SURVEYING AND MAPPING FOR FIELD SCIENTISTS

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Longman Scientific & Technical
Copublished in the United States with
John Wiley & Sons, Inc., New York

Longman Scientific & Technical,
Longman Group UK Limited,
Longman House, Burnt Mill, Harlow,
Essex CM20 2JE, England
and Associated Companies throughout the world.

Copublished in the United States with
John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158

This is a new edition of *Mapping for Field Scientists*, first
published by David & Charles Publishers plc 1977
This edition first published 1988

British Library Cataloguing in Publication Data

Surveying and mapping for field scientists.
– New ed.
1. Cartography
I. Ritchie, W. II. Ritchie, W. : Mapping
for field scientists
526 GA105.3

ISBN 0-582-30086-X

Library of Congress Cataloging-in-Publication Data

Surveying and mapping for field scientists.

"This is a new edition of Mapping for field
scientists, first published by David & Charles
Publishers, 1977" – Verso t.p.
Bibliography: p.
Includes index.
1. Topographical drawing. 2. Surveys – Plotting.
3. Aerial photogrammetry. I. Ritchie, William,
1940– . II. Mapping for field scientists.
TA616.S87 1987 526.8 87-3185
ISBN 0-470-20846-5 (Wiley, USA only).

Set in 9½/12pt Linotron 202 Times Roman

Produced by Longman Singapore Publishers (Pte) Ltd
Printed in Singapore

PREFACE

Aims and objectives

This book is designed as a comprehensive practical introduction and guide to a range of sources and techniques that can be used by a wide group of people (collectively embraced by the term field scientists) who are required from time to time to obtain measurements of distances, heights, distributions and dimensions of areas and features in the field. Three main conventional techniques are described and explained.

1. Consultation of existing sources of maps, aerial photographs, etc.
2. Ground surveying.
3. Measurements on aerial photographs and remotely sensed imagery.

These three methods form the core of the book and are followed by a substantial section on cartographic presentation. At the outset, however, there is a short section that introduces the factors involved in the selection of the optimum solution to the particular mapping task in hand, bearing in mind equipment available, personnel, time, cost and, most important, the nature of the end product.

In each section the emphasis is placed on techniques that require basic equipment and resources. In the cartography section, for example, there is little discussion of digital cartography and computer graphics.

In the surveying and photogrammetric sections, more advanced techniques are omitted if it appeared unreasonable to expect that access to the necessary equipment and materials would be available. There is, however, no hard boundary between traditional and new technology and techniques. In the last decade, the advent of cheap hand calculators, and less expensive but increasingly powerful microprocessors, has initiated major changes in mapping science. Electromagnetic distance measurement equipment, once only described in advanced surveying courses, is now seen along many roadsides and in many building sites. Many popular books and magazines contain superb colour photographs from satellites. Accordingly, towards the end of each section of the book, more modern and expensive methods are introduced. Their introduction can be justified not only by an awareness of the rapidity with which mapping science is developing but also in the knowledge that many field scientists may be in a position to commission relatively large and complex mapping programmes. Thus, although the objective of the book is to serve the needs of the field scientist faced with the problem of producing his own map or series of measurements, it is essential to go a little way beyond this basic practical level. In addition, since the emphasis is on empirical solutions, mathematical proofs and theories are, more or less, omitted, but considerable emphasis is placed on recording and translating field and office measurements into the final form of presentation. Indeed, as will be described in the ensuing section, one of the underlying themes of this book is to advocate an approach that begins with a clear definition of the end product and then works backwards to a consideration of the techniques and methods that are available for the achievement of the necessary levels of scale and accuracy. Finally, although the book has to be divided into a series of chapters, it is realised that in many situations there is the possibility that the optimum solution is frequently obtained by combining techniques and sources. This might be illustrated by a simple example of a vegetation survey, whereby the actual distributions are recognised and defined on an aerial photograph which is then taken into the field where the boundaries are confirmed and the composition established. These boundaries are then transferred to an existing base map by some conventional ground-surveying technique.

The main factors affecting the appreciation of the nature of the mapping problem and guidance on how to select the appropriate techniques are given in the subsequent section.

ACKNOWLEDGEMENTS

We are indebted to the following for permission to reproduce copyright material:

British Aerospace for fig. 4.2; Jet Propulsion Lab., California for fig. 4.11; Letraset for fig. 5.8; Macaulay Institute for fig. 4.4 (plate 2); National Remote Sensing Centre, Farnborough for figs. 4.19 & 4.21; Natural Environment Research Council for fig. 4.10; Royal Aircraft Establishment, Space Dept. for fig. 4.7; Spectral Data Corporation for fig. 4.20; University of Michigan for fig. 4.14; Westinghouse Corporation for fig. 4.8

CONTENTS

Chapter 1 THE PROBLEM, AND HOW TO APPROACH A SOLUTION

1.1 MAIN FACTORS AFFECTING CHOICE OF TECHNIQUE

Faced with the problem of producing a map which determines a distance or an area, or demarcates a zone of interest, the field scientist may consider the tasks of topographic surveying or mapping from aerial photographs to be either outside his training and knowledge, or routine tasks to be completed roughly and quickly (and consequently inaccurately) by the first means available. Similarly, the use of remotely sensed sources is either a most superficial exercise, or is perceived as a daunting technical task. Neither of these two extreme viewpoints can be justified. As demonstrated in subsequent sections, there is always at least one course of action that realises the objectives of the survey or interpretation, conveniently and economically. Basic topographic surveying or elementary photogrammetry contain no techniques or principles that are beyond the ability of anyone with basic mathematical and fieldwork capacity. Common sense is more important than mathematical or technical ability. The initial perceived difficulties can be resolved if a few basic rules are satisfied and if there is a willingness to consider alternative solutions to the particular problem. Perhaps the most important 'rule' is for the surveyor or photogrammetrist to ask the questions, 'What is the nature of the end product?' and 'What are its format, content and accuracy requirements?'

One of the most common procedural errors is a loose definition of the real purpose of the survey. Three elements must be considered. What are the boundaries of the area of survey? What are the dimensions of the smallest object or distance that must be shown clearly on the final map or diagram? (This concept might be termed 'map resolution'.) Will measurements of areas or distance be taken subsequently from the final map? The answers to these questions determine the scale of the final graphical output, be it a map or a diagram. The surveyor must remember that distances, areas and dimensions can only be plotted (or measured) with an accuracy equal to the finite limits imposed by the scale factor, line thickness and the plotting or measuring device used, e.g. a ruler.

An appreciation of the limitations imposed by the scale of this end product, be it diagram or topographic map, is one of the fundamentals of efficient surveying. If, for example, the finest line plotted on the final map is 0.2 mm, then, at the large scale of 1:1000, on the map it is equivalent to 1000×0.2 mm, or 0.2 m in the field. At the reduced scale of 1:10 000 this line becomes 2.0 m on the ground (see Table 1.1). The knowledge that the scale of the final map determines the limits to which one requires to measure objects or distances has several practical consequences. The field equipment or, if one is using aerial photographs, the measuring devices used, should always permit measurements to be made to an accuracy greater than the predetermined plottable error. As a rule-of-thumb, a field accuracy of about half the plottable error is normal.

The constraints imposed by scale do not apply if the end product of the fieldwork or photographic measurements is expressed numerically. The physical limitations of line thickness, paper size and scale requirements are irrelevant: it is the inherent precision of the equipment used and the skill of the surveyor that are important. Whether a distance is measured as 102.7 m or 102.74 m depends on the capacity of the equipment used and the precision of its manufacture. The skill and training of the surveyor determine whether or not any specific item of equipment is used to its full accuracy potential. The fallibility of human recording of observations is well known, and most surveying practices include checks and other procedures that reduce the chance of errors and, at worst, indicate that an error has been recorded somewhere in the survey work. Simple rules of procedure such as 'working from the whole of the part' also confine errors and discrepancies to well-defined limits or controls.

Once the surveying problem is defined and the decision taken on the manner and, if applicable, scale of presentation, the following factors should be considered.

1. Provision of existing surveyed information and data (usually in map form but including aerial photographs, and lists of coordinates/heights).
2. Provision of control.
3. Time available.
4. Cost.
5. Equipment available.
6. Training and skill of survey team.
7. Number of assistants available.
8. The logistic situation.

Quite often, expensive and laborious topographic surveys are made when adequate maps already exist. Ignorance of the existence of a wide range of maps and other published data at various scales for many parts of the world is widespread, particularly among those whose normal vocation does not require them to use maps other than road maps or popular series. The ensuing section (1.2) on source evaluation outlines, in particular, the major existing series of maps of Britain and indicates availability and coverage for other regions. The first question for a surveyor is, therefore, 'What maps exist for this area?' A few hours in a map library, local planning office or regional office of the Ordnance Survey may obviate the need for many weeks of field work.

Ignorance of the existence of aerial photographs is even more widespread; there are few parts of Britain, for example, that do not have reasonable aerial photographic coverage which is at least adequate for the reconnaissance stage of every survey project. Additional questions may then be asked: 'Is field mapping necessary?'; or 'Does the aerial photograph display the desired distribution?' It is thus possible that the best way of conducting a topographic survey is to use aerial photographs or other remote sensing techniques. A combination of field and aerial-photographic measurements may be the ideal solution to a given problem.

An existing map will rarely fulfil exactly the requirements of the field scientist, but it may be taken as a base and the worker's own surveyed data can then be added to its outline. If aerial photographs are used, this work becomes a process of transference and several simple techniques are available (see Ch. 3). If field methods are preferred, the base map may be taken into the field and information and measurements added to it (see Ch. 2), or the additions may be compiled later in an office or laboratory with or without an intermediate computation stage.

Control is almost synonymous with 'framework' or 'limits', and refers to the skeleton around which the body of the survey is built. This is discussed in Chapter 2, but, as a simple example, consider the planimetric survey of a quadrilateral area of ground whose four corners, A, B, C and D, form the control framework (Fig. 1.1). The corners determine the limits of the area to be surveyed. Moreover, since topographic detail or the dimensions or locations of features are enclosed within this framework, its accuracy of construction defines the limiting (best) accuracy of the total survey. It therefore follows that the measurement or procurement of this framework should be made to an order of accuracy that is higher than the specifications of the topographic mapping. A distinction may be drawn between control measurements, which may be used in computation and subsequently to produce other measurements, and the measurements made to obtain the topographic detail that is surveyed within the control framework. The survey of detail is often plotted to graphical accuracy, and it can therefore be made to a lower order of accuracy than the framework. Equivalent control procedures apply to the use of aerial photographs for surveying purposes.

The control framework may be determined by

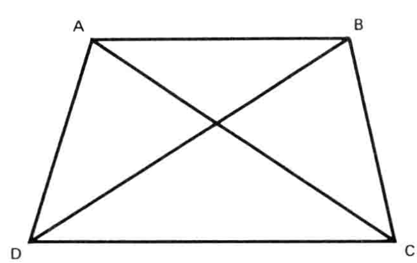


Fig. 1.1 Braced quadrilateral control framework.

one of the following methods: ground surveying; abstraction from aerial photographs, existing maps or charts; or the acquisition of numerical values. The coordinates of the corners of the quadrilateral may be used to determine this control framework, or, for heighting, the Ordnance Survey (and equivalent national surveying organisations elsewhere in the world) provides lists of bench-mark elevations to which one can relate the height information of the particular topographic survey.

It is worth noting that the framework lines are often omitted from the final map, since the purpose of the map is usually to present details of the ground within the area of the control. The control framework, therefore, may be compared to scaffolding – necessary for construction but removed in order that the final product can be seen.

Surveying is expensive, and the cost rises rapidly with area, accuracy requirements and amount of detail surveyed. One of the major cost components is related to time. Preparation work, provision of materials, survey measurements, computations and draughting can absorb many days of skilled work. It is highly pertinent to see the solution to the problem of surveying an area as a time/cost/accuracy equation. This approach places a premium on selecting the right method for each task, reducing measurements to the minimum, eliminating time-wasting errors and using the equipment that most rapidly satisfies the precision requirements. Measurements should not be taken to millimetres if the plottable error is measured in centimetres. This does not mean that an instrument which measures to millimetres should not be used: it may be quicker to use, although it will probably cost more to buy.

The cost of equipment should be related not only to its precision capabilities and its speed of operation but also to the number of functions it can perform. A theodolite used as a tacheometer can measure distance to an accuracy of 1:500 to 1:1000, but will currently cost £500–2000; a man can pace out a distance with some degree of accuracy and the 'equipment' cost is nothing. A theodolite, however, can measure angles in the vertical and horizontal planes, distances, and can indirectly measure heights; a man's pace can only measure distance.

If funds are short and the surveyor is provided with a limited range of equipment from existing stock, then, assuming he has the skill to use the equipment, the choice of method is circumscribed by availability. If there is adequate funding, the costing exercise must extend beyond capital purchasing to an evaluation of operator time, speed, flexibility and precision against the demands of the end product.

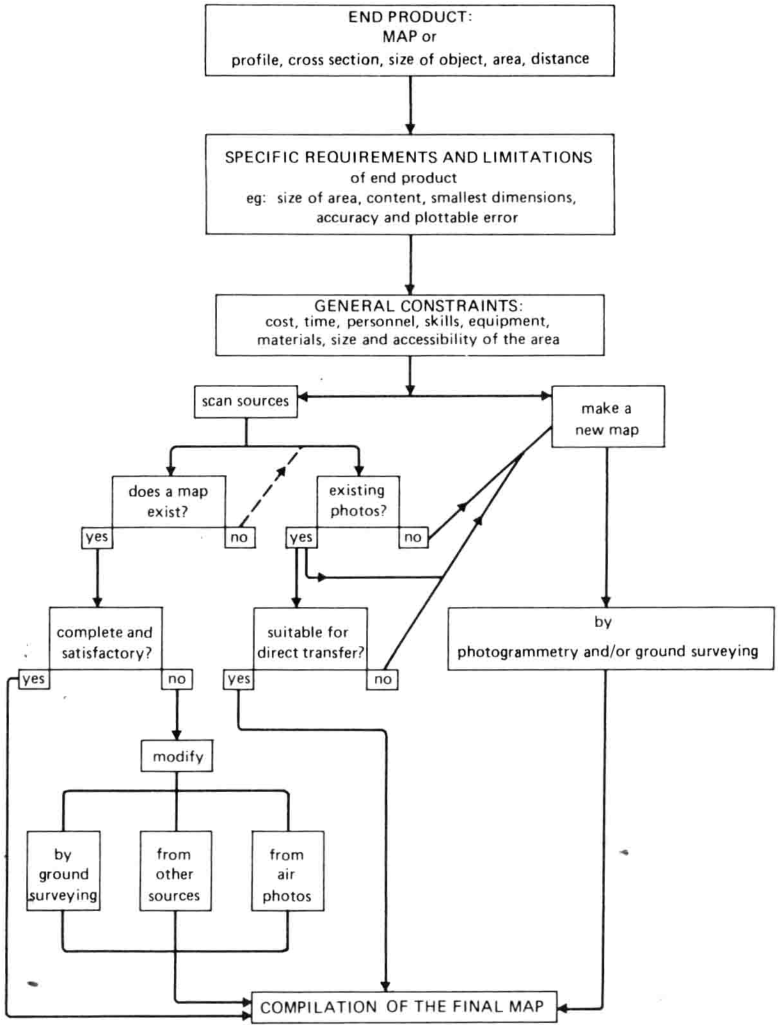
In other circumstances, it may be worth considering hiring from one of the survey manufacturers or their agents a piece of equipment for a special task. The possibility of borrowing equipment from an educational institute or the engineer's office of a local authority could also be investigated. Other factors enter into the decision-making process. Is there a sufficient level of skill and training available in the survey party? Is there a sufficient number of assistants available to do ancillary tasks such as staff-holding or booking? Is logistic support required for the transport of equipment and personnel?

Any field survey can be broken down into several stages: definition of requirements; reconnaissance; appraisal of methods; field work; compilation and computation (if necessary); and presentation. Each stage poses inter-related questions. The evaluation of the total field survey can be likened to a flow diagram where the earlier stage conditions the next one or permits complete sections of the evaluation to be bypassed. Such an approach is shown in Fig. 1.2, which may be used as a check-list before beginning any ground-surveying project. It also serves as a summary of the factors involved in planning a survey and as a memorandum of the alternatives available.

1.2 SOURCES OF MAPS AND AERIAL PHOTOGRAPHS

The surveyor's problem should be defined clearly at the outset, e.g. 'a planimetric map of an area 1 km square containing field boundaries . . . and on which can be represented short walls, 50 cm thick, to scale'. The search for a solution may be brief, since a suitable map may already exist in an official map series or as a commercial product (Fig. 1.3). Photographs may also be available, either for the direct tracing of detail (in certain circumstances

Fig. 1.2



only) or for use directly in mapping by photogrammetry (Ch. 3). The available map may be complete, though it is more likely to require revision, modification or amplification in order to meet the project specifications. This additional work could be completed either by ground survey or from aerial photographs. Possible short-cut solutions, through the use of existing maps or photographs, should be explored at the outset. Most forms of survey should not be proceeded with before a routine examination of existing sources, which may produce a map that requires only a few days' work to bring it to the desired standard. If the area is small and the level of complexity low, however, it is possibly more expedient to make the map directly.

1.2.1 MAPS

Although some surveying techniques may be used merely to add items of information to small-scale maps (e.g. the barometer at 1:50 000), the most common mapping problems assumed for this book would generally relate to small areas (e.g. 100 m square to 2 km square), thus making it unnecessary to consider map sources at scales smaller than 1:25 000. The 1:25 000 scale map, useful in certain situations, has been derived in some regions from larger scales through a degree of generalisation of form and content which is undesirable in maps normally used by field scientists. But in some countries, such as the USA, the corresponding map,

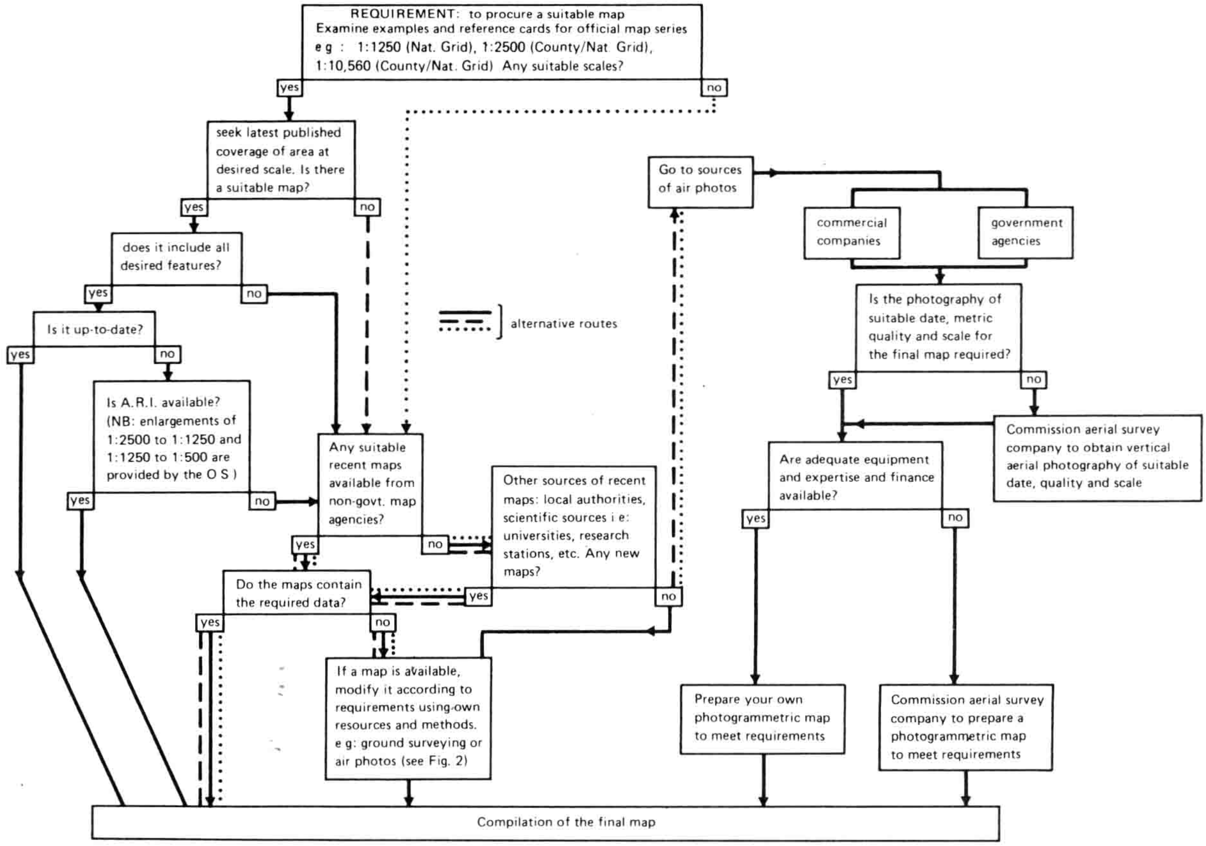


Fig. 1.3

1:24 000, may have been produced to a high order of accuracy, there being no other official larger-scale maps available.

The major map sources useful to surveyors are official maps which are currently published or are of recent date. Other maps may be available from private companies and earlier scientific surveys (Fig. 1.3).

The following questions should be asked when evaluating maps as basic information sources.

1. *What are their scales, their outstanding characteristics of design and content and the areas for which they are available?*
   Current official map series normally cover extensive regions. Small-scale maps (e.g. 1:50 000) are normally available for the whole inhabited area of developed countries, but very large-scale maps (e.g.1:2500) have coverage restricted to well-populated areas on the grounds of economics and requirement. (The Annual Report of the Ordnance Survey details the official mapping of Britain.) In developing countries or sparsely populated areas, complete map coverage, even at small scales, is seldom available.

   As the mapping of a country evolves, several editions of one map scale may be available for different regions, and users should anticipate the problems associated with this. It is important to become familiar with the system for locating the sheets in a series, and with the coordinate system used to locate features within any given sheet. These matters are normally explained in the map margin.

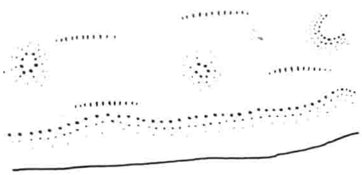
2. *How accurate are the maps?*
   Survey work in the nineteenth century was occasionally inconsistent and generally less accurate than similar modern work. Accuracy varied regionally, more remote areas receiving less rigorous attention. These variations are seldom obvious, as mapmakers preferred to give the impression that all areas were treated equally well, and the design echoes this apparent

uniformity of standard! For example, in Britain, treatment of trees and shrubs at the 1:1250 and 1:2500 scales is conventional rather than precise, and trees are indicated by different symbols. Other features, such as sand dunes and cliffs, are not mapped in detail in spite of the high graphic quality of the symbols (Figs 1.4 and 1.5).

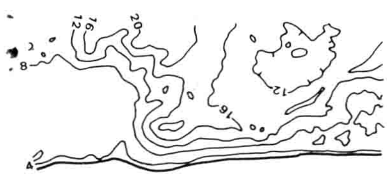
coastal rocks – older large-scale map series

coastal rocks – air photo interpretation

Fig. 1.4



sand dune coast – older series



sand dune coast – from modern photogrammetric map (contour interval: 4 m)

Fig. 1.5

Attention to notes in the margins of the map sheet on date of survey and compilation is consequently important.

The problem of inconsistency in accuracy and content is exaggerated in smaller-scale maps that have been compiled from larger-scale map sheets of varying quality. In addition to this unapparent variable reliability, the content may have been generalised, be highly subjective and thus unpredictable. Today, certain new maps, e.g. the Ordnance Survey 1:25 000 Second Series, may have been produced partially by photographic reduction from a larger-scale photogrammetrically surveyed map, and the intricacy of the image reflects the lack of generalisation, in contrast to the generalised image of earlier editions.

3. *Have the maps been revised, and if so, when and to what extent?* Complete revision of map sheets is rare, although changes in communications and settlement are frequently incorporated on newer editions. When the extent of revision is not indicated on the map, information should be sought from the responsible organisation.

   The field scientist, having discovered maps at several dates and scales for his area, may attempt to seek evidence of environmental change. While this is possible in certain instances (e.g. successive maps of a coastal spit), a careful check should be made of the dates of survey and revision and what they mean. Publication obviously post-dates the survey itself, but it may be hard to determine by how long.

4. *What features are normally included in large-scale topographic maps?*
   The choice of content or symbols in official maps evolved in response to military and civilian needs over the years. The selection of features and the design of certain symbols may date from mid-nineteenth-century surveys, and thus will not conform to current design or user requirements. Consequently, the Ordnance Survey in Britain undertook a re-examination of the content of the 1:1250, 1:2500 and 1:10 000 scale maps. Users should be aware of the origins of the maps they select and the consequent effect on their appearance.

1.2.1.1 OFFICIAL MAPS OF GREAT BRITAIN

Three official organisations produce maps of the British Isles: the Ordnance Survey, for Great Britain; the Ordnance Survey of Northern Ireland; and the Ordnance Survey of the Irish Republic.

Table 1.1. presents the range and some of the characteristics of the larger-scale maps produced by the Ordnance Survey of Great Britain.

Table 1.1 Characteristics and coverage of larger-scale Ordnance Survey maps

Scale	*The approximate ground width represented by a map line of 0.2 mm gauge*	*Coverage of one sheet*	*National Grid line intervals depicted*	*Planned area of coverage*	*Remarks*
1:1250	25 cm (10 in. approx.)	500 m × 500 m	100 m	Towns of 20 000+	Completely new, introduced in 1945
1:2500	50 cm (20 in. approx.)				
County Series		1½ ml × 1 ml	None	As above and rural areas	Adopted in 1840s
National Grid Series		2 km × 1 km	100 m	As above	Introduced in 1949, but production halted in 1973 in areas where 1:1250 existed
1:10 560	2 m (6.5 ft approx.)				
County Series		6 ml × 4 ml (full sheet) 3 ml × 2 ml (quarter sheet)	None, although some received National Grid	Whole country	Introduced in mid-nineteenth century; quarter sheet came later
National Grid Series		5 km × 5 km	1 km	As above	Appeared after 1945 and includes contours at 25 ft intervals which vary in accuracy
1:10 000		As above	As above	As above	Metric specification adopted in 1969 for all new '6 Inch' maps, 5 m vertical contour intervals (10 m in mountains)
1:25 000	5 m (16.5 ft approx.)				
Provisional Edition		10 km × 10 km	1 km	Almost all but Scottish Highlands and Islands	Published after 1945
Second Series 'Pathfinder'		10 km × 20 km	1 km		Commenced in 1965

All new maps are based on the National Grid. This is a system of lines parallel to and at right-angles to the central meridian (2° W) of the Transverse Mercator Projection, on which the maps of Great Britain are drawn. The grid lines are scaled in metres and the resulting rectangular coordinates can be used to make reference to any point in Great Britain. The origin (zero) of the grid system lies on the central meridian, but, in order to provide positive eastward and northward values, a so-called 'false origin' has been selected about 150 km west and 20 km south of Land's End. The precision achieved with such grid references depends upon the scale of the map. An accuracy of 10 m can easily be estimated on the 1:1250 map, while at the 1:50 000 scale this drops to about 100 m. An index of the National Grid squares and their designated letters appears inside the covers of most folded Ordnance Survey maps and in the map catalogue.

The two largest scale maps, printed in black only, contain detailed information of buildings, communications and boundaries, with spot heights but no contours. The smaller scales, 1:10 000 and 1:10 560, have both spot heights and contours, although the latter vary widely in reliability. On these maps contours are shown in brown. The maps also contain important control information for plan and height which can be used directly for some lower-order mapping purposes, e.g. amplification of existing maps by ground survey or photogrammetry. For more precise work the Ordnance Survey publishes sheets containing the descriptions, exact coordinates and current heights of benchmarks (Appendix 1).

The earlier County Series versions of both 1:2500 and 1:10 560 were constructed on Cassini's Projection, centred on local meridians. This projection leads to distortion of angles which increases rapidly away from the selected central meridian. The projection could therefore only be applied to small local areas (groups of counties – hence the name 'County Series'), unlike the Transverse Mercator Projection which is now the basic national projection and serves the whole country from one location of its central meridian. The complex variety of sizes and interlocking regions of the County Series led to the occurrence of unequal degrees of distortion at the common boundary of two or more county groups. Mismatching of detail at map edges is the outcome. Such failings contributed to the eventual demise of the series, but since the maps will remain in use for some years, the Ordnance Survey provides the National Grid coordinates for the corners of 1:2500 County Series sheets to allow comparison with new maps based on the National Grid.

The National Grid Series of the 1:10 560 map appeared first as a provisional edition compiled from the old maps but on National Grid sheet lines. The most recent Regular Edition is being produced from original surveys, where possible, or is derived from the larger scales where they exist. The earliest 1:10 560 map had a fine intricate design, with very small point and line symbols; later these were changed slightly, with the introduction of the Provisional Edition. The very much bolder, coarser, new Regulation Edition will not withstand much further enlargement. It was planned as a base for detailed field mapping.

Revision information

Owing to the cost and time taken in production, revised editions of large-scale maps are slow to appear, so the information on the published sheet may be considerably out of date. Once the maps at the 1:1250 and 1:2500 scales have been published, however, local Ordnance Survey surveyors are responsible for carrying out continuous revision of the master survey drawings (MSDs) of their own areas.

This information is available in two forms.

1. SUSI (Supply of unpublished survey information). It is possible to call at local Ordnance Survey Offices to ascertain if the relevant MSDs provide the information required. Copies can also be provided at some offices. This is the most up-to-date form in which local survey data can be obtained.

2. SIM (Survey information on microfilm). Microfilm copies are produced of published maps at 1:1250 and 1:2500; and Master Survey Drawings at fixed stages of revision. Ordnance Survey Microfilm agents in various parts of the country carry the latest issues of these and can provide enlarged printed copies, at the appropriate scales, on film or on paper. Microfilm copies can also be purchased, but full details should be sought from the

Ordnance Survey in Southampton. SUSI and SIM are not available for the 1:10 560 or 1:10 000 scale maps.

Various other services are available for large-scale maps such as enlarging, i.e. 1:1250 to 1:500, 1:2500 to 1:500, 1:2500 to 1:1250 and 1:10 560 to 1:10 000. Reductions will also be prepared from 1:1250 to 1:2500 and 1:10 000 to 1:10 560.

Since the early 1970s the O.S. has been preparing FORTRAN-readable computer tapes containing the large-scale maps, including the 1:10 000, in digital form. This expanding service has the advantages of making it possible to plot selected information for customer selected sheet lines – without having to accept the rigid sheet boundaries of the standard map series; specialised advice can be obtained from the O.S.

The new 1:25 000 series (Pathfinder) provides, for the Scottish Highlands and Islands especially, a new and detailed record of the landscape. It is produced for an area whenever the appropriate sheets at the 1:10 560 or 1:10 000 scales have been completed. The aerial survey method employed for the most recent maps has permitted very detailed depiction of rock exposures. The facility of obtaining gradient measurements from the contours is now greatly improved. Elsewhere, various methods are used for major revision of the older editions. The 1:25 000 does suffer from extensive generalisation, e.g. the exaggeration of road width, the simplification of building outlines, and the broad classification of trees. It is worth observing, however, that unlike the Provisional Edition, the new Regular 1:10 560 and 1:10 000 maps have almost the same level of generalisation as the 1:25 000 scale maps, in spite of the difference in scale.

Users of Ordnance Survey publications should become familiar with all the series with SUSI and SIM, where available and also with the copyright regulations governing their use. The most valuable initial source of information is the current O.S. Catalogue and the Ordnance Survey Annual Reports, which may be obtained from the Southampton headquarters of the Ordnance Survey (Appendix 1). Early editions of County Series maps, if required, are still available in some of the larger libraries, and elsewhere, but the Ordnance Survey will provide advice on this.

1.2.1.2 OTHER SOURCES OF MAPS

Other official mapping is generally of a thematic nature, and details of Soil Survey and Geological Survey publications can be obtained from the Ordnance Survey. Land utilisation maps, however, are obtained through the Geography Department, Kings College, University of London. Important addresses, etc., appear in the current Ordnance Survey map literature. In Britain, private mapping is carried out by several commercial firms (Appendix 2). A more complete list for most countries might be obtained by reference to the corporate membership list of an appropriate professional society; these lists often appear in journals such as *The Survey Review*, *Photogrammetric Record* and *Photogrammetric Engineering and Remote Sensing*.

Commercial firms carry out varied work. In Britain, much of it consists of contouring and updating Ordnance Survey large-scale maps for particular clients, notably local authorities. Original mapping from new, specially commissioned photography is also carried out. These companies do not provide a 'library service' of the work undertaken, for, strictly speaking, it is the private property of the clients. For seekers after source maps, carefully worded enquiries to various organisations may bring favourable results. On the other hand, initial contact with newly surveyed material may be obtained through a local planning office.

Similar source facilities and services exist in many countries (Appendix 2), some details of which follow.

The United States of America

In the USA the largest-scale map series is 1:24 000, and this series, with the other official topographic maps, is the responsibility of the US Geological Survey. The sheet lines of US maps are based on the earth's graticule system of parallels and meridians, the 1:24 000 measuring $7\frac{1}{2}$ minutes of latitude by $7\frac{1}{2}$ minutes of longitude, and the 1:62 500, 15 minutes by 15 minutes.

In general, the content of the 1:24 000 map is similar to that of the Ordnance Survey 1:25 000, but, what is more important is that the topographic detail is frequently much fuller and more precise. Not only are there additional symbols for surface deposits, etc., but the contour interval varies from