Solutions for all Geography
Grade 11
Learner’s Book

J Brett
A Gelling
K Marimuthu
S McIntyre
C Vlok
Contents

Dear learner ............................................................................................................... v
Programme of Assessment ................................................................................... vi

**Topic 1: Geographical skills and techniques** ......................................................... 1
Mapwork skills ........................................................................................................ 5
1:50 000 topographic maps ................................................................................... 16
Aerial photographs and orthophoto maps ............................................................... 31
Using atlases ......................................................................................................... 42
Geographical Information Systems (GIS) ............................................................. 49
Fieldwork .............................................................................................................. 77

**Topic 2: The atmosphere** .................................................................................. 91
The Earth’s energy balance .................................................................................. 93
Global air circulation ............................................................................................ 99
Africa’s weather and climate .............................................................................. 125
Droughts and desertification .............................................................................. 143

**Topic 3: Geomorphology** ................................................................................ 161
Topography associated with horizontally layered rocks ........................................ 163
Topography associated with inclined/tilted rock strata ....................................... 171
Topography associated with massive igneous rocks .......................................... 177
Slopes .................................................................................................................. 186
Mass movements and human responses .............................................................. 196

**Topic 4: Development Geography** .................................................................. 213
The concept of development .............................................................................. 215
Frameworks for development ............................................................................. 232
Trade and development ...................................................................................... 250
Development issues and challenges ................................................................... 263
Role of development aid ...................................................................................... 275

**Topic 5: Resources and sustainability** ............................................................... 287
Using resources .................................................................................................. 288
Soil and soil erosion ............................................................................................ 295
Conventional energy sources and their impact on the environment................. 311
Non-conventional energy sources ..................................................................... 327
Energy management in South Africa .................................................................. 334

Exemplar papers .................................................................................................. 343

Word list .............................................................................................................. 366
Dear Learner

Welcome to another year of discovering the wonders of the Earth, our place in the world as living beings and expanding your skills as a geographer.

In Grade 11 geographical skills and techniques will again be integrated with the other topics that you will study this year. A few examples are given below:

<table>
<thead>
<tr>
<th>Topic title / Term</th>
<th>Integrated skill / technique</th>
<th>Page reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The atmosphere (Term 1)</td>
<td>Aerial photos and satellite images / GIS</td>
<td>91, 114, 115, 122, 123, 141, 142, 143, 144, 158, 159</td>
</tr>
<tr>
<td>Geomorphology (Term 2)</td>
<td>Topographic 1:50 000 maps</td>
<td>166, 167, 176, 180, 181, 183, 184, 190</td>
</tr>
<tr>
<td>Development Geography (Term 3)</td>
<td>Using atlases</td>
<td>224, 231, 234, 269</td>
</tr>
<tr>
<td>Resources and sustainability (Term 4)</td>
<td>GIS</td>
<td>313, 323, 341</td>
</tr>
</tbody>
</table>

However, skills tend to get rusty ... but do not fear; we have a solution! Topic 1 of this course serves as a handy reference section that you can consult whenever you feel that you need to refresh your memory in how to perform certain skills and techniques. The units in Topic 1 have been presented in a logical, step-by-step manner and offer both in-depth theoretical background as well as additional exercises in order to equip you to deal with the integrated skills in the rest of the book with ease and absolute confidence.

Enjoy the year and good luck!
Programme of Assessment

In Grade 11 the requirements for the Programme of Assessment are as set out in the table below.

**Note to teacher:** sample tests and examination papers (and their memoranda) appear in the *Teacher’s Guide* so that they remain unseen. You are allowed to photocopy these for your learners.

This course offers more than one option for every formal assessment task:

<table>
<thead>
<tr>
<th>Term 1</th>
<th>Term 2</th>
<th>Term 3</th>
<th>Term 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data handling task</td>
<td>Mapwork task</td>
<td>Research/Essay writing task</td>
<td>End-of-year exam</td>
</tr>
<tr>
<td><em>Page 53 or 78 or 158</em></td>
<td><em>Page 183 and/or 184</em></td>
<td><em>Page 266/267 or 274</em></td>
<td><em>Teacher’s Guide</em></td>
</tr>
<tr>
<td>Test</td>
<td><em>Teacher’s Guide</em></td>
<td>Test</td>
<td><em>Teacher’s Guide</em></td>
</tr>
<tr>
<td><em>Teacher’s Guide</em></td>
<td><em>Mid-year exam</em></td>
<td><em>Teacher’s Guide</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Test</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Teacher’s Guide</em></td>
<td></td>
</tr>
</tbody>
</table>
Geographical skills and techniques

What you will learn about in this topic

- Basic mapwork skills that require frequent practice
- How to use the scale of a map and measure exact location (geographical coordinates), relative location (direction and bearing), and areas on maps
- Different landforms that can be identified by reading their contour patterns
- How landforms are analysed through contour patterns, cross-sections and gradients
- Vertical aerial photographs and orthophoto maps that offer more detailed spatial information than maps. Special skills are required to read and interpret photographs
- The value of satellite remote sensing as a data source to monitor local to global environments
- Geographical Information Systems (GIS) that can integrate maps, photographs and images and offers a technologically advanced way of analysing spatial data
- Using atlases to be geographically literate
- Fieldwork, often required to investigate specific geographical problems. It should be very well planned.

Let’s talk about this topic

In a geographer’s toolbox you will find tools that will assist him or her to gather, display and analyse spatial data that are required to answer the traditional geographical questions such as ‘Where is …?’ , ‘What are they?’ , ‘How many are there?’ , ‘Why is it here and not there?’ . These tools are maps and atlases; photographs; images; satellite image processing and GIS software; and a large variety of measuring devices such as GPSs (global positioning systems), rain gauges, thermometers, anemometers and magnetic compasses. In this and other topics these tools will be further explored. Which of the tools shown in the above collage can you identify and with which are you already familiar?
Geographical skills and techniques

In Grade 10 you learned:

- Some very basic skills, such as how to locate and indicate the **exact position** (absolute location) of places and phenomena by using the geographical reference system based on the imaginary lines of latitude and longitude.

- The geographical coordinate system is not always the most suitable reference system to use in everyday life. Imagine a visitor to your town approached you at the main gate of the school and asked you for directions to the nearest petrol filling station. If she does not have a GPS she will be stunned if you tell her to go to a certain geographical coordinate. In such a case it would be more appropriate to explain the **relative position** (location) of the filling station by referring to **direction and distance**. You can simply say, “drive 1.2 km in an easterly direction from the main gate of the school and you will find a filling station on your left”.

- A **map scale** is simply the ratio between a distance on a map and the corresponding distance in reality. You also learned that map scales can be expressed as word scales, ratio scales and line scales.

- The symbols used on the official **1:50 000 topographic map series of South Africa**; how to identify landforms by looking at the patterns of contour lines; and how to go about drawing simple cross-sections of the landscape.

- The characteristics, advantages and disadvantages of **oblique and vertical aerial photographs** as well as orthophoto maps.

- Why the technology of **Geographic Information Systems** (GIS) developed and that real world phenomena are represented in a GIS in an abstract manner as spatial objects by means of points, nodes and lines.

- How a **satellite remote sensing system** works and that the data it provides can be integrated with GIS systems to monitor weather patterns and our use and abuse of the Earth’s resources.

- That an **atlas** should always be at hand to find out where places you heard of or read about are situated.

- **Fieldwork** is often necessary to find the data that are needed to investigate a geographical problem.

This year we will deal with the same broad topics in slightly more detail. This specific study unit provides the “how to” knowledge about using these geographical skills and techniques. After you have learned how to use these skills and techniques you will be required to apply the skills and techniques to real world problems and challenges dealt with in other topics: The Atmosphere, Geomorphology, Development Geography, and Resources and Sustainability.
Figure 1.1: Extract from the official 1:50 000 map 3319BC De Doorns

Mean magnetic declination 24°33’03” West of True North (June 2013). Mean annual change 3.3” Westwards.
### Reference

<table>
<thead>
<tr>
<th>National Freeway; National Route</th>
<th>Nationale Deurpad; Nasionale Roete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial Route</td>
<td>Hoofverwersroete</td>
</tr>
<tr>
<td>Main Road</td>
<td>Hoopad</td>
</tr>
<tr>
<td>Secondary Road; Bench Mark</td>
<td>Sekondere Pad; Hoogtemerker</td>
</tr>
<tr>
<td>Other Road; Bridge</td>
<td>Ander Pad; Brug</td>
</tr>
<tr>
<td>Track and Hiking Trail</td>
<td>Diewe Pad en Voetstalleepad</td>
</tr>
<tr>
<td>Railway; Station or Siding</td>
<td>Spoorweg; Stasie of Slyn</td>
</tr>
<tr>
<td>Other Railway; Tunnel</td>
<td>Ander Spoorweg; Tunnel</td>
</tr>
<tr>
<td>Embankment; Cutting</td>
<td>Opvulling; Deurgraving</td>
</tr>
<tr>
<td>Power Line</td>
<td>Kraglyn</td>
</tr>
<tr>
<td>Built-up Area (High, Low Density)</td>
<td>Beboude Gebied (Hoë, Lae Digtheid)</td>
</tr>
<tr>
<td>Buildings; Ruin</td>
<td>Geboue; Murasie</td>
</tr>
<tr>
<td>Post Office; Police Station; Store</td>
<td>Poskantoor; Polisie staasie; Winkel</td>
</tr>
<tr>
<td>Place of Worship; School; Hotel</td>
<td>Plek van Aanbidding; Skool; Hotel</td>
</tr>
<tr>
<td>Fence; Wall</td>
<td>Dredheining; Muur</td>
</tr>
<tr>
<td>Windpump; Monument</td>
<td>Windpump; Monument</td>
</tr>
<tr>
<td>Communication Tower</td>
<td>Kommunikasierting</td>
</tr>
<tr>
<td>Mine Dump; Excavation</td>
<td>Mynhoop; Uitgraving</td>
</tr>
<tr>
<td>Trigonometrical Station; Marine Beacon</td>
<td>Peibaken; Seevaartbaken</td>
</tr>
<tr>
<td>Lighthouse and Marine Light</td>
<td>Vuurtoring en Seevaartlig</td>
</tr>
<tr>
<td>Cemetery; Grave</td>
<td>Begraafplaas; Graf</td>
</tr>
<tr>
<td>International Boundary and Beacon</td>
<td>Internasionale Grens en Baken</td>
</tr>
<tr>
<td>Provincial Boundary</td>
<td>Provsionale Grens</td>
</tr>
<tr>
<td>Protected Area</td>
<td>Bewarings Gebied</td>
</tr>
<tr>
<td>Perennial River</td>
<td>Standhoudende Rivier</td>
</tr>
<tr>
<td>Perennial Water</td>
<td>Standhoudende Water</td>
</tr>
<tr>
<td>Non-perennial River</td>
<td>Nie-standhoudende Rivier</td>
</tr>
<tr>
<td>Non-Perennial Water</td>
<td>Nie-standhoudende Water</td>
</tr>
<tr>
<td>Dry Water Course</td>
<td>Droë Loop</td>
</tr>
<tr>
<td>Dry Pan</td>
<td>Droë Pan</td>
</tr>
<tr>
<td>Marsh and Viel</td>
<td>Moeras en Viel</td>
</tr>
<tr>
<td>Pipeline (above ground)</td>
<td>Pyplyn (bo die grond)</td>
</tr>
<tr>
<td>Water Tower; Reservoir; Water Point</td>
<td>Watertoring; Reservoir; Waterpunt</td>
</tr>
<tr>
<td>Coastal Rocks</td>
<td>Kuslynrote</td>
</tr>
<tr>
<td>Prominent Rock Outcrop</td>
<td>Prominente Klipbank</td>
</tr>
<tr>
<td>Erosion; Sand</td>
<td>Erosie; Sand</td>
</tr>
<tr>
<td>Woodland</td>
<td>Beboste Gebied</td>
</tr>
<tr>
<td>Cultivated Land</td>
<td>Bewerkte Land</td>
</tr>
<tr>
<td>Orchard or Vineyard</td>
<td>Boord of Wingard</td>
</tr>
<tr>
<td>Recreation Ground</td>
<td>Ontspanningsterrel</td>
</tr>
<tr>
<td>Row of Trees</td>
<td>Rye Bone</td>
</tr>
</tbody>
</table>

**Figure 1.2:** A legend for the official 1:50 000 maps used in this book
You need to write down and keep your answers to the three questions. You will be required to submit the answers later.

The two regions represented in the illustration below both lobbied for the building of a new hospital to serve the community. The illustration shows the sub-areas within the regions as well as the number of people staying within each sub-area.

1. What is the true bearing from the proposed new hospital on the existing hospital?
2. In your opinion, which region has the strongest case to get funding to build a second hospital?
3. What is the approximate location (in degrees and minutes) of the proposed new hospital for Region A?

### What you still need to know

#### Mapwork skills

#### Word bank

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>cardinal compass directions</td>
<td>a description of the relative position of places by referring to north, south, west and east and their combinations (e.g. north-east)</td>
</tr>
<tr>
<td>denominator</td>
<td>the value (e.g. 1 000) written below the line in a fraction such as $\frac{1}{1000}$</td>
</tr>
<tr>
<td>hectare</td>
<td>a unit to indicate area. An area of 100 m × 100 m equals one hectare (1 hm²)</td>
</tr>
<tr>
<td>land cover</td>
<td>it refers to the type of phenomenon found on the Earth, e.g. cultivated land, natural veld, dams, woodlands, and build-up area to name a few. Land use refers to how the land is used. A land cover named “dam” could be classified as recreation if the dam is used mainly for recreational fishing as opposed to irrigation</td>
</tr>
<tr>
<td>Magnetic North Pole</td>
<td>a point in the arctic regions of Canada that continually changes position based on the activity of the Earth’s magnetic fields</td>
</tr>
<tr>
<td>numerator</td>
<td>the value (e.g. 1) written above the line in a fraction such as $\frac{1}{1000}$</td>
</tr>
</tbody>
</table>
Basic mapwork skills require frequent practice

Revising your skills regarding locating places in absolute as well as relative terms and using map scales is, as in Grade 10, part and parcel of the Grade 11 syllabus. This makes sense because skills tend to get rusty if they are not frequently practiced and used. In the next couple of sections we will provide opportunities to revise your skills regarding:

- describing relative position
- locating exact position in terms of degrees, minutes and seconds
- use of map scales to calculate:
  - straight and curved line distances
  - the area of regular and irregular shaped phenomena.

Since most of these skills have been dealt with in Grade 10 (and even in lower grades) we will in some cases not share detailed explanations with you. If you have forgotten how to calculate for example a geographical coordinate, you need to read your Grade 10 textbook once again or ask a classmate or your teacher to quickly refresh your memory by explaining the basics steps.

Many of the activities are based on the official 1:50 000 map of De Doorns (Figure 1.1 on page 3 and also the map legend shown in Figure 1.2 on page 4). The purpose of the activities is to give you the opportunity to provide evidence that your teacher can use to establish whether he/she can proceed with the explanation of new skills or whether further revision of topics dealt with in Grade 10, is required.

Practice makes perfect — describing relative position

You will be required (in Classroom activity 1) to explain the position (location) of a place relative to another place on the 1:50 000 map of De Doorns by making use of true and magnetic bearing. Look at Figure 1.3 below and read the following tips to refresh your memory:

1. The “North” shown on maps is known as true north (TN) or geographic north. True north points to the North Pole.
2. True bearing is expressed in degrees varying between 0° and 259° and is measured clockwise from the north-south baseline on a map. The true full circle bearing from point A to point B on Figure 1.3 is 30°.
3. When we are in the field we can use a magnetic compass to take a bearing on a place. The needle of a magnetic compass points to magnetic north and not true north. The Magnetic North Pole is not fixed but is in constant movement.
4. For all places in South Africa, magnetic north is west of true north.
5. The angle by which the magnetic north deviates from true north is called the magnetic declination. On each of the 1:50 000 maps of South Africa, the magnetic declination is indicated by a diagram similar in layout to the one in the bottom right corner of Figure 1.1 on page 3. Note that it indicates for which year the magnetic declination is specified as well as the annual change and direction of the change.
6. To convert a magnetic bearing taken in the field (in South Africa) to a true bearing you need to **subtract** the magnetic declination.

7. To convert a true bearing measured on a map (of South Africa) to a magnetic compass bearing you need to **add** the magnetic declination. The magnetic full circle bearing from point A on point B is therefore 39° (30° + 9°).

**Figure 1.3: True and magnetic full circle bearing**

You need to remember that:

- direction can also be explained by referring to the **cardinal compass directions** you already know about
- bearing alone does not tell you the exact position of something. It only tells you that the place is in a certain direction. You can make the description more precise by also referring to distance or time. You can say that place B is:
  - situated 4 km from point A in a north-north west direction
  - about a 4 minute walk from point A and that the true bearing from point A on point B is 45°.

**Classroom activity 1**

Use the 1:50 000 map of De Doorns on page 3 to complete questions 3, 4 and 5.

1. What is the answer to the first Check myself activity? (3)
2. Calculate the true bearing as well as magnetic bearing from point A to point D shown in Figure 1.3 above. (4)
3. Calculate the true bearing from spot height 907 (see block A2) on spot height 1144 (block A1). (3)
4. Calculate the magnetic bearing from spot height 907 (see block A2) on spot height 1144 (block A1) without considering the annual change in magnetic declination. (4)
5. Describe the route followed by the N1 freeway from block A5 to block E2 by referring to cardinal compass directions and distances. (4)
**Practice makes perfect — locating exact (absolute) position**

Imagine the following: While hiking in the mountains near De Doorns, you broke your ankle when you stepped onto a slippery wet rock. Fortunately you had a cellphone with you. You were able to phone a friend in De Doorns and tell her “I’m stranded at a place of which the true bearing taken from the railway station is 136°”.

The problem is that your friend only knows in which direction (from the railway station) you are. She does not know how far from the railway station you are. This dilemma would be solved if you had a map from which you could have read the **geographical coordinate** of where you are stranded.

To work out the exact position of a place in terms of degrees, minutes and seconds, we need to:
- use (read) the indications of latitude and longitude shown on the map
- apply very basic arithmetic.

In Figure 1.4 we marked the location of a borehole as point A. We want to calculate the absolute location of the borehole. Our explanation of the steps to be followed only covers the calculation of longitude — later you will need to calculate the latitude as a homework activity. We recommend that you do all the measurements and calculations we have provided below yourself. You will learn much better by doing than by just reading. *Figure 1.4: Steps in calculating longitude*

**Steps in calculating the longitude location of the borehole in the diagram**

1. The borehole is between 20° and 21° East.
2. On the map the distance between 20° and 21° is 40 mm. One degree (or 60 minutes) is therefore represented by 40 mm.
3. On the map the borehole is located 25 mm east of the 20° E line of longitude.
4. Because we know that 1° is equal to 60 minutes and that in this instance 60 minutes are equal to 40 mm, we can now apply the follow reasoning and arithmetic:
   - 40 mm on map represents 60 minutes
   - ∴ 25 mm on map represents 60 × (25 ÷ 40)
   - The answer: 37.5’ or 37.5 minutes
5. The decimal portion, which we calculated in step 4 means 0.5 or \( \frac{1}{2} \) of a minute. Remember there are 60 seconds in a minute. The 0.5 therefore actually means 0.5 of 60 seconds.

6. \( \therefore 0.5 \times 60 \text{ seconds} = 30 \text{ seconds.} \)

7. The longitude of the borehole entrance is therefore:
   20 degrees \( + 37 \) minutes \( + 30 \) seconds East.

8. We write it as \( 20^\circ37'30" \text{ E} \)

You are now equipped to describe and locate location by referring to degrees, minutes and seconds. Remember that when describing a geographic coordinate the latitude position is always given first. A coordinate situated at the intersection of \( 15^\circ45' \) east longitude and \( 20^\circ20' \) south latitude must therefore be described as \( 20^\circ20' \text{ S; } 15^\circ45' \text{ E}. \)

**Homework activity 1**

Use the 1:50 000 map of De Doorns on page 3 to complete questions 2, 3 and 4.

1. Calculate the geographical coordinate of the borehole shown as point A in Figure 1.4. (6)
2. What is the exact position (absolute location) of spot height 650 (block D4 on the map of De Doorns)? (6)
3. What feature on the map of De Doorns is situated at 33\(^\circ\)28'36"S; 19\(^\circ\)40'54"E? What is the feature’s function? (4)
4. What type of land cover do you associate with the geographical coordinate 33\(^\circ\)27'40"S; 19\(^\circ\)41'48"E? How would you classify the feature in terms of land use? (4)

**Practice makes perfect — understanding map scales**

Before you can interpret any map you need to familiarise yourself with the scale of the map. Let us revisit the first Check myself question on page 5. You should have noticed that the two imaginary regions are, with one exception, exactly the same. The only exception is that Region B is a much bigger area than region A. This fact is revealed by the labelling of the lines of latitude and longitude. Area A covers one degree square whereas Area B covers 4 degrees square. Region A is therefore shown at a much larger scale than Region B. Because the inhabitants of Region B have to travel much further to visit the existing hospital, we are of the opinion that they have a much stronger case to receive funding for a new hospital.
The following list serves to refresh your memory about map scales.

- A map scale reveals the ratio between distances on a map and distances in reality.
- Map scales can be expressed as word, ratio and line scales.
- Scales are not influenced by the unit of measurement. A ratio scale of 1:10 000 \( \left( \frac{1}{10\,000} \right) \) can be interpreted as 1 mm on the map represents 10 000 mm in reality or 1 cm on the map represents 10 000 cm in reality.
- The larger the scale of a map, the more detail we can show about a smaller area.
- The smaller the scale of a map, the less detail we can show about a larger area.
- A ratio scale is always expressed as a fraction in which the numerator is always one (1).
- The larger the denominator of a ratio scale, the smaller the scale — a scale of 1:4 000 (or \( \frac{1}{4\,000} \)) is therefore smaller than a scale of 1:1 000 (or \( \frac{1}{1\,000} \)).
- A ratio scale of 1:4 000 \( \left( \frac{1}{4\,000} \right) \) can be expressed as:
  - A word scale: 1 cm on the map represents 40 m in reality or 1 mm on the map represents 4 m in reality.
  - A line scale as illustrated below (Figure 1.5). Note that line scales have the advantage that the scale remains correct even when you enlarge or reduce the map when making a photocopy. This is not the case with word and ratio scales.

![Figure 1.5: A \( \frac{1}{4\,000} \) line scale](image)

**Homework activity 2**

1. The map of De Doorns on page 3 has a scale of 1:50 000. Express the scale as a word scale by referring to:
   - a) mm and m (3)
   - b) cm and km. (3)
2. Convert the scale of 1:50 000 to a line scale. (4)
3. Convert the line scale shown below (Figure 1.6) to:
   - a) a word scale (2)
   - b) a ratio scale. (3)
4. What is the answer to the second Check myself activity? (3)

![Figure 1.6: Your turn: Convert this line scale to word and ratio scales.](image)
Using the map scale to calculate distances

When working with scales you often need to convert from one decimal unit to another. It is therefore essential to have a thorough understanding of the metric system. Ask your teacher to share a rhyme with you that will help you to do metric conversions.

How to measure the real length of straight line distances

1. Measure the distance accurately from one point to the other with a ruler.
2. Use the scale to convert this map distance to real distance, e.g. 10 cm on the map × scale factor of 50 000 = 500 000 cm.
3. Convert 500 000 cm to metres (5 000 m) or kilometres (5 km).
4. Alternatively you can argue that 50 000 cm equals 500 m (or 0.5 km). When multiplied by 10 you will again get an answer of 5 000 m (500 × 10 = 5 000).

How to measure the real length of curved (sinuous) lines on a map

We can share four methods with you.
1. One method is to use a piece of string to curve along the route.
2. Another method of measuring the length of curved lines is to break up each curve into straight-line segments (see Figure 1.7 below).

![Figure 1.7: Breaking a curved line up into straight-line segments](image)

3. Set a pair of dividers at a practical width and ‘step off’ the entire length of the line (see Figure 1.8 on the left).
4. A fourth method for measuring curvilinear map distances is to use a mechanical device called an opisometer (see Figure 1.9).

![Figure 1.8: Stepping off the map distance with a pair of dividers](image)

![Figure 1.9: An opisometer](image)
Using the map scale to calculate areas

As with the calculation of distances we will distinguish between straightforward calculations based on using a ruler only and more complex (irregular) shapes.

Calculating the area of regular shapes

Rectangles or squares
If the shape is regular, e.g. rectangular (see Figure 1.10 on the right) measure the length and width with a ruler. Convert both map distances separately to real distances and then multiply the two distances to get area.

\[
\text{Area} = (\text{length} \times \text{scale factor}) \times (\text{width} \times \text{scale factor})
\]

Did you notice that we printed the phrase “both map distances separately” in bold? The reason is that people often make the mistake of multiplying length by width and then multiplying their answer by the scale factor. You will get completely different answers.

Classroom activity 2

1. The distances measured on maps should be considered as approximate distances because it is difficult to measure units smaller than 1 mm using a ruler. Divide the class into four groups and compare the effect of measurements (made on the 1:50 000 map of De Doorns) that are wrong by 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm respectively. Decide which group will do the calculations for which error factor: Group A for 0.5 mm, Group B for 1.0 mm, etc. (2 marks per group)

2. Repeat the activity you have just done but base the calculations on a scale of 1:5 000. (2 marks per group)

3. Write a short explanation supported by scale calculations about the relationship between incorrect measurements and the scale of a map. (3)

4. Ask learners to measure the distance from 33°30’S;19°38’E to 33°25’S;19°42’E. What is the range of the measurements? In other words, what is the difference between the longest and shortest measurement? (3)

Homework activity 3

Refer to the De Doorns map on page 3 to complete the questions below.

1. We spoke about a spot where you stepped on a slippery rock and broke your ankle. The true bearing from spot height 650 (block D4) on the spot is 42°. How far is this spot from the railway station of De Doorns? (6)

2. Calculate the real length of the railway line west of De Doorns station by using a pair of dividers set at a distance of 4 mm. (5)

3. Calculate the real distance of the entire length of the N1 national road shown on the map by breaking the road up in straight-line segments. (5)

Figure 1.10: The measurements required to calculate the area of a rectangle or square
Circles
The formula for calculating the area of a circle is \( \pi r^2 \) where:
- \( \pi \) = a constant value of approximately 1.6180339 (rounded off). The symbol \( \pi \) is pronounced as phi.
- \( r \) = the radius of the circle (see Figure 1.12 on the left).

When applied to a circular phenomenon on a map (for example land under pivot irrigation), the map scale should be taken into consideration as shown in the formula below.

Real area of circular phenomenon on map = \( \pi (r \times \text{scale factor})^2 \).

Triangles
The formula for calculating the area of a right-angled triangle such as the triangle illustrated in Figure 1.12 is \( \frac{1}{2}b \times h \) where:
- \( b \) = the base length of the triangle (side A in Figure 1.12)
- \( h \) = the height of the triangle (side B in Figure 1.12).

When applied to a map, the map scale should be taken into consideration as illustrated below.

Real area of triangular area on map = \( \frac{1}{2}[b \times \text{scale factor}] \times [h \times \text{scale factor}] \). Note once again that it is not \( \frac{1}{2}(b \times h \times \text{scale factor}) \).

Calculating the area of irregular shapes
The easiest way to calculate map areas of irregular shapes is of course to use a GIS, which you were introduced to in Grade 10. You simply select the area and then click the area measurement tool to get an answer. If you have to do it by hand it takes some time and the answer will not be as accurate as the answer provided by a GIS. We can share two methods with you:

1. You can divide the area into sub-sections with regular shapes such as squares, rectangles, circles and triangles. You can then calculate the areas of all the sub-sections and add them together to get a final approximate answer.

2. A second strategy can be to use a graphical method. Outline the shape of the area (the thick black boundary line shown in Figure 1.13) onto graph paper or create your own grid of equal-sized squares. A count can then be made of all the squares on the graph paper to calculate the area. Figure 1.13 below illustrates the technique.

   a) We created a grid of eight rows and seven columns.
   b) The size of each block (square) is 5 mm \( \times \) 5 mm. Since the scale is 1:50 000 it means that the real length of the sides is 5 mm \( \times \) 50 000 = 250 000 mm.
   c) Suppose we want to express our answer in hectares. It will then be good practice to immediately change the 250 000 mm to hectometres (it is 2.5 hm) because multiplying hectometres by hectometres will give an answer that is already in hectares (hm\(^2\)).
   d) The area of one block is therefore 2.5 hm \( \times \) 2.5 hm = 6.25 ha.
e) Count all the whole squares (shown in yellow) within the perimeter of the area. Where squares are divided by the boundary of the area (the green shaded squares in the figure) you have to use a process of “give and take”. Determine how many squares are represented by all the quarter, half and three-quarter squares. For example, that portion of the area that falls within the square marked a is added to the area of the square marked b. Together a and b represent one whole square. We have counted a total of 32 squares.

f) We can now simply multiply 32 by 6.25 ha (the area of one block).

g) The answer is approximately 200 ha. We used the word “approximately” since the graphic method is not a perfectly accurate method of calculating area.

Homework activity 4

The calculations required for questions 1, 2 and 3 should all be based on a scale of 1:10 000. In all instances the answer should be given in hectares.

1 Calculate the area of the rectangle shown in Figure 1.10. (5)

2 Calculate the area of the circle shown in Figure 1.11. (4)

3 Calculate the area of the triangle shown in Figure 1.12. (5)

4 Calculate (by using the graphic method) the real area of the irregular shaped phenomenon shown in Figure 1.14. Suppose the map scale is 1:25 000. (7)

Figure 1.14: What is the approximate real area of the irregular shaped feature?
Questions 2, 5, 6, 7 and 10 are based on the 1:50 000 map of De Doorns (Figure 1.1 on page 3).

1. Calculate the true bearing as well as magnetic bearing from point A to point G shown in Figure 1.3 on page 7. (4)

2. Calculate the magnetic bearing from spot height 907 (see block A2) on spot height 1144 (block A1). You need to take the annual change in magnetic declination into account. Suppose you are doing this task in June. (6)

3. What is the approximate location (in degrees and minutes only) of the proposed new hospital for Region A referred to in the ‘Check myself’ question 3? (5)

4. What is the location (in degrees, minutes and seconds) of the proposed new hospital for Region B referred to in Test Myself activity 3? (8)

5. Calculate the geographical coordinate (in degrees, minutes and seconds) of the De Doorns post office. (6)

6. Describe the direction in which the Sand River flows by referring to cardinal compass directions (and distances if you wish). (2)

7. Calculate the approximate surface area (in hectares) of the Groothoek Dam (block D3) on the map of De Doorns. Regard the dam as a rectangle. Slightly adjust your answer to make up for the fact that the dam is not a prefect rectangle. Our guess is that about five per cent of the rectangle would not be part of the dam. (6)

8. Calculate (by using the graphical method) the real area (in hectares) of the irregular shaped nature reserve shown in Figure 1.15 below. Suppose the map scale is 1:100 000. (7)

9. Calculate the real area (in hectares) of the irregular shaped plant nursery shown in Figure 1.16 below. Suppose the map scale is 1:10 000. Hint: the figure consists of a semi-circle, a rectangle and a triangle. (10)

10. Suppose we reduce the map area of the De Doorns map (see Figure 1.1 on page 3) from 185.2 mm × 136.4 mm to 92.6 mm × 68.2 mm. What would be the scale of the map after the reduction in size? (3)
You learned in lower grades that the key to reading landforms from the contours on topographic maps is to be aware of the distance between contour lines and the shape of the contours.

1. The **distance between contour lines** reveals the steepness or gradient of the landscape. Areas are steeper where the contour lines are close together and flatter where the contour lines are further apart. Let us explain by referring to Figure 1.17:

Figure 1.17(a) represents two hiking trails. Each is 300 m long. The height above sea level of the starting point of each trail is 100 m. The only difference is that the end points of the trails are respectively 60 m and 200 m higher than the starting points.
How will we go about drawing a 1:10 000 contour map with 20 m contour intervals to graphically illustrate that:

- both trails are 300 m long?
- the end point of trail 1 is 60 m higher than the starting point of trail 1?
- the end point of trail 2 is 200 m higher than the starting point of trail 2?

The answer is easy – just follow the steps we have listed below:

a) A scale of 1:10 000 (1 cm on map represents 100 m in reality) means that we have to draw each of the trails as 30 mm lines on the map [see Figure 1.17(a)].

b) If the end point of trail 1 is 60 m higher than the starting point (100 m above sea level), then the end point of the route should be 160 m above sea level. The end point of trail 2 would be 300 m above sea level (100 m + 200 m).

c) Because we have to use a contour interval of 20 m and the starting and end points of route 1 are 100 m and 160 m above sea level respectively, we have to draw in four contour lines for trail 1. The four lines are shown on Figure 1.17(b) as the 100 m, 120 m, 140 m and 160 m contour lines. Because we do not have an idea of the shape of the land between the start and end points, the contours are evenly spaced. This means that it is equally steep along the entire route.

d) Using the same contour interval of 20 m we need 11 contours to illustrate the fact that the end point of trail 2 is 200 m higher than the starting point.

From Figure 1.17(b) we can therefore conclude that the greater the difference in height between places that are the same horizontal distance from each other, the more contour lines we have to draw in on the map and the closer together we have to space the contours. The reason why the horizontal distance between the contour lines on the two maps in Figure 1.17(b) differs is that the trails are not equally steep.
2. The **shape of the contour lines** as well as the **height associated with the individual contour lines** tells us more about the appearance of the landscape and its elements (e.g. the valleys, ridges, plains, mountains, escarpments). The contour patterns of items (a) and (b) in Figure 1.18 below are identical. Only when we also consider the contour values can we infer that (a) represents a river valley while (b) is a mountain spur. Did you notice that the contours of items (a) and (b) are V-shaped? In the case of the river valley the points of the Vs point in the direction of higher ground. In the case of the mountain spur the Vs point in the direction of lower ground. The contour pattern shown in items (c) and (d) is also identical – it is again the contour values which reveal that (c) is a conical-shaped hill while (d) is a 150 m deep hole.

![Figure 1.18: Without contour values we cannot distinguish between different landform shapes.](image)

The contour lines on maps are of course only imaginary lines that help you to visualise the landscape. The constant interplay between the rocks and minerals in an area and the processes which shaped these rocks and minerals are however not imaginary. In the topic dealing with geomorphology you will learn about different landforms and the processes that shape these landforms. To whet your appetite we are sharing a couple of examples of contour patterns (and thus landscapes and landforms) and the processes that lead to the specific landscapes and landforms with you.

**Landforms associated with horizontal strata**

The photograph and contours shown in Figure 1.19 below represent a mesa in the Karoo. From the contour pattern we can see that a mesa is a table-top shaped hillock with steep cliffs. (In Topic 3 you will learn how a mesa is formed.)

![Figure 1.19: Photograph and contour map of a mesa](image)
Another Karoo example of landforms associated with horizontal strata is a butte. Figure 1.20 below shows two prominent buttes (Koffiebus and Teebus) near Steynsburg in the semi-arid Great Karoo. A butte is a convex shaped isolated hill with steep, often vertical sides and a small, relatively flat top [Koffiebus in Figure 1.21(b) below]. The contour patterns are concentric. (In Topic 3 you will learn how a butte is formed.)

Topography associated with massive igneous rocks

In Topic 3 you will learn what igneous rocks are. A very good example of igneous rock that formed as a result of lava flow is the oval-shaped granite dome of Paarlberg (or Paarl Mountain) just west of Paarl in the Western Cape. (You will learn more about Paarlberg in Topic 3.) Another excellent example is the Pilanesberg National Park in the North West province of South Africa. Note the ring-shaped feature shown in Figure 1.21(a) above – a satellite image. You will see the same ring-shaped contour in Figure 1.21(b) on the left – a 1:500,000 topographical map. The ring can be explained in terms of a volcanic eruption that happened about 200 million years ago. In other words, the site of the Pilanesberg Nature Reserve is in fact that of an extinct volcano.
Topography associated with folding and mass movement

The majestic mountains of the Western Cape are examples of folded mountains. We can distinguish between a western section stretching northwards and an east-west section stretching southern section. The two sections meet in the southwest forming the Hex River Mountains. The east-west stretching section is formed by two parallel sets of mountain ranges, one in the north and one in the south.

About 250 to 200 million years ago the Cape sediments were covered by the sediments of the Karoo system. When the south and southwestern Cape experienced the first tremendous internal crustal forces about 200 million years ago, the sandstone of the Cape system was still buried beneath the Earth’s surface. The Cape sediments as well as the cover of Karoo sediments were thus forced out of their horizontal position and contorted into huge folded and twisted sedimentary strata (see Figure 1.24 below). Subsequently the softer sediments from the Karoo systems were stripped by erosion and the much more resistant sandstones were exposed as mountain ranges.

Around 100 million years ago the breakup of Gondwanaland lead to the separation of South America from Africa. The Gondwanaland rifting caused numerous faults. An example of the influence of such a fault is illustrated in Figure 1.25(a) on the next page. A huge block of Table Mountain sandstone moved down in a north-westerly direction creating the only natural passage [Tulbagh Poort – see Figure 1.25 (b)] through the Obiekwa and Voëlvlei Mountains.

Figure 1.23: The quartzitic sandstone of the Cape Folded Mountains is a sedimentary rock

Figure 1.24: Folded strata
Classroom activity 3

In the box below we have arranged the names of the largest individual ranges within the Cape Fold Belt in alphabetical order.

Baviaanskloof, Cederberg, Drakenstein, Hex River, Hottentots-Holland, Langeberg, Olifants River, Outeniqua, Swartberge, Tsitsikamma

Copy the table below. Use your atlas to categorise the mountains ranges in the three groups described below. You can use Table 1.1 to enter the names of the mountain ranges associated with the three groups.

1. the western section
2. the northern ranges of the east-west alignment
3. the southern ranges of the east-west alignment.  (6)

<table>
<thead>
<tr>
<th>Table 1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranges of the western section</td>
</tr>
</tbody>
</table>
### Cross-sections on 1:50 000 topographic maps

From the knowledge gained in previous grades you should know that:

- A map offers a **plan view** of the landscape. A plan view represents a view of the landscape as if you are viewing it from above.
- We can draw a line between any two points on a contour map and draw a cross section that resembles a side-view or profile of the landscape along the line we have drawn.
- A cross-section is basically a graph with two axes [see Figure 1.26(a) below].
  - The vertical axis represents height which is read from the contour lines.
  - The horizontal axis represents distance measured from an origin.
  - Everywhere along the line for which we want to draw a cross-section, we mark the points where the line intersects a contour line. These intersections are plotted as points (coordinates) on the graph (the cross-section).
  - By joining the points we create a profile of how the landscape would look when we view it from the side [Figure 1.27(b) on the next page].

---

**Homework activity 5**

The purpose of this activity is to establish whether you can still apply the knowledge about contours that you have learned in lower grades.

Make an enlarged copy of the map of De Doorns (Figure 1.1 on page 3). Study the contour patterns on the map and identify a typical example of each of the types of landscape shown in the box below. Draw lines (pointers) from each of the identified contour patterns listed in the box below to the white space around the enlarged map. Add the name and a brief description of each landform in the margin.

- a narrow river gorge
- extremely rugged relief
- a watershed
- a concave slope
- a steep, even slope
- a flat-topped hill
- a perpendicular cliff or rock face
- a mountain spur

---

*Figure 1.26: Showing the profile (cross-section) of a landscape in graph form*
Study Figure 1.27 on the left. Item (a) of Figure 1.27 is a contour map showing points A and B. Item (b) represents the coordinates depicting the distance from point A and height above sea level. In item (c) of Figure 1.27 we drew lines between the pairs of coordinates — the line is the cross-section (profile) of the landscape along line AB. Note the annotation of the two axis of the cross-section — without the annotation nobody would be able to make any sense out of the cross-section.

![Figure 1.27: Steps in drawing a cross-section of a landscape](image)

**Classroom activity 4**

This activity is based on the map of De Doorns (Figure 1.1 on page 3). Divide the class in two groups (A and B). Draw a cross-section of the relief of the landscape between spot height 610 (block A3) and spot height 686 (block B5).

- Both groups should use a scale of 1:50 000 for the horizontal x-axis.
- Group A should use a scale of 1 cm = 40 m for the vertical y-axis while group B should use a scale of 1 cm = 80 m.
- The vertical axis should start at 400 m.
- Make sure you label both axes of the cross-section. The horizontal axis should indicate ‘Distance from spot height 610’ while the vertical axis should indicate ‘Height above sea level’.

### Intervisibility

Cross-sections are ideal to establish the intervisibility between two or more points in the landscape. Do you think point B on Figure 1.27 (a) above is visible from point A? You need not guess the answer. You can simply draw a straight line between points A and B on the cross-section — this line is known as an intervisibility line. Should the line in all instances be above the cross-section we can assume that point B is visible from point A. However, should the line representing the profile of the landscape be above (as is indeed the case – see Figure 1.27[c] above) the intervisibility line, it means that point B is not visible from point A. Why? There are hills blocking your view of point B.
**Manipulating the cross-section view — vertical exaggeration**

We need to point out slight dilemma that faces us when drawing a cross-section of the landscape. Have a careful look at the scale we have specified for the vertical axis of Figures 1.27(b) and (c) on page 23. It is not the same scale as the scale of the horizontal axis. The horizontal scale is 1:50 000 whereas the vertical scale is 1:10 000 (5 mm = 50 m represents a scale of 1:10 000). Although the ideal is to show the vertical and horizontal planes at the same scale, it is seldom possible or practical. If the landscape is very level (showing little variation in relief) and/or the scale of the horizontal scale is very small (it shows a big area) we will have the problem that our profile will show very little variation in relief. In such cases we emphasise the relief to make it more distinct. This is done by exaggerating the vertical scale. Do not overdo vertical exaggeration – it can create a false impression and lead to errors of interpretation, such as making low hills look like very high hills.

**Calculating vertical exaggeration**

The vertical exaggeration (VE) is the amount by which the vertical scale of a cross-section is larger than the horizontal scale. The larger the vertical scale, relative to the horizontal scale, the more the height and steepness of hills are exaggerated. Follow these steps to calculate the amount of vertical exaggeration.

\[
VE = \frac{\text{vertical scale}}{\text{horizontal scale}}
\]

1. **Determine the vertical scale**
   - It was stated that 5 mm represents 50 m in reality. You can measure this on Figure 1.27(c).
   - This implies that 1 mm represents \(\frac{50}{5} = 10\) m in reality.
   - We need to compare apples with apples – the 10 m in reality needs to be converted to millimetres. It is 10 000 mm.
   - The vertical scale is therefore 1:10 000.

2. **Determine the horizontal scale**
   No calculations are required because the scale of Figure 1.27(a) was given as 1:50 000.

3. **Calculate the vertical exaggeration (VE) factor**
   - The question is: How much larger is the vertical scale than the horizontal scale?
   - The VE factor is calculated by dividing the denominator of the horizontal scale by the denominator of the vertical scale.
   - Thus,
   \[
   VE = \frac{50 000}{10 000}
   \]
   - The answer is 5, which means that the vertical scale is **five times larger** than the horizontal scale.
Steepness matters — gradient

Because you are familiar with the term “steepness” we are sure that you will find it very easy to arrange the set of triangles (or landscapes) shown below (Figure 1.29) in an order of either decreasing or increasing steepness. However, we also suspect that you will find it difficult to clearly explain why certain triangles are considered steeper than others. Prove us wrong by doing question 2 of Classroom activity 5 on page 27.

There are many examples in everyday life where it is not good enough to simply say that it is steeper from \(x\) to \(y\) than from \(y\) to \(z\) or “do not build the stairs too steep”. This is too relative. Very often we need to express steepness in quantitative terms (as numbers that we can compare) to address real world problems. Think about:

- the staircases in shopping centres – if they are too steep, shoppers might fall down the stairs and the shop owners might be confronted with huge claims
- the warning signs along steep descending roads urging truck drivers to engage to lower gears
- the erosion that would be triggered by clearing steep mountain slopes for cultivation of crops (you will learn more about erosion in Topic 3).

Homework activity 6

1. This task is based on Figure 1.27. Draw an intervisibility line on Figure 1.27(c) on page 23 to find out whether point D is visible from point C (by using binoculars). What is your finding and why did we refer to binoculars? (3)

2. Draw a cross-section (profile) of the relief of the landscape between point A and point B as shown in Figure 1.28.
   a) The vertical scale should be 1:10 000.
   b) A scale of 1:25 000 (not 1:50 000) should be used for the horizontal x-axis.
   c) The vertical axis should start at 150 m and the horizontal axis at 0 m. (8)

3. Calculate the vertical exaggeration of your cross-section. (5)
One way to describe steepness is to refer to the relationship (ratio) between a distance in a horizontal direction (plane) and a distance in a vertical direction (plane). We refer to the distance in the vertical plane as height. The relationship between the distance in a horizontal plane and the distance in a vertical plane is expressed as a ratio that we call gradient. In mathematical terminology we express gradient as \( \frac{VI}{HE} \) where VI stands for ‘vertical interval’ and HE stands for ‘horizontal equivalent’.

Look at Figure 1.17 on page 17 again. For **trail 1** (from point A to point C):

- the value of HE is 300 because you have to walk 300 m in a horizontal direction
- the value of VI is 60 because the difference in height between points A and B equals 160 – 100
- The gradient is therefore \( \frac{60}{300} \), which equals \( \frac{1}{5} \). It means that for every 1 unit of measurement in the vertical plane the distance in the horizontal plane is 5 times as long.

We can illustrate this graphically as shown in Figure 1.17(c). Note that the horizontal distance of the triangle representing trail 1 is 5 times as long as the height in the vertical plane. Complete question 3 of Classroom activity 5 on the next page.

What can we learn from the calculated gradients? Since we agree that it is steeper from D to F than from A to C we must accept that a ratio or gradient of 1:1.5 (e.g. that of trail 2) is steeper than a gradient of 1:5. Therefore the smaller the denominator of the ratio, the steeper the gradient. We can also say that the closer the ratio to 1:1, the steeper the gradient.

We can also express steepness as an angle of slope. Because the angle FDE in Figure 1.17(d) is larger than the angle CAB in Figure 1.17(c), trail 2 is steeper than trail 1.

**Gradient**

The gradient refers to how steep or how gentle the slopes are. It is calculated using the following formula:

\[
\text{Gradient} = \frac{\text{VI}}{\text{HE}} \quad (\text{difference in height between two points}) \\
\quad \quad \quad \quad \text{HE} \quad \text{(distance between two points)}
\]

Example: Calculate the gradient from point A to point C on Figure 1.17 on page 17.

\[
\text{Gradient} = \frac{\text{VI}}{\text{HE}} \\
= \frac{160 \text{ m} - 100 \text{ m}}{300 \text{ m}} \\
= \frac{60 \text{ m}}{300 \text{ m}} \\
= \frac{1}{5} \quad (\text{derived from dividing 60 by itself to get 1}) \\
\quad \quad \quad \quad \frac{5}{\text{ derived from dividing 300 by 60 – you must do to the bottom \ what you do to the top}} \\
= 1:5
\]
Classroom activity 5

1. Arrange the three triangles shown in Figure 1.29 on page 25 in order of decreasing steepness. (3)
2. Why would it be more tiring to walk the 300 m from point D to point F shown in Figure 1.17(a) on page 17 than the 300 m from point A to point C? (3)
3. Replace all the question marks shown in Figure 1.17(d) with the correct values. (3)
4. Use a protractor to measure the size of angle FDE in Figure 1.17(d). (2)

Homework activity 7

1. Calculate the gradient of triangle (a) in Figure 1.29. (2)
2. Use a protractor to measure the angles of slope of triangle (a), (b) and (c) in Figure 1.29. (6)
3. List at least five examples from everyday life to prove that gradient matters. (5)

Extra practice activity 2

1. There are some features that cannot be accurately represented on a contour map. Write a short explanation why overhanging cliffs are considered a cartographer’s nightmare. (3)
2. Name the landforms represented by numbers 1 to 7 on Figure 1.30 on page 29. (7)
3. This task is based on Figure 1.31 on page 29.
   a) Draw a cross-section to illustrate the profile of the landscape along line AB. Do not change the horizontal scale. Use a scale of 1 cm = 100 m for the vertical axis. Draw an intervisibility line on the cross-section to find out whether point B is visible from point A. What is your finding? (8)
   b) Indicate the location of the following features on the map by writing down the number of the landform on the map. (4)

<table>
<thead>
<tr>
<th>Number</th>
<th>Landform</th>
<th>Number</th>
<th>Landform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cliff</td>
<td>3</td>
<td>Plain</td>
</tr>
<tr>
<td>2</td>
<td>Neck (saddle)</td>
<td>4</td>
<td>Area above 1 000 m</td>
</tr>
</tbody>
</table>

4. Indicate the river course (use a solid blue line) and the watershed (use a dashed blue line) on a copy of Figure 1.28 on page 25. Alternatively you can draw the river and the watershed on tracing paper. (4)
5. Calculate the gradient of triangle (b) in Figure 1.29 on page 25. (3)
6. Measure the angle of slope of triangle (b) in Figure 1.29. (2)
7. Draw two triangles to clearly illustrate gradients of 1:4 and 1:8 respectively.

8. Draw two triangles to clearly illustrate the different gradients between:
   a) Spot height 1114 (block A1) and spot height 531 (block B2) on the map of De Doorns (Figure 1.1 on page 3).
   b) Spot height 743 (block B1) and spot height 531 (block B2) on the map of De Doorns (Figure 1.1 on page 3).

9. We made the statement that a cross-section is in fact a graph showing height above sea level and distance from an origin. Graphs can be drawn from data in a table. Study the cross-section shown in Figure 1.32 on page 29. Copy and complete the table below by inserting the correct values derived from the cross-section. Your table has to have 10 rows, not only 3.

<table>
<thead>
<tr>
<th>Coordinate number</th>
<th>Height above sea level</th>
<th>Distance from origin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. In Classroom activity 4 we deliberately made provision for drawing the cross-section at two different vertical scales to illustrate the effect of vertical exaggeration. Calculate the vertical exaggeration of each of the two cross-sections.

11. This question is based on the collage of eight contour maps shown in Figure 1.33. In Table 1.2 below we listed the alphanumeric reference number of the contour maps as well as one or more questions about the contour maps. Copy the first and last columns (the ‘Answer’ column) of the table. Write your answers in the ‘Answer’ column.

Table 1.2: Your turn — answer the question about contour patterns shown in Figure 1.33 on page 30.

<table>
<thead>
<tr>
<th>Collage element</th>
<th>Question</th>
<th>Marks</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>What landform do you associate with the shaded area labelled 1 in the figure? Name at least one South African example of such a landform.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>Describe the landscape represented by the contour map. What would you call the area represented by the shaded area labelled 2 in the figure?</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>Describe the landscape represented by the contour map.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>What type of landform do you associate with the contour patterns?</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>What type of landform do you associate with the contour patterns?</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td>What is unique about the landscape?</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>g)</td>
<td>Describe the landscape represented by the contour map. Name at least one South African example of such a landform.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>h)</td>
<td>What landforms do you associate with the areas labelled 1 and 2 in the figure?</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1.30: Name the landforms associated with numbers 1 to 7.

Figure 1.31: Show the location of a plain, neck, pass and cliff.

Figure 1.32: A cross-section showing the profile of the landscape.
Figure 1.33: Answer the questions listed in Table 1.2 about these contour patterns.
What you still need to know

Aerial photographs and orthophoto maps

Word bank

nadir point: the point on an aerial photograph that is directly below the aircraft when the photograph is taken.

principal point: the centre point of a vertical aerial photograph. If the camera lens was absolutely perpendicular (i.e. not tilted) to the ground, the principal point and the nadir point would coincide to be the same point.

terrestrial photographs: photographs taken from ground level.

Oblique and vertical aerial photographs as resources to identify landforms and landscape features

In Grade 10 (and even in previous grades) you learned about the uses, advantages and disadvantages of different types of photographs – terrestrial photographs, oblique and vertical aerial photographs, orthophotos and orthophoto maps. All these types of photographs are rich sources of information which you should be able to use and interpret.

We are sure you would agree that the terrestrial photograph shown in Figure 1.34 is very effective in communicating the fact that we are dealing with a serious environmental problem, namely water pollution. Those of you who have smart phones can use such devices to capture photographs of the interesting geography around you or to capture evidence while doing fieldwork.

The saying “A picture is worth a thousand words” is very true. Figure 1.35 on the next page illustrates very clearly that (a) is a mountainous landscape characterised by many streams eroding and shaping the landscape. In the case of (b) the landscape is characterised by plains and an isolated table mountain. Oblique aerial photographs such as (c) and (d) can also very effectively convey how the land is used and what people do for a living. Photograph (c) illustrates subsistence cattle farming whereas photograph (d) illustrates intensive commercial crop farming that is very dependent on irrigation.
Terrestrial and oblique aerial photographs are easy to interpret because they provide views we are accustomed to. In the case of oblique aerial photographs we see the landscape and its features as if we are looking at it from a mountain or a high building. A disadvantage of terrestrial and oblique aerial photographs is that it lacks the plan view of maps and vertical aerial photographs. We therefore cannot use it to measure distances and to calculate areas because the foreground is at a much larger scale than the background. Often it also contains “dead ground” as the foreground hides the background.

Vertical aerial photographs come much closer to the plan view offered by maps and are in fact, extensively used as sources of spatial information to draw new maps or to update existing maps. Examples of different landscapes are provided as a series of vertical aerial photographs [Figure 1.36(a)–(f)]. Another example of a vertical aerial photograph is the photograph of the Hex River Valley shown in Figure 1.37 on the next page. Compare this photograph with the 1:50 000 map of the same area shown in Figure 1.1 on page 3.
Figure 1.37: A vertical aerial photograph of the Hex River Valley in the Western Cape
1. Figure 1.38 shows a rural area near Tugela in KwaZulu-Natal. A hut has been marked to show you how it looks on the photograph. Write a short paragraph in which you describe the spatial distribution of the huts shown in the photograph. Pay attention to how the huts are distributed in relation to each other; the relief of the landscape. What evidence can you find that the location of the huts is environmentally friendly? (6)

2. Study Figure 1.39 and indicate which of the photographs labelled (a), (b) and (c) you associate with radial, dendritic (tree-like) and parallel drainage patterns. (3)
Clues for the interpretation of photographs

One of the biggest obstacles to the identification of features on a vertical aerial photograph is that the photograph is taken from an unusual angle — a line from the camera to the focus point on the ground strikes the Earth at an angle of approximately 90°. It takes some imagination and practice to relate the view (from directly above) of an aerial photograph to the view from ground level. There is no way we or your teacher can teach you within a week or two how to become an expert when it comes to reading or interpreting a vertical aerial photograph. It is not that difficult but it takes continuous practice to become a master in photo-interpretation. Ask your teacher to obtain maps and vertical aerial photographs of an area familiar to you. Then study the photographs together with the maps. An even better strategy would be to visit the photographed area so that you can experience how features in the landscape appear on photographs. Learners often think they are cheating when they rely on additional sources such as maps or field visits when doing photo-interpretation. It is not cheating – it is clever use of available resources.

When interpreting aerial photographs you can also use the clues of size, grey tone (or colour), texture and shadows to identify features or to distinguish between features.

Size

Just as objects and features in the real landscape vary in size, so they vary in size on aerial photographs (see Figure 1.40 below). The relative sizes of unknown features can be compared with the size of familiar objects such as a house, a street, a railway line, a soccer field or a parked vehicle.

The freeway (1) is wider than the roads (2) to the residential area.
The townhouse units (3) are bigger than the single houses (4).
The factory (5) is much bigger than the clustered housing units (6). Note the ridged roof of the factory.

Figure 1.40: Using size as a photo interpretation clue
To work out size accurately, you need to know the scale of the photograph. Study the steps below to understand how the scale of a vertical aerial photograph is calculated when you have a map of the same area.

1. Choose two points that are clearly visible on both an aerial photograph and on a map of which the scale is known.
2. Measure the straight-line distance between the same two points on the map. Name this value map distance.
3. Measure the straight-line distance between the two points on the photograph. Name this value photo distance. Note that the unit of measurement on the map and the photo should be the same, e.g. millimetres.
4. Substitute the two values into the following formula:

\[
\text{Scale of photograph} = \frac{\text{photo distance in mm}}{\text{map distance in mm} \times \text{scale factor of map}}
\]

Suppose you do not have a map of the area. You then have to measure distances in reality (e.g. the length of a soccer field you can see on the photograph) and simply replace the map distance measurement with the real distance measurement.

**Grey tone or colour**

Grey tone on photographs (see Figure 1.41) is determined by:

- the actual colour of objects – light-coloured objects such as a beach reflect more light and appear more white than a dark coloured object such as a tarred road
- the reflectivity of objects – concrete surfaces such as the walls of buildings and houses reflect more light (more white) than green vegetation
- the position of the sun in relation to the camera and the photographed object
- the time of year at which the photograph was taken, for example the foliage on deciduous trees is far more dense and the colour of grass much greener in the rainy season than in the dry season.

![Different crops in different growth stages have different colours and tones.](image)

![The same dam looks different on different photos. The dam on the left appears lighter because the rays of the sun were reflected from the water surface onto the camera lens.](image)

![Rough surfaces such as shrub land or plantations appear darker because the light rays are dispersed.](image)

![Figure 1.41: Using colour and tone as a photo interpretation clue](image)

**Texture**

You can distinguish between different objects with the same tone through different textures – see Figure 1.42(a)-(e). Texture is the degree of smoothness or coarseness of a feature.

(a) The fine and smooth texture of bowling greens.
(b) The wheat fields have a medium texture. The vineyards appear striped.
Shadow

Although shadows occasionally obscure (hide) details, they also reveal the elevation (height) and relief of the landscape. Shadows that fall outwards indicate an elevation, e.g. a mine dump. Shadows that fall inwards indicate a depression or hole, as shown in Figure 1.43(a) below.

Always interpret a vertical aerial photograph with the shadows falling towards you. If you do not follow this rule, the result is a pseudoscopic (false) image where relief is inverted (reversed or turned upside down). For example, by turning your book 180°, the open pit mine shown in Figure 1.43(a) would become a ‘hill’.

If it is known at what time of the day a photograph was taken, you can use the shadows to work out the cardinal (main points on a compass) directions. For example, the shadows on photographs taken before noon are towards the south-west. Often shadows are the only indication of the presence of objects that are tiny in plan view, such as chimneys, floodlights, pylons and canals (see Figure 1.43[b]). The shadows of the oil storage tanks in Figure 1.43(c) show that the tanks are not sunken into the ground. They also tell us that some of the tanks are not full.
Geographical skills and techniques

Orthophoto maps — true to scale snapshots of reality

A vertical aerial photograph has the disadvantage that it is only true to scale at the nadir point. The further an object on a photograph is situated from the nadir point, the greater the distortion. Distortions can be removed using a photogrammetrical process to form a true-to-scale product called an orthophoto (see Figure 1.45 on the next page). When background information such as a coordinate grid, contours, spot heights, place names and road numbers are added to enhance the orthophoto, it is known as an orthophoto map.

Homework activity 8

1. Calculate the approximate scale of the vertical aerial photograph of the Hex River Valley in the Western Cape shown in Figure 1.37 on page 33. Base your measurements on the distance between any two points that are visible on both the aerial photograph and on the 1:50 000 map (Figure 1.1 on page 3).

2. Figure 1.44 on the right is a vertical aerial photograph that shows the following categories of land use and land cover:
   - forest and woodland
   - vineyards and orchards
   - cropland
   - fallow land
   - residential
   - water.
   a) Apply photo interpretation clues to identify the categories listed above on the photograph in Figure 1.44.
   b) Place tracing paper over the photograph. Draw the frame of the photograph and the boundaries of the categories listed above on the tracing paper.
   c) Make a map of your drawing by giving it:
      - a descriptive title – tell the reader what the map shows
      - an appropriate legend – you can use colours to distinguish between the land cover and land use categories

Figure 1.44: This aerial photograph shows different types of land cover.

38 • Geographical skills and techniques
Topic 1

Homework activity 9

This activity is based on the vertical aerial photograph of Hex River Valley (Figure 1.37 on page 33). You should also make use of the topographical map of De Doorns (Figure 1.1 on page 3) to answer the questions.

1. The aerial photograph of the Hex River Valley is more recent than the 1:50 000 map of the same area (see Figure 1.1). Compare the two figures by focusing on the changes that have taken place since the map was published. Describe at least three changes. (3)

2. Explain why we refer to the area shown on the photograph as a river valley. (3)

3. At what time of the year was the photograph taken? Explain your answer by referring to the tone of the vineyards. (3)

4. Look closely at blocks G11 and H10 on Figure 1.37. Name and describe the interesting feature related to transport that can be ‘seen’ in these two blocks. (3)

5. The farms in this area are not large. Give evidence for this statement by referring to the distribution pattern of the farmsteads. (3)

6. Several rectangular areas on the photograph are almost white. Explain what the rectangular white area in block E4 is. (3)

7. Identify and explain the function of the features listed below. Note that you might have to refer to the topographical map of De Doorns (Figure 1.1 on page 3) to show some of the functions.
   - The light coloured area in block H12 labelled a. (2 x 4 = 8)
   - The small area (labelled b) in block I11 that has been cleared of vegetation.
   - The linear feature in block D6 labelled c.
   - The light coloured area in block B13 labelled d.
Orienting aerial photographs and orthophoto maps with another map

To orientate a photograph in the field means that the photograph should be held in such a position that the photo directions correspond with real-life directions. Remember that in the southern hemisphere shadows always fall in a southern direction. By attending to the direction of shadows you can avoid holding the photograph upside down. You then need to locate two or more features that you can see in the landscape as well as on the photograph. Now you need to make slight adjustments to which way you are holding the photograph so that the relative positions of the features that you have identified correspond with the relative positions of the same features in the landscape.

You can do exactly the same to orientate a photograph with a map. Simply look for features that appear on the photograph as well as on the map.

Extra practice activity 3

1. Aerial photographs show more detail than maps. Provide evidence in support of the statement by referring to the map (Figure 1.1 on page 3) and aerial photograph (Figure 1.37 on page 33) of De Doorns (Hex River Valley). (3)

2. You are required to update an existing map by using an orthophoto. Figure 1.46 on the next page is an extract from the official 1:50 000 map 2528CC Centurion. Although a more recent edition is available, we have purposefully decided to use the 1995 edition.

   The map shows an area that was in a process of change. The area once had a rural character because of the many smallholdings – labelled on the map as Lyttelton Agricultural Holdings. As the city of Centurion expanded, new land was needed to satisfy the needs of the growing urban population. The smallholdings had to make way for higher-density residential neighbourhoods, business areas and services such as hospitals and schools.

   Figure 1.47 on the next page is an orthophoto illustrating the development that has taken place since the publication of the 1:50 000 map. We want you to use the orthophoto map to make a thematic map showing the changes that have taken place. Your map should show the following land use categories:
   - area already developed before 1995
   - area already since 1995.

   Your map should have:
   - a suitable title
   - a legend
   - a north arrow or geographical references
   - labels. (10)

3. Figure 1.48 on the right clearly shows a soccer field. Estimate the scale of the photograph. (6)
Figure 1.46: Extract from official 1:50 000 map 2528CC Centurion

Figure 1.47: Orthophoto of Centurion. An orthophoto is produced from an aerial photograph of which the scale distortions have been removed. (Compare this orthophoto with the orthophoto map [Figure 1.44] on page 39 to see the difference between an orthophoto and an orthophoto map.)
Using atlases

**Word bank**

**alpha-numeric reference system:** a system used in atlases to indicate the position of places on a page in the atlas. The page is divided into rows and columns. A reference such as B3 means that the place can be found where row B and column 3 intersect – see Figure 1.50.

**decimal degrees:** a compact way of describing latitude and longitude. A latitude position such as 32°34′12″S can also be written as 32.57 °S.

**geographic variable:** a measurable characteristic of a geographic phenomenon. Rainfall is a geographic phenomenon. It varies across the Earth. The amount of rainfall is a geographical variable since we can measure the amount of rainfall recorded at different places.

**thematic map:** see Figure 1.52 on page 48 for three examples of thematic maps. As opposed to a general purpose map that shows a large range of different features (e.g. height above sea level, roads, railway lines, rivers, land use et cetera) on a single map, a thematic map focuses on a single theme. Think about themes such as level of development, population density, level of literacy, religion, type of government, level of employment and major economic activities in a single region or country. Often some of the information we find on general purpose maps is also shown on thematic maps but then it is simply provided as background to better understand the purpose and main theme of the thematic map.

**Gross Domestic Product (GDP):** an indicator of the size of a country’s economy. It is the value of a country’s total output of all goods produced and services rendered during a financial year. It excludes money earned by citizens while being abroad. The Gross National Product (GNP) is basically the same as GDP with the difference being that money earned by citizens while being abroad is also taken into consideration.
Using an atlas index

Being a citizen of the global village it is essential that you are geographically literate. You need to know what is going on out there, where it is happening and why. Newspapers and news bulletins on radio and television will inform you about what is happening. Atlases will help you to find out where events are happening. To establish whether you still remember the basics about the use of an atlas index and to make sure that you indeed use your atlas, you need to complete questions 2 and 3 of Classroom activity 7.

Classroom activity 7

1. Open the first page of the index in your atlas. Describe how the index is structured by referring to the place or feature listed first in the alphabetical index. You need to explain the meaning of all the numbers, letters and abbreviations that are associated with the place or feature in the alphabetical index. (5)

2. Formulate a proposal on how your teacher can go about continuously testing whether the class uses their atlases on a regular basis to find out where events are happening. (4)

3. Set up a quiz (at least five questions) based on your proposal to test the knowledge of your classmates regarding the location of events making headlines in newspapers, on the radio and television. (5)

Locating places on maps using degrees and minutes

An alphanumeric reference system simply tells us in which row and column of a specific atlas page can we find a certain index entry. The reference is unique to the specific atlas and cannot be used to explain to somebody else what the exact location of the place of interest is. To give exact location we need to use the geographic reference system based on coordinates of latitude and longitude. Because it is a more compact way of referencing location, atlas indexes often provide the coordinate of a place in decimal degrees of latitude and longitude instead of degrees, minutes and second. To locate the place on the relevant atlas page it might be easier to first convert the decimal degrees to degrees, minutes and seconds. Remember the following:

- There are 60 minutes in one degree.
- There are 60 seconds in one minute.

A decimal degree of say 30.75°S should be read as 30 degrees plus .75 (three-quarters) of a degree. We can convert the portion of .75 to minutes by multiplying 0.75 by 60.

- 0.75 degrees × 60 = 45 minutes.

The latitude of the place is therefore 30°45’S.
Suppose we have an atlas index entry stipulating that the location of a place is 32.28°S; 24.03°E.

The decimal portion of .28 can be converted to minutes by multiplying 0.28 by 60
- 0.28 degrees × 60 = 16.8 minutes

If you can convert decimal degrees to minutes, you should have no difficulty in converting decimal minutes to seconds. The decimal portion of 0.8 minutes can be converted to seconds by again multiplying by 60.
- 0.8 minutes × 60 = 48 seconds

Latitude of 32.28°S is therefore the same as 32°16'48"S.

We can apply the same arithmetic to change decimal degrees 24.03°E to 24°1'48"E

**Homework activity 10**

1. Convert the coordinate 31.95° S; 28.5166667° E to degrees, minutes and seconds. What is special about this coordinate? (5)
2. While writing this section NASA (National Aeronautics and Space Administration) announced that a defunct (out of use) bus-sized science satellite fell harmlessly in a remote area. The satellite entered the Earth’s atmosphere at approximately 14.1 degrees south latitude and 170.2 west longitude. The debris was scattered over an area of between 480 km to 1 300 km from the re-entry point. Use your atlas to explain where the satellite fell and why it was not a catastrophe claiming human lives. (3)
3. Use an atlas to find out which place has a location of 32.28°S; 24.03°E. Write down the name of the place and also describe the relative location of the place. (4)

**Comparing information from different maps**

The beauty of an atlas is that it contains a wealth of spatial information about different regions and different geographical themes. We can compare different regions (e.g. the provinces of South Africa) in terms of a singular geographic variable such as rainfall. By looking at rainfall only (Figure 1.51 on the next page – see the map at the bottom) we can easily infer that the rainfall in South Africa decreases from east to west. Alternatively we can focus on a single region and analyse the character of the region by looking at different geographical variables (themes). This is made possible because atlases contain thematic maps. By using your atlases you should be able to focus on a country and learn more about what the people are doing for a living, what languages they speak, what religions they follow, etc.
Figure 1.51: Maps extracted from the Macmillan School Atlas showing South Africa's climate

Most of South Africa lies between the Tropic of Capricorn and the thirty-four degree line of latitude. This is a subtropical area where temperatures are generally warm. The climate graphs on page twenty-one indicate that for most parts of the country, the coldest months are June, July and August and the warmest months are December, January and February. Climate is affected by latitude, ocean currents, wind and the height of the land.
A requirement of the syllabus is that you should study concepts of development (see Topic 4). Your atlas is a great resource of information about development on a continental and global scale. In the past economic factors were rather over-emphasised when categorising countries in terms of development status. It was argued that countries with high income per capita and high **Gross Domestic Product** (GDP) are developed. It was also argued that countries in which the tertiary and quaternary sectors of the economy are dominant are developed. Today, the importance of social factors is also recognised as very important indicators of development. The Human Development Index (HDI) developed by the United Nations Development Programme (UNDP) regards development as a function of three dimensions namely:

- a long and healthy life: life expectancy at birth
- access to knowledge: mean years of schooling and expected years of schooling
- a decent standard of living: an indication of the average income earned by citizens.

To evaluate your ability to compare maps and put your observations on paper, you need to complete Homework activity 11. The task is based on an extract (Figure 1.52) from a page in an atlas we are using. The three maps in the extract show how three indicators of development (life expectancy, food insecurity and income) vary on a global scale.

**Homework activity 11**

Study Figure 1.52 on page 48 by focussing on the African continent. Compare the three maps and make a judgement about differences and similarities between the three maps. Write down all your observations. Use the observation notes you have made to write a paragraph summarising your interpretation of the state of development on the African continent.  

**Extra practice activity 4**

1. It has been argued that countries that are tropical and landlocked are handicapped in terms of development. Use your atlas to compile a table listing all African countries in alphabetical order. Your table should clearly indicate which countries are situated in the tropics, which are coastal countries and which are landlocked. For the purpose of the task tropical countries are regarded as countries of which more than 50% of the area is situated between 23½°N and 23½°S.  
2. Draw a pie diagram to graphically illustrate how many African countries are coastal countries and how many are landlocked countries.  
3. In Table 1.3 we provide a geographical coordinate and a brief description of a place/region/feature. Copy the table and use your atlas to write down the name of the place/region/feature in the last column.
Table 1.3: Your turn: Name the place/region/phenomenon described in the table.

<table>
<thead>
<tr>
<th>Item number</th>
<th>Latitude/Longitude</th>
<th>Description</th>
<th>Name of place/region/feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44°45’ N; 49°3’ E</td>
<td>Largest lake in the world.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29°18’38” N; 12°57’05” E</td>
<td>Largest lake in Africa.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18°55’ S; 47°31’ E</td>
<td>The capital city of the fourth largest island in the world.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>30°54’ N; 31°7’ E</td>
<td>The coordinate is associated with the delta of the world's longest river (± 6,690 kilometre).</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>05°57’ N; 62°30’ W</td>
<td>The world's tallest waterfall has a drop of 979 meters.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>15.525376° S; 71.567188° W</td>
<td>The coordinate is associated with the source of the river that has the largest drainage basin (6,144,727 km2) in the world.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>—</td>
<td>Most volcanoes in the world are associated with the Ring of Fire. You need to explain the relative location of the Ring of Fire in the next column.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>—</td>
<td>The wide, treeless, grass-covered plains of the La Plata river system in South America.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>32°39’ S; 70°14’ W</td>
<td>More than 200 mountaineers have climbed all “Seven Summits”—the highest peak on each of the seven continents. The summit we are thinking of is the second highest of the seven summits.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>35,40° N; 139,45° E,</td>
<td>One of the largest cities in the world (population in excess of 33 million).</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>41°54’ N; 12°27’ E</td>
<td>The world's smallest state.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>This desert runs as far north as 36 degrees north and as far south as 14 degrees north and from 16 degrees, 44 minutes west to 33 degrees, 10 minutes. East.</td>
<td>Largest subtropical desert in the world.</td>
<td></td>
</tr>
</tbody>
</table>

Note: Item 7 counts 3 marks. All other items count one mark each.
Figure 1.52: Maps extracted from the Macmillan School Atlas showing spatial variation in life expectancy, food insecurity and income on a global scale.
Geographical Information Systems (GIS)

What you still need to know

Google Earth: a free software that gives you access to a virtual globe, map and geographical information system. When you zoom into an area of interest a satellite image of moderate resolution covering the area is displayed.

Image processing system: in the context of satellite remote sensing it is the computer software that deals with the preparation (e.g. removal of scale distortions), and enhancement (e.g. for visual analysis) of satellite data followed by the extraction of desired information.

μm: the symbol for micron or micrometre. A micrometre is one-millionth of a metre or one-thousandth of a millimetre.

Spatially referenced data

In Grade 10 you were introduced to the fascinating spatial technologies of remote sensing and GIS. You learned:

- about the reasons for the development of GISs
- about GIS concepts such as spatial objects, lines, points and nodes
- how remote sensing works.

In this unit we will resume our journey that will ultimately culminate in Grade 12 with you being able to produce a “paper GIS” based on data extracted from existing maps, aerial photographs and other sources of spatial information.

A GIS is a computer system that is tailor-made to use spatial and attribute data in an integrated manner in order to give quick answers on the Where? What? How many/much? and Why? questions geographers have asked over centuries.

The word “Where?” refers to the location of spatial objects — in other words the GIS knows exactly where the towns, monuments, rivers, different rock types, areas of high crime rate, or countries of Africa are located. To know this, all spatial data in a GIS need to be spatially referenced. A better phrase is perhaps spatially georeferenced. Since the prefix geo is a Greek word meaning “Earth”, spatially georeferenced literally means that the location of a place or spatial object is described in terms of its location on the Earth. To do so is much easier than you might think. You already know that the geographical reference system is a system of imaginary lines of latitude and longitude that can be used to describe the location of places in exact (absolute) terms.
If we want to capture a geographical feature (phenomenon) such as the distribution of the capital cities of South Africa in a GIS, we simply have to create a file in the database of the GIS listing the degrees of latitude and longitude of each city together with a unique number for each capital city. Such a file is illustrated in Table 1.4 below. Note that, since the file is supposed to only contain information about location, the names of the capital cities shown in column 4 are not really required – we struck the names out to remind you that the names are solely for explanatory purposes.

Table 1.4: In a GIS the locations of our selected three capital cities are spatially referenced in terms of their geographical co-ordinates.

<table>
<thead>
<tr>
<th>Unique number</th>
<th>Latitude (degrees, minutes) South</th>
<th>Longitude (degrees, minutes) East</th>
<th>Name of capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33° 55’</td>
<td>18° 26’</td>
<td>Cape Town</td>
</tr>
<tr>
<td>2</td>
<td>29° 12’</td>
<td>28° 10’</td>
<td>Pretoria</td>
</tr>
<tr>
<td>3</td>
<td>29° 06’</td>
<td>26° 13’</td>
<td>Bloemfontein</td>
</tr>
</tbody>
</table>

From Table 1.4 a GIS would be able to place the coordinates of our capital cities in its correct position on any map.

Classroom activity 8

1. How would you georeference your school in a GIS to be used at national level? (2)
2. Speculate how you will georeference the roads leading to your school in a GIS. We know that we have not explained this to you but the chance is good that you might figure out for yourself how coordinates can be used to define a line. (3)
Different types of data

In a GIS we break our dynamic world down into smaller parts and analyse the association or links between the parts in order to better understand the processes giving shape and character to our world. With “parts” we mean two things:

- A GIS contains different layers of information. A GIS being used to study weather patterns will contain layers related to temperature, rainfall, atmospheric pressure, wind speed, hours of sunshine, cloud cover and definitely the locations where data was gathered.
- As with maps we cannot put the real world on a map. The real word is simplified and captured as points, lines and areas in a GIS.

The database of a GIS consists of layers of different information

The world out there is complex and we will be totally overwhelmed when confronted with all the information in one shot. To investigate a geographical problem in an area we also do not necessarily need all the available information about the area — we only require the information that is relevant to the problem. To investigate a problem such as air pollution in the Witbank area we do not need to know what languages the residents of Witbank speak, which political party they support or where the roads, rivers, and best agricultural land are located. To investigate the problem of air pollution we need information such as:

- where the sources (the coal-fired power stations) of the air pollution are located and how many pollutants are emitted by each pollution source
- the climate of the region especially the prevailing wind directions during the year
- the topography of the region
- where the people of Witbank live and work.
In a GIS the real world is therefore structured as different layers of information (see Figure 1.54 on page 51) all collated for a single location or area. These layers can be broad themes such as topography, natural resources, and facilities and we can activate (show) or deactivate (hide) these layers as determined by the nature of the problem we are investigating.

**In a GIS the real world is captured as points, lines, areas and attribute information**

As mentioned earlier we cannot put a real tree, house, river, city, weather station, maize field or nature reserve in the GIS. As on maps, we can simplify real world phenomena to spatial objects such as points, lines and areas — see Figure 1.55 on the right. A single tree (or house) is a good example of an object that lends itself to be represented as a point. A river (or a road) resembles a line whereas a maize field (or a city, such as Bloemfontein) resembles an area. Do you agree that it makes sense? Should we not qualify our statement? You need to give an answer as part of Classroom activity 9.

Earlier we explained that a GIS requires a file (see Table 1.4 on page 50) explaining to the GIS where features are located.

**In a GIS the characteristics of the points, lines, areas are captured as attribute information**

On page 50 we wrote that the file containing the geographical coordinates (the “Where are?” information) of the capital cities do not really require the names of the cities. It is definitely not a case of names of capital cities not being important but rather that such non-spatial information is provided for in a different file in the GIS database. Information such as the name of the city, the province in which it is situated, the population size, and the number of foreign visitors per year is called attribute information. The attribute information tells us more about the characteristics (information about what things are like) of the points, lines and areas we have selected for inclusion in the GIS. An example of an attribute file is illustrated in Table 1.5 below. Compare the unique numbers in the table with the unique numbers in Table 1.4 on page 50. You will notice that the three cities each have the same unique number in the two files. The unique numbers therefore provide a link between the spatial data and the attribute data.

**Table 1.5: In a GIS the “what features are like” information is stored in the database as attribute files.**

<table>
<thead>
<tr>
<th>Unique ID</th>
<th>Name of city</th>
<th>Province</th>
<th>Population (2007)</th>
<th>Area of municipality (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cape Town</td>
<td>Western Cape</td>
<td>3 497 097</td>
<td>2 460</td>
</tr>
<tr>
<td>2</td>
<td>Bloemfontein</td>
<td>Free State</td>
<td>752 906</td>
<td>6 284</td>
</tr>
<tr>
<td>3</td>
<td>Pretoria</td>
<td>Gauteng</td>
<td>2 499 447</td>
<td>6 345</td>
</tr>
</tbody>
</table>

By clicking on the point associated with Cape Town on the map (Figure 1.53 on page 50 or on the GIS screen), the attribute data will pop up (see Table 1.6 on the next page) telling us that object 1 of the feature capital cities of South Africa:

- is known as Cape Town
- has a population of 3 497 097 people
- covers an area of 2 460 km².
Table 1.6: By clicking on the point associated with Cape Town, the attribute data of Cape Town will be displayed on the computer screen.

<table>
<thead>
<tr>
<th>Unique number</th>
<th>Name</th>
<th>Population</th>
<th>Area (km²)</th>
<th>Province</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cape Town</td>
<td>3 497 097</td>
<td>2460</td>
<td>Western Cape</td>
</tr>
</tbody>
</table>

We explained that by clicking on spatial objects we get access to the attribute information associated with the object. The reverse is also possible. When clicking on unique number 1 in the attribute file, the point associated with Cape Town will be highlighted on the map so that we can easily distinguish it from the other points representing other capital cities.

We deliberately struck out the names of the provincial capitals on the map (Figure 1.33). Let us explain why.

The real world feature we have captured is named *capital cities of South Africa*. For purposes of the above explanation we captured the three capital cities as three points. The location of each point has been described in terms of a geographical coordinate — nothing more. However, we agree that it would make sense to also include the names of the capital cities on a map displayed on the screen or printed via the GIS. To do so is easy but you need to understand that to do so the GIS will need an instruction from us to find the data in the attribute file and to write it next to the point with which it is linked via the unique reference number. By using the unique numbers we can go even further and decide to vary the sizes of the points representing our capital cities by taking the population numbers stored in the attribute file into consideration.

### Classroom activity 9

#### Possible formal assessment task: Data handling

1. Why did we say that information about topography is required when studying spatial variation in air pollution? (2)

2. On page 52 we asked the question whether we should not qualify our statement that a road resembles a line whereas a city such as Bloemfontein resembles an area. What is your opinion? (3)

3. Discuss what layers of information will be required for one of the topics listed below. You also need to indicate whether you will capture the layers as points, lines or areas.

   **Topic A:** The Department of Education wants to set up a GIS to analyse the spatial variation in Grade 12 Geography pass rates per school in your province. What factors do you think have an influence on Geography pass rates?

   **Topic B:** A community has decided to implement a GIS to monitor and prevent crime in their neighbourhood. What layers of information should they consider for capturing in the GIS?

   **Topic C:** Think about an entrepreneur who wants to open a fast food franchise in a fairly large town in your province. What spatial information is needed to decide which one of the seven available locations is the best option? (4)
Storing data in raster spatial models

You already know that we show the real world as points, lines and areas in a GIS. The question remains “How do we capture the points, lines and areas in a computer? Figure 1.56 illustrates the two most common methods namely, raster and vector models of reality.

Although the word raster might be new to you, you should be familiar with the basic concept. The pictures you take with a digital camera and the images you see on a television or computer screen are all raster images. Another good example is satellite images. A raster image consists of millions of tiny cells. Together the cells form a grid called a raster. Individual cells within the grid are known as picture elements or pixels. This is exactly the format of a satellite image or digital photograph. What you see as a picture is actually thousands of numbers of cells that are displayed in shades of grey or in different colours. The shade of grey or the colour of a cell is determined by the numeric value associated with the cell.

Imagine the Earth’s surface being covered by such a rectangular grid of cells. In other words – we overlay the landscape of rivers, forests, nature reserves, streets, varying population densities, and varying levels of energy consumption with a grid of cells. As illustrated in Figure 1.56(a) and (d) we can transform the real world features that we find within the cells to codes in a raster model. We simply write 1s in all the squares representing houses, 2s in all squares representing forests, and 3s in all the cells representing rivers. Figure 1.56(d) illustrates how we can transform the numeric data to a map that we can view – we allocated different colours to the different codes.
Note the following regarding Figure 1.56(d).
1. The house (a point-like feature) is represented as a single cell.
2. The river (a line-like feature) is represented as a string of cells.
3. Together the cells indicating presence of trees forms an area that we can call forest.

Before we can advance to the next section we still need to answer three questions.
- How do we georeference a satellite image that consists of rows and columns?
- Where and how do we save the attribute information in a raster file?
- What are the ideal applications of raster spatial models?

1. Georeferencing a raster image

We can explain the position of the house in Figure 1.56(b) by saying it is the cell which you can find at the intersection of row 6 and column 9. Do you agree that it is easy? We trust that you said “Yes, but …..”. The problem with the reference is that it only applies to the specific image. We still do not know where in the world the house is. Fortunately the problem can be easily solved using a GIS. We simply need to look for about four prominent points (called control points) that are clearly visible on the image. What is important is that we also know the latitude and longitude of these control points or that we can calculate it from a map. By specifying the latitude and longitude as well as the row and column position of the control points and applying a mathematical function the entire raster image is georeferenced in terms of its proper position in the world. In other words – the GIS system knows what the latitude and longitude of each cell is.

2. Dealing with attribute data

Raster models have a very convenient way of dealing with attribute data. The attribute data is simply entered in the cells of the matrix. Suppose we are dealing with a phenomenon such as average January temperature. By covering South Africa with a grid and entering the temperature values in the grid cells we have a file describing how the average January temperature varies across the country. How would we go about making a map of the average January annual temperature values saved in the cells of the grid? It is easy. We will provide the computer with an instruction similar to the summary described below:
- make all cells that have a value of less than 20 dark blue
- make all cells that have a value between 20 and 22.9 light blue
- make all cells that have a value between 23 and 25.9 yellow
- make all cells that have a value between 26 and 28.9 orange
- make all cells that have a value of 30 and more red.
3. Ideal applications

Raster files are excellent for modelling phenomena that have a continuous distribution. By continuous we mean being present everywhere. Can you think of examples of continuous phenomena? Are harbours and houses continuous? No, they are not – we do not find harbours inland and we do not find houses in the sea. Continuous phenomena do not have definite boundaries that we can see in the landscape. Think of phenomena such as height above sea level, temperature, and average annual rainfall. We can go wherever we would like on Earth and we can measure these variables – they are present everywhere implying that we can enter a value in each cell of the raster file.

Some pros and cons

Computers are very fast at comparing numbers. The simple grid structure of a raster GIS is a format that is very easily analysed by a computer. Also, satellite images are typically obtained in raster format. Because of the identical formats such images can be easily integrated with a raster GIS.

The disadvantage of raster models is that they take up a lot of storage space. If you want to create a layer in your raster GIS to show the location of marine lighthouses in South Africa, the raster file will have a small number of ‘1s’ indicating the presence of a lighthouse. However, there will be many thousands of cells with the attribute value ‘0’ to show ‘you will not find a lighthouse here’. Also, raster models do not describe the shape of phenomena accurately. We can improve the appearance of shapes and outlines by using smaller cells but this will have a big impact on the volume of data.

Homework activity 12

1. Figure 1.57(a) on the next page shows the course of a river. In Figure 1.57(b) the landscape is covered with the cells of a raster grid. Create a raster database by completing Figure 1.57(c). Your database must show the location of the river. Follow these steps:
   a) Copy Figure 1.57(c) in your exercise book.
   b) Enter either a ‘0’ or a ‘1’ in the cells of Figure 1.57(c). The ‘1s’ indicate the presence of the river. The ‘0s’ show that the river is not present in the areas represented by the cells.
   c) Show the river by colour-coding all the ‘river cells’. Use another colour code for all the cells that have a 0 value. (6)

2. Count the number of ‘river cells’ and express it as a percentage of the total number of cells in the grid. (3)

3. Figure 1.58 (a) on the next page shows grassland and forest. You need to create a raster file that will indicate where you will find grassland (code 1) and forest (code 2) respectively. For your convenience we already covered the area with a grid. You will find that in some cells we find grassland as well as a forest. Think about how you will solve this problem and enter the codes in the cells of Figure 1.58(b). (5)

4. Write down comments on how accurately the raster method represents the grassland and forest. Can you think of a way how the accuracy can be improved? (2)
You now know that the building blocks of the raster world are cells or pixels. In the case of the vector world it is points. Now you are on very familiar territory because to some extent we have already dealt with vector spatial models when we described how one can georeference the location of our capital cities (points) in a GIS. We now need to further elaborate because we still need to explain how lines (e.g. rivers) and areas (e.g. a forest) are captured in a vector model.

As you know, the location of any place on the Earth’s surface can be explained in terms of its location in space. Earlier we used the geographic reference system based on latitude and longitude to georeference our three capital cities. For explanatory purposes we will now use a Cartesian reference system. You are familiar with such a system – the two axes that we used to plot coordinates for drawing cross-sections of a landscape is an example of a Cartesian coordinate system.

Take a close look at Figure 1.56(c). It illustrates that we can define the location of the house, the shape of the river and the boundaries of the forest in terms of points. The location of the points can be described numerically in terms of their latitude and longitude or distance from an origin in a vertical (y) and a horizontal (x) direction.

**Storing data in vector spatial models**

You now know that the building blocks of the raster world are cells or pixels. In the case of the vector world it is points. Now you are on very familiar territory because to some extent we have already dealt with vector spatial models when we described how one can georeference the location of our capital cities (points) in a GIS. We now need to further elaborate because we still need to explain how lines (e.g. rivers) and areas (e.g. a forest) are captured in a vector model.

As you know, the location of any place on the Earth’s surface can be explained in terms of its location in space. Earlier we used the geographic reference system based on latitude and longitude to georeference our three capital cities. For explanatory purposes we will now use a Cartesian reference system. You are familiar with such a system – the two axes that we used to plot coordinates for drawing cross-sections of a landscape is an example of a Cartesian coordinate system.

Take a close look at Figure 1.56(c). It illustrates that we can define the location of the house, the shape of the river and the boundaries of the forest in terms of points. The location of the points can be described numerically in terms of their latitude and longitude or distance from an origin in a vertical (y) and a horizontal (x) direction.
What we see in Figure 1.56(c) can be described as follows:

1. **Points**: Features such as houses resembling points can be defined as single coordinates (points).

2. **Lines**: The shape of features which resemble lines can be defined as a string or chain of coordinates. By drawing lines between the points that are used to define the shape of the feature, a line is created. The more points we use to define the shape, the more accurate we can represent the line in a GIS.

As illustrated in Figure 1.59 below different terminology is used for points and lines serving different functions in a vector GIS.

- The coordinate that we use to indicate a point feature such as a single tree is called a point in a GIS. When we are dealing with lines and polygons, we no longer refer to the coordinates as points. The start and end coordinates of lines are called nodes. Think of the four nodes shown in Figure 1.59 as four sets of traffic lights. The stretches of roads between the traffic lights will be captured as unique features in the GIS. Each stretch of road will carry a different number of vehicles during the course of a day and each stretch might have a different name and perhaps a different type of surface. The line between two nodes are referred to as a chain or an arc in a vector GIS.

- Vertices are not real phenomena – the sole purpose of these kinds of coordinates is to indicate where a line or chain (road in this case) changes direction.

### Areas

In GIS we refer to areas such as the forest in Figure 1.57(c) as polygons. In its simplest form we can regard a polygon as a closed loop of points. “Closed” implies that the start (first) and end (last) points should be identical in order to close the area. Another way to think about a polygon, is to regard it as a single chain (thus a line consisting of points) of which the start and end nodes are identical.

Before we can advance to the next section we still need to attend to three aspects.

- Where and how do we save the attribute information in a vector model?
- What are the ideal applications of vector spatial models?
- We suspect that you might ask whether this is all that you need to know about capturing vector data in a GIS. The answer is “Yes” and “No”. The syllabus does not require more detailed knowledge. However, our experience is that learners are often intrigued with GIS and want to know more. The detail we have shared about vector GISs is very basic. Those of you who are eager to know more, should ask your teacher to explain how the points, lines and areas are structured topologically in a vector GIS.

![Figure 1.59: In a GIS lines start and end at nodes. The purpose of a vertex is to indicate where the line changes direction.](image)
Dealing with attribute data

Raster GISs deal with attribute data in a very simple manner. Attribute data such as temperature are simply entered into the cells of the matrix. In vector GIS the data are entered in attribute tables similar in structure to that of Table 1.5 on page 52. Such a table can however not function on its own. The table needs to be linked to the table describing the spatial information of the feature. Such a link is provided by the unique number of the feature. You will notice that in Tables 1.4 and 1.5 on pages 50 and 52 the two rows containing information about Cape Town both have a unique number of “1”.

Ideal applications

Vector models are good to describe the location of discrete features – features that do not have a continuous distribution. To capture the features we only need to specify the geographical coordinates which define the location and shape of the features. Vector GIS files therefore take up much less storage space in the computer.

Pros and cons: Vector GISs are similar to a map-like drawing of features. Lines are not broken into cells or fragments. The shape of features is better retained and the spatial accuracy (e.g. the location of points, lines and areas) is also better than with raster models. Vector models have the advantage that they can be topologically structured. Without getting into too much technical detail, remember that topology has to do with how the nodes, lines and polygons are related to each other. When topology is in place we can analyse the flow of dynamic features such as traffic, water and electricity. A disadvantage of vector models is that it cannot effectively deal with continuous data.

So, when asking which is the best model; vector or raster, remember that it depends on the kind of feature (phenomenon) you are dealing with and the type of analysis you want to do. Sophisticated GISs make provision for both and even allow you to change raster data to vector data and vice versa.

Homework activity 13

1 Figure 1.60 on the next page shows the course of a river. Copy the figure in your exercise book. Explain and illustrate how you will capture the river in a vector GIS by using 12 coordinates. Compare the shape of the river with the raster shape you created as part of task 1 of Homework activity 12. Also compare the file sizes of the vector and raster models. (5)

2 Figure 1.61 on the next page shows two types of land cover – pasture and maize. Copy the figure in your exercise book. Explain and illustrate how you will capture the maize field in a vector GIS. Do not forget to show an attribute table. (10)
Spatial, temporal and spectral resolution

When dealing with spatial data such as satellite images in a GIS we need to be very aware of the resolution of the data. We can distinguish between spatial, temporal and spectral resolution.

Spatial resolution

The spatial resolution of a satellite image refers to the size of the smallest feature that we can distinguish on the image. The higher the spatial resolution, the smaller the individual features which we can distinguish on the image or photograph. In other words, the higher the spatial resolution the more detail. Turn to page 115 in Topic 2 to view Figure 2.18(b). It shows a satellite image captured by the Eumetsat satellite. Compare the image with the Quickbird image of Greenpoint stadium shown in Figure 1.62 in terms of the detail you can extract from the two images.
The size of the pixels of a satellite image indicates the spatial resolution and thus the level of detail. In the case of some older meteorological satellites the pixel sizes are the equivalent of several kilometres on the ground. Such images have a low spatial resolution and we cannot for example see small features such as roads or houses on such images. A very high spatial resolution is however not necessary because weather conditions do not differ dramatically over short distances.

Unlike weather conditions, other features (phenomena) differ dramatically over short differences. One side of a fence might have pristine natural vegetation while on the other side the land might be extremely degraded as a result of overgrazing, bad farming practices and consequent erosion. To monitor these differences we need data with a high spatial resolution. Such data are captured by earth resource satellites such as SPOT (Système Pour l’Observation de la Terre), LANDSAT, QuickBird and Ikonos. The pixel size or spatial resolution of earth resource satellites vary from 30 m (Landsat TM) to 2.5 m (SPOT – see Figure 1.63 below) and an incredible 60 cm in the case of QuickBird – see Figure 1.62 on the previous page). These satellites cover much smaller areas than meteorological satellites but their spatial resolution is much higher.
Temporal resolution

To be functional, meteorological satellites should have a high temporal resolution – an image of the same area needs to be captured several times during the course of a day. This is necessary since weather conditions can change rather quickly. The advantage of high temporal resolution is illustrated in Figure 1.64 below. The figure shows a series of images captured by Meteosat on 29 November 2011 – it clearly shows how the weather changes during the course of a day.

The temporal resolution of Earth resource satellites is lower than that of meteorological satellites. The same area is only captured every sixteen days in the case of LANDSAT and every eighteen days in the case of one SPOT satellite. This rather long period can be reduced by launching more than one satellite of the same type. By putting two or more satellites carrying the same type of sensor into space and carefully planning their orbits one can achieve a situation where images of the same area are captured every two to three days.

Spectral resolution

In Grade 10 you learned how a remote sensing system works. You learned that satellite sensors are designed to measure reflection in different bands of the electromagnetic spectrum. To refresh your memory we can briefly mention that:

- The electromagnetic spectrum (EMS) illustrated in Figure 1.65 on the right can be described as a continuum of electromagnetic waves of varying lengths.
- The visible spectrum is a tiny part of the EMS and is also the only part that we can sense with our naked eyes.
- Within the visible spectrum of wavelengths we can distinguish narrow bands of wavelengths namely the colours of the rainbow.
Satellite sensors are designed to measure reflectance in both visible and non-visible regions of the electromagnetic spectrum (EMS). Spectral resolution refers to the sensitivity of the sensor for reflection in different bands of the EMS. A sensor such as LANDSAT TM that can measure reflection in seven different spectral bands has a higher spectral resolution than a sensor that can detect reflection in one band only. This is very important in remote sensing. In some bands two different phenomena might have very similar reflection characteristics. It will therefore not be easy to distinguish between the phenomena on the basis of their reflection in that specific band only. To solve the dilemma we need to use more spectral bands — in other words a satellite sensor that has a higher spectral resolution. You also need to understand that different spectral bands tell different stories – by looking at a well groomed soccer field, the reflection of visible green waves by the grass “tells” you that you are looking at grass. In Table 1.7 we summarised the different uses of data captured in different bands of the electromagnetic spectrum.

**Table 1.7: Application areas associated with sensing in different spectral bands**

<table>
<thead>
<tr>
<th>Colour/Spectral band (Wavelength)</th>
<th>Application area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible blue (0.4 to 0.5 μm)</td>
<td>Mapping of shallow water and to distinguish between soil and vegetation.</td>
</tr>
<tr>
<td>Visible green (0.5 to 0.6 μm)</td>
<td>Detection of vegetation health.</td>
</tr>
<tr>
<td>Visible red (0.6 to 0.7 μm)</td>
<td>To distinguish between different vegetation species.</td>
</tr>
<tr>
<td>Near infrared (0.7 to 1.2 μm)</td>
<td>To detect vegetation stress (or health) and to classify different types of vegetation.</td>
</tr>
<tr>
<td>Mid-infrared (3.0 to 5.0 μm)</td>
<td>To distinguish between land and water boundaries and to detect soil moisture.</td>
</tr>
<tr>
<td>Thermal infrared (5.0 to 14.0 μm)</td>
<td>Detecting heat sources.</td>
</tr>
<tr>
<td>Microwave (radar)</td>
<td>Can be used at night and in overcast weather conditions.</td>
</tr>
</tbody>
</table>
Geographical skills and techniques

Application of GIS integrated with satellite remote sensing

The syllabus requires you to have an idea of how GIS can be applied in the real world. When we consider that between 75% and 90% of the information that most organisations use every day is spatially or geographically based, it is no surprise that geospatial technology and especially GIS have become extremely important and has such wide application. To give you an idea of what GIS is used for we decided to do an internet search. We typed the phrase "GIS applications" into an internet search engine and also specified that we are only interested in South African applications. Unfortunately we cannot share all 15 300 hits with you! However, the following items should convince you of the wide range of applications - land reform; monitoring of service delivery; sustainable land use; precision farming – farm planning and crop yield management; disaster prevention and management; environmental and water management; crime analysis and prevention; assisting the Endangered Wildlife Trust in securing biodiversity; health and epidemiology; route planning, location-based business intelligence – best locations for services centres, stores, warehouses, or corporate offices, based on proximity to customers, transportation infrastructure, demographics, location of competitors, environmental risk factors, etc.

Classroom activity 10

Divide the class into three groups. Each group has to discuss the ideal resolution (spatial, spectral and temporal) characteristics of images that will be needed to deal with one of the scenarios described below. You simply have to mark the relevant cell in the table below to indicate the desired level of resolution agreed upon by each group. Note that you may mark more than one cell if you feel that the resolution requirement varies from low to medium.

**Group A:** An oil tanker has been seriously damaged during a storm 65 km off the east coast of South Africa. Monitoring the consequent oil spill and planning for protection of the coastline against possible oil pollution is of vital importance.

**Group B:** Run-away fires have caused the total destruction of crops and grazing in a farming region in the Free State. All the farmers have been insured against such losses. The insurance company wants to make use of satellite imagery to assess how large are the areas that have been destroyed by the fires.

**Group C:** A municipality has decided to invest in satellite images in order to identify structures such as swimming pools and extensions to houses for which no building plans have been submitted for approval.

<table>
<thead>
<tr>
<th></th>
<th>Very low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spectral resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

64 ● Geographical skills and techniques
One of the most important applications of GIS and satellite remote sensing is in the atmospheric sciences. We will focus on two sub-disciplines of the atmospheric sciences namely meteorology and climatology as well as a very important related discipline namely oceanology.

Applications in meteorology

Meteorologists study the atmosphere and meteorological phenomena which we experience as the weather. The weather is influenced by variables such as temperature, air pressure, water vapour, and the gradients and interactions of each variable, and how they change in time. If we want to predict weather we have to measure all these variables around the clock (thus high temporal resolution) and around the world and share it (via the Global Observation System (GOS) with other countries in order for them to prepare their forecasts and warnings. Such a huge task cannot be done without using the data from satellite images and the computing capabilities of computers.

Several examples of satellite images related to meteorology will be shared with you in Topic 2. When looking at these images you need to remember that satellite images are actually huge files containing numbers. These numbers represent the measurements that have been made by the sensors on board satellites. An example of such measurements extracted from an image is shown in Figure 1.66(a). Computers are used to display the individual cells of a raster layer (in this case spectral band 3) as a grey tone based on the numerical value contained in the cell. The millions of values can then be seen as an image – see Figure 1.66(b).

Figure 1.66: A satellite image consists of numerical values representing reflection in different bands of the electromagnetic spectrum. To “see” the numbers we show it in shades of grey.
You will find references to the words true colour and false colour satellite images in this and in other topics. A true colour image is made from measurements in the visible spectrum only or the image has been manipulated to mimic true colours. As with true colour images a false colour image is a composite of three spectral bands. In Figure 1.67 below band 3 represents measurements outside of the visible spectrum. The colour on the image is “false” because the phenomena do not appear in colours that we are accustomed to. Why does strong growing vegetation appear bright red on false colour images? Vigorous vegetation reflects much stronger in the near infrared band than in others (including the green band). The colour in which the near infrared band is shown will therefore be the dominant colour. Since near-infrared reflection is usually shown as red on a false colour image, vigorous vegetation appears red.

![Diagram showing false colour image creation]

---

**Figure 1.67**: A false colour image is a composite of three spectral bands of which at least one band is from outside the visible spectrum.

On 27 July 2011 South Africa experienced heavy snowfalls. We wanted to share a satellite image showing the distribution of snow with you. It was not that easy because the most spectacular images also showed cloud cover. It would not have been fair to expect you to be able to distinguish visually between the snow and the cloud cover. Eventually we found an image dated 30 July on which there were very few clouds. We noticed that the image was also available in a KML format. We got excited. Why? Spatial data in KML format is compatible with Google Earth. Because we had Google Earth software installed on our computer, we could simply click on the name of the image file. This action opened Google Earth and placed the image in its correct position (thus properly georeferenced) at the back of the layers in Google Earth. To help you with question 2 of Extra practice activity 5, we decided to overlay the image with a Google layer showing the boundaries of our provinces. The result is shown in Figure 1.68.
Climate change is now widely recognized as the major environmental problem facing the globe. A global response is required to better understand the natural resource, climate, which is vital to our well-being, health and prosperity. The problem is that climate is a very complex phenomenon. If it is already difficult to predict what the weather will be over the next four days, imagine how difficult it is to predict the climatic conditions of different regions 50 or 100 years into the future.

In order to predict climate we need to develop mathematical models to simulate how all the factors impacting on climate interact to produce the phenomenon known to us as the climate of the place we are living in. Think of the interaction within and among the atmosphere, oceans, land surfaces and ice caps.
The basic laws of chemistry, physics, and movement of fluids need to be built into the prediction models. To the above laws we can also add assumptions. The models need to make provision for different scenarios related to the future world population, the amount of energy we are expected to use in future, and the type of energy we will use (e.g. using fossil fuels vs. renewable sources such as wind and the heat from the sun).

Are you beginning to see the bigger picture? To integrate all data related to climate indeed requires a global response and effort from scientists. Climate models are typically raster-based. A raster GIS that is used to integrate all the data and run the modelling techniques on the data will consist of multiple layers of grids (each layer representing a variable related to climate). Each cell in a grid contains a numerical value that represents the value of the variable measured or estimated at that specific position on the Earth. Mathematical functions are then applied to the layers and the outputs are again mathematically integrated with other layers. As the process of modelling and integration of data continues, the layers become fewer and fewer until we finally end up with an end result. It is indeed true when we say that even super computers might require several months to complete one such simulation of future climate to produce the end result.

Figure 1.69 below illustrates an example of how GIS software has been used to overlay and merge different images and to remove duplicate information (overlapping images). The image is regarded as the most detailed true-colour image of the entire Earth that has ever been created. It offers a view of the land surface (e.g. global city lights), the oceans, sea ice and clouds. Months of observations (mainly from the MODIS sensor but also from the Advanced Very High Resolution Radiometer and images from the Defence Meteorological Satellite Program) have been combined to create a single mosaic of images at a one km square spatial resolution. It is a pity we cannot show you the image at the large scale at which it is intended to be used.

**Figure 1.69:** The original image has a one km × one km spatial resolution and is regarded as the most detailed true-colour image of the entire Earth that has ever been created.