering, urban sociology and economics, as well as urban aesthetics. Since height is readily measured off aerial photographs using stereophotogrammetry, future investigations concerning the third dimension in urban analysis will, it is envisaged, be undertaken more conveniently using aerial photography, with particular reference to the CBD. The concept of the Digital Terrain Model can readily be extended to most problems in planning where masses of spatial data have to be processed prior to decision making. At present decision-making is confined to the selection of optimum routes for highways, etc., but there is no reason why the technique could not be adapted to any other location problem, be it transportation, commercial, residential or industrial.

Considerable space has been devoted in this study to stressing (perhaps with a degree of repetition, but this is inevitable in a multi-disciplinary field such as planning), the widespread applications of aerial photography in all the contributory activities of the planning process. Many of these applications are not obvious at first sight but they should be sufficient to convince even the most sceptical of the very definite advantages and benefits that can accrue to the planner, if the full potential of aerial photography is realised.

It is not suggested that aerial photography is a panacea for all problems associated with data collection in planning. The ground survey will still be essential in certain instances, be it a door-to-door canvass, a sample survey or even a rapid "windshield" survey. The planner however should always bear in mind the considerable advantages of photo-based data insofar as speed, economy and handling are concerned and investigate whether by exercising his ingenuity and inferential powers still further, additional data might not conveniently be obtained from aerial photographs and the necessity for costly, time-consuming (and often as accurate or inaccurate) ground surveys eliminated.

7. APPENDICES A - N

Appendix A : Geometry of the Vertical Aerial Photograph

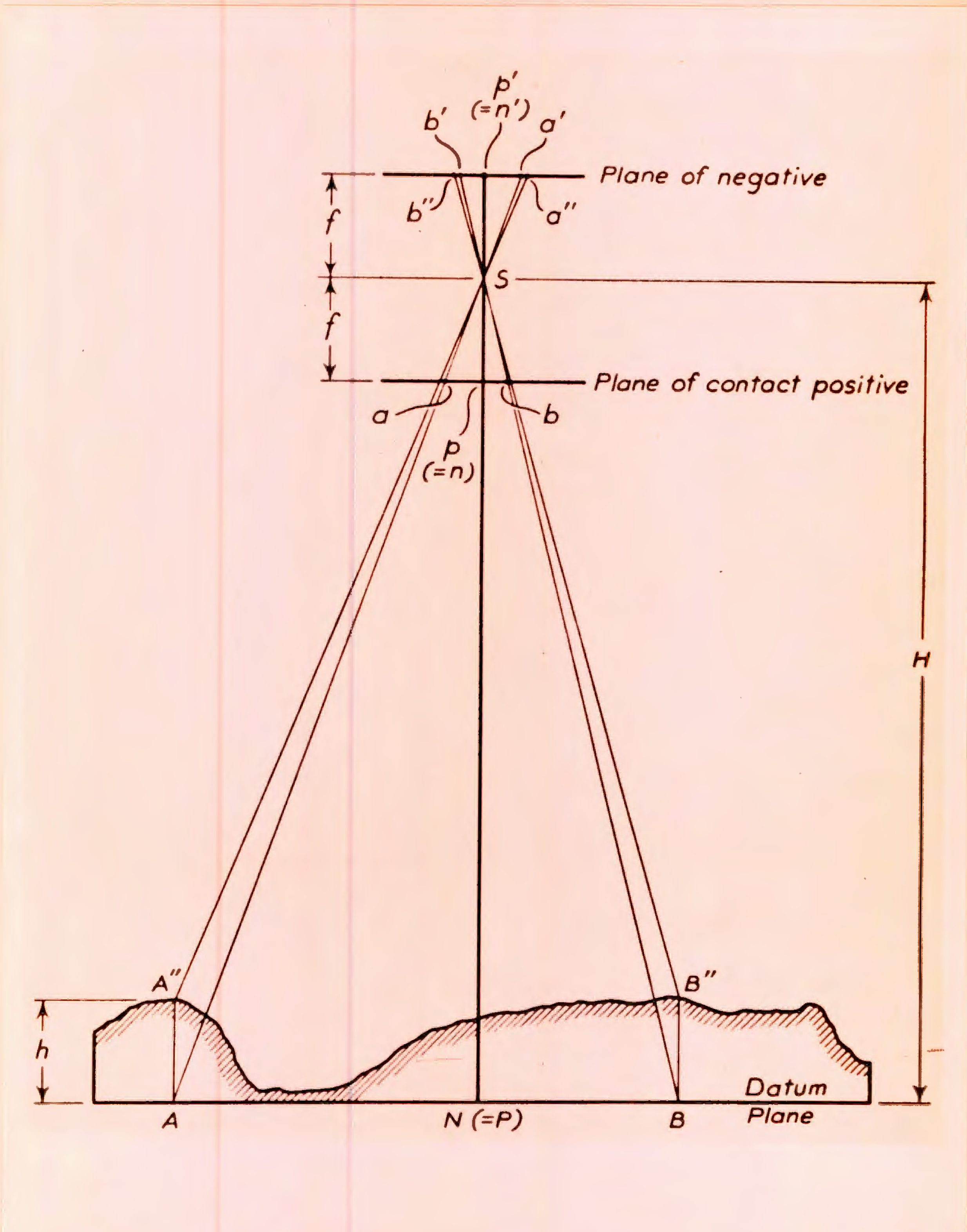

Fig. 1 : Geometry of Vertical Aerial Photograph
(From Plane Surveying : Sandover)

The aerial photograph is a perspective projection of the terrain, S being the perspective centre, through which all taking rays pass. Terrain points A and B give rise to image points a and b on the positive or a' and b' on the negative : if they were located at A" and B", a height h above datum, they would be imaged at a" and b", i.e. their photo positions have been displaced by the distances a'a" and b'b" due to a change in terrain height h. These displacements are radial from the nadir point n which coincides with the principal point p when the camera axis is vertical. The radial nature of these height distortions is clearly shown in Fig. 16 where all vertical building lines, if produced intersect at the principal point. A further effect of altering the terrain elevation is to change the scale of the photographic image expressed by $\frac{f}{H}$, where f is the focal length of the camera and H the flying height. The denominator now becomes H-h and the scale of all points located h above datum is now $\frac{f}{H-h}$.

Appendix B : Electronic Scanning

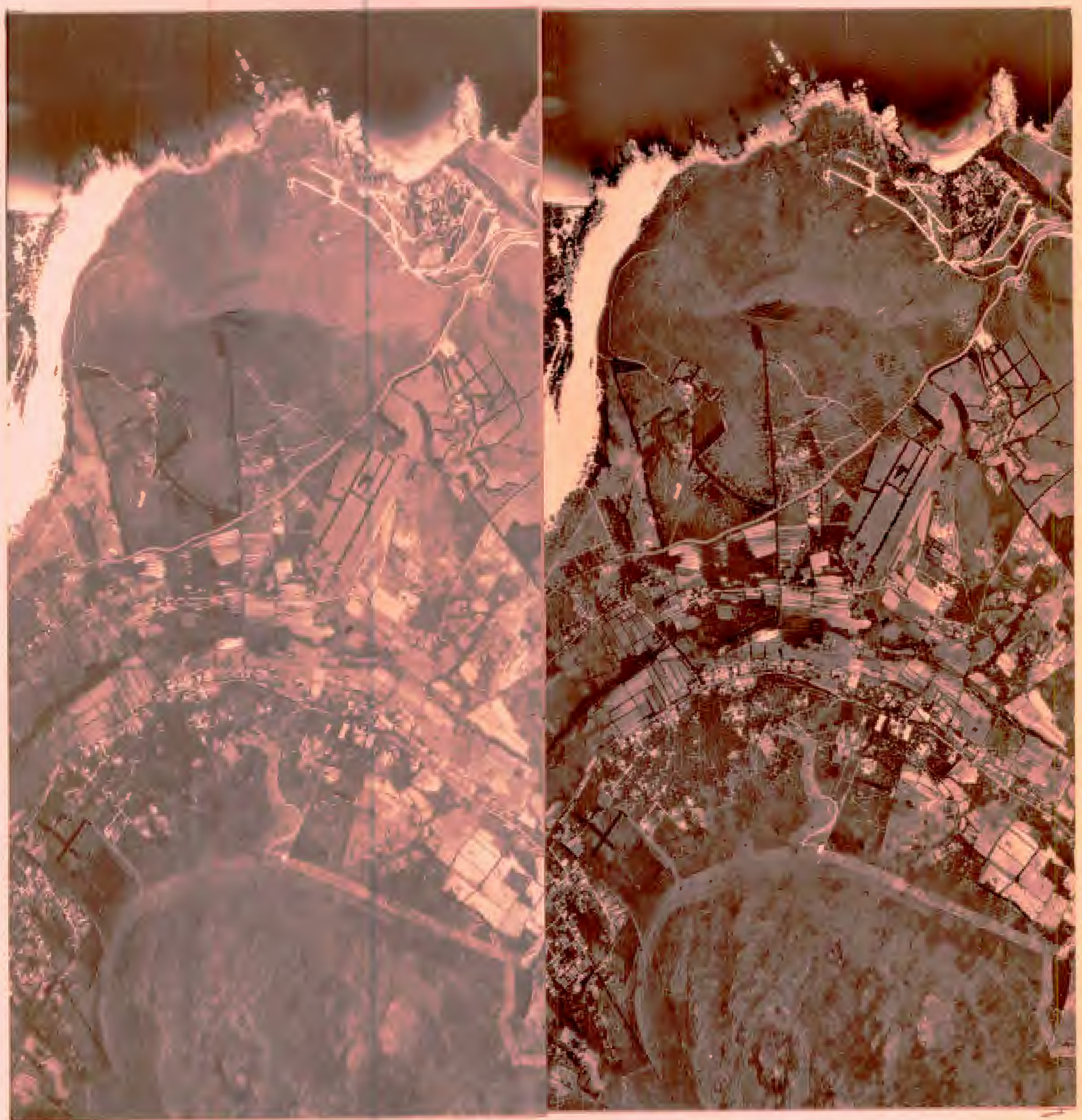

Fig. 2 : These two prints of the Llandudno-Hout Bay area have been prepared from the same negative. The left hand print was made in the normal manner, while the right hand print was made on an electronic scanning printer, where a cathode ray tube emits a beam of light which scans the negative. As the beam encounters a dense region of the negative its intensity is automatically increased and vica versa. The result is a print which is evenly exposed, of reduced overall contrast and on which detail is readily visible. The prints are particularly suitable in mosaic preparation and data extraction.

Fig. 3

Fig. 4

Appendix C

Fig. 3 is a simple uncontrolled mosaic (approximate scale 1/46,000) compiled to investigate a possible New Town in the vicinity of Cape Town. The existing 1/50,000 mapping cover was out of date particularly as regards current land use and roads. The mosaic was compiled from latest available photography, rephotographed on 35 mm. film and then enlarged to the required scale to provide suitable base material as well as up to date data regarding drainage, land use and communications. The cost including the original photography as less than R5 !

Appendix D

Fig. 4 is a typical example of an elementary large scale (approximately 1/3,200) photomosaic of the Southern Suburbs. Such a mosaic could be prepared by most planning organisations. The mosaic is uncontrolled and no embellishments or additional information such as names have been included. Production costs would be of the order of R25 per square mile, to which must be added the costs of appropriate large scale photography (refer Appendix N). This material would provide a suitable base for the direct tracing of plans of low planimetric accuracy, as well as a considerable amount of spatial data of the urban environment.

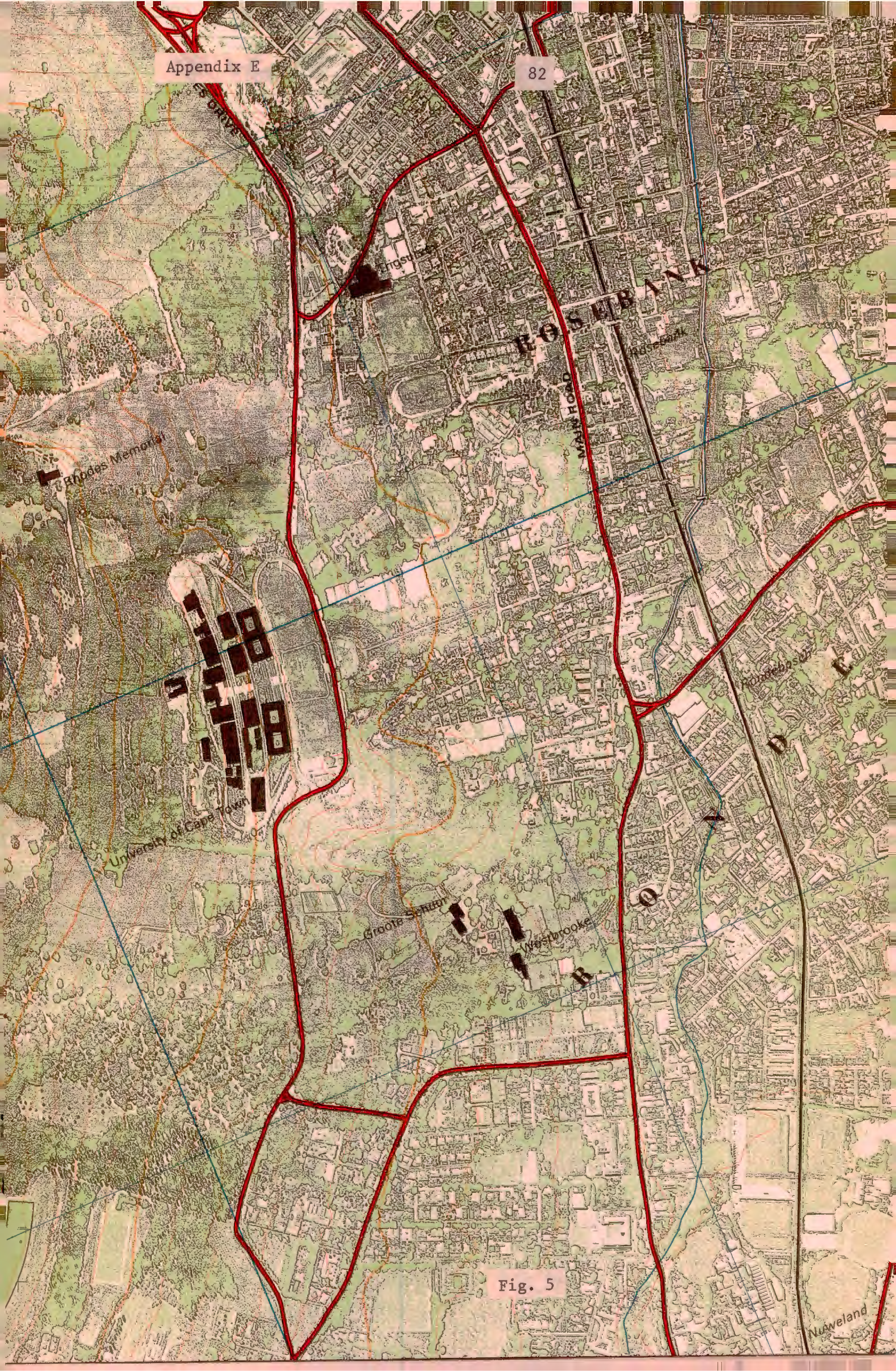
ROSEBANK
Rosebank
MAIN ROAD
Rhodes Memorial
University of Cape Town
Groote Schuur
Westbrooke
Nuweland

Fig. 5

Appendix F : Panchromatic and Infra-Red Photography

Fig. 6 : Comparative panchromatic and infra-red photography.

Appendix G : Colour, False Colour and Infra-Red Photography

Fig. 7 : Comparative Colour and False-Colour Photography.

Fig. 8 : Comparative Colour and Infra-Red Photography.

Appendix F

The three photo strips printed side by side in Fig. 6 are sections of the same area from comparative photographs, using panchromatic and infra-red emulsions. The left hand photo strip was exposed using panchromatic emulsion, while the central and right hand strips were exposed using infra-red emulsion with different filters. Of particular interest are : the water features (1, 5 and 6), the dry stubble field being ploughed (7) - the ground moisture shows clearly on the infra-red photography, and the oak plantation (2) compared with mixed conifers and beech (3) and the conifer plantation (4). The definite advantage of infra-red emulsion in extracting data concerning vegetation and water features is apparent.

Appendix G

Fig. 7 illustrates comparative colour and false colour photography of a rural area in Switzerland. The photo scale is 1/8,000 and the level of interpretation is high for both emulsions. The false colour is clearly superior in analysing moisture and vegetation.

Fig. 8 shows the comparison between colour and infra-red photography of the same area. Each emulsion has its particular attributes, depending on the requirements of the photo interpreter.

Appendix H : Optical Filtration

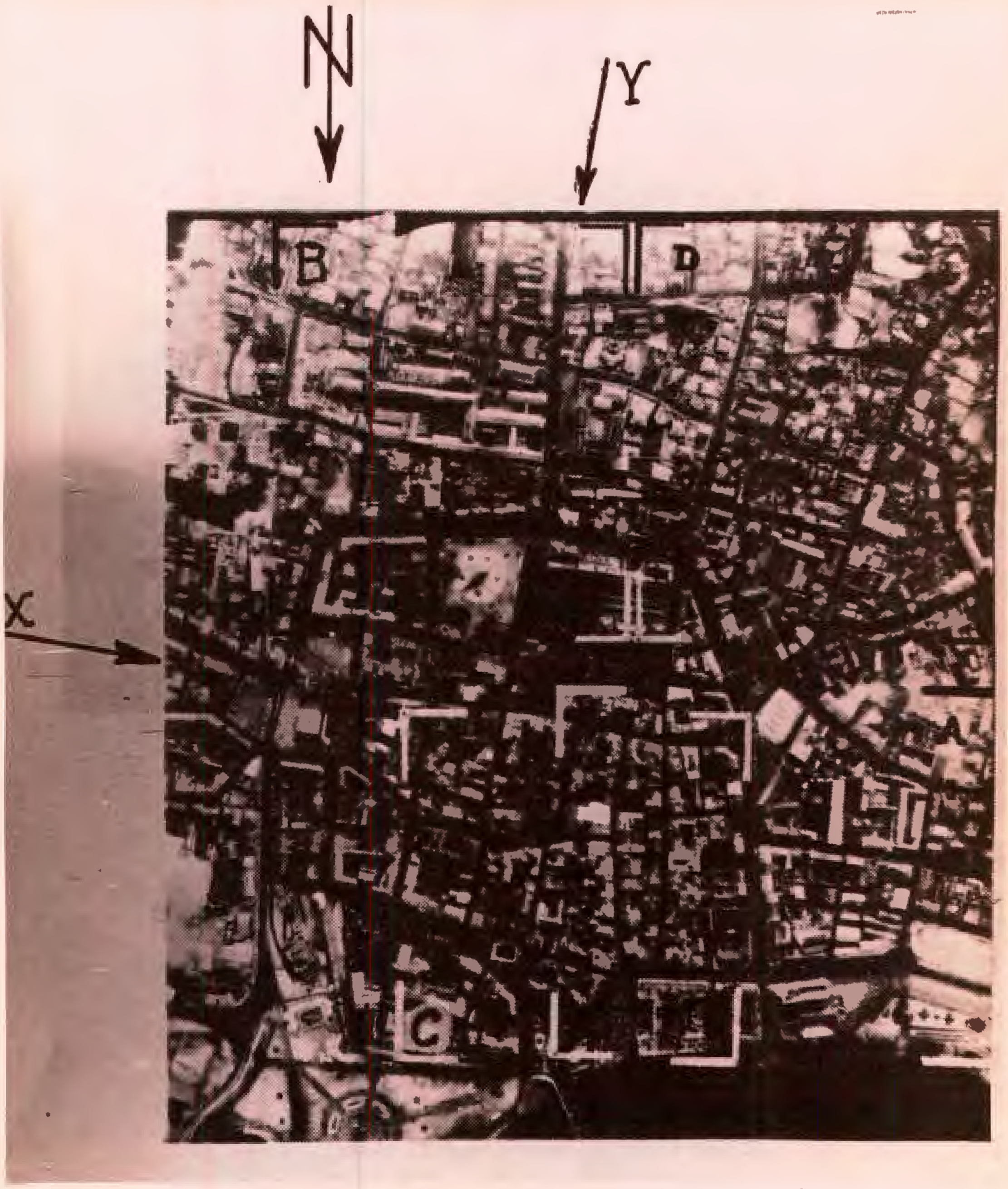

Fig. 9 : Aerial Photograph of Dax (12)

Subjecting the aerial photograph of Dax to optical filtration in coherent light yields the trace shown in Fig. 10. Analysis of this trace shows an X - Y system of rectangular axes inclined approximately at $12\frac{1}{2}^{\circ}$ to the meridian, with a range of between 9° and 17°, indicating the rigidity or otherwise of building orientation. The trace also shows a strong concentration along the Y axis,

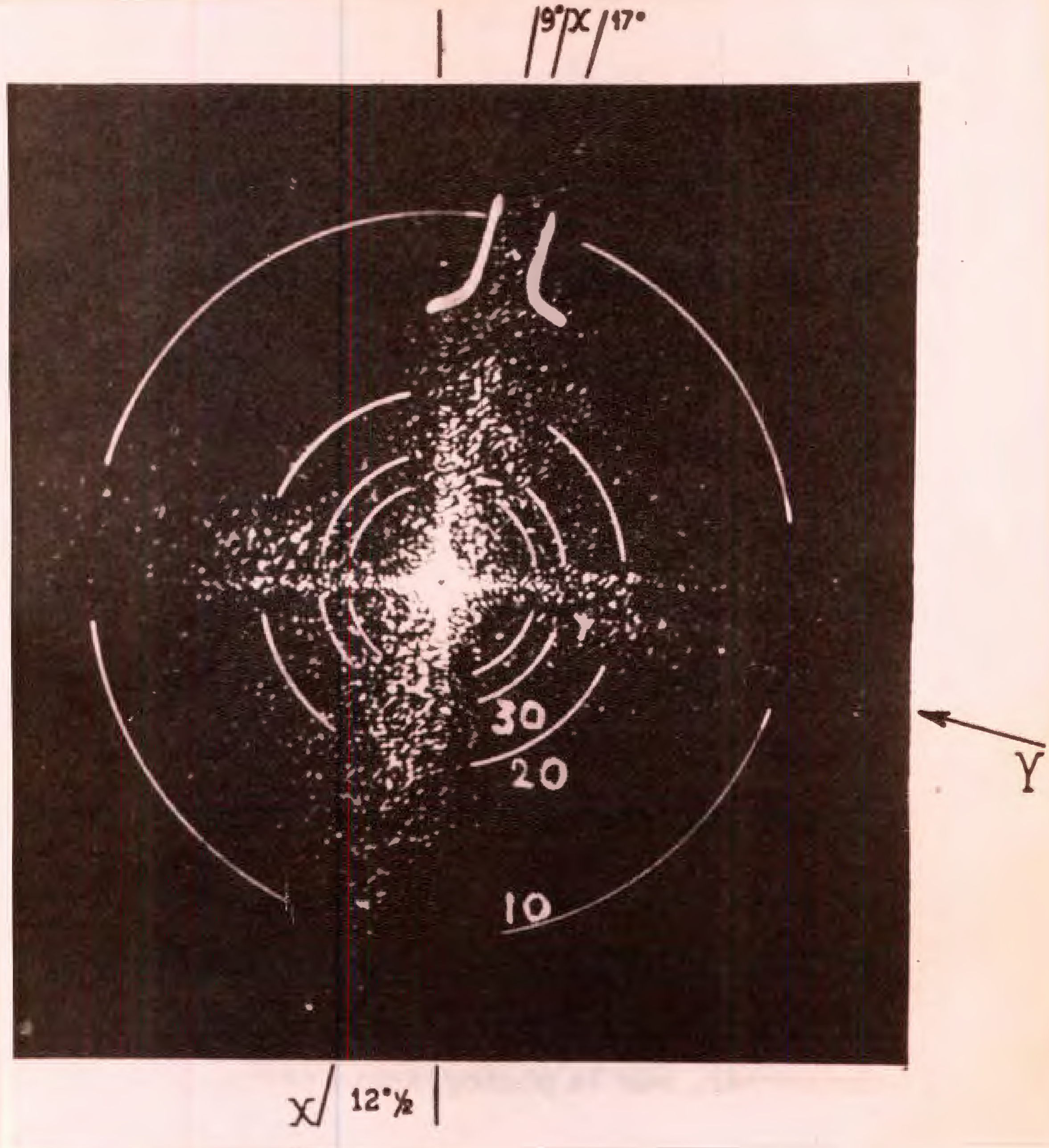

Fig. 10 : Optical Trace of Aerial Photograph

in the frequencies corresponding to spacings of 20-30 metres, while the pattern tends to be more dispersed in the 10-20 metre range on the X axis. This lack of symmetry is not evident at a first inspection of the aerial photograph but on closer examination one finds that most buildings are aligned approximately E - W along the Y axis; their mean length in this direction is of the order of 20-30 metres and their mean dimension in the other direction is 10-20 metres. Optical filtration has promising possibilities in the analysis of urban pattern and grain.

Appendix I : Densitometry

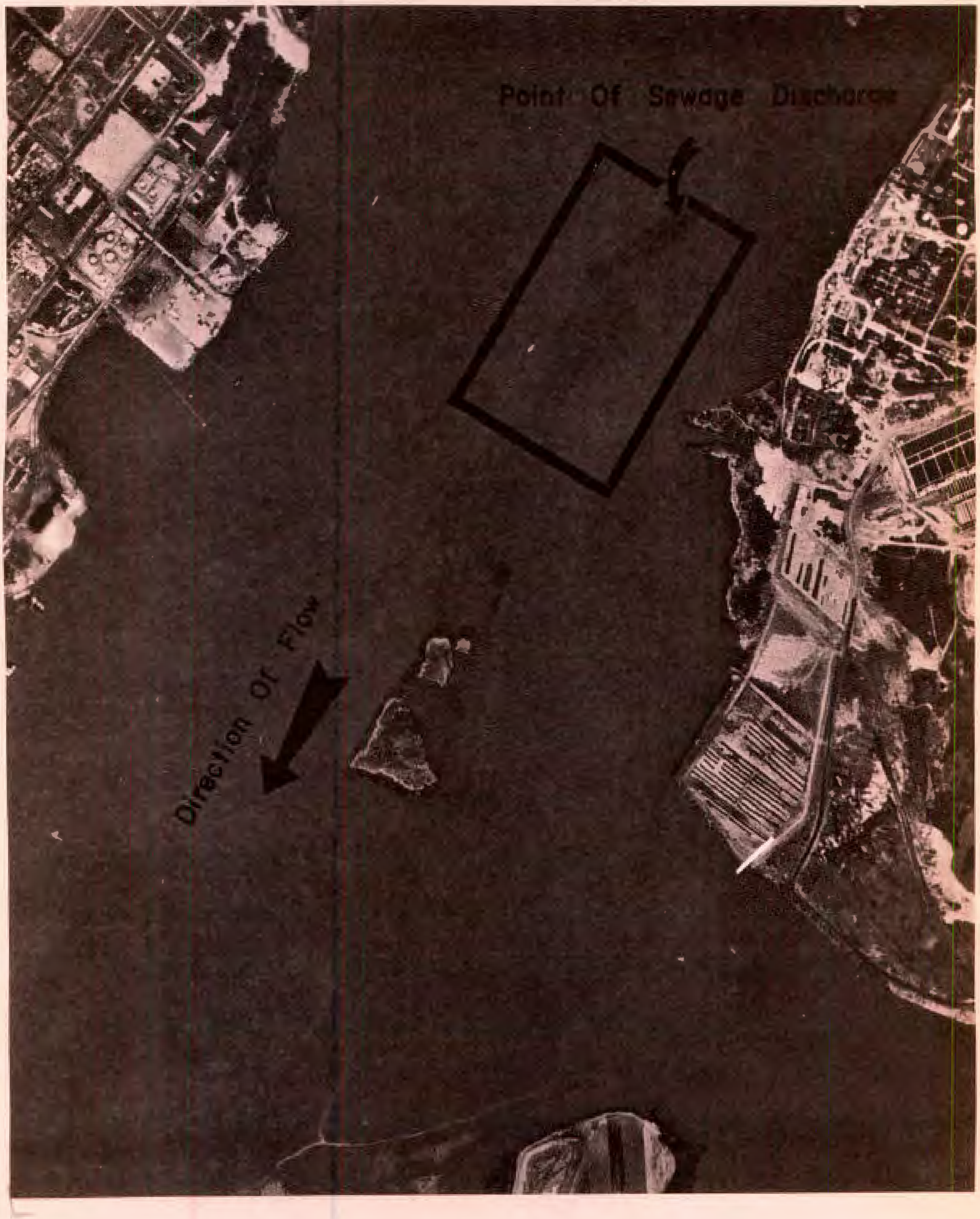

Fig. 11 : Aerial Photograph depicting water discolouration due to sewage discharge (13).

The discolouration is difficult to discern optically but using microdensitometric methods a coded trace as shown in Fig. 12 results. This coded trace can then be interpreted to yield a map on which lines of equal density are plotted - Fig. 13. The "peaks" indicate concentrations of effluent.

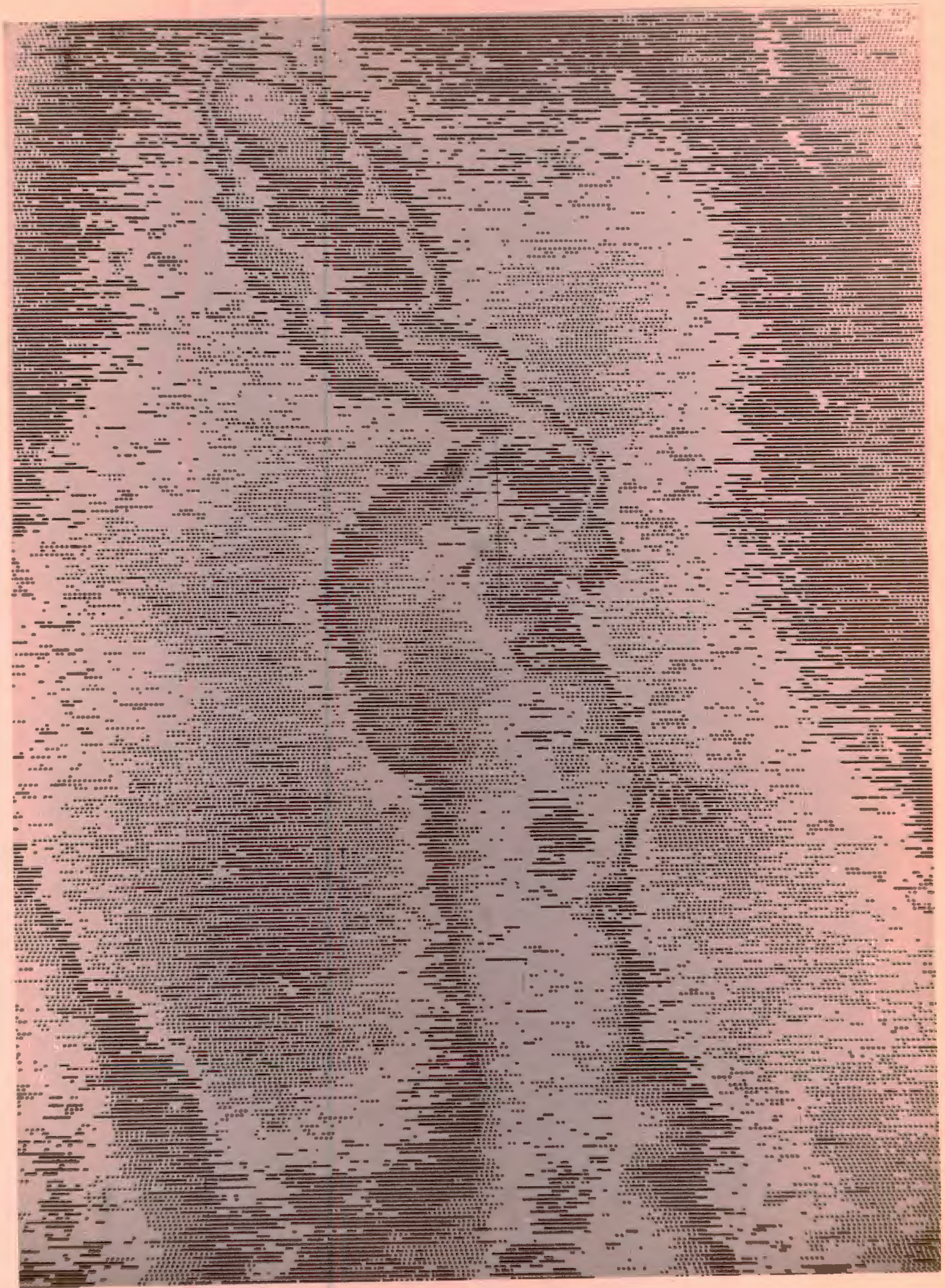

Fig. 12 : Coded Isodensitrace (13).

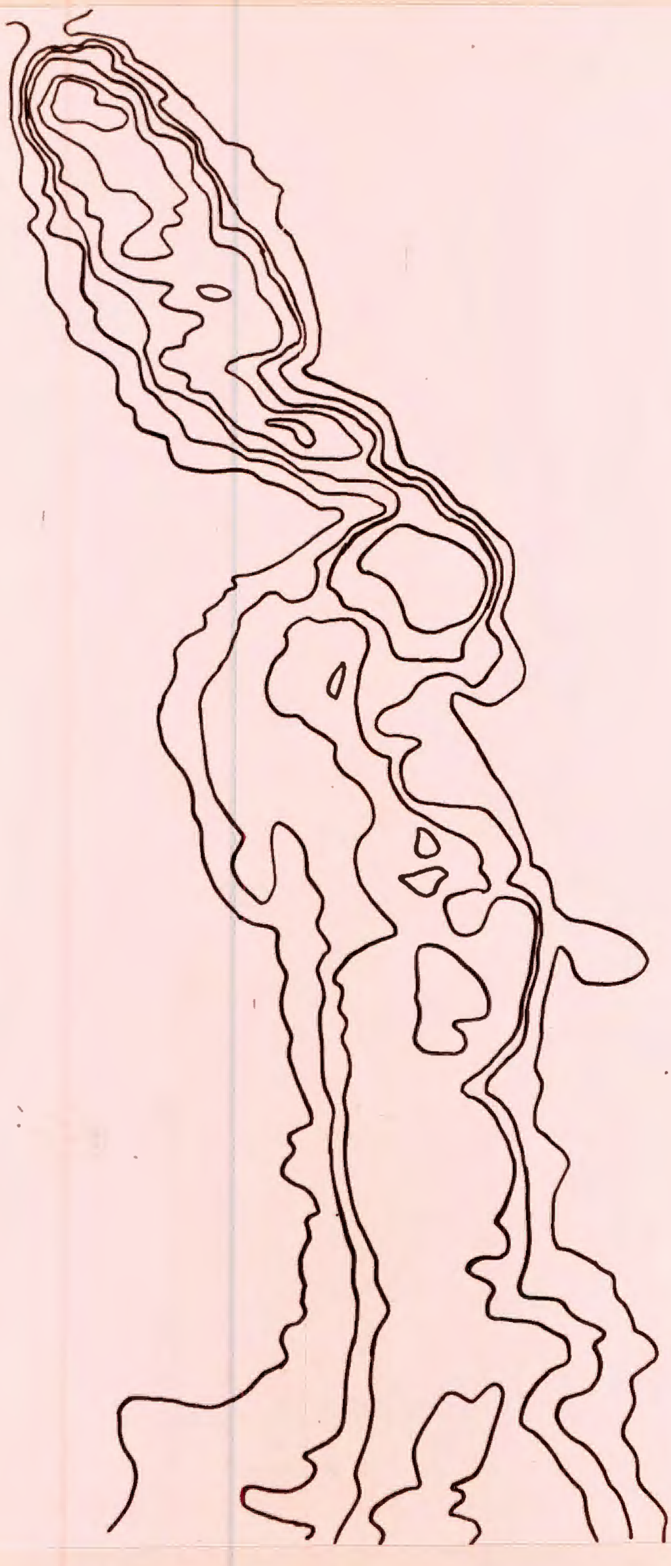

Fig. 13 : Contour lines of equal density from Isodensitrace (13).

Appendix J : Sequential Photography

Fig. 14 : Comparative sequential photography at identical scale - 1/36,000 - of the Bellville-Durbanville area. The right hand print was exposed about five years after the left hand print in 1958. Considerable residential development at A, B, C and D, a new mental hospital under construction at E, a new farm dam at F, an improved road at G, new road access to Durbanville at H and many minor alterations in the pattern of cultivation are among the land use changes discernible.

Appendix K : Typical Photography covering Urban Areas

Fig. 15 : Vertical Aerial Photograph - East Central Johannesburg - Scale 1/4,400 - exposed with normal angle lens. The resolution is excellent - under magnification pedestrians and cyclists can be detected by their shadows. Identification of vehicles is possible even at contact scale and considerable information regarding buildings is available, both directly and under stereoscopic observation. Contrast the reduced height distortion on this photograph with Fig. 16, due to use of normal angle lens.

Fig. 16

Fig. 17

Fig. 18

Fig. 16 : This photograph was taken with a wide angle lens of the Cape Town Foreshore at about 1.50 p.m. on 4th June, 1968. The approximate scale is 1/3200 or about 270 ft to the inch. Points to note are the radial nature of the height distortion - the principal point is located at P; the wealth of information concerning buildings especially away from the centre, where the sides are visible and the number of stories, etc. can be determined; the movement patterns of vehicular traffic as recorded by a change in tone on the road surface; pedestrian movement patterns in vacant areas; the distortion of rectangular blocks due to rising ground at lower left corner; the horde of parked vehicles; pedestrians are visible under magnification; variation in building types with the newer tower blocks easily evident; direction of traffic flows as given by arrows and direction that motor vehicles are facing; detail of statue at S given by shadows; church at C surrounded by commercial buildings immediately evident by its incongruity in general pattern.

Fig. 17 : This photograph of Woodstock was exposed during the same flight as that of the Cape Town foreshore and is approximately the same scale. Points to note are the mixed land usage - commercial and industrial buildings have intruded into the lower class residential area; the nature of the residences - a considerable amount of row housing in poor condition as an inspection of their roofs indicates; the lack of pattern and planning in street layout; public transport vehicles along the two main roads traversing the area; general lack of open space and trees; timber yard at T; parking infringements at P - cars parked in loading zones and busstops.

Fig. 18 is a wide angle photograph of new non-European housing in the vicinity of Bonteheuwel-Langa exposed in August 1967. The scale is 1/7200, i.e. approximately 600 ft to the inch. Points to note are the planned layout with adequate open space; fairly high density as evidenced by the number of schools in the area; traffic circulation pattern; difference between native (lower left) and coloured housing; pedestrian patterns indicate need for pedestrian walkways in planning; reasonable amount of vegetation and trees around houses; double storey blocks are evident by larger shadows as well as stereoscopic examination; contrast with housing shown in Fig. 17.

Fig. 19 : A photomontage prepared from an oblique aerial photograph with a proposed new highway superimposed. The applications of this technique include the presentation of proposals, assessing the degree of improvement of the environment and the provision of data for highway engineering and landscaping (84).

Appendix M : Aerial Photograph and Analysis

Fig. 20 : A Residential District in Colman, characterised by single and multiple family dwelling-units. From an examination of the original (72) shops can be discerned by an absence of front gardens and their location mostly along the main artery. The shops are also social meeting places within the neighbourhood and their number and distribution gives an idea of their service function. Industrial buildings are identified by their size and environmental detail. With this data as a starting-point, the social interactions and groupings within the neighbourhood can be inferred.

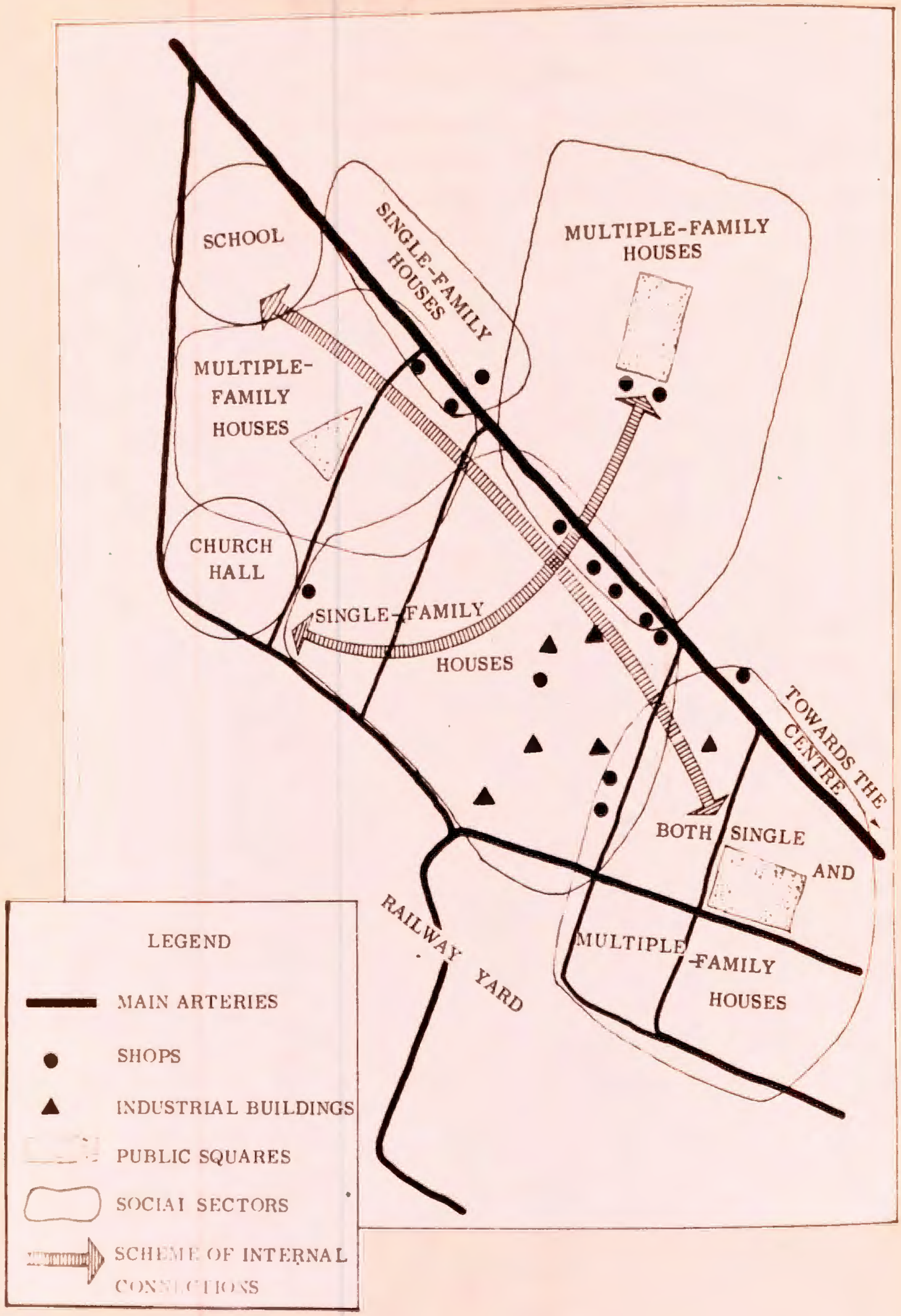

Fig. 21 : Analysis of Fig. 20 resulting from primary and secondary data extracted from the photograph.

Grade of Detail	Planning Unit Size	Range of Approximate Scales	Mean Scale	Approximate Cost R./Sq.Mile
Micro-Detail	Block, CBD, Urban Highway Strip	1/1500-1/4000	1/3000	R100
Fine	CBD, Neighbourhood, Village, Rural Highway Strip	1/2500-1/10000	1/6000	R80
Average	Town, Urban Area	1/10000-1/25000	1/15000	R20
Coarse	Urban, Metro, Region	1/20000-1/50000	1/30000	R7
Broad	Region	1/50000-1/70000	1/60000	R4

Note:

(i) The scale referred to is the scale of the negative. This may be enlarged (or reduced) by factors of X6 or more with good quality photography to increase (or decrease, in the case of reduction) the grade of detail visible.

(ii) Scales as large as 1/1500 require low-flying aircraft and this may create certain practical difficulties.

(iii) The costs of photography vary greatly according to specification, urgency, size and location of area, positioning costs of aircraft and many other factors. The above represent typical average costs according to current costs.

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