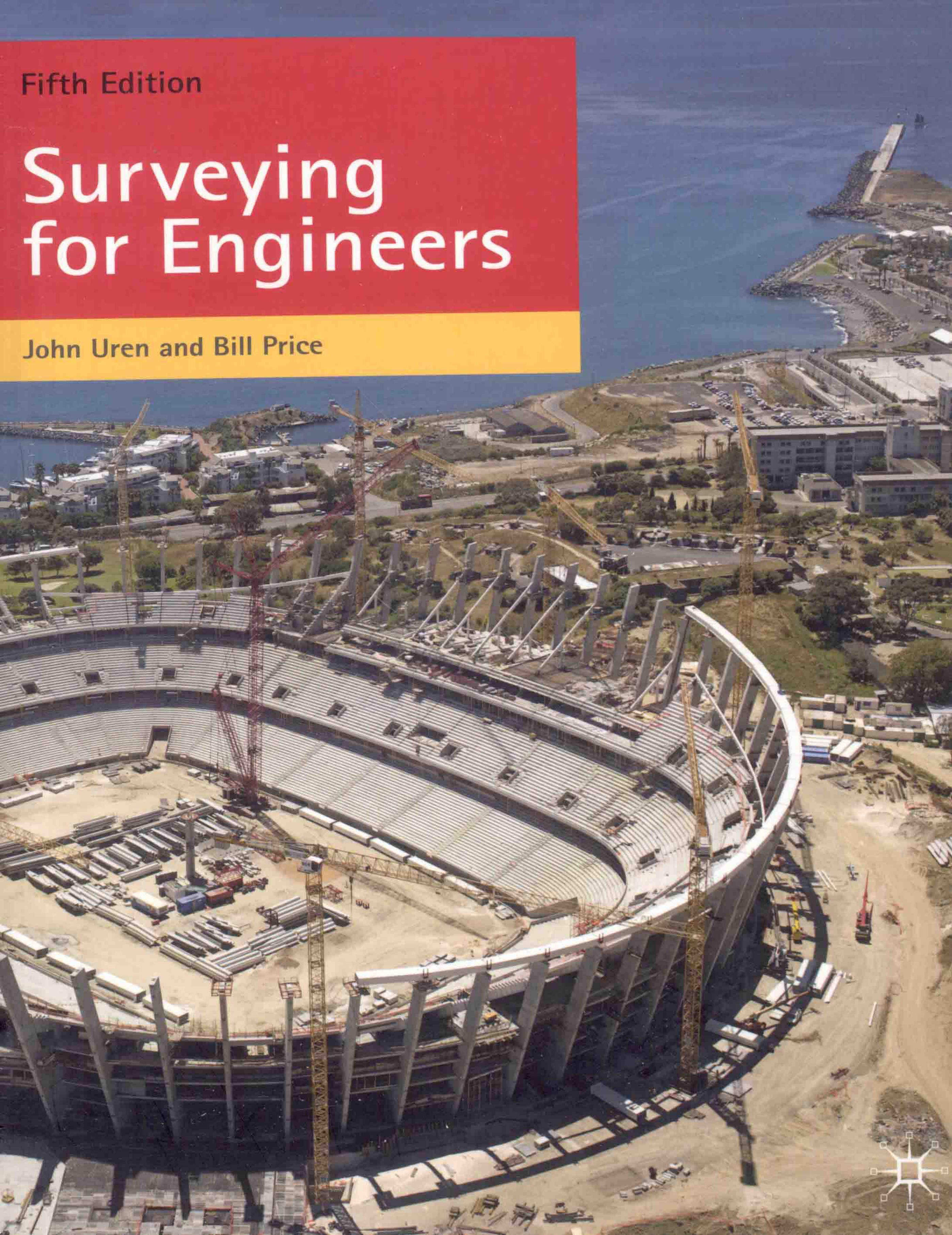
Fifth Edition

# Surveying for Engineers

John Uren and Bill Price



# Surveying for engineers

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5th edition

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# Preface

It is now more than 30 years since the publication of the first edition of *Surveying for Engineers*, and in that time the equipment and techniques used in engineering surveying have undergone incredible changes. Electronic theodolites and total stations, digital levels, laser scanners and machine control systems, to name just a few, were all unheard of when the first edition was published in 1978, which by pure coincidence was the same year that the first GPS satellite was launched. Since then the discipline into which engineering surveying falls has developed almost beyond recognition, having even been given a new identity with the name of Geomatics. There can be few disciplines that have changed so quickly and dramatically. Subsequent editions of *Surveying for Engineers* have always tried to reflect this evolution and this new fifth edition is no exception.

Satellite surveying systems continue to have a major influence on engineering surveying and, to reflect this, recent developments in Global Navigation Satellite Systems (GNSS), particularly the introduction of network RTK and OS Net, have been included. In addition, the latest survey instruments, methods and digital technologies are covered, including image processing with total stations and laser scanners, developments in data processing and integration as well as updates on Ordnance Survey mapping products. New topics include techniques for locating underground services and the use of Earth observation satellites for mapping in civil engineering and construction.

However, alongside all of the sophisticated equipment currently available, fundamental topics such as levelling, measurement of angles, measuring distances using tapes and how to carry out traversing and compute coordinates are still covered in some detail, as they are still as relevant on site today as they were in 1978, as are the calculations required for curves, areas and volumes, which have also been retained. This mix of modern and well-established techniques is one of the enduring features of *Surveying for Engineers* in that it not only covers the basic skills required on site but also gives details of the latest technologies available. This edition also continues the theme introduced in the previous one of making extensive use of Internet resources throughout and it is hoped that the adoption of a new page format and layout will further enhance the appeal of this classic surveying textbook to students and practitioners alike.

As with all previous editions, the fifth edition of *Surveying for Engineers* has been written with civil engineering, building and construction students in mind. However, it will also be found useful by any other students who undertake surveying as an elective subject and it is anticipated that practising engineers and those engaged in site surveying and construction will use *Surveying for Engineers* as a reference text.

John Uren and Bill Price
February 2010

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# Contents

Chapter 1

# Introduction

**Aims**

After studying this chapter you should be able to:

- Define what surveying is and what its various disciplines are
- Explain that engineering surveying is that part of surveying used mostly for civil engineering, building and construction projects
- State the main purposes of engineering surveying
- Discuss the reasons why the terms *geospatial engineering* and *geomatics* have been introduced to describe the activities of surveyors
- Describe, in outline, the methods by which engineering surveying is carried out and the equipment and methods that are used for this
- Give reasons why engineering surveyors now play a major role in data management for engineering projects
- Recognise those areas of surveying that will develop in the near future and appreciate why engineering surveyors have an important part to play in this
- Obtain information about surveying from a variety of sources, including the main institutions that promote surveying

This chapter contains the following sections:



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## 1.1 Engineering surveying

After studying this section you should be able to explain what geospatial engineering and geomatics are and why these terms have been introduced. You should be aware that engineering surveying is used extensively in building and construction, but that this can also involve many specialist areas of surveying. You should have an outline knowledge of the equipment and methods used in engineering surveys and have some appreciation of the way in which these are expected to develop. You should also have a clear idea of the aims of this book.

This section includes the following topics:

- Engineering surveying, geospatial engineering or geomatics?
- What is engineering surveying?
- How are engineering surveys carried out?
- What will be the role of engineering surveyors in future?
- What are the aims of this book?

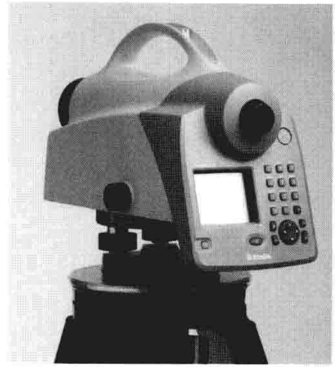
### Engineering surveying, geospatial engineering or geomatics?

To many, the traditional role of a surveyor has been to determine the position of features in both the natural and built environment on or below the surface of the Earth and to represent these on a map. Even though this view of surveying is still true in some respects, in an age when the acquisition, processing and presentation of data are paramount, surveyors today will be familiar with many different methods for collecting spatial data about the Earth and its environment, they will be able to process this data in various formats and they will be able to present this in an assortment of media.

Although this gives an idea of what contemporary surveying is, to the majority of engineers working on construction sites surveying is the process of measuring angles, distances and heights to help in the design and construction of civil engineering projects. This gives rise to the term *engineering surveying*, which is defined as *any survey work carried out in connection with construction and building*. This also involves all of the different methods of data acquisition, processing and presentation now available in surveying. Engineering surveying is one of the most important areas of expertise in surveying and to reflect this, it is the main subject of this book.

Many on site think that engineering surveying is a labour-intensive method that uses old-fashioned instruments for taking measurements and requires never-ending calculations to be done. Although theodolites, levels and tapes are still used and engineering surveying will always require some calculations to be done on site, the way in which surveys are carried out for civil engineering and construction projects has been transformed in recent years. For example, most measurements of distance, angle and height are now recorded and processed electronically using total stations and digital levels similar to those shown in Figure 1.1. Global Navigation Satellite Systems (GNSS) are in everyday use, and airborne technologies such as LiDAR (Light Detection and Ranging) are used by engineers for mapping as well as laser scanners. These are shown in Figure 1.2.

Total station



Digital level

**Figure 1.1** ● Total station and digital level (courtesy Phoenix Surveying Equipment Ltd and Trimble & KOREC Group).

The large amounts of data that can be collected by these measuring systems are easily processed by computers that are capable of handling data and performing calculations in a fraction of the time taken to do this a few years ago. Another benefit of the digital age in data recording and processing is that data can be transmitted between instrument and office using a mobile phone or WiFi to connect to the Internet.

Not surprisingly, all of these new technologies have resulted in some changes to the way in which engineering surveying is carried out. Up till now, the main purposes of engineering surveying have been to supply the survey data required for preparing maps and plans for site surveys, together with all aspects of dimensional control and setting out on site. However, even though these are still relevant, there is now much more emphasis on providing survey data and managing this for both engineering and built environments.

With all these developments in mind, one of the institutions that regulates the activities of surveyors working in civil engineering in the UK, the Chartered Institution of Civil Engineering Surveyors (the ICES), has introduced the term *geospatial engineering* to reflect the changes in the way in which survey data is collected and processed for civil engineering projects today. For example, in addition to the traditional activities associated with engineering surveys, geospatial engineers may also be involved in specialist areas such as photogrammetry, remote sensing and geographic information systems, as well as cartography and visualisation. It is the addition of these to the engineering surveyor's role and the change of emphasis towards information management that has given rise to the term *geospatial engineer*.

Another institution that regulates surveying in the UK is the Royal Institution of Chartered Surveyors (the RICS). It takes a much broader view of surveying, which is organised into professional groups covering areas ranging from arts and antiques to valuation. The professional group that is responsible for land surveying is known as the *geomatics professional group*.

*Geomatics* is the word that is used to describe surveying as it is today and not only covers the traditional work of the surveyor in mapping and on site but also reflects

GNSS equipment on site

LiDAR survey of railway

Laser scanner

**Figure 1.2** ● GNSS, LiDAR and laser scanner technology in surveying (courtesy Trimble & KOREC Group, Fugro Inpark and Leica Geosystems).

the changing role of the surveyor in data management. As discussed above, this has arisen because of the advances made in surveying, which make it possible to collect, process and display large amounts of spatial data with relative ease using digital technology. This in turn has created an enormous demand for this data from a wide variety of sources: for all of these, data is collected and processed by a computer in a Geographical Information System (GIS). These are databases that can integrate the spatial data provided by surveyors with environmental, geographic and social information layers (see Figure 1.3) which can be combined, processed and displayed in any format according to the needs of the end user. Without any doubt, the most important part of a GIS is the spatial data on which all other information is based, and the provision of this has been a huge growth area in surveying. Because of the different emphasis in surveying and other advances made in instrumentation for data col-

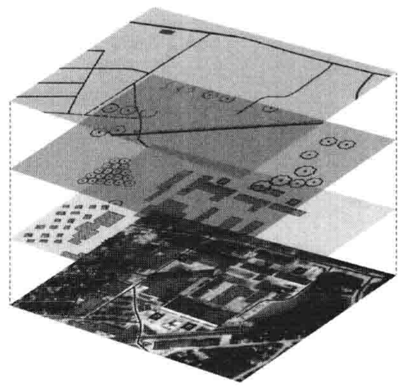


**Figure 1.3** ● Layers in a GIS (courtesy Leica Geosystems).

lection and processing, it is now felt that a change of name from surveying to geomatics reflects the nature of the profession as practised today in the same way that geospatial engineering describes surveying in a construction environment. Throughout *Surveying for Engineers* the term *surveying* will continue to be used, but the use of the term *geomatics* to replace this is noted here.

Bearing in mind the reasons for the use of geomatics in surveying, the geomatics professional group of the RICS gives the following definition:

> *Geomatics is the science and study of spatially related information and is particularly concerned with the collection, manipulation and presentation of the natural, social and economic geography of the natural and built environments.*

Within the professional group, engineering surveys and geodesy are identified as specialist areas, but others such as mapping, GIS, photogrammetry and remote sensing, together with spatial data capture and presentation, are also included.

## What is engineering surveying?

Both the ICES and RICS include engineering surveying in their definitions of geospatial engineering and geomatics. Taking the ICES definition, geospatial engineers and engineering surveyors can be responsible for:

- Locating the best positions for the construction of bridges, tunnels, roads and other structures
- Producing up-to-date maps and plans
- Setting out a site, so that a structure is built to scale and in the right place
- Monitoring the construction process
- Providing control points so that future movement of structures, such as dams and bridges, can be monitored

Both institutions also identify some of the other types of survey that might be used on civil engineering projects as the following:

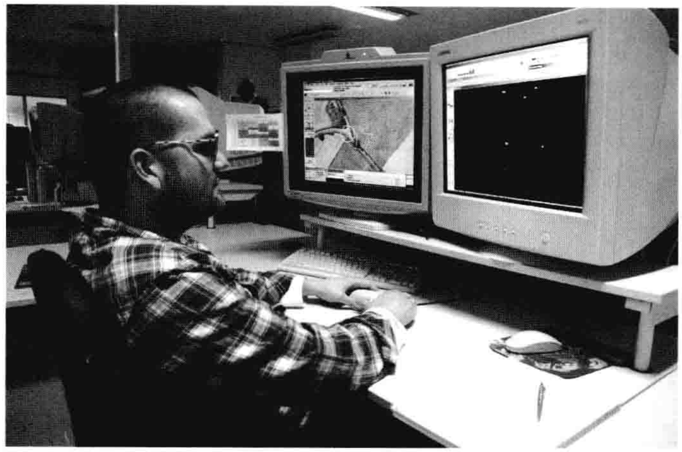


**Figure 1.4** • Photogrammetric soft copy workstation (courtesy Fugro-BKS).

- *Hydrographic surveying.* This is surveying in a marine environment where the traditional role for centuries was to map the coastlines and sea bed to produce navigational charts. More recently, many hydrographic surveys have been carried out for offshore oil and gas exploration and production. Hydrographic surveys are also used in the design, construction and maintenance of harbours, inland water routes, river and sea defences, flood plain mapping, in control of pollution and in scientific studies of the ocean.
- *Photogrammetry.* This is the technique of acquiring measurements from photographic images. The use of this in topographic mapping for engineering is well established and is carried out today using digital aerial photography and computers with a high-resolution display in a soft copy workstation similar to that shown in Figure 1.4. The photographs are taken with special cameras mounted in fixed wing aircraft or helicopters. Because it is non-contact, photogrammetry is particularly useful in hazardous situations. Another of its advantages is that it produces data in a digital format, which makes it ideal for use in GIS and CAD.
- *Remote sensing.* This technique is closely allied to photogrammetry because it also uses imagery to collect information about the ground surface without coming into contact with it. Remote sensing can be carried out for engineering projects using satellite imagery, spectral imaging (in which different colour images are analysed) and, more recently, with airborne platforms such as LiDAR and IFSAR.
- *Geographical Information Systems (GISs).* These are computer-based systems which allow spatial information to be stored and integrated with many other different types of data. As far as geospatial engineering and geomatics are concerned, they involve obtaining, compiling, input and manipulation of geographic and related data and the presentation of this in ways and formats specifically required by a user.
- *Cartography and visualisation.* This is the art and technique of making maps, plans and charts accurately and representing three dimensions on a variety of media.

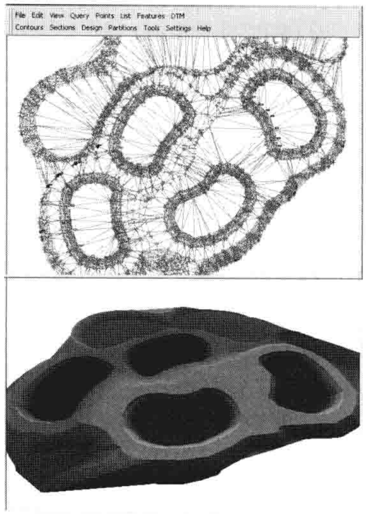



**Figure 1.5** ● Computer visualisation produced from survey data (courtesy AiC).

Cartography and map making can be considered to be the traditional role of the surveyor, and anyone who uses a map to find their way round town or countryside is using information gathered and presented by surveyors. Compared to this, visualisation is a new technology that uses spatial data to show computer generated views of landscapes, as shown in Figure 1.5. These could be used for preparing environmental impact assessments.

As can be seen, engineering surveying involves a number of specialist areas, all of which will overlap from time to time. Although geospatial engineering and geomatics encompass these, this book concentrates on engineering surveying. Guidance on how to obtain information on the other specialist areas in geospatial engineering and geomatics is given at the end of this chapter.

## How are engineering surveys carried out?

Recalling the bullet points given above for the responsibilities of geospatial engineers and engineering surveyors, an engineering survey usually begins by undertaking a control survey to establish a control network on which the subsequent mapping and setting out can be based. Control surveys, mapping and setting out all require modern surveying equipment and data collection, communication and processing hardware and software; ideally combined into a seamless field-to-finish integrated surveying system. An introduction to all of these is given in this section.

### Control surveys

All types of engineering survey are based on control networks which consist of a series of fixed points located throughout a site whose positions are determined on some coordinate system. The process of measuring and defining the positions of the points is known as a *control survey*.

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