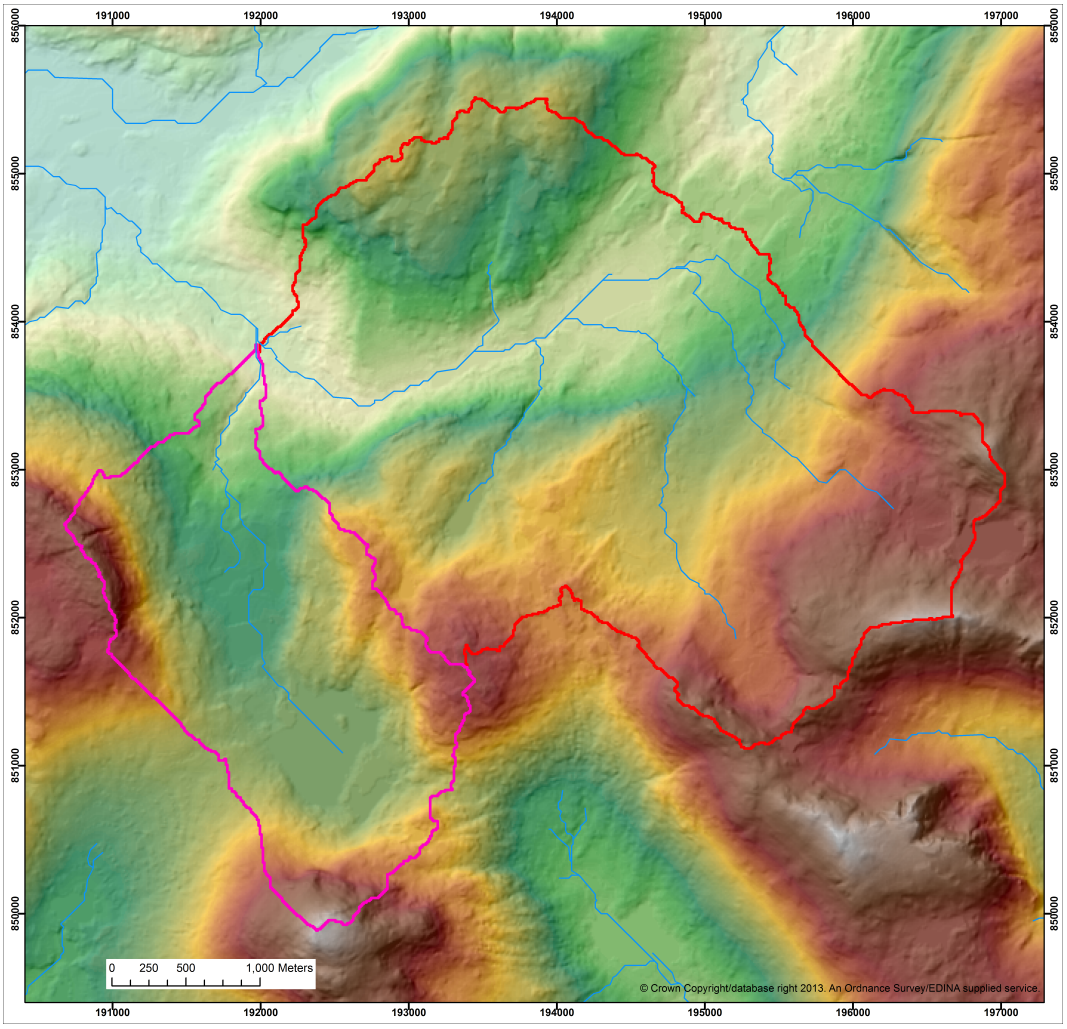
Introduction to GIS with ArcGIS

for Environmental Science



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University of Leeds

For ArcGIS version 10.4
10th October 2019

Contents

Major changes to workbook

Major changes to the workbook with the date on which they were made are listed here. If you have been using an older version of the workbook, please check to see which sections have been changed. The date of the workbook will always be shown on the front cover.

Table 1: Major changes to workbook. Newest first.

Date of change	Section no.	Summary of change
23rd August 2018	Chapter 5, page 49	Instructions updated for new versions of Roam and Data Download in all collections.
6th November 2017	Chapter 9, page 117	Added more figures to information on model building.
27th July 2017	Multiple sections	Added direct links to video clips. Clips are now available without needing to log in.

Continued on next page

Table 1 – continued from previous page

Date of change	Section no.	Summary of change
29th Sept. 2016	Section 12.6.1, page 169	Added alternative instructions for converting gpx files/gps data in version 10.4.1 of Arc.
Aug. 2016	Section 8.6.1, page 106	Changed to simpler method of adding XY data from Excel or csv.
Aug. 2016	All chapters	Added further video clips to VLE with references in the workbook.
Aug. 2016	All chapters	Change from Personal Geodatabases to File Geodatabases for storage. ESRI recommends this as more up-to-date format.

How to use this workbook

If you need this workbook in a different format, e.g. large print or a different font, please contact me - details at the end of this section.

It is worth reading through each little section before you start to follow the instructions. Certainly if you get stuck read the section fully to check that you haven't missed something!

The following conventions are used in this workbook to show things that you need to do:-

Tip boxes
Some handy tips and definitions have been put in tables through out the workbook. Check these for more information. You can find a list of these in the List of Tables at the beginning of the booklet.

Table 2: Tip boxes

Video Clip available in Minerva - Using the measure tool in ArcMap.
Direct link: `http://bit.ly/2h5ir8u`

This icon indicates that there is a video clip available for this task. The text next to the icon will explain where to find the video clip - either a web link or in Minerva. Note that many of the video clips have sound **- on cluster machines these will require that you plug in your own headphones. Computers in clusters do not have speakers.**

Menu items are formatted as "buttons" so the following statement -

File › New… › Blank Document indicates that you should click on the **File** command on the toolbar, then click on **New…** then select **Blank Document**.

Keys that you should press are shown as follows: Esc means press the **Escape** key on the keyboard.

Where tool names in programs are mentioned these can usually be found by hovering over the buttons in Arc to activate **tool tips**.

Question 0.1. Questions that you need to answer or exercises that you need to do on your own are in boxes in large font. If a question is numbered, then a possible answer will be given in the answers section at the back of the workbook (check the contents list). If there is an empty box below use it as a space in which to record your answers.

Write your answer here!

Techniques that are covered in earlier chapters of the workbook will not be repeated in later chapters, but will be referred back to, so remember to bring the workbook to each practical so that you can refer back to it. The workbook will remain available in Minerva, but further printed copies will not be provided.

Contact Details

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Chapter 1

Introduction to ArcMap

1.1 Learning outcomes

When you have completed this section of the workbook you should be able to

- demonstrate how to open a map in ArcMap
- select appropriate tools to navigate in a map document
- use layers to organise and display information on a map
- add information to a map layout and prepare it for printing or display

1.2 Introduction

As a GIS specialist you have been asked by your local MP to produce a map of the proposed High Speed Rail Link showing which parliamentary constituencies will be directly affected by the route, and which political parties hold those constituencies at the moment. The High Speed Rail Link is planned to run north from London, firstly to Birmingham and then in a second phase (also known as HS2) to Manchester and Leeds. The project is controversial and arguments both for and against can be found on the web.

For this first exercise I have created the basic map so that you can explore the ArcMap application and get used to basic navigation and functions. In future sessions you'll be preparing the data and setting up the basics for yourself.

1.2.1 Obtain the sample map

The sample map is based on the proposed route of the High Speed rail link from the West Midlands to Leeds and uses data from a number of sources with which you will become familiar during this module.

- download the **Chapter01_Data.7z** file from Minerva and save it on your M:/ drive.
- Extract the contents of the file to a folder called **gis** on your M:/ drive (see table 1.1 on page 2 if you need instructions for unzipping files). **Never try to use the contents of a zipped file in Arc without extracting them first - it won't work.**

NOTE: for the purposes of this module always navigate to your M:/ drive directly via your username, then create a folder called **gis** at the top level, and use that for all of your GIS projects. Even though you end up in the same place as **My Documents**, for some reason Arc recognises this route as not having any spaces in the path, something to which it objects.

Unzipping files
Zipping files is a way of compressing them to save space and make it easier to store and download them. You'll frequently need to extract or unzip files during this module. Zip files may have extensions of either `.zip` or `.7z`, both will extract or unzip if you use the instructions here. • In **My Computer** right-click on the zip file. • 7-Zip ⟩ Extract files... select the location to save the files to OK Right-click and **Extract all** (which is the unzip utility provided by Windows) will usually work on `.zip` files, but occasionally doesn't extract **all** of the files in the archive. 7-zip seems to be more reliable and works for `.7z` too. 7-zip is also open-source so if you want to install a copy on your own computer you can - just download it from `http://www.7-zip.org/`

Table 1.1: Unzipping files

1.2.2 Open the sample map

- Open Arc by searching for **ArcMap** in the start menu and clicking on it. Be patient - Arc opens slowly!
- From the Getting Started dialog select to Browse for maps... If you don't have the Getting Started dialog use File ⟩ Open...
- Navigate to the folder in which you unzipped the downloaded file and open **HS2_2017.mxd**.
- Your ArcMap window should look similar to figure 1.1, though the layers probably won't be opened out and the map itself won't look as colourful.

1.3 Navigation

The Tools toolbar (figure 1.2) gives you the tools to move around your maps and zoom in and out. Hover over the buttons to see the tooltips that explain what each button will do, or click on the **What's This** button on the standard toolbar and click on whichever button you are wondering about. Arc will give you a longer description of what the button will do.

Question 1.1. Try out each tool on the tools toolbar in turn and see what it does. Make notes for yourself in table 1.2 on page 2.

(Remember that possible answers to questions in the workbook are given in appendix A starting on page 203)

Table 1.2: Navigation tools in ArcMap

Tool	What it does
Zoom in	

Zoom out	
Full extent	
Zoom to layer (this one isn't on the tools toolbar. Right-click on the title of a layer in the table of contents zoom to layer)[1]	
Pan (also try holding down the mouse wheel and panning - useful when you're using another tool)	
Select features (try clicking on the map, and click and hold then drag and let go)	
Identify	
Find (try searching for **Cutting** in the **Feature** tab. Once you have a result, right-click a record and have a go with the commands from the menu, e.g. **Flash**)	

Video Clip available in Minerva - Using the "Find" button to find features in ArcMap. Direct link: `http://bit.ly/2h5hWeC`

1.3.1 Change scale

To change to a particular scale, e.g. 1:100 000, simply use the drop down box at the top of the window (figure 1.3) to select the scale you want. You can also type a scale in this box particularly if the scale you want isn't in the list, e.g. 50000 (note no punctuation), and it will change to that when you press **return**. This can be a useful way of zooming in or out.

1.3.2 Catalog window

The Catalog window in ArcMap allows you to explore and find out more information about your data. You'll find out more about this component in the next chapter but for now you'll just have a quick look the basic function.

- Click on the **Catalog** button at the right-hand side of the map window. (If the button isn't there go to Windows > Catalog to open it.)
- Explore the tree in the Catalog window - you should be able to see a heading such as **Home - HS2** which is the folder from where you opened this map. Look at the other files in the folder. Some of them should be the files that go with the layers in the table of contents.

[1] **Zoom to layer** is a very useful tool. It can be particularly useful if you have zoomed in or out too far and can no longer see your map properly. Zoom to layer and you'll usually be able to see enough to find the bit of the map that you really want to see.

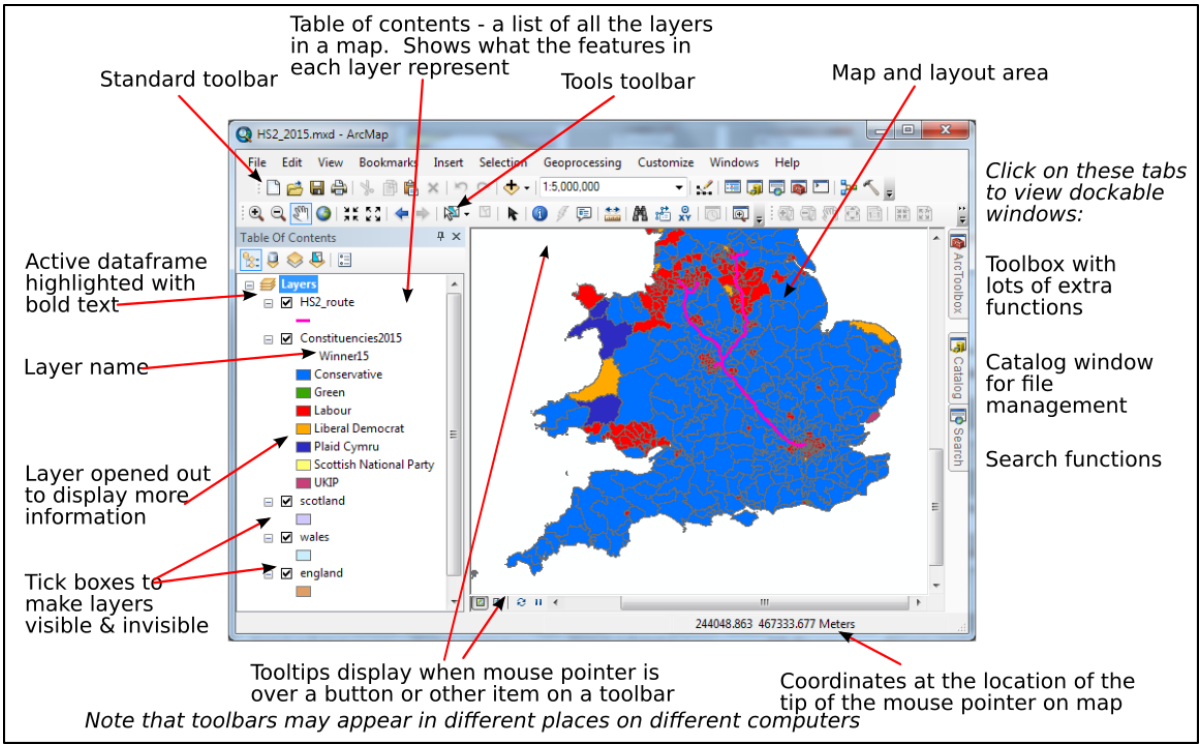


Figure 1.1: The ArcMap window (Esri software graphical user interfaces are the intellectual property of Esri and are reproduced herein by permission. All rights reserved.)

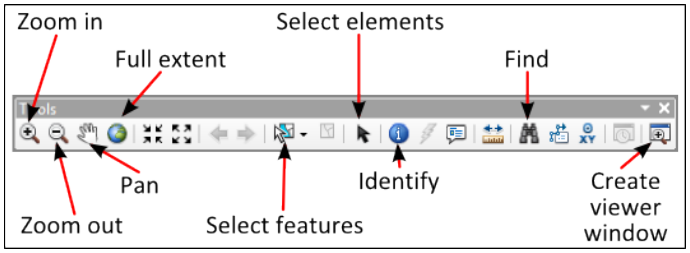


Figure 1.2: The tools toolbar

1.3.3 Spatial bookmarks

Spatial bookmarks enable you to go back to a view you have set up earlier. The map of the HS2 rail link has a bookmark set up for a particular scale and location for printing.

- Bookmarks » For printing.

To set up your own bookmarks

- Bookmarks » Create... type a name for your bookmark OK.
- The bookmark should be visible when you click on Bookmarks again.

Question 1.2. Change the scale of the map and pan to a different view, then go the bookmark that you have just set and check the scale again. How has the bookmark affected that?

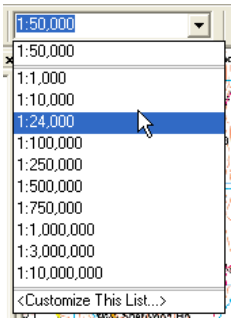


Figure 1.3: Scale dropdown box

Video Clip available in Minerva - Spatial bookmarks in ArcMap. Direct links: `http://bit.ly/2eQmVPA`

The **Bookmark manager** allows you to view all of your spatial bookmarks, sort them, and remove any that you no longer need.

- Bookmarks > Manage Bookmarks...
- Try **creating** another bookmark in the manager
- Experiment with the options in the manager, including **Zoom To** and **Pan To**,
- **Remove** the last bookmark that you created.

1.4 Working with map layers

Layers are an essential part of any GIS. Each layer is a reference to a particular data source. In the HS2 map file the layers include

- Constituencies 2017
- and HS2_route

Question 1.3. What are the names of the other layers in the HS2 map?

Layers are controlled from the **table of contents** to the left of the map window.

Go to this module in Minerva and watch the video clip on "Working with layers in ArcMap". Then get used to working with layers by following the instructions below.

Video Clip available in Minerva - Working with layers in ArcMap. Direct link: `http://bit.ly/2ttzfdJ`

1.4.1 Viewing contents of layers

- Click on the little cross symbol next to a layer to open the layer out and view the contents.
- Click on the little minus sign next to a layer to close an open layer.
- The table of contents also acts as a key to your map and shows the symbols for map features.

1.4.2 Renaming layers in the table of contents

You can make the layer names more useful by changing them in the table of contents. This also means that names are clearer when you generate legends prior to printing or exporting maps.

Note that you are not renaming the original data file by doing this, but just how the name appears in ArcMap.

- Right-click on **Constituencies2017** in the table of contents or slowly click twice
- Type the new name, e.g. **Party holding Parliamentary constituencies since 2017** and then press Return

1.4.3 Turn layers on and off

- Click in the box next to the **Constituencies2017** layer title to turn the constituencies off.
- Once a layer is in the table of contents you can turn the layer on and off to view other data without removing it.
- Turn other layers on and off and see what the map looks like but finish with all of the layers visible.

1.4.4 Add new layers

There are two simple ways to add new layers.

While it is possible to add data by dragging and dropping from Windows file explorer it really isn't a good idea to do that. It might look as if it has worked at first, but things can go horribly wrong... Instead use one of the following methods.

Video Clip available in Minerva - Adding new layers to ArcMap and Connect to Folder. Direct link: `http://bit.ly/2sueGtH`

Add data command

- File > Add data... navigate to the folder in which you unzipped the map. Go to the `Miniscale` folder and add **MiniScale_mono_R19.tif**.
- When you add tif or jpg files to ArcMap as a layer for the first time it will ask you whether you want to create pyramids. It's your choice! Pyramids can save time when you are zooming in and out of your map but take a while to create when you first load the file.[2]

[2] If you want more information about how pyramids work, search for **raster pyramids** in the Arc Desktop Help.

- If you can't find the folder in order to add the image follow the instructions in the **Connect to a folder** tip box (table 1.3).

This is a general basemap of the whole of the UK. Zoom in closer and you'll be able to see more detail (you will probably need to switch off the constituencies layer to be able to see it - if you need a reminder of how to do this check back to section 1.4.3).

Drag and drop

Instead of clicking on add data, the alternative is to simply find the file in the **Catalog** view and drag and drop it onto the map area.

- In **Catalog** open the `Miniscale` folder and drag and drop **MiniScale_standard_R19.tif** on to your map. If you drag it over to the table of contents you can choose whereabouts in the layer structure it will appear - add it to the top so that you can see it.
- If you can't find the folder to add the image follow the instructions in the **Connecting to a folder** tip box (table 1.3).

This layer is similar to the previous Miniscale layer, but is in colour rather than black and white.

Connecting to a folder
If you can't see your M:/ drive or USB device in the list of folders when adding data or viewing the catalog you need to **Connect to folder**. • Click on the **Connect Folder icon** (figure 1.4) and select your top level gis folder then click OK. • Now select your files from the folders that you can see. On cluster machines you'll probably find that you have to repeat this each time you start work in Arc, unfortunately.

Table 1.3: Connecting to a folder

Figure 1.4: Connect to Folder button

Video Clip available in Minerva - Connect to Folder. Direct link: `http://bit.ly/2sp6mA3`

1.4.5 Make layers transparent

You should be able to see that the polygons for the Constituencies layer are symbolised in a solid colour which hides the detail of the base map underneath. We need to make the layer **transparent** so that it is still possible to see the detail of the layers below it in the table of contents.

- Start by making sure that you have the constituencies layer switched on then right-click on the constituencies layer in the table of contents Properties > Display then enter a value in the box labelled **Transparent**.
- 0% is fully opaque, 100% is fully transparent. Try several steps between 30 and 60% and see what difference it makes.
- Click Apply to try out the value, OK to finalise it.

1.4.6 Change the order of layers

Changing the order of layers is simple once you remember that they "stack up" in the order in which they appear on the table of contents.

- To change the order of layers so that the **constituencies** layer is below the **MiniScale** layer, simply use the mouse to drag the layer to where you want it to lie in the table of contents.

> ***Using the above instructions move the layers around in the table of contents and change transparency for various layers, just to see what the possibilities are.***
>
> ***You may find that the England, Scotland and Wales layers are covering up the Miniscale layer, try moving them downwards in the table of contents.***

1.4.7 Grouping layers

The Wales, Scotland and England layers are related to each other and could be grouped together to organise the map. Amongst other advantages this would make it easier to turn all of the country outline layers on and off together.

- Right-click on the word **layers** in the table of contents. New Group Layer click on the New Group Layer that appears and give it a name such as **Country outlines** that tells you what the group is. Now use the mouse to drag the country layers so that they appear indented underneath the layer name.
- Try turning off the Country group layer to check that all of your layers are actually together. Don't forget to turn them back on again!

1.4.8 Remove layers

Perhaps we don't need the **England, Wales and Scotland** layers in our map after all.

- Right-click on the layers one by one then Remove.

Note that this doesn't delete the data from your disk, it just removes the link to it from your map.

Video Clip available in Minerva - Working with attribute tables in ArcMap.
Direct link: `http://bit.ly/2s9y1k9`

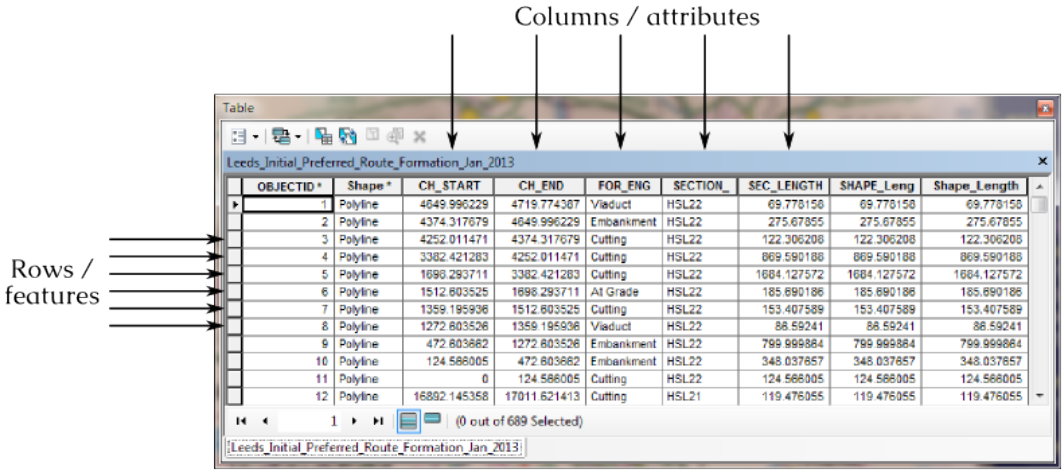


Figure 1.5: Attribute table

1.5 Viewing an attribute table

Data for GIS is stored in tables as **feature attributes**. You can view the attribute tables to get an overview of your data, and to carry out some useful operations.

- Right-click on the **HS2_route** layer in the table of contents and Open Attribute Table.

You should have a window similar to figure 1.5.

Have a look at the structure of the table -

- Each row contains one record - the details for one **feature** on the map.
- Each column is one field - or **attribute**. That is, related information for each feature, such as Label.
- If you are working with polygon features in a geodatabase[3] the **SHAPE_Length** and **SHAPE_Area** fields will automatically be created and filled in with the length of the outline and the area of the polygon.
- If you are working with line features in a geodatabase, such as you are here, the **SHAPE_length** field will automatically be created and filled in with the length of the line.

The measurements will be in **map units** - find out what these are set to by going to View > Data Frame Properties > General in the main ArcMap window. Look at the **Units - Display field**.

Question 1.4. What are the map units of the current map? Make a note in the box below. This information will be useful later.

[3] You'll find out more about geodatabases later so don't worry too much about this for now.

1.5.1 Selecting features in the attribute table

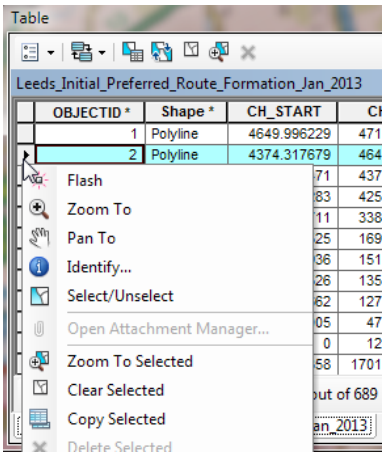


Figure 1.6: Selecting a feature in the attribute table - the "little grey area"

Figure 1.7: Attribute table options button

Video Clip available in Minerva - Selecting features with the attribute table. Direct link: `http://bit.ly/2fb3j8T`

- In the attribute table click on the little grey area to the left of the one of the records (see figure 1.6). The feature will be selected in the table, and will also be selected on the map. Move the attribute table to one side if you need to, to check this on the map.
- You'll probably need to right-click on the little grey area, then select Pan to. The map will move so that the selected feature is in the centre, and the selected feature will flash.
- Use the **Select Features** tool from the tools toolbar to click on a part of the route on the map and notice that this selects the same feature in the attribute table.
- In the attribute table click on the first of the features. Now hold down the Ctrl key and click on the third feature. In this way you can select more than one feature at a time.
- To view only your selections click on the Selected button at the bottom of the window. To view all records again click on Show all records. Remember that if you hover over a button you'll see a tooltip telling you what the button does.
- To clear selections click on the Options button (figure 1.7) Clear Selection.
- Right-click on the **SHAPE_Length** column heading and click on Sort Ascending. This will reorder the table from low to high by the length of the line.

Play around with the attribute table and explore what else you can do.

1.6 Some simple analysis: Buffering

ArcMap provides a wide range of tools with which to analyse data. For this introduction you'll run one of the simpler tools to create a layer which shows the areas within 10 kilometres of the proposed route.

- Right-click on the **HS2_route** layer in the table of contents and **Zoom to Layer**
- From the menu at the top select Geoprocessing > Buffer to open the dialog box
- Fill in the fields as shown in figure 1.8
  - To add **HS2_route** as the input click on the down arrow next to the **Input Features** box
  - Click on the browse button and choose where you want to save the output, don't forget to give it a sensible name
  - Set the **Linear Unit** as **10 Kilometers**
  - Set the **Dissolve Type** to **ALL** - this means that the buffer will be calculated for all records as a whole, rather than for each one individually.
- Click OK

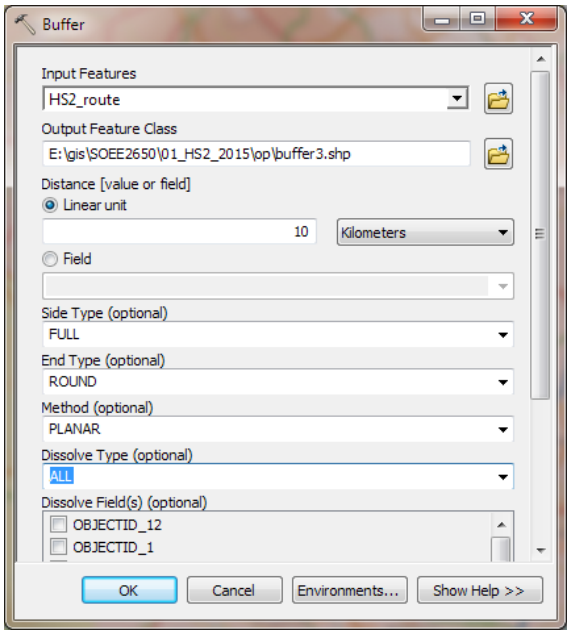


Figure 1.8: Filling in the Buffer tool

Figure 1.9: Map showing a 10 km buffer around the proposed route of HS2

You'll need to wait for a while for the tool to finish running but when it does the **Cancel** button will change to **Close** and the output layer should be automatically added to your map. If you make the buffer layer transparent (section 1.4.5 on page 7) it should make it possible to see the places underneath it.

1.7 Saving a map

IMPORTANT: Develop the habit of saving your maps at regular intervals. ArcMap can crash when carrying out some operations and you don't want to lose all of your work. Crashes can also corrupt data files, so copy the whole of your gis folder to another location or drive at frequent intervals (i.e. create a **backup** copy). It can be useful to rename each backup folder with the date of the backup, then you can make sure you keep a couple of copies to go back to if there are problems.

- File > Save.

1.8 Symbolising a layer

Open the attribute table for the **Constituencies** layer again and have another look at the data that it contains. The column headed **Winner2017** contains information on which political party is in power in each constituency. In Arc it is easy to colour, or **symbolise** the data so that you can visualise it.

- Close the attribute table.
- Right-click on the **constituencies** layer and click on **Properties**
- Go to the **Symbology** tab

Video Clip available in Minerva - Symbolising a layer by categories in ArcMap. Direct link: `http://bit.ly/2ePRqVG`

At the moment the layer is symbolised as a single symbol - a single random colour which is used for all polygons.

- Select **Categories** in the list on the left of the properties dialog
- then select **Unique Values**
- in the **Value Field** box that appears select **Winner2017** - the field we were looking at earlier.
- click on Add All Values

You should find that you get a list of the values of Winner2017 to which Arc will have assigned random colours - figure 1.10.

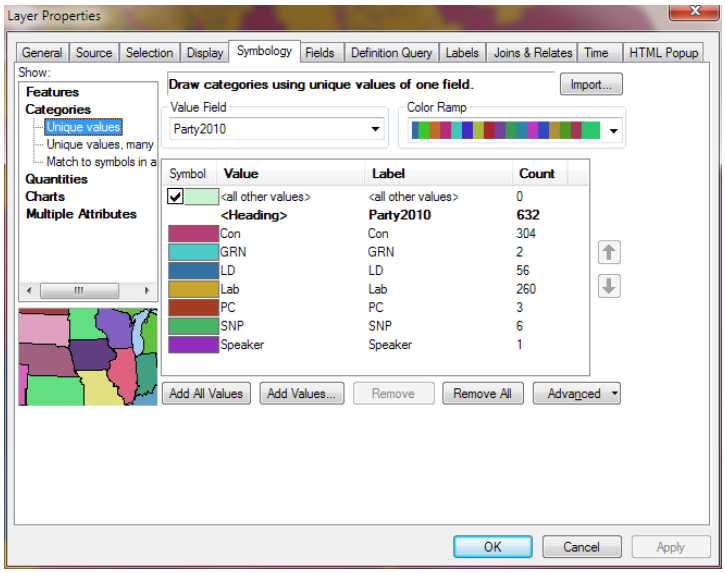


Figure 1.10: Setting symbols for a layer with multiple categories

- You can change the colours of the fill and thicknesses of the outlines by double-clicking on each symbol in turn - have a go now. Try making some of the outlines thicker, and change the fills to the usual colours associated with the political parties, Con to blue, Lab to red, for example.
- Click on Apply to see the result and OK when you are happy with it.
- You may find it easier to see what you are doing if you turn off the base map layers.

1.9 Select by location

Symbolising the constituencies does make it a bit easier to see which political parties hold the constituencies affected by the rail line, but now that you have your data in a GIS, why not take advantage of its power?

We'll use **Select by location** to select and export the constituencies through which the route is planned to pass.

Video Clip available in Minerva - Select by location. Direct link: `http://bit.ly/2fb67CP`

- Selection > Select by Location...
- fill in the dialog following figure 1.11
  - **Target layer(s)** should be the layer which contains the features that you wish to select
  - **Source layer** is the layer that indicates the location you want to select against.
  - We'll also add a small margin so that constituencies which have parts within 1 km of the route will also be selected, so tick **Apply a search distance** and enter the distance you wish to use, in this case **1000** meters.
- OK

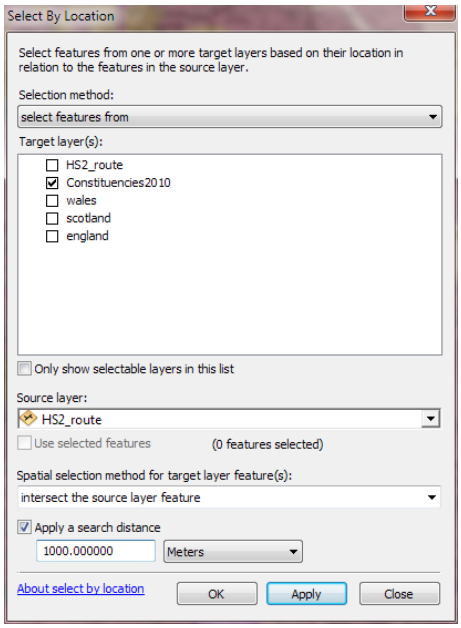


Figure 1.11: Select by location

Now your map should show the constituencies which are either intersected by the planned route, or within 1 km of it, outlined in the selection colour - probably bright blue in this case.

Once you have selected the features you can, if you wish, make the selection permanent by exporting it to a new feature class.

- Right-click on the layer containing the selection

- Data > Export Data...
- Check that you are exporting **Selected features**, choose where to save the new Output feature class and give it a name, making sure that you save it as a shapefile for now, not a geodatabase feature class - see figures 1.12 and 1.13 then OK
- Choose to add the new layer to your map

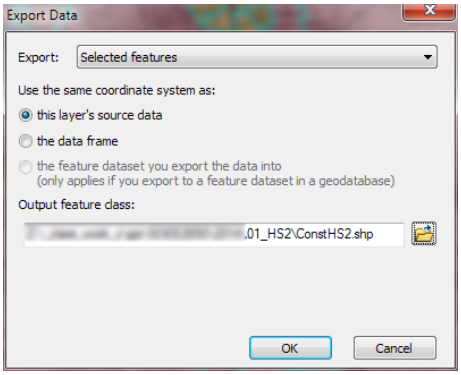


Figure 1.12: Exporting a selection to a new feature class

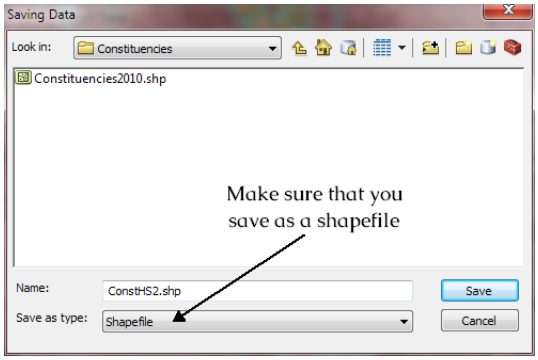


Figure 1.13: Saving exported data as a shapefile

Now **remove** the original constituencies layer and you should be left with just those constituencies which you had selected. Follow the instructions in section 1.8 on page 12 to symbolise the constituencies according to political party again.

1.10 Layout view - printing a map

So far we have been using the **Data view**. If you print the map from the data view you have little control over it's appearance. To produce a professional-looking map you need to use **Layout view**. The information given here is just a quick introduction, you'll cover layout and presentation in more detail in a later chapter.

- View > Layout View.
- Go to the bookmark "**for printing**" to select the predetermined location and scale.

The layout window (shown in figure 1.14) looks similar to the data window, but shows the layout as it will appear when printed. You still have the table of contents on the left of the screen, and the tools toolbar visible, but you now also have the **layout toolbar** available. (If the layout toolbar isn't visible go to Customize > Toolbars > Layout toolbar to activate it.)

- Explore the layout toolbar. Use the buttons to zoom in and out of the layout and move around it.
- The final button on the toolbar changes the template. Try this out, but you probably won't want to save the end result!
- Try the tools on the tools toolbar in this view too.

Question 1.5. What is the difference between zooming with the tools in the layout toolbar and with the tools in the tools toolbar in layout view?

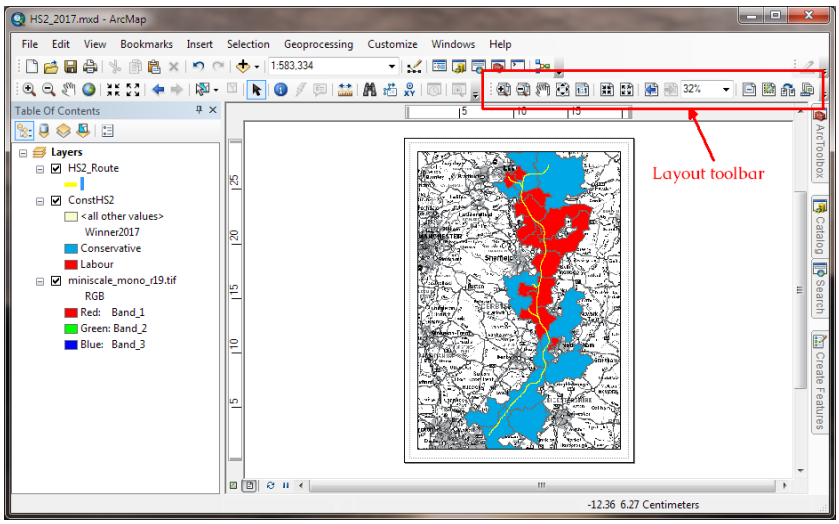


Figure 1.14: Layout view and toolbar (your toolbar will probably open in a different place in the window)

1.10.1 Resizing the data frame in a layout

When you first change to layout view the area of the map that you see in the data frame will not necessarily be the area that you want to show. Changing the size of the data frame is easy, but can take a little experimentation!

Video Clip available in Minerva - Resizing the data frame in a layout.
Direct link: `http://bit.ly/2h2YQWp`

- Click once on the data frame (that is the main map area)
- When the data frame is selected you should be able to see that it is outlined (usually in turquoise) with small boxes at the corners and on each side.
- Use the boxes as “handles” to resize the data frame by dragging.
- Keep an eye on the scale dropdown! You may need to put this back to your required scale and then resize the data frame again.
- Keep repeating this until the size/extent and scale of your map are correct

1.10.2 Adding objects to the layout

Most of the maps that you create will need to be printed out with additional content such as a title, a key or legend, a scale bar and some text. These can all be added in layout view.

Video Clip available in Minerva - Adding a scalebar, title and text to a layout. Direct link: `http://bit.ly/2s9iMYO`

To add a title

- Insert > Title type your title, e.g. "Parliamentary consituencies on the proposed route of the High Speed Rail Link" then press Return.
- Use the **Select Elements** tool (the black arrow head) from the tools toolbar to move the title to the top of the page where it doesn't overlap the map.

To add a scale bar

- Insert > Scale bar... Select a format from the examples available OK.
- The scale bar will be added to the centre of your view. Use the **Select Elements** tool to move the scale bar to the space just below the map.
- You can resize the scale bar by dragging the blue boxes around the edges when it is selected (figure 1.15). Note that as you resize it, the scale stays the same as the map scale.

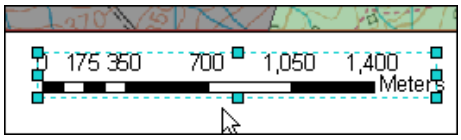


Figure 1.15: Changing the size of the scale bar

To add text

Use the **Insert** menu to add the following text to the remaining space at the bottom right of the map, replacing **(yy)** with the current year. (See the box below for how to add the copyright symbol.)[4]

> ***© Crown copyright and database rights 20(yy). Ordnance Survey (100025252)***
> ***Contains public sector information licensed under the Open Government Licence v3.0.***

- Double-click on the text once you have added it and use the **Change Symbol** button to change the font to **size 8**.

Copyright acknowledgement is important! You will all have agreed to the Digimap terms of use when you registered. Every map that you produce using data from Digimap should have the copyright statement printed on it as above. If you are using data from another source check the terms and conditions for that source.

[4] You can check the current form of the copyright text via the Resources link on the Digimap homepage. Under **Popular Resources** on the right, look for **Digimap Licence Agreements** and look for the appropriate dataset. In each case the recommended statement is part of the way down the page under **In return, You must:** (April 2019)

Adding the copyright symbol to your text
To add the **copyright symbol** - ©- to your text • check that the Num lock is on on the keyboard • hold down the Alt key • use the number pad to type 0 + 1 + 6 + 9 • release the Alt key

Table 1.4: Adding the copyright symbol to your text

If you are using data from another source check the terms and conditions for that source. The HS2 route is under the Open Government Licence[5].

There is more information about adding text and copyright acknowledgements in section 6.4.2 on page 72.

Adding a basic legend to a layout

For now we'll add a legend using default options.

Video Clip available in Minerva - Adding and editing a map legend. Direct link: `http://bit.ly/2urgYuF`

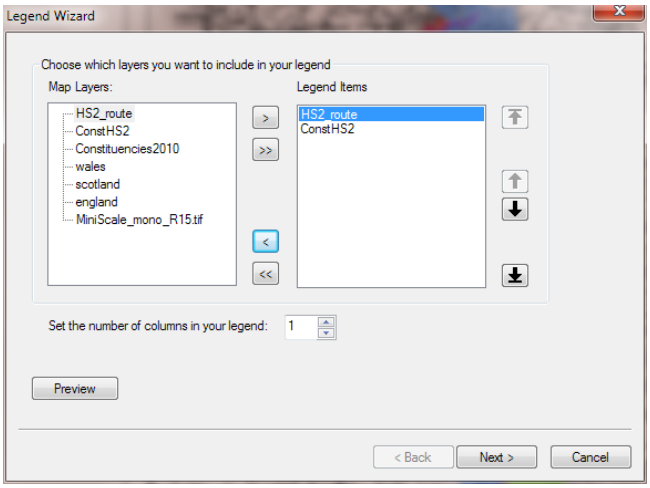


Figure 1.16: Creating a legend with the legend wizard

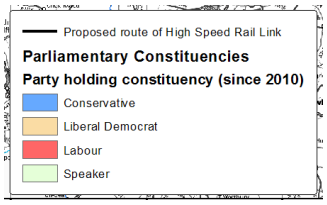


Figure 1.17: Example of a legend for the HS2 map

- In layout view - Insert » Legend...

[5] `http://www.nationalarchives.gov.uk/doc/open-government-licence/` Last visited: 18th September 2018

- The legend wizard should open (figure 1.16). ArcMap will probably add all of your layers to the right-hand box automatically. Use the arrow keys to remove and add layers and to order them as you want them to appear. See the example legend (figure 1.17) for the list of layers to add.
- Set the number of columns
- Next then change the legend title to something appropriate and Next.
- If your legend will be overlapping your map set the background to white. If you want to, try giving it a border.
- Next » Next » Finish.
- Move your legend to an appropriate position on your map.

You can double click on the legend to change its properties and settings. Experiment to see what you think looks best - it doesn't matter if your legend looks different from mine as long as it is clear and gives all of the information that it needs to.

Try the following -

- Double-click on the legend to open the Legend Properties » Items.
- Make sure that the **All items** check box is checked, then click on the Symbol... button.
- Use the **Options** to change the colour, font, size and style or text.

To add a measured grid

Measured grids add labelled grid lines to a layout. If you are using Ordnance Survey data then you can easily add National Grid lines and numbers making it easy to include coordinates around the edge of your map and read grid references.

Video Clip available in Minerva - Adding a measured grid to a map. Direct link: `http://bit.ly/2uruf6q`

- View » Data Frame Properties » Grids » New Grid » Measured Grid.
- Select the appearance that you prefer. Check that the coordinate system is set to <**Same as data frame**>, and check that the Intervals are suitable to the scale and units - in this case set both of the axes to **10000**.
- Next » Next » Finish » OK.

1.11 Printing or exporting a map

To **print** your layout:

- Change paper size and direction using the File » Page and Print Setup... dialog.
- To print - File » Print... then select the correct printer.
- Check the image at the bottom right of the print dialog to make sure that your map fits properly onto the paper you have selected. If you need to make any changes click on the Setup... button next to the printer selection box. Then click on OK to print.

To **export** a map to pdf or an image:

- Change paper size and direction using the File > Page and Print Setup... dialog.
- To export - File > Export Map...
- Select the format that you wish to export and give your file a name. Check the other options and change as appropriate (you may find that the defaults are OK) and then Save

1.11.1 Suggested layout

Your final map could look something like figure 1.18. It is unlikely to look identical as you should make your own decisions about where to place elements and how to display your map.

Print your final layout and bring it to the next class. I will try to speak to all of you individually during the course of the practical and will give you feedback on this exercise.

1.12 Recommended reading: Introduction to GIS

Many of the books in the reading list[6] have a general introduction to GIS which explain what it is and how it is used. Suggestions include the following:

- Chapter 1: *What is GIS?* IN Heywood, I., Cornelius, S. and Carver, S. (2011), pp. 2-30.
- Chapter 1: *Systems, Science, and Study* IN Longley, P.A. et al. (2011), pp. 3-37.

In addition have a look at the other books under **Geography K-13** on level 9 in the Edward Boyle Library.

For more information about basic use of ArcMap, ArcCatalog and Arc Help look at the book by Kennedy, M. (2013). He specifically covers using ArcCatalog and ArcHelp - use the index to find the sections that you need.

1.12.1 Videos online

If you find videos helpful then search online for specific tasks in ArcMap and you will find plenty. Make sure that you are viewing videos for ArcMap/ArcGIS rather than ArcOnline or ArcGIS Professional, though.

Examples include:

A basic introduction to ArcMap 10 - `http://bit.ly/1C08CKj` - from the University of Toronto Library

`http://bit.ly/1u3RWk4` - longer videos from Cornell University which cover a lot of the basics.

[6] Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

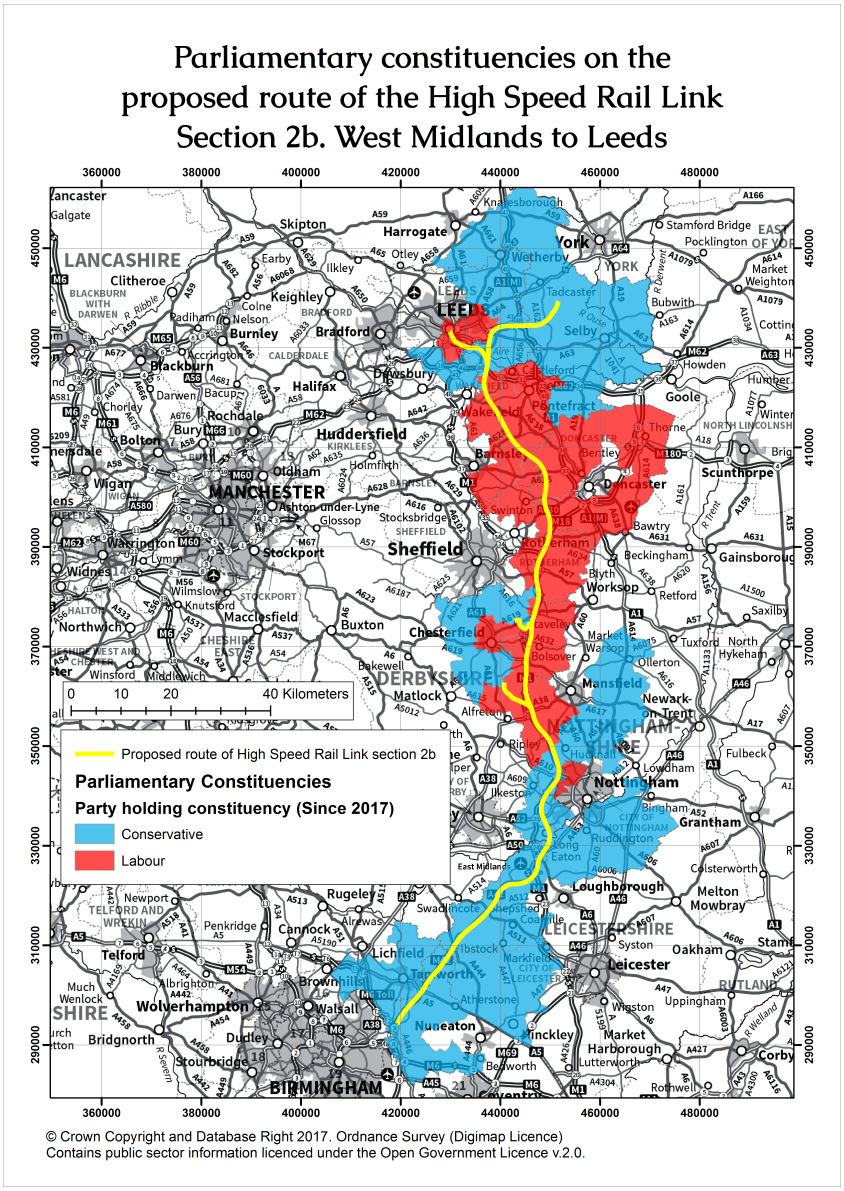


Figure 1.18: Possible layout for HS2 map. Your map should not look identical to this as you should make your own decisions about how to lay it out.

Chapter 2

Introduction to the Catalog

Use the **Catalog window** in ArcMap to manage your GIS data[1], and particularly for tasks such as moving and deleting files, where you would usually use My Computer. Changes to GIS layers often affect several other files and tables and Catalog helps to maintain the correct relationships.

2.1 Learning outcomes

When you have completed this section of the workbook you should be able to

- understand the basic principles of file management for GIS
- identify when to use the Catalog to manage GIS data
- use the Catalog to view GIS files

2.2 *****Warnings about file management*****

Boring, but **essential!**

You don't want to spend lots of time creating a map only to find that it won't open when you come to print it, or that you can't find the files that go to make up your map. A lot of students have wasted a lot of time because they didn't follow the file management rules which are laid out in table 2.1 on page 22.

The table summarises the rules, more detailed information was given in the lecture segment. See the slides and the video in Minerva.

Video Clip available in Minerva - File management for ArcGIS. Direct link: `http://bit.ly/2gNqFBN`

2.3 Absolute and relative paths between maps and data

Arc layers **reference** datasets rather than contain them.

[1] there is also a standalone catalog application called **ArcCatalog**. Open it by searching for ArcCatalog in start menu

Summary of file management rules - ignore at your peril!

If you have problems with a project in ArcGIS check that you have followed the rules below before you ask for help.

- Keep your files organised - create a folder for each project and keep all the files for that project in that folder. Make sure that you remember where you are saving files. If you forget you'll probably have to waste time downloading the files and processing them again.
- Don't use spaces or non-standard characters in folder or file names - these can cause problems for ArcGIS. Stick to alpha-numeric characters.
- Keep file paths short but informative - that is the whole list of folders and the file name. The total should be less than 256 characters. Make sure you use names that mean something to you for future reference!
- If you have problems opening / moving / unzipping files - check disk space! Remember GIS data needs a lot of space and can quickly fill your M:/ drive.
- Don't save files to **My Documents** or **Documents and Settings** because of the spaces in their pathnames. On the University system start at the root of your M:/ drive (your username rather than your full name) and navigate from there.
- Don't save files to the **Desktop, the harddisk of a cluster machine** or any **temp or temporary** folder. The files will have disappeared by the next time you look for them.
- Don't save zip files to a temp or temporary folder or open them without saving them first - you may be refused permission to unzip them.
- Use ArcCatalog or the Catalog window in ArcMap to move and delete gis files, not Windows Explorer or My Computer. ArcCatalog is specially set up to handle gis files with more than one part without breaking them.
- If you are having trouble carrying out an operation in ArcMap check that ArcCatalog is not open too - and the reverse if you are having problems in ArcCatalog.
- Keep a backup copy. Arc does crash and can damage datafiles as well as your map.

Table 2.1: Summary of file management rules

By default layers link to datasets through their source property using absolute paths. This means that once you have saved a file created in ArcMap or ArcScene to a drive, e.g. your M:/ drive, if you then move it to a different drive, e.g. a USB stick, you will lose the links to your data. This is not a problem if you always use the map from your M:/ drive, but if you want to work on it in a different environment or save it to a memory stick it can become a problem. It is advisible to change paths to relative and instructions for this are given in section 4.3.1 on page 38.

2.4 Opening Catalog

Most of the operations below will work in ArcCatalog too, but sometimes in a slightly different manner.

- Open ArcMap.
- You may have a tab on the right-hand side which says **Catalog**, if you have, just click on it.
- Otherwise, Windows > Catalog will open the Catalog which should look something like figure 2.1.

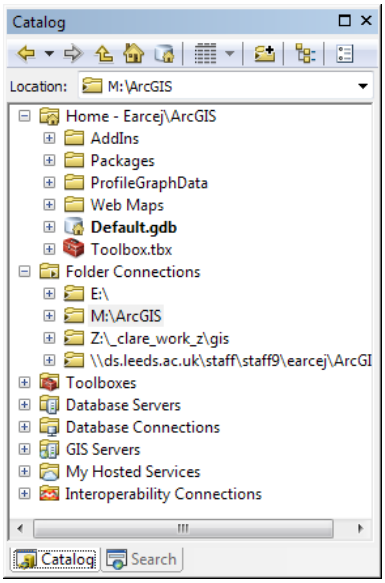


Figure 2.1: The Catalog window in ArcMap

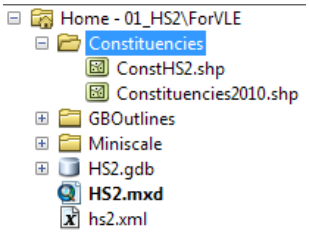


Figure 2.2: File tree in Catalog

2.5 Navigation

- Use the tree view to navigate to the folder in which you saved the downloaded files, using **Connect Folder** if necessary (see table 1.3 on page 7 or view the video in Minerva.)
- Open out the `Constituencies` folder by clicking on the **+** sign next to the folder name. The contents should look something like figure 2.2.

Displaying file extensions in Catalog
You may not be able to see the file extensions such as "**.shp**". The exercises in this section will assume that you can so make them visible as follows - • To turn file extensions on click the **Options** button at the top right of the Catalog window • Make sure you are on the **General** tab and click to remove the tick in the box next to Hide file extensions > OK.

Table 2.2: Displaying file extensions in ArcCatalog and Catalog

Open My Computer from your desktop and have a look at the `Constituencies` ***folder.***

Question 2.1. What is the main difference between the contents of the folder in Catalog and the contents of the same folder in My Computer? (Apart from the different icons)

Shapefiles are a specifically GIS format which can be read by many different GIS programs. The exercise above should show you why it is best to move files around in the catalog rather than the usual file manager.

In a similar way open out the `HS2.gdb` ***folder in Catalog (note that it has a different icon to folders) and have a look at the contents, then look at the same file in My Computer.***

Question 2.2. What is the main difference between the contents of the folder in Catalog and the contents of the same folder in My Computer?

This is a file geodatabase[2]. File geodatabases are a specific Arc format, though more GIS programs are starting to use them. They are useful as a much more efficient method of storage than shapefiles. You will need to be familiar with both for future exercises.

2.6 Viewing files and file information

You can open a window which shows you more details about the files that you select in the table of contents.

2.6.1 Previewing data and the attribute table

- In the Catalog window open out the **HS2.gdb** file. Right-click on **HS2_route_Leeds** and click on Item Description, then click on the **Preview** tab at the top of the window. Your screen should look similar to figure 2.3.
- This view is useful for quickly checking the contents of layers. Click on other folders and files in the same folder and preview them. Also open the **Miniscale** folder and preview the tif files in there.
- Return to the **HS2_route** feature class and this time select **Table** from the preview drop-down box at the top of the window. Now you can look at the details of your data in the **attribute table** (figure 2.4).

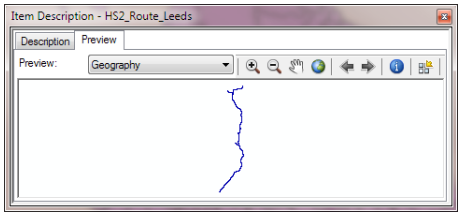


Figure 2.3: Previewing a feature class in ArcCatalog

[2]If you're not sure what a database is then you can find a brief definition by searching at `http://support.esri.com/en/knowledgebase/GISDictionary/search`

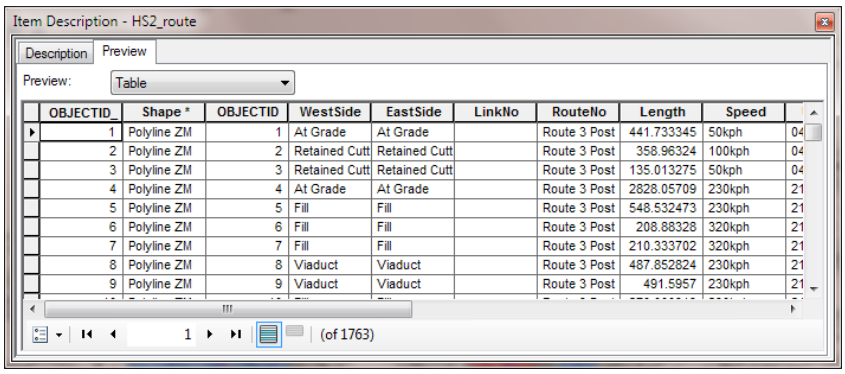


Figure 2.4: Viewing the attribute table of a feature class in ArcCatalog

2.6.2 Viewing file descriptions or metadata

- Finally, click on the **Description** tab for **HS2_route**. This tab gives you background information, or **Metadata**[3], about the file that you have selected.
- Have a look at the information that is available about this layer and then close the window.

2.6.3 Viewing file properties

Other important information about the file will be available through the properties.

Video Clip available in Minerva - Viewing file properties and information in ArcCatalog. Direct link: `http://bit.ly/2h49Z9s`

- Once again right-click on **HS2_route_Leeds** in the catalog but this time select Properties.
- Have a look at the contents of the various tabs that are available. Don't worry if most of this doesn't mean anything to you at the moment.
- You will find that you need to use the **XY Coordinate Systems** tab frequently. Click on it now and have a look at the information.

Question 2.3. What are the coordinate details for the HS2_route layer? Make a note of them below.

Current coordinate system:
Projection (if Projected Coordinate System):
Linear unit:

Finish by closing the properties.

[3] **Metadata** is data about data. It is important because it helps to organise information. Think of the library catalogue which contains metadata about books and electronic resources. In this case the metadata should include information about the source and contents of the file.

Chapter 3

ArcGIS Desktop Help

ArcGIS Desktop Help is actually very helpful - unlike some software help information. There are detailed instructions and tutorials on how to do all sorts of useful things in ArcGIS.

3.1 Learning outcomes

When you have completed this section of the workbook you should be able to

- use ArcGIS Desktop Help to answer your questions about using ArcGIS.
- demonstrate different ways of finding information in ArcGIS Desktop Help.

3.2 Where to find ArcGIS Desktop Help

The same information is available either from within the program, or on the web.

3.2.1 From within Arc

- Help > ArcGIS Desktop Help on the menu bar in either ArcMap or ArcCatalog, or just press the F1 key (figure 3.1).

3.2.2 On the web

If you find that some of the links don't work via Arc, or for some reason it appears in a language other than English (it does happen in the computer cluster, for some reason!) Desktop Help is also available on the web (figure 3.2) at

`http://desktop.arcgis.com/en/arcmap/`

This looks like a page which is trying to sell you ArcGIS Desktop, but the links underneath - e.g. **Build Maps** and **Perform Analysis**, give access to all of the help information, and the **SEARCH** button on the grey bar at the top of the page will allow you to complete the following exercises.

When searching make sure that you choose answers that refer to ArcGIS Desktop and not to ArcGIS Professional or ArcGIS Online.

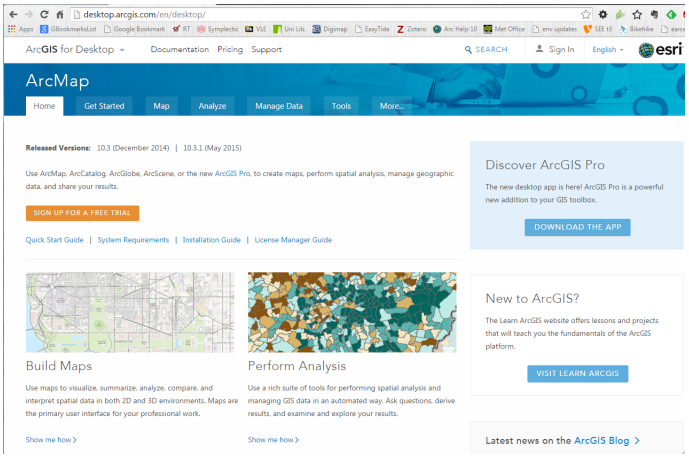


Figure 3.1: ArcGIS Desktop Help

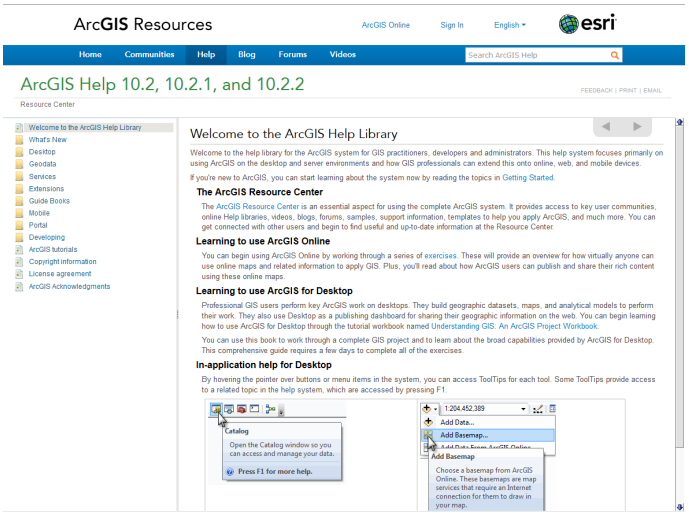


Figure 3.2: ArcGIS Desktop Help on the web

3.3 Using ArcGIS Desktop Help

- Browse by using the **Contents** tab or search by using the **Search** tab.
- There is an extensive **GIS Dictionary** which can be very useful when you are wondering what a particular term means. Go to `http://support.esri.com/en/knowledgebase/Gisdictionary/browse` on the web.
- Look under Contents > ArcGIS Tutorials in the version of help avialable via ArcGIS Desktop, to find detailed tutorials for all sorts of tasks.

Practice using ArcGIS Desktop Help by completing the exercises below.

"Raster" and "Vector" are the two main types of data structure used in ArcGIS.

Use the GIS dictionary to find out what "Raster" and "Vector" mean and write definitions in the boxes below, using diagrams if it will help you to remember the difference.

Question 3.1. Raster:

Question 3.2. Vector:

One particular data format that you will come across on several occasions is the shapefile. Search Arc Help for shapefile.

Question 3.3. What types of geographic features can be stored in a shapefile? What is the file extension that shows you that this is the format of a file in Catalog?

Use the search (on the web) or Search tab (locally) to look for "Go To XY" and click on "Using the Go To XY Tool". This is a technique that you will find useful in future exercises. Follow the instructions there to navigate to

x = 437600
y = 429689

on the map of the HS2 route and draw a callout at the location. (Note: measurements should be in meters).

Question 3.4. Use the Identify tool (section 1.3 on page 2) to find out the name of the Constituency at that location and write it in the space below.

Data preparation for Chapter 4: Finding and using spatial data

Being able to find, download and prepare your own data is an essential part of using GIS. For the exercises in the next class you will need to download several datasets. While these should not take too long to download and prepare, don't leave it until the last minute. Websites can become unavailable either permanently or temporarily, or computers can crash.

If there are problems with a website then try again later. If the problems persist please get in touch with me (c.e.gordon@leeds.ac.uk) and I will try to contact the site or find an alternative source of data.

Data required

Download the following data from the web before the next class. Full instructions are in the sections below.

- ***Rivers from ArcGIS Online***
- ***European River Catchments from the web***
- ***Ordnance Survey miniscale map of the UK***
- ***SRTM height data for part of Skye, off the West coast of Scotland***

You will also need to download `Chapter04_Data.7z` from Minerva. Please unzip it to your GIS folder using 7-zip (table 1.1 on page 2). Instructions for using this file will be given during the class.

Rivers from ArcGIS Online

ArcGIS Online is a fantastic resource of maps and data that you can add to your own maps. The **Search** tab on the right of the ArcMap window provides an easy way to look for data.

- Open a new blank map in ArcMap
- Click on the **search** tab on the right of the window (if it isn't visible you need to go to Windows > Search to open it).
- Use the dropdown to change the search from Local Search to **ArcGIS Online**
- To limit this search click on **Data**
- Search for **rivers Europe**

You are looking for a layer with yellow diamond symbol - see figure 3.3. These are **Layer packages** which can be added to your own maps, rather than complete maps. For this exercise use the layer package **Rivers and lake centerlines of Europe**.

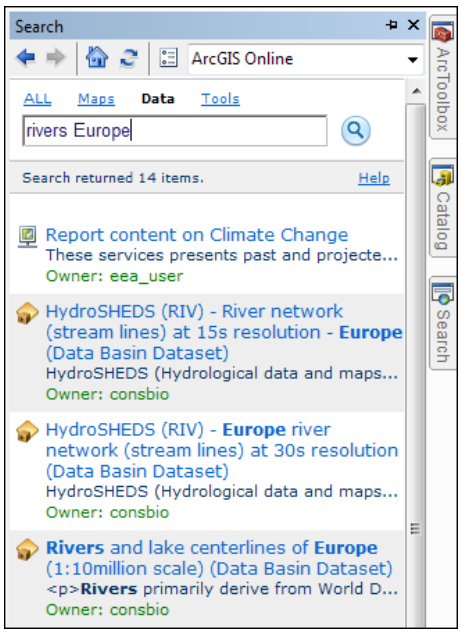


Figure 3.3: Searching for data in ArcGIS Online

- You can see more information about the layer by hovering over it.
- Click on the title to add to ArcMap.

ArcGIS automatically saves the layer package to your default location - on computers in University clusters that is a folder called **ArcGIS** on your M: drive. From there it is easy to save the data to the location in which you want to store it for future use, by **exporting** it.

Export a layer

To export a layer to a location and format of your choice:

- Right-click on the rivers layer in the table of contents then Data > Export Data...
- Export **All features** using the same coordinate system as **this layer's source data**.
- select a location to save the new feature class (NOT the default geodatabase - it probably won't save if you select that on a University cluster) and give it a name that means that you will be able to remember what it is in future and check that you are saving it as a **shapefile** (look at the drop-down choices) then Save > OK

It doesn't matter whether you select to add the layer to the map or not as you'll be closing this map without saving it anyway, but the layer will still be stored separately.

Once you are sure that you have all of the data you need safely stored where you want it, you can go ahead and delete the packages from the default location to save space.

European River Catchments from the web

Inevitably the web is an extremely rich source of spatial data. A lot of government and related bodies make data publically available online. Sometimes you have to register first even when the data is available without charge, but the European source below allows you to download data without registering.

`http://www.eea.europa.eu/data-and-maps/data/european-river-catchments-1`

Download the zip file from the above URL which has the title **Zipped shapefile, vector polygon**, you may need to tick a box to show what purpose you will be using the data for, select **Education**. Unzip the downloaded file to your GIS folder using 7-zip (table 1.1 on page 2). You should find that you have a shapefile with a name something like `ERC110108v2.shp` (plus the other files that together make up a shapefile).

Ordnance Survey Miniscale map of the UK

You will also use a general map of the UK which you can find in the `Chapter04_Data.7z` file which can be downloaded from Minerva. This file was originally downloaded from Digimap which you will explore for yourself during the practical.

SRTM data via Earth Explorer

The web page at `https://lta.cr.usgs.gov/SRTM1Arc` gives detailed information about the SRTM data sets and it is worth having a look at this to understand the data that you are going to use.

If you are working in the UK then you will have more detailed height data available to you, but SRTM data is possibly the best height data easily available for many areas, e.g. Turkey. One limitation is that it is not available above 60 degrees north, and below 60 degrees south - so it doesn't cover most of the Shetland Islands to the north, for example.

Obtaining SRTM data

Original data is available for download from:

`http://www2.jpl.nasa.gov/srtm/`

But we'll be using the postprocessed data (this has data voids filled, and accuracy improved in some areas) which is available from

`http://earthexplorer.usgs.gov`

- Navigate to `http://earthexplorer.usgs.gov` and if this is your first visit click on Register and set a username and password (**don't use your University log in**, but don't forget to make a note of the ones that you do set up! You'll need to use them again in future.)
- if you have already registered click on Log in and enter your username and password
- once you have the viewer open use the map to navigate to the area that you require data for - in this case look for **Skye** off the NW coast of Scotland - figure 3.4 shows the location, but zoom in closer than this to Skye itself.
- On the **Address/Place** tab click on Use Map to select the area. You can change the area by moving the markers if necessary. Figure 3.4 shows the map with Skye selected.
- Now click on the Data Sets button to move to the next tab.
- Digital Elevation › SRTM - this should give you 4 choices. Click on the i buttons to see more information about the products. It's worth having a look at what other data is available to you through this interface too - there is a lot there.
- For this exercise select **SRTM 1 Arc-Second Global** by putting a tick in the box next to it.

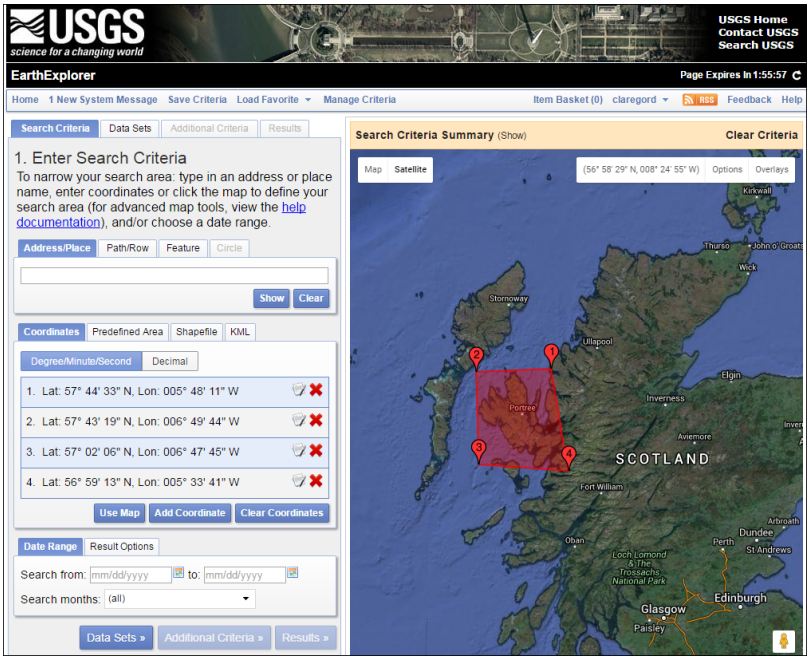


Figure 3.4: Selecting data in Earth Explorer - Skye

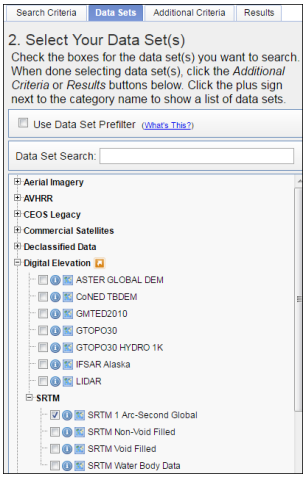


Figure 3.5: Selecting data in Earth Explorer - SRTM data choices

- Click on the Results button - you may need to scroll down to see it.

Now Earth Explorer should give you a list of data covering your chosen area, but you'll need to explore a bit further to see exactly which tiles to download.

- Figure 3.6 shows the results of a search for SRTM 3 for Skye. To see the coverage for a tile of data click on the "footprint" icon under it.
- To download a file click on the fifth icon (a green arrow) - it has a tool tip which says **Download Options** if you hover over it
- From the choices that appear click on the Download button next to the **GeoTIFF** format and then wait for the download to complete
- If you want multiple tiles you'll need to click on each one separately.

Download two tiles of data covering Skye as shown in figure 3.6 and save them to use in the exercises in this chapter.

If you need to do multiple searches then Earth Explorer works best if you close your browser between each search and start again!

Make sure that you have all of the data that you have just prepared available to you for the class.

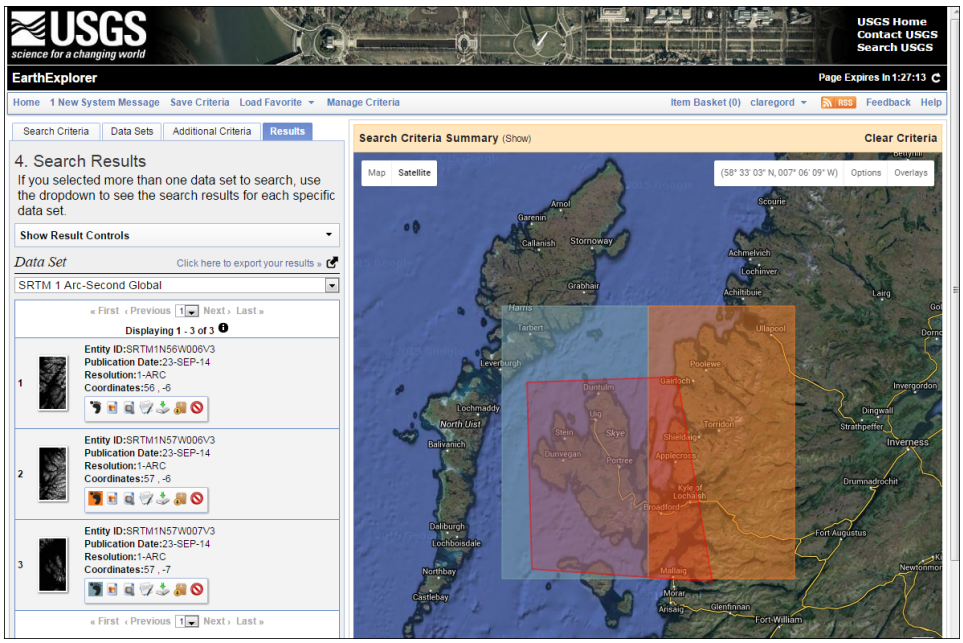


Figure 3.6: The SRTM results screen - showing the footprints of two of the result tiles

Chapter 4

Finding and using spatial data: Coordinate systems, projections and transformations

4.1 Learning outcomes

When you have completed this section you should be able to

- describe the main types of data used in GIS
- find spatial data from a wide range of sources
- find out essential information about the data and apply that to your use of the data in ArcGIS

4.2 Experimenting with coordinate systems

In this exercise you will use a map of the World that has already been set up for you to experiment with different coordinate systems and projections and investigate the different effects of each on distance and area.

Video Clip available in Minerva - Opening map packages (.mpk) in Arc.
Direct link: `http://bit.ly/2h31ICx`

- You should already have downloaded `Chapter04_Data.7z` from Minerva and unzipped it. If not, do so now (instructions in table 1.1 on page 2).
- One of the files in that archive should be **CoordinateSystems.mpk** which is a **Map package**.
- Open the map package either by double-clicking on the file, or by opening ArcMap and dragging the file into the map window. There is more information about map packages in table 4.1.

You should find that you have a map of the World open in ArcMap.

The data for this map is taken from **Natural Earth** which is a general data set made available under an open source licence. It is well worth investigating for future use[1] - `http://www.naturalearthdata.com/`

[1] URL last visited 17/9/18

4.2.1 Finding out the project coordinate system

The first step is important, you need to know what the coordinate system of the current project is. To do this you need to look in the **Data frame properties**.

- View ▸ Data Frame Properties ▸ Coordinate System

The Coordinate System tab gives you information about the current setting, including its name, units, projection (if it is projected) etc.

Question 4.1. What is the coordinate system of this map? Write it below. Is it a Geographic Coordinate System or Projected Coordinate System and what makes you think that it is one or the other?

Map and Layer packages and default storage

When you open a map or layer package in ArcMap it will automatically be stored in the default location. In the case of University computers this will be under
`M: ▸ ArcGIS ▸ Packages`
It is worth checking this folder from time to time as data may use up too much of your limited disk space. If you are sure that you are no longer using particular packages you can delete them. You could also use Catalog to move data and maps to another location. (You'll need to close the map first, though.)

Table 4.1: Map and Layer packages and default storage

4.2.2 Using the Measure tool

We'll use the **Measure tool** to compare the effect of different projections on this map of the World. You can find it's button on the tools toolbar at the top of the ArcMap window.

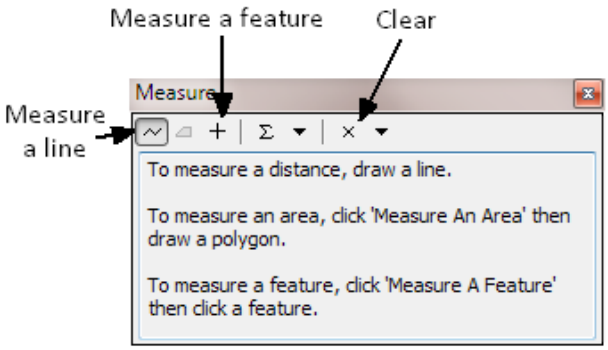


Figure 4.1: The Measure tool

The tool gives you a choice between measuring distance, area or a particular feature. There are also options to change the unit measurement, and to clear the previous measurement.

Video Clip available in Minerva - Using the Measure Tool in ArcMap.
Direct link: `http://bit.ly/2h5ir8u`

Zoom in to the map until you can see city names. Use the Measure a line tool to measure the distance from London to Istanbul.

Question 4.2. Write the distance that you come up with in the box below. What units have been used for the measurement?

- Click on the **Clear and reset results** button on the measure tool.
- You may also need to double-click on the map to get rid of the measuring line!

Now you can start trying out different projections and see what effect they have on distances and areas on the map. Each time you change the coordinate system zoom out to the full extent of the map and have a look at the result. Then zoom back in and make some measurements.

4.2.3 Changing the data frame coordinate system

To change a coordinate system

- Right-click on the data frame title (right at the top of the table of contents - it's probably called **Layers**) and select Properties
- Select the **Coordinate System** tab
- Browse to the required coordinate system in the **Select a coordinate system** box, for example browse to `Projected Coordinate Systems‣World‣Azimuthal Equidistant` then click OK
- If you get a warning click Yes to **Use this coordinate system anyway** - you'll find out later why this is a bad idea, but for this exercise it is fine.

Fill in table 4.2 by setting the data frame to the following Projected coordinate systems and using the measure tool to measure the distance from London to Istanbul, and the area of the polygon for Algeria in North Africa (select the Measure a Feature tool). Don't forget to include the units that you are using - check the selections in the Measure tool window.

Table 4.2: Distance and area measurements in various projections

Projection	London to Istanbul	Area of Algeria
Azimuthal Equidistant - `Projected Coordinate Systems‣World`		
Cylindrical Equal Area - `Projected Coordinate Systems‣World`		

Cassini - Projected Coordinate Systems▸World		
North Pole Stereographic - Projected Coordinate Systems▸Polar		

Try out some more projections from the list yourself. Notice that some of the projections cover limited geographic extents - these tend to be specific to an area such as a particular country and are designed to minimize distortion for that area.

Question 4.3. Looking at the results in table 4.2 what do these tell you about different projections? How do distance and area compare in different examples?

I hope this shows you that it is important to be aware of coordinate systems, and to have some idea how to find out which system works best for which part of the world, and for what purpose. There is a lot of information available - have a look at the general GIS books on the module reading list[2] for some ideas to start you off. For more specific information try Snyder (1987) or Maher (2010) from the Coordinate Systems and Projections reading list.

4.3 Setting projections for a data frame

For this next exercise you will be using the data that you downloaded before the class and exploring what happens when you add layers with different coordinate systems to the same data frame. This exercise should show the importance of understanding coordinate systems and how they work in ArcGIS.

You should already have downloaded and prepared the following data for this exercise as detailed in the section on **Data preparation for finding and using spatial data** on page 29. If you haven't, follow the instructions there now.

- ArcGIS rivers layer
- European river catchments
- Miniscale map of the UK
- Two tiles of SRTM data for Skye

[2] Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

4.3.1 Changing links to data files to relative

Before we start this section it will be useful to set the links from ArcMap to datafiles to relative.

ArcMap layers reference datasets rather than contain them. By default layers link to datasets through their source property using ***absolute*** paths. This means that if you save a map file to a drive, e.g. your M: drive, if you then move the folder containing all of your files to a different location you will lose the links to your data. It is advisable to change paths to ***relative*** before you start creating a map, then as long as your files remain in the same relationship to each other between folders it doesn't matter if the drive letter changes.

- Customize » ArcMap Options » General tick next to Make relative paths the default for new map documents » OK » OK.
- Now check that the setting is correct for this map File » Map Document Properties » General check that **Store relative pathnames to datasources** has a tick next to it.

Repairing broken file links

If you use absolute file paths and you have to move the files from one location to another you will find that the broken links are marked by a red exclamation mark next to the layer name (as in figure 4.2).
To check the file name and repair the links

- Open the layer properties and go to the Source tab
- Under **Data Source** you will see which file Arc is looking for
- To repair the link click on Set Data Source… and look for the missing file - which won't be in the location that is listed
- Once you find it, select it and click Add and then OK

If you are really lucky any other missing layers will appear too, but if not, repeat as necessary. If you already know which files you need to look for, do the following to repair the links:

- Right-click on the layer
- Data » Repair Data Source…
- Navigate to the file Add » OK.

Table 4.3: Repairing broken file links

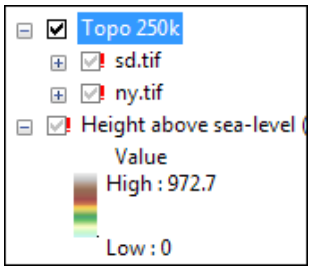


Figure 4.2: The red exclamation mark showing that the links to the data for these layers is broken

Video Clip available in Minerva - Repairing broken file links. Direct link:
`http://bit.ly/2h2X1J3`

4.3.2 Adding layers to your map

Open a new blank map and add the three layers in the following order (for the purposes of this exercise ignore any warnings or just click on Close):

1. ***ArcGIS rivers layer***
2. ***European river catchments***
3. ***Miniscale map of the UK***

What happens? Can you see all of the layers? What is the coordinate system of the data frame?[a] What can you see when you "zoom to layer" on each layer in turn?[b] What about when you zoom to full extent?[c]

[a] find a reminder of how to check this in section 4.2.1 on page 35
[b] table 1.2 on page 2
[c] again, table 1.2 on page 2

Open a new blank map without saving the previous one. This time add the three layers in the following order:

1. ***European river catchments***
2. ***ArcGIS rivers layer***
3. ***Miniscale map of the UK***

What happens? Can you see all of the layers? What is the coordinate system of the data frame? What can you see when you "zoom to layer" on each layer in turn? What about when you zoom to full extent?

Open a new blank map without saving the previous one. This time add the three layers in the following order:

1. ***Miniscale map of the UK***
2. ***European river catchments***
3. ***ArcGIS rivers layer***

What happens? Can you see all of the layers? What is the coordinate system of the data frame? What can you see when you "zoom to layer" on each layer in turn? What about when you zoom to full extent?

The lesson from this exercise should be **don't ignore warning boxes!**.

The data frame is set to the coordinate system of the first layer to be added. If the coordinate systems don't match Arc will try to project the subsequent layers "on the fly". Whilst this is very useful, the result is not often successful and the result is a map where the layers are not all visible together or, if they are, may not line up exactly on top of each other. Even if all of the layers line up, if the coordinate systems are not set correctly you'll have trouble editing data, and running the analysis tools using those layers.

The really important lessons here are:

- Make sure that you know the coordinate systems of your data
- Once you know that, don't ignore the warnings, but use **transformation** to match your layers

4.4 Working with coordinate systems in Arc

In this section we'll take two of the layers from the previous exercise and project and transform them so that they appear in the same geographic space and could be used for doing analyses.

Use Arc to find out the projections of the Miniscale and rivers layers and make a note of them in table 4.4.

To find out the projection of the layers rather than the map project, you'll need to look at the **properties** of each layer in turn. So right-click on each layer to open the properties dialog and have a look at the Source tab.

Question 4.4. Write the coordinate system of each layer in the table below.

Table 4.4: Projections for European region map

Layer	Projection
Miniscale map of the UK	
ArcGIS rivers layer	

4.4.1 How not to do it

If you have a layer which is in the wrong coordinate system the simplest way to change the coordinate system is to do so in the properties. Despite Arc apparently letting you do this, **this is not the right way!** In effect, all you're doing here is changing what the coordinate system is called. You haven't changed how the layer is displayed or how Arc handles it.

I recommend watching the video below because it gives a clear explanation of why this is not the right way to change the coordinate system. (He's using an earlier version of Arc so it does look a bit different, but the general principle is the same.)

Video Clip available - See a video on YouTube about how not to change the coordinate system - `http://bit.ly/1PlGPZj`

The sections below show how you *should* set coordinate systems.

4.4.2 Defining projections

Again, start with a new blank map. Don't bother to save the previous one.

You should have found that the projection of the Miniscale layer is **Undefined**. To be able to use it with other data you need to use the **Define projection** tool to project it. The Ordnance Survey data from Digimap is provided in the **British National Grid** projection. This is an important bit of information, but has to be discovered from the supporting website!

You'll use one of the tools in **ArcToolbox** to define the projection. ArcToolbox gives you the opportunity to do a lot of very advanced processing tasks without needing to use a command-line interface. You'll be using it a lot in the rest of this course.

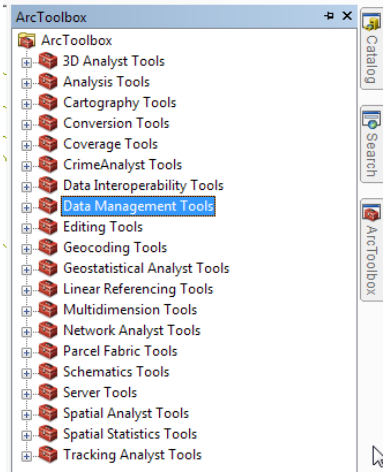


Figure 4.3: ArcToolbox

- Open ArcToolbox by clicking on the tab at the right-hand side of the ArcMap window (figure 4.3) If it isn't there click on Geoprocessing > ArcToolbox to add the tab.

- ArcToolbox > Data Management Tools > Projections and Transformations > Define Projection
- Select the Miniscale file for the **Input Dataset**
- Select British National Grid for the Coordinate System by clicking on the button to the right of the field and going to Select > Projected Coordinate Systems > National Grids > Europe > British National Grid > Add > OK
- then run the tool

Arc will project the file and should automatically add it to your map. You should be able to see immediately that it is now possible to select a scale and the units of measurement are now **Meters**. Look at the bottom right of the map window to see the current units. Check the data frame to see what the coordinate system of the map is now.

4.4.3 Transforming projections

It should now be possible to add the rivers layer, which has a projected coordinate system of **WGS1984, Web Mercator Auxiliary Sphere**, to the map and transform it "on the fly". This will allow you to display the layers together on one layout, but the transformation is only temporary and only affects this map project.

- Add to your map the **rivers** layer that you exported from ArcGIS Online.
- this time when you get a warning click on the **Transformations...** button (figure 4.4) [3]
  - Select to convert from **GCS_WGS_1984**
  - Into **GCS_OSGB_1936**[4]
  - Using **OSGB_1936_To_WGS_1984_Petroleum** (see figure 4.5)
- OK > Close

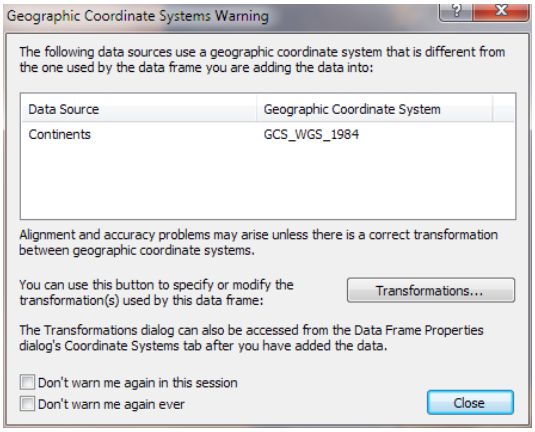


Figure 4.4: Geographic Coordinate System Warning

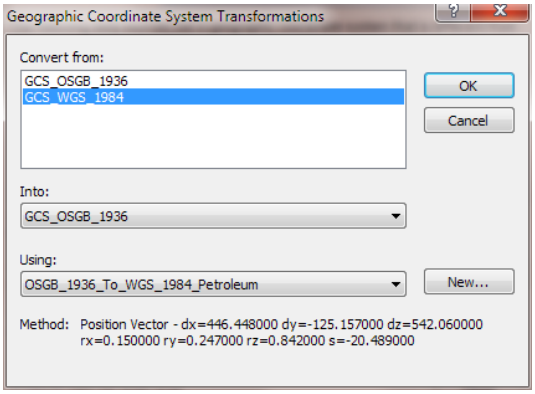


Figure 4.5: Choosing a transformation

As if by magic the rivers layer should now fit exactly with the Miniscale layer (making allowances for generalization of the rivers layer).

[3] You might find that you don't get the warning at this point. If you don't, follow the first two points in the instructions in section 4.2.3 on page 36 to change the data frame coordinate system. Only this time you won't need to change the coordinate system. Instead, there should be a Transformations button there to press on - then just follow the instructions here.

[4] OSGB 1936 is the datum that underlies the British National Grid

Choosing a transformation
It can be difficult to know which transformation to choose, and Arc doesn't actually support all possible combinations. Sometimes it is necessary to reproject a layer to an interim projection before using it in a map. There is information for choosing the correct transformation on the ESRI support website at `http://support.esri.com/en/knowledgebase/techarticles/detail/21327` The files themselves are listed at the bottom of the page. Download the zip file for the version of Arc that you are using, e.g. 10.6.

Table 4.5: Choosing a transformation

4.4.4 Reprojecting data: vector data

On the fly transformation is fine if you are just looking at the map, but if you need to do any measuring or analysis then you need to reproject the data layers into the same coordinate system.

To be able to reproject a layer the following is required

- Your layer must already have a projection - if it is undefined you first need to define it as above.
- You need to know whether your data is vector or raster
- You need to know which coordinate system and datum you want your data to be in.

We want to reproject the rivers layer to British National Grid which uses OSGB 1936 as its datum. This is a **vector** layer so proceed as follows

- Toolbox > Data Management Tools > Projections and Transformations > Project
- Fill in the dialog box as in figure 4.6 selecting an appropriate location and name for your projected file then run the tool

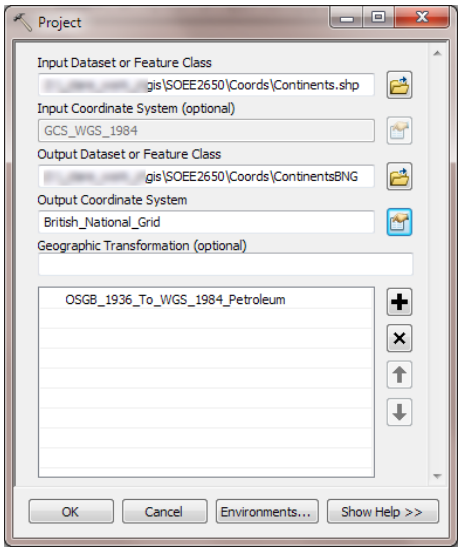


Figure 4.6: Feature Project tool

Open a new blank map in ArcMap and add the Miniscale map first. You shouldn't get a warning this time as it should be projected now. Next add the new rivers layer. Again, you shouldn't get any warnings this time as this layer should now be in the same GCS as the Miniscale layer. If this isn't the case stop and think about what may have gone wrong, and have another try.

4.4.5 Reprojecting data: raster data

The previous section shows how to reproject vector data, now let's reproject an example of raster data using the SRTM data that you downloaded earlier as an example.

SRTM data

You should already have downloaded two SRTM tiles following the instructions on page 31. If you haven't, do so now before continuing with this exercise.

Question 4.5. Open ArcMap and using catalog have a look at one of the SRTM files. What is the coordinate system?

To add the SRTM tiles to the same map as the Miniscale and reprojected rivers data you will need to **project** it. (You'll see in a later chapter how to merge raster layers together.)

- Toolbox > Data Management Tools > Projections and Transformations > Raster > Project Raster

The form is very similar to the form for reprojecting vector formats so go ahead and fill it in for one of your tiles - see figure 4.7.

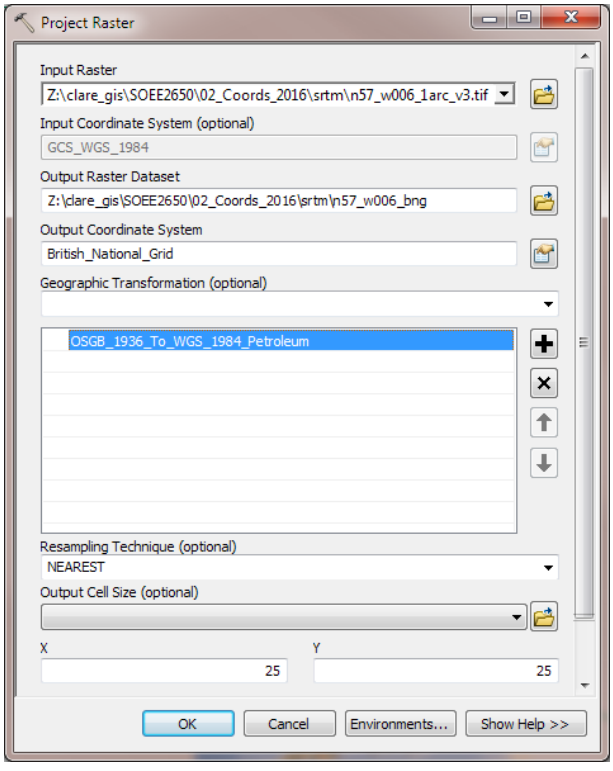


Figure 4.7: Project Raster dialog

The main difference is that you need to select the output file type by adding an extension to the filename. In this case leave the name with no extension to save the dataset as an **ESRI Grid** file. These are more useful for future processing in Arc than most of the other formats.

For now, leave the other options, e.g. Output cell size, as the default.

Process the file (this may take some time. . .) and add it to your map, if Arc doesn't do so anyway. You should find that you have a grey-scale layer that shows the elevation of part of Skye, off the West coast of Scotland (figure 4.8).

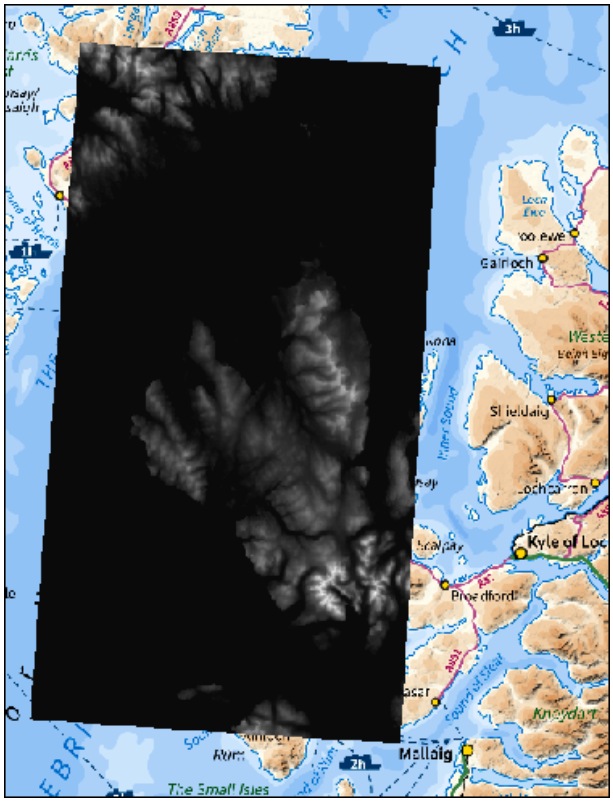


Figure 4.8: Newly projected raster overlying the Isle of Skye

Does the layer line up correctly with the other layers (allowing for generalization)? You may need to make the layer transparent[5] to be able to check. If it doesn't line up think about what may have gone wrong and have another try.

4.5 Summary of defining projections and projecting data

This summary of the main points from this section of the workbook should help you to remember what you need to do each time that you obtain a new dataset. Read it through, and then remember where to find it so that you can refer back to it. If you don't follow these steps then you can give yourself a major headache when trying to load data for a project.

In addition to the text summary and the link to a video, there is a step-by-step diagram in figure 4.9 on page 48 which you could use as a reminder each time you have data to load into GIS.

4.5.1 What is the current coordinate system?

Always start by checking the coordinate system / projection of your data. You won't be able to do much if you don't know what system the data uses.

[5] (instructions in section 1.4.5 on page 7)

Video Clip available in Minerva - Summary of defining projections and projecting data in GIS. Direct link: `http://bit.ly/2ePANtg`

1. Check the file/layer properties or the metadata using the catalog.
2. If that doesn't help (e.g. if it's listed as **Undefined**), look at any documentation that came with the data (e.g. sometimes there is a text file in the folder)
3. If that still doesn't help, check with whoever or where ever you got the data from, e.g. the web page if you downloaded it from the web.
4. If you still haven't found the answer check Maher (2010)[6] and follow her instructions to work it out for yourself.

4.5.2 Define Projection

If the coordinate system is **Undefined** you first need to define it (see section 4.4.2 on page 41) - to its original coordinate system which you should have worked out in the previous section. You can not *change* the coordinate system by redefining projection - **define first**, *then* use the vector or raster project tools.

4.5.3 Project layer and Transform

If/when your data is projected it is not in the same projection as the rest of your data, or your map, then you need to **Project** the layer. Remember that you use a different tool depending on whether the data is raster (see section 4.4.5 on page 44) or vector (see section 4.4.4 on page 43). You will probably also need to **Transform** the layer (see section 4.4.3 on page 42). To choose the best transformation for the geographic area/projection see Table 4.5 for the link to information provided by ESRI.

It is possible to transform **on the fly**, but if you are using your data for further analysis it is more reliable to **Project** to a new layer using the appropriate tools.

Also remember that you don't change the projection by changing it in the properties of the layer (section 4.4.1 on page 41 explains why this is wrong). You do have to use the tools.

4.5.4 Projection all correct

If your data is projected, and is in the same projection as your map or the rest of your data, then there is no problem and you can just use it as it is.

4.6 Recommended reading: Coordinate systems and projections

This is a complex subject but it is essential to have a good grasp of the principles and techniques before you start using your own data in GIS. For more detailed information have a look at the following references from the module reading list[7].

Longley, P.A. (2011) Chapter 5, section 7.

Maher, M.M. (2010) the whole book is a practical guide to using coordinate systems and projections.

The free ESRI online course at `http://arcg.is/1iOYEpw` gives a clear overview of Geographic Coordinate Systems and is worth working through.

[6] Full reference in reading list. Book available from my office - SEE 10.140b

[7] Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

4.6.1 Videos online

The videos below give background information on using coordinate systems in GIS.

Karl Olsen gives an overview of geographic and projected coordinate systems at `http://bit.ly/1NEoOjx` (USA examples)

Eric Compas has produced a series of 4 videos which show:

- Coordinate system basics - `http://bit.ly/1hMdgW5`
- Defining coordinate systems - `http://bit.ly/1J3F1Ah`
- Coordinate systems - projecting - `http://bit.ly/1Pz9omJ`
- Coordinate systems: the biggest mistake! - `http://bit.ly/1PlGPZj`

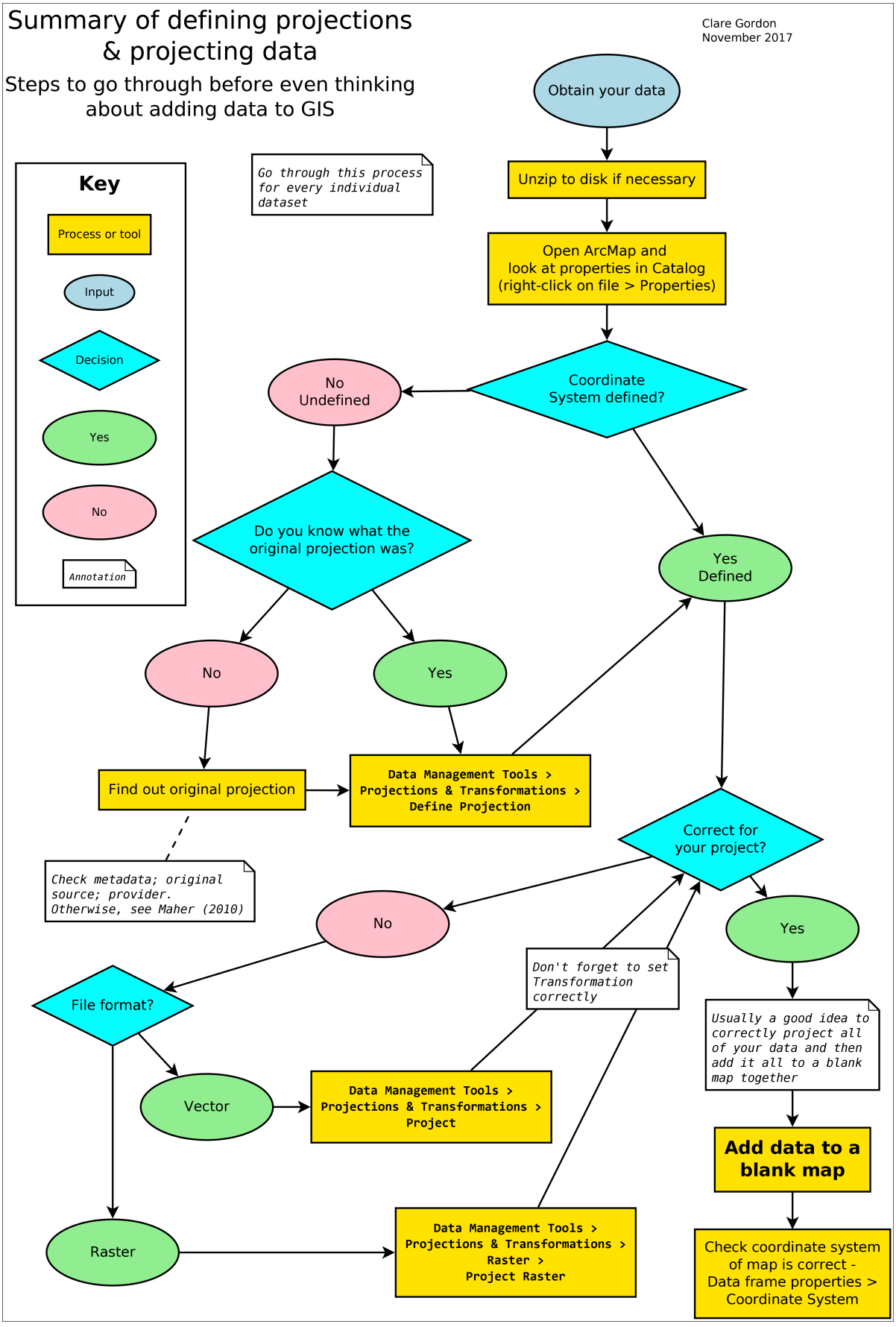


Figure 4.9: Summary showing the decision process and actions necessary to prepare data for GIS

Chapter 5

Digimap

5.1 Introduction

Digimap is a service provided to Higher Education in the U.K. by EDINA at Edinburgh University. Digimap provides a front end to digital maps and data of Great Britain from the Ordnance Survey and the British Geological Survey. As a member of the University of Leeds you have access to maps and data for use as part of your studies.

5.2 Learning outcomes

When you have finished this workbook you will

- be aware of the UK data available to you through the Digimap service
- understand how to use the Roam browser in the Digimap Collections to make a digital map displaying a selection of features
- know how to download images and pdf maps from the Digimap Collections for printing and use in other programs
- know how to use Data Download to download data from Digimap Collections for use in GIS programs

5.3 Logging in to Digimap

5.3.1 Registering

If you have not used Digimap before you will need to register using your University id, that is the username and password that you use to access University systems. Full instructions for registering and logging in are on the Digimap help pages at

`http://bit.ly/1yQusPx`

Start by selecting **University of Leeds** and logging in with your usual University username and password. Please do not use any other email address to register - it will only cause you problems when it comes to obtaining data later.

You need to register for each collection separately, but can do it in one go. For this workbook you won't need to use all collections, but it is worth registering for all that are available to you so that you can explore them for yourself. The University of Leeds does not subscribe to Marine or Global Digimap[1].

In the **Purpose** dropdown select **Academic Works (coursework, projects, dissertations etc.)**

[1] as of September 2018

5.3.2 Logging in

To log in go to the Digimap Collections page (figure 5.1) at

`http://digimap.edina.ac.uk`

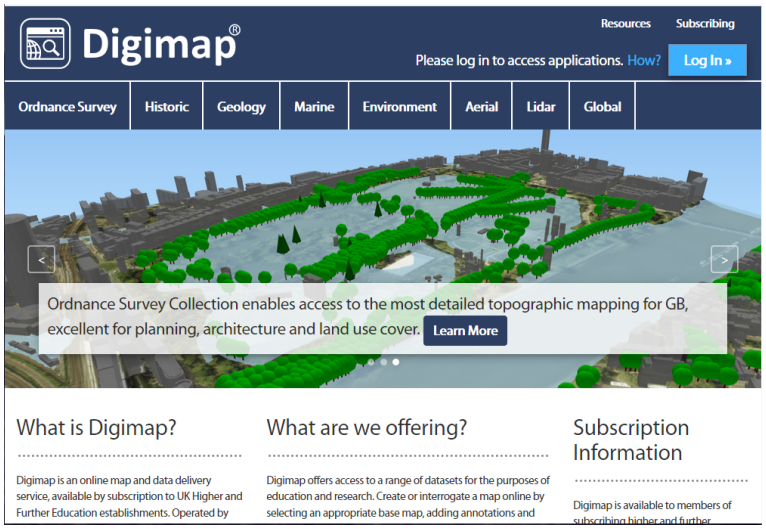


Figure 5.1: Digimap initial page

- Click the **Login** button at the top right of the screen and type **Leeds** in to the box and select the **University of Leeds** from the list of available institutions
- You should get the familiar University of Leeds login page, so type your **University username and password** into the appropriate boxes and then click the **Log in** button. If you are already logged in to Minerva you may find that you don't have to enter your login details again.

You should be taken to the Digimap initial page again (figure 5.2), but this time with your name at the top right.

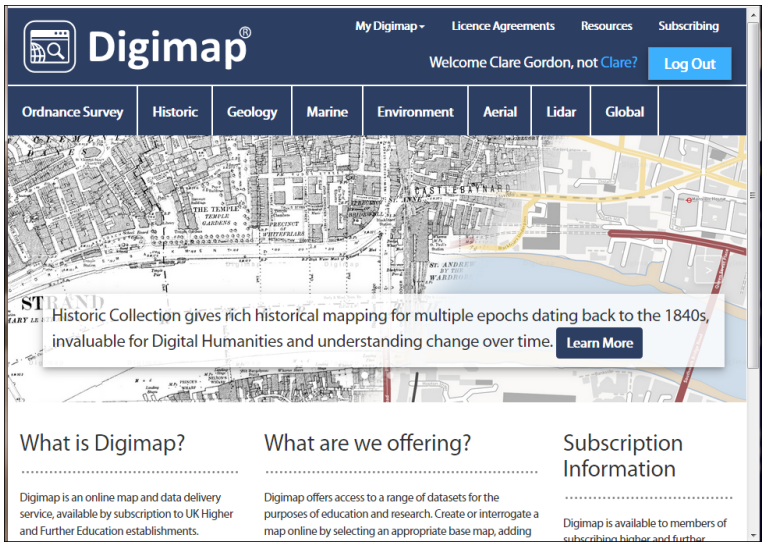


Figure 5.2: Choosing a data collection

The list includes options for a large number of collections. In this workbook we'll only be looking at the collections that are most relevant for creating the maps you'll need during your course, but if you are interested in any of the others feel free to explore them. Edina have worked to make all of the tools similar across each collection so just have a go!

5.4 Ordnance Survey Collection

We are going to start by looking at the **Digimap - Ordnance Survey Collection**. (Figure 5.3.) Click on the Ordnance Survey heading at the top of the screen and you'll be shown which services are available to you and information about the collection.

Figure 5.3: Ordnance Survey Collection

The list includes links to **Roam** and **Data Download**. We'll look at both of these in the sections below.

Roam and Download are fairly standard across all collections in Digimap (making allowances for the differences in the data) so once you've used them in the OS Collection you'll have a good idea of how they are likely to work for Geology, Aerial etc.

5.4.1 Digimap Roam

In this section you will learn how to use Roam to view and create maps using Ordnance Survey data.

- Click on the **Roam** heading.
- You may be presented with the copyright statement page.
- Read the copyright notice carefully and click on the **copyright terms and conditions link**. This launches the "Digimap: Ordnance Survey Data Sub-licence Agreement" page which shows the full terms and conditions. You signed up to these terms and conditions when you registered so make sure that you follow them. Click your browser's **back** button to return to the copyright notice, then click on the green button to acknowledge your agreement to the copyright statement.

Video Clip available - The Digimap video on Digimap Roam is available at `https://youtu.be/kSdO-2lnRGc` (this video has sound). Note that this video shows the beta version of Roam so there may be some differences.

Figure 5.4: The Digimap Roam window

Overview

Digimap Roam enables you to view and print maps using Ordnance Survey data at various pre-defined scales. PDF prints can be created in A4 or A3 size and landscape or portrait orientation. See figure 5.4 for an annotated overview of the Roam window.

The service is being actively developed at the moment so keep an eye open for new buttons or headings and try them out.

1. = **Map window** - Where the maps are displayed
2. = **Home** - return to the Digimap home page
3. = **Search** - enter a place name, postcode or map coordinates here to search for them
4. = **Print** - produce a printable PDF file of your map
5. = **2 up** - open a second map window - allows you to look at two different maps of the same area side-by-side
6. = **Click and drag to zoom in** - as it says!
7. = **Zoom slider** - use to zoom in and out
8. = **Zoom to max extent** - Click to zoom out to full G.B. view
9. = **current view** and **scale bar** - shows current view type and the scale on the map
10. = **Overview map** - when you're zoomed in use this to show where in the country you are
11. = **Map content** - view map legend and customise map content when possible
12. = **My Maps** - previously saved map views and content

13. = **Overlays** - Enables hill shading at certain levels of zoom
14. = **Drawing tools** - Tools to create annotations, import your own data, or export data in various formats
15. = **Measurement tools** - Tools to measure distance and area
16. = **Map information** - current map product, data licence, date of map and other essential information
17. = **Basemaps** - Enables different map styles at certain levels of zoom
18. = **Opacity** - slider to change the transparency of the basemap

Searching for a location

You can search for a location in Roam by using a place name, postcode or grid reference.

To search using a **place name**:

- Type the place name (for this example type **Leeds**) in the search box and press Enter or click on the magnifying glass button.
- If there is more than one match for your place name the search results will be displayed below the search box - see figure 5.5. Click the place name that you are interested in to view it in the map window - in this case click on **Leeds (Leeds)**.

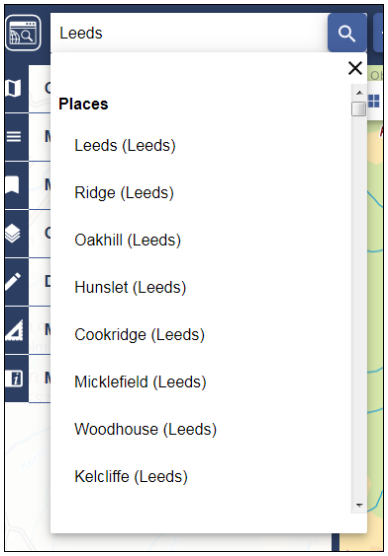


Figure 5.5: Search box and results of a search for “Leeds”

You’ll need to click on the cross on the search results to close the list but when you do you’ll lose the marker showing the centre of your search area.

To search using a **full postcode**:

- Try searching for the University postcode - **LS2 9JT**. Roam should take you straight to the centre of this postcode area.

To search using a **Grid Reference**:

- Type the grid reference, e.g. **SE4435** in the **Grid Reference** box and click **Find**. Roam will automatically navigate to that location.

Navigating in Roam

You can navigate in Roam by panning (moving the map in any direction by dragging it with the mouse) and by zooming in and out of the map.

To zoom in/out of the map you can:

- Double click to zoom in
- Use the zoom slider bar to zoom in or out either by clicking on the **+** and **-** signs or dragging the blue marker on the bar.
- Or click anywhere on the slider bar to zoom to that scale.

Controlling map content and basemaps

In some of the views in Roam it is possible to customise which features are displayed on the map - e.g. display only A class roads and/or railways.

To customise the map view:

- Zoom to **Neighbourhood view** - the type of view is shown in the bottom right of the map.
- Click on **Basemaps** (top left of the map window) and select **VML Streetview**[2] See figure 5.6
- Click the **Map Content** tab in the task menu panel. The map content panel contains a list of the feature types that are included in the map so it can also function as a key.
- Switch features or groups of features (such as all roads) on and off by checking or unchecking the tick box next to the feature name.
- All features can be switched off by unchecking the **Clear/select all layers** tick box. **N**B: clearing all layers will result in a blank map, so remember to switch at least one layer back on!

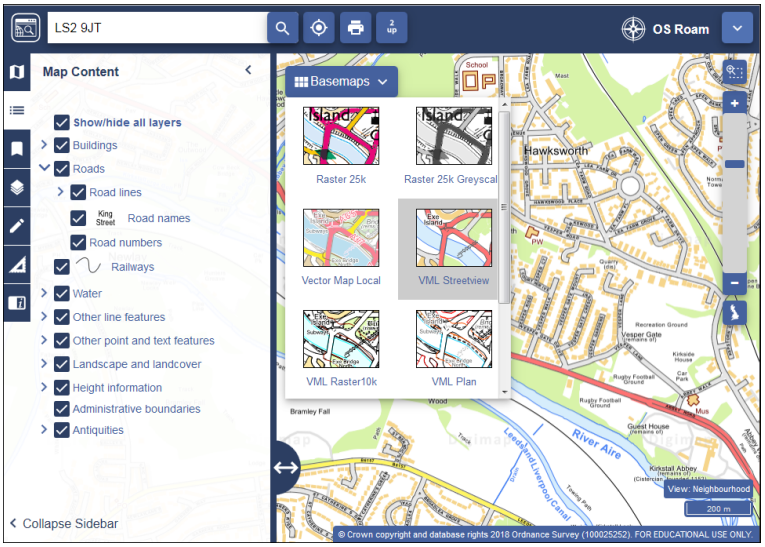


Figure 5.6: Choosing a basemap in Neighbourhood view in Roam. Note the tickboxes next to the features for the VML Streetview basemap.

Note: Many other views cannot be customised because the Ordnance Survey data used in these views are in raster data format which do not allow selection of features. You will still be able to see the features listed in the map content control panel but there won't be tick boxes next to them.

[2]VML stands for VectorMap Local and refers to a particular Ordnance Survey product which is used in many of their web mapping applications.

Question 5.1. Name some other view and basemap combinations besides Neighbourhood >> VML Streetview that allow you to select content?

Using the measuring tools

Roam provides tools for measuring distance and area.

- Click on Measurement Tools on the sidebar to open them (figure 5.7).
- Click on the first button - **Measure Distance**.
- Click on the map to start measuring, click for each corner, then double-click to stop measuring. The measurement in metres will appear on the toolbar as well as on an overlay on the map.

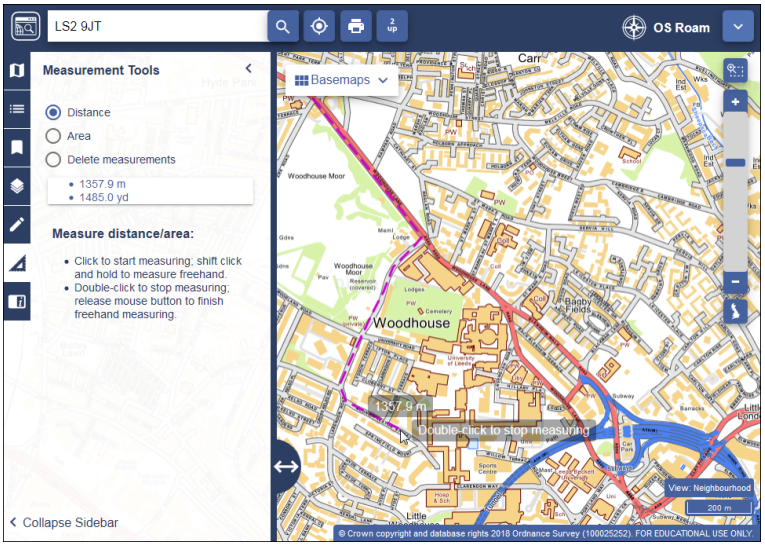


Figure 5.7: Measurement tools - click on the map to start measuring, double-click to stop

Question 5.2. Use the Measure Distance tool to measure your route to the University. How far away do you live?

In a similar way try out the **Measure Area** tool.

Try very roughly to measure the area of Woodhouse Cemetery (now disused and known as St George's Fields) which is just north of us here in Earth and Environment.

Question 5.3. What is the area of Woodhouse Cemetery?

Printing from Roam

Roam allows you to create printable PDF (Portable Document Format) maps or export jpg or png images in A4 to A0 size and in portrait or landscape layout. The image formats make it possible to import maps into Word or Powerpoint.

You won't be printing directly from Roam, really this is more of an **export** function.

Video Clip available - The Digimap video on Printing Roam maps is available from `https://youtu.be/mPZOyGp75h0` (this video has sound)

Using the map that you were looking at in the previous exercise create a pdf map which you'll save to your M:/ drive. You don't need to print it unless you particularly wish to.

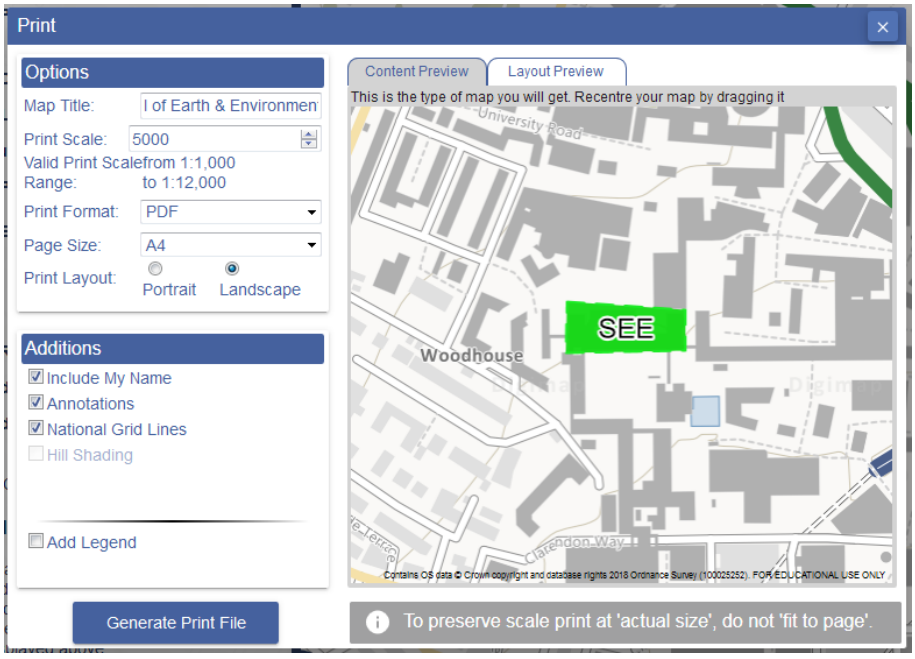


Figure 5.8: Printing to pdf or image file from Roam

- Click the **Print icon** at the top right to open the print options in a new browser window (figure 5.8).
- Enter a map title in the appropriate box.
- Click to add National Grid Lines.
- Select the page size and layout using the drop down menus.
- Look at the **Layout Preview** tab to check that the area that you want will be printed and move the map, or rescale it if you need to
- Click **Generate Print File**, depending on your choice this will either produce a PDF file which you can save or print, or an image file that you can include within other documents.

See section 5.6 on page 64 for information on how to print and edit PDF files.

Saving map views for future use

Once you have set up a view and, maybe, added annotations, Roam allows you to bookmark it so that you can go back to it later.

- Click on My Maps on the sidebar
- Click on Save and give your map a name that will help you to identify the map later then click Save on this screen.
- Next time you want to use that map click on Open and open it from the list that appears there - figure 5.9.

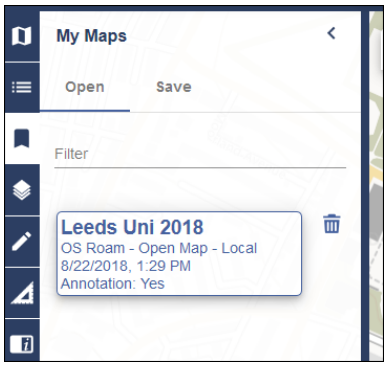


Figure 5.9: My Maps

5.4.2 Data Download

Data Download is a tool for downloading Ordnance Survey data for use in GIS or CAD software. The format that the data is delivered in will determine whether you will be able to open it directly in a software package or whether you will need to convert it.

We'll be using data from Digimap in ArcGIS later in the module so you need to know your way around this section. Instructions for converting, importing and viewing file types that need it will be given during the ArcGIS part of the course.

Selecting your Ordnance Survey data

- Go to the Digimap home page
- Click on **Ordnance Survey** in the menu at the top of the page
- From the Ordnance Survey page choose **Data Download** (Figure 5.10.)

Data download takes you to a map that looks very similar to Digimap Roam but with some important differences.

Selecting an area

On the left there is a menu panel with options for selecting an area with a search box above it (figure 5.11).

- Click in the **Search** box and type **University Road, Leeds**, then press Enter or click on the magnifying glass to search.
- When you get the results click on **Roads (100+)** then select **University Road (University - Leeds)** to zoom in then close the search results.
- Under **Draw** click on the rectangle and use the mouse to draw a box around part of the University, clicking to start and finish the box. (Figure 5.12)

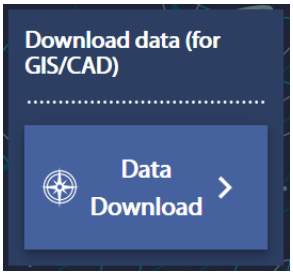


Figure 5.10: Data Download

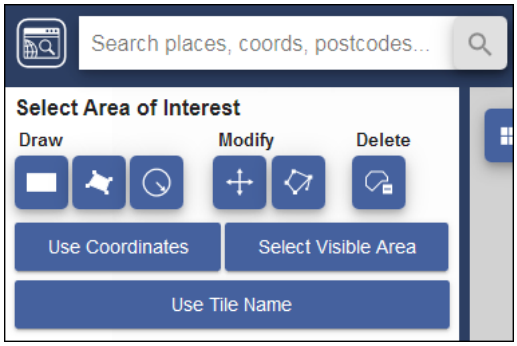


Figure 5.11: Search for & select an area

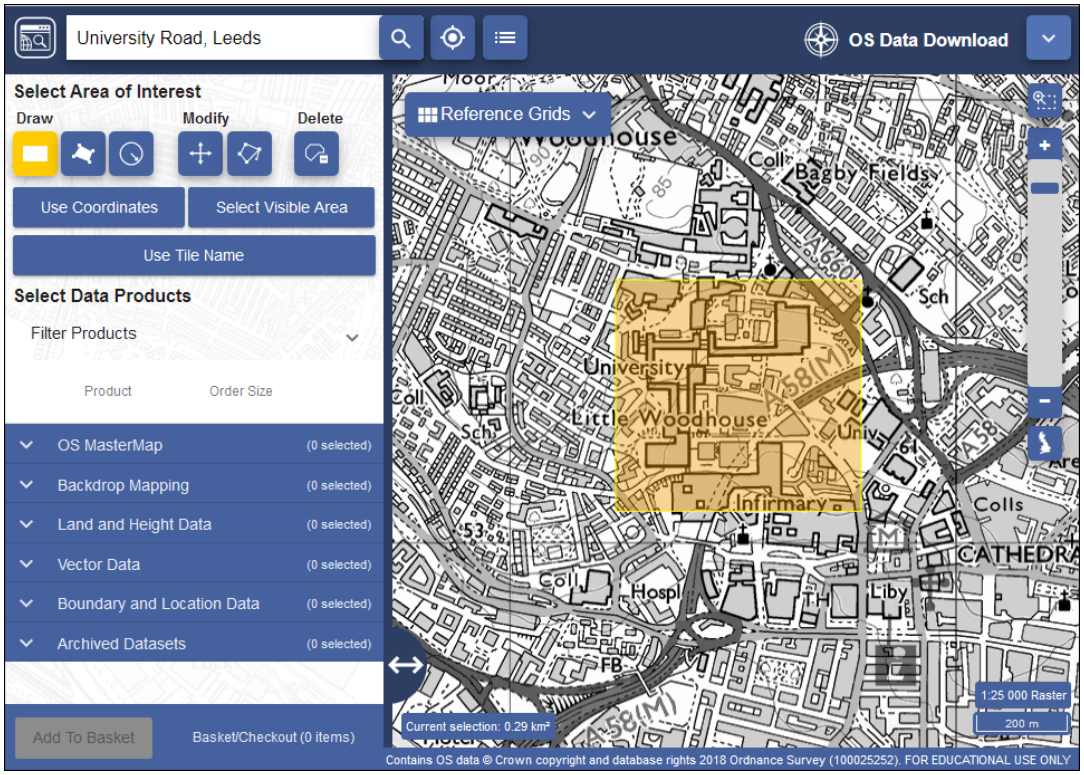


Figure 5.12: Selecting an area in Digimap Download

Note: The map that you see on the screen only shows the area that you will be downloading data for, **not** the actual data that you'll be downloading. You'll select the data separately so don't worry what it looks like for now.

Selecting data sets

Now that you've selected an area you have to select the data that you need.

- Back in the panel on the left, under **Select Data Products**, drop down each of the headings in turn. (Figure 5.13.)
- There are a lot of different data sets here and most of them won't mean anything to you. For now select the following datasets when you find them by putting a tick in the box next to them.

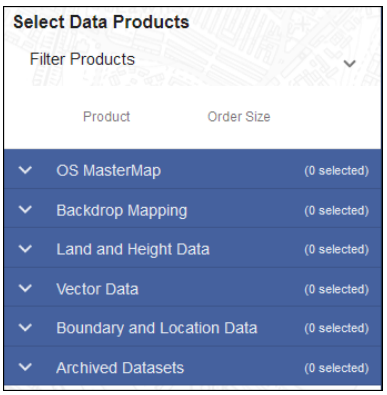


Figure 5.13: Select products from the list

Backdrop mapping: VectorMap Local Raster
Land and Height data: OS Terrain 5 Contours

You can get more information about the datasets by clicking on the arrow next to them. This includes information on licences.

The figure on the right in brackets under **Order Size** shows how many tiles your selected area uses out of the maximum downloadable number.

- When you have selected the data you require click on **Add to Basket**. (Don't worry - despite the Shopping Basket and Checkout you won't be charged. The University has already paid the subscription!)

Your basket should appear with details of your order. (Figure 5.14.)

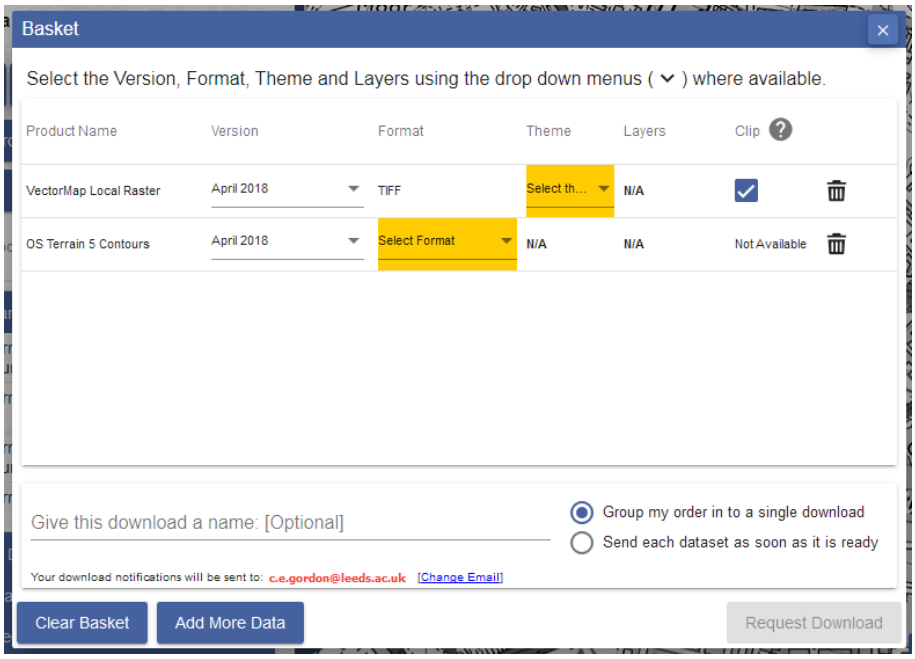


Figure 5.14: Details of your order in the Basket

- Some datasets will give you an option to change the format (highlighted in yellow). In this case click on **Select Format** next to the contours. The choices are **Shape**, **GML3** or **DWG**. Choose **Shape** in this case.
- You may also need to select a theme - for the VectorMap Local Raster there is a choice of themes - pick whichever one you like this time!
- Some items will have a **Clip** option. This means that the data will be sent to you clipped to the area outline that you requested. If you are really short of disk space this could be useful, but it doesn't usually hurt to have extra data around the outside of your study area. I prefer to untick this box and download full map tiles.
- Give the order a name, e.g. **Leeds**. This will be part of the file name of the zip file that you download so try to make it short but helpful!
- Click on **Request Download**.

Downloading your data

You'll receive an email confirming your order, then another with a download link. Make sure that you are still logged on to Digimap before you click on the download link (figure 5.15).

Figure 5.15: The download link in the email - click on this not on any of the other links in your email!

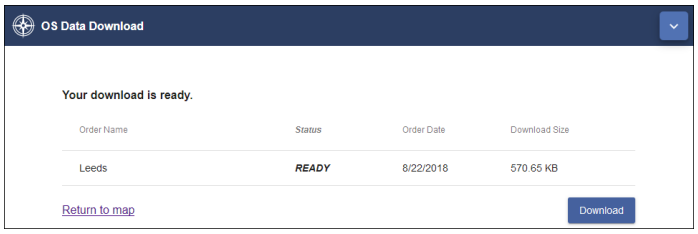


Figure 5.16: Order ready to download

Once you have clicked on the link a window should open telling you that your order is ready to download (figure 5.16).

- Click on **Download**.
- You'll download a zip file. **NOTE:** Don't run or open the file directly from your browser, and make sure that you **DON'T** save your zip file to a **temp** folder where you will probably be unable to unzip it.

Make sure that you remember where you have saved the zip file.

Now open **My Computer** and navigate to the location where you saved the zip file. Right-click on the compressed map data file that you downloaded and choose 7-zip ▸ Extract files... . Select where you want to save the extracted files, and make a note of where you save them to. You should end up with a folder for each dataset that you requested.

Viewing your data

In this case the files that you have downloaded are either tiff graphics files or shapefiles. Navigate to the downloaded folder called something like `vml-raster_746810▸se` (your order number will be different) and look at the contents. Open one of the .tif files from the VectorMap Local Raster download by double-clicking on it. These files should open in a graphics program. In future classes we'll be using

these in our own maps. Try opening one of the .shp files too. It's unlikely that you will be able to. These are a specific format for use in Arc and other GIS programs and we'll look at that in the ArcGIS sessions[3].

The download facility includes a lot of different formats and products, but the basic method of download is the same for all of them. The challenge tends to be in knowing how to use them once you have downloaded them and you'll be looking at that in future sessions.

5.5 Aerial Digimap

Since 2016/2017 Digimap has given access to 25cm resolution aerial imagery from Getmapping. This is a fantastic resource and enables you to see a great deal of detail. It's well worth downloading imagery for your field areas. As in other collections in Digimap, you have a choice of Roam or Data Download and these work in a similar way, so refer back to the previous sections if you need a reminder, but there are inevitably some differences because of the different nature of the data.

5.5.1 Aerial Roam

From the Digimap home page click on the **Aerial** heading and then on **Aerial Roam**

The Aerial Roam map window is basically the same as the Ordnance Survey Roam window and the functionality is very similar so I won't go through it all here.

- Open the **Search...** menu and enter the University of Leeds postcode - **LS2 9JT** then click on **Search**
- You should be taken to a view which looks something like figure 5.17

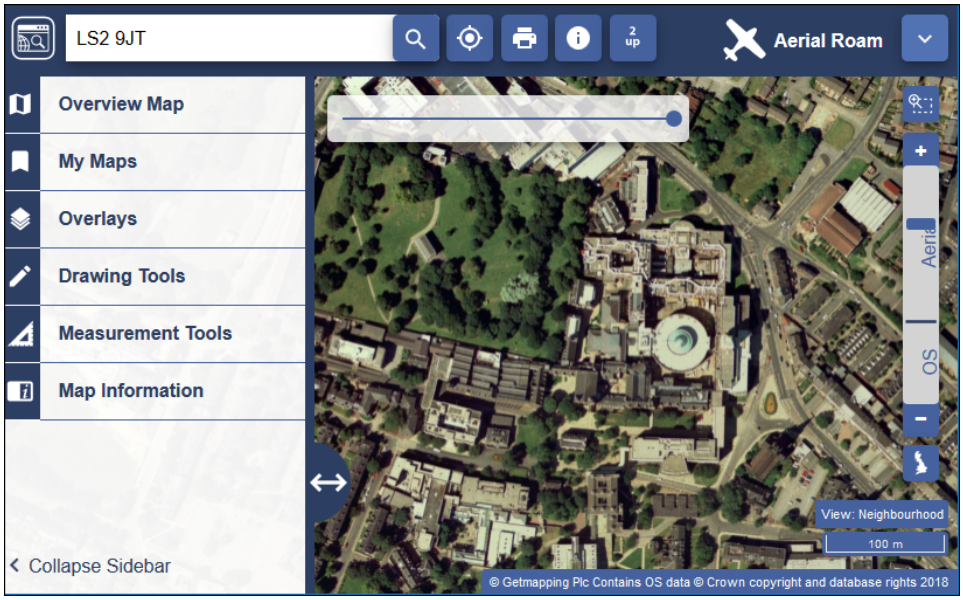


Figure 5.17: The Aerial Roam window

Note that the imagery isn't available to browse at all zoom levels. Look at the bar on the right of the window (figure 5.17) and you'll see that the most zoomed out levels are labelled **OS**. As you zoom in closer the map will change to imagery.

Zoom in and out and move around the map to see what is available.

[3]Note that there may also be other files in the VectorMap Local folder with a **.tfw** extension. These won't open in any program but, if present, are essential for using the tif file in GIS programs such as ArcGIS, so make sure that you keep this together with the tif file.

Opacity and viewing place names and roads

You can use the opacity slider at the top of the screen (above the zoom control) to allow the map to be shown through the aerial photograph.

If you don't want to make the aerial layer transparent, but do want to be able to see the names of places and the roads, click on Overlays > Road/Place names in the sidebar. This is a toggle, so do the same again to switch the names off.

Finding the date of the imagery

If you have searched for **LS2 9JT** and are looking at a view of the University, move the map so that you can see the SEE building. There is a lot of building work going on around the University so it would be useful to know when the imagery was taken to have some idea of how much is likely to have changed since. To find out the date it was flown do the following:

- Click on the **i** for information button at the top of the screen (next to the Overlays)
- Now click somewhere on the map, close to the SEE building.
- You should be shown a panel with the Tile name, Date Flown and the eastings and northings of the location that you clicked - see figure 5.18

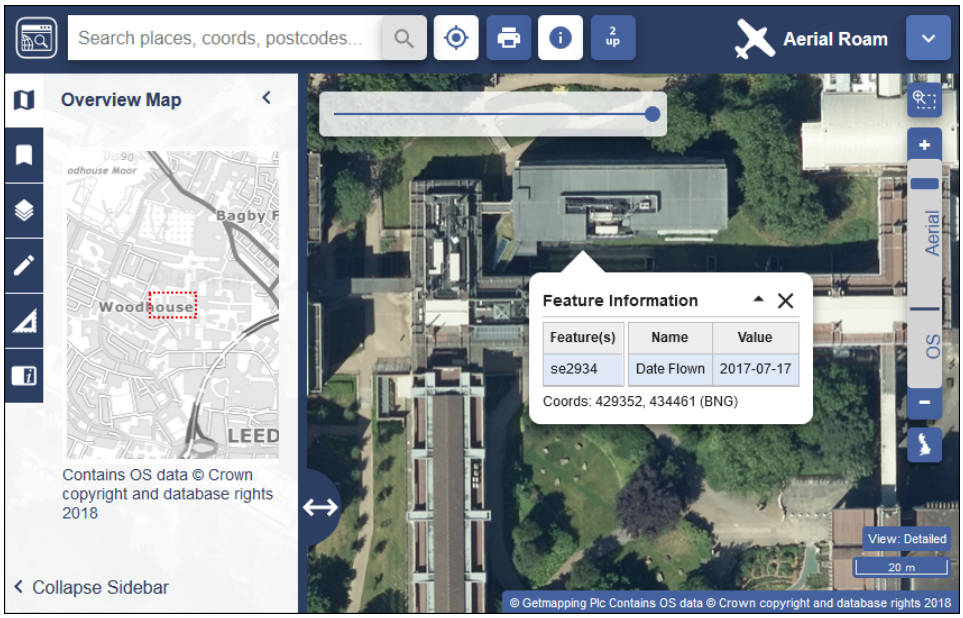


Figure 5.18: Information about the tile of aerial imagery, including the date that it was flown

In 2000 the company Getmapping flew aerial imagery for the whole of the UK - which is extremely impressive given that they were obtaining high resolution, cloud-free data. For how many days in the year is the UK completely cloud free?

Most of the data available in Aerial Digimap has been flown much more recently.

Note that when you click on the map for information you are also shown a red outline for the tile that you have clicked on. You may need to zoom out and move the Tile Name dialog out of the way to see this.

Search for the following British National Grid easting and northing using the search box:

- ***289576, 812418***

Question 5.4. What is the Tile Name at this location, and on what date was the aerial imagery at this location flown? As a bonus, what town is this point within?

5.5.2 Aerial Download

Return to **Digimap Home** and now select

- **Aerial** and **Aerial Data Download**

As with the other download interfaces the map that you see on the screen is only an indicator of the area that you will be downloading, it is not the actual data.

Use **Search** to go to British National Grid coordinates **254042, 271408**. You'll see that this is a coastal area of Wales with a rocky foreshore. Use the **Rectangle** tool to draw a rectangle around a small part of the rocky coast. These imagery downloads can be very large so for now just pick a very small area, at the bottom right of the map you can see the size of your current selection in km^2, try to go for something of about 0.25 km^2.

- Go to **Aerial Imagery (Latest)** in the panel on the left and put a tick in the box next to **High Resolution (25cm)**
- The number in brackets after this shows how many tiles you have selected to download out of the maximum of 100. If you have selected to download more than 4 files then I'd suggest that you outline a smaller area just for the purposes of this exercise.
- If you click on the arrow next to the dataset you are given more information about it, including the recommended copyright acknowledgement. Make a note of this and add it to any document or map that you create with this data.
- Now click on **Add To Basket** and give your download a name, then **Request Download**

This works in exactly the same way as OS and Geology download, so having requested the data you need to wait for an email which contains the download link. Once you have this, download the data, move it to your M: drive and **unzip it** (Right-click on the zip file - 7-zip 〉 Extract here).

View the files in ArcGIS

You can open the jpg files in a graphics editor if you want a quick look at them, but for our purposes it makes more sense to add them to a map.

- Open ArcGIS, set up a new map and add the jpg file(s) that you have downloaded.
- You should be able to zoom in on an area of the rocky coast and have a look at the amount of detail that is available
- The files are georeferenced so can be used alongside map tiles from Digimap Ordnance Survey download
- If you are using this in a map for coursework or your dissertation, or indeed for showing to anyone else, don't forget to add the correct copyright acknowledgement.

Using aerial imagery for fieldwork

If you are setting up a map for geological fieldwork in an area of the UK it is well worth downloading this data and creating a set of aerial images too. Data may be available for other countries but it won't be downloadable via Digimap. If you can't find any aerial imagery for your area try searching for **World Imagery** in ArcGIS Online or the basemaps and add that to your map. It won't be as detailed as 25cm resolution, but will be better than nothing.

5.6 Printing and editing PDF files

5.6.1 To print

PDF files can be viewed and printed in any PDF reader, such as Adobe Acrobat Reader.

- From **My Computer** double-click on the pdf file and it should open automatically in the default reader.

For your own computer there are a lot of different programs that will read PDF files. See the list at

`http://en.wikipedia.org/wiki/List_of_PDF_software#Viewers_4`[4]

5.6.2 To edit

PDF files can be edited in Adobe software such as Photoshop and Illustrator, and in CorelDraw. It is also possible to edit files in Inkscape. Open the file as follows -

- File > Open > OK.

5.7 Copyright acknowledgements for Digimap data

Copyright is important. Remember that most data providers ask you to sign up to conditions that include an obligation to add a copyright acknowledgement to your map. Check what that copyright statement is and add it.

e.g. when you signed up to use the Digimap collections you agreed to add copyright acknowledgements whenever you created a map with the data. These do change from time to time so it's worth knowing how to check it for yourself.

- To find these copyright acknowledgements go to the **Digimap Resource Centre** (**Resources** at the top of the main Digimap page)
- Look for a link to **Digimap Licence Agreements** and click on it.
- Click on the End User or Sub-licence agreement for the data that you've used
- then look for the information under **In return, you must:** - that gives you the acknowledgement text.

[4] Last accessed: 17th September 2019.

For example, as of April 2019 when you use Ordnance Survey data obtained from Digimap you are expected to add the following text to your map.

> ***© Crown copyright and database rights*** `year`***. Ordnance Survey (100025252).***

Where *year* is replaced by the current year.

Remember that you do have to acknowledge each different dataset that you use and will have signed up to that when you registered.

Adding the copyright symbol to your text
To add the **copyright symbol** - ©- to your text • check that the Num lock is on on the keyboard • hold down the Alt key • use the number pad to type 0 + 1 + 6 + 9 • release the Alt key

Table 5.1: Adding the copyright symbol to your text

If you are *not* using U.K. Ordnance Survey data this is **not** the correct copyright acknowledgement to use, for example if you are using data for Spain or the United States, or indeed UK data that you haven't downloaded from Digimap. You'll need to find the correct copyright acknowledgement for yourself. The web page[5] at `http://bit.ly/1ZSifnd` gives some information about how to cite GIS materials - including the software as well as the data. Have a look at that and follow the suggestions to cite non-Digimap data.

Advice on citing Digimap data, as opposed to the copyright acknowledgement is at `https://digimap.edina.ac.uk/webhelp/resources/citation/services.html`

5.8 Further help with Digimap

5.8.1 Additional Digimap collections

This booklet has only covered the basic collections from Digimap. The University of Leeds also subscribes to Geology, Aerial, Historic and Environment collections.

All of the collections have a Roam and a Data Download interface which work in a similar way to the examples you have used.

You have access to all of these collections, feel free to have a look at what is available and make use of any of the data or maps in your work.

[5] Last viewed: 18th September 2018

5.8.2 Digimap Collections online help

Digimap help is available from both the Digimap Ordnance Survey and Geology home pages. Click on the links in the left hand menu for more information about how to use the services and file formats.

Alternatively use the Help links from within Roam or Download or use the videos that Edina have uploaded to YouTube at -

`http://www.youtube.com/user/EDINADigimap`[6]

If you want more detailed information Edina provide e-learning units which are linked from the main Digimap home page.

5.8.3 School of Earth and Environment

Clare Gordon can provide help and advice on using Digimap. Contact her in room 10.140b at the back of the Kennedy Library or on **c.e.gordon@leeds.ac.uk**.

The most up to date edition of this workbook will be available in Minerva for those modules on which it has been used.

[6] Last accessed: 29th August 2019

Chapter 6

Layout and presentation

Once you've put in all of the hard work to produce a map of your field area or project, it is worth making the extra effort to ensure that you lay it out clearly and print it, or export it in a professional fashion. Make sure that you allow the time to do this. Care and patience can make the difference between a scruffy, unimpressive map that loses you marks, and a clear, professional map that gives a good first impression.

Don't underestimate the time that the final details can take and don't leave this until the last hour before a deadline!

You won't need to use all of the elements and features outlined here for every map. Equally, this is not an exhaustive list of possible elements. You should already have some idea of what elements are useful, and should be able to make a decision for each case based on your existing knowledge of maps. If you think that you need to add something that is not listed here, e.g. a report based on a table, then use the extra information available in the bibliography, further information and on-line to find out how to add it.

This chapter also includes some information on map evaluation and a useful checklist which should help you to think about how maps are used and what needs to be included.

So this chapter isn't necessarily for working through in order. Make sure that you are aware of the contents and of what Arc is able to do, and then make your own decisions and further investigations.

6.1 Learning outcomes

When you have completed this section of the workbook you should be able to

- layout a map in such a way that it effectively communicates the content and purpose of your work to a user
- select map elements to include in a layout and set their properties to match the requirements of your map
- print or export your map to show it to it's best advantage
- evaluate your maps and maps by other people or organisations based on a checklist

6.2 Viewing a map layout

In ArcMap **Layout view** allows you to control the format and scale at which you print your map, and lay out additional elements to complete the final product.

- Open the map that you created in the previous chapter in ArcMap

- Go to layout view by clicking on View > Layout View or by clicking on the Layout view button - see figure 6.1

In this view you will see your map laid out as it will be when it is finally printed or exported with the page outlined on screen and the content on top of it - figure 6.1.

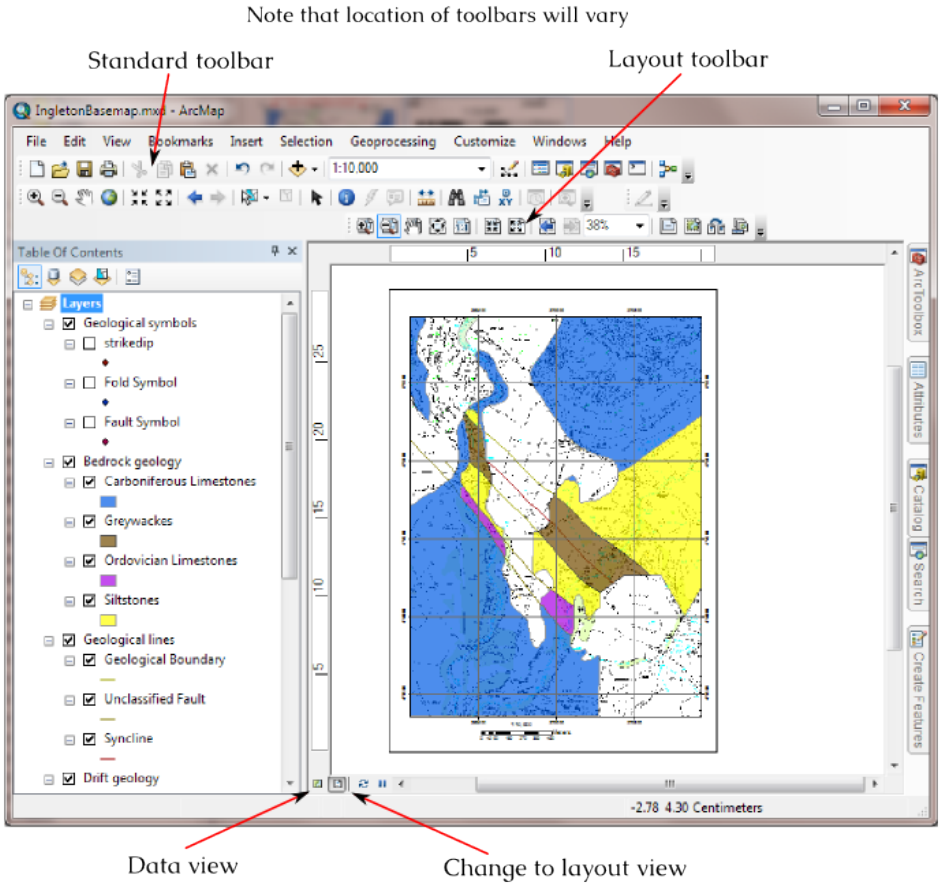


Figure 6.1: Layout view

6.3 Size and scale of a layout

6.3.1 Page size and scale

Changing the size of the page can also change the scale, so each time you alter this check the scale of your map again!

Video Clip available in Minerva - Setting the size and scale of a map layout. Direct link: `http://bit.ly/2h33WSu`

- File > Page and Print Setup... - see figure 6.2.
- Check whether **Use Printer Paper Settings** is ticked or not.

  - If it is the settings used are those in the **Paper** area above
  - If it isn't then the settings used are those in the **Page** area below.

- If you want a standard paper size such as A0 or A4
  - Select the size in the dropdown list in the **Page** or **Paper** area
  - Select the correct orientation (portrait or landscape)

- If you need a non-standard paper size
  - Choose **Custom** in the dropdown box
  - type your required measurements into the **width** and **height** boxes
  - select the orientation if necessary (portrait or landscape)

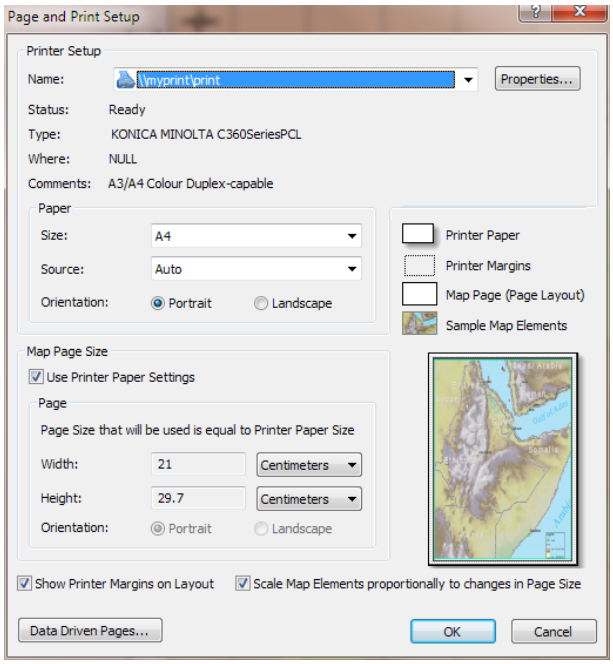


Figure 6.2: Page and Print setup: Choosing page size

Start with the paper size as A4 in Page and Print setup; set the map scale to 1:25 000. Next set the paper size to A3 and tick the Scale Map Elements proportionally to changes in Page Size box. Now click OK
Now what scale is your map?

The scale will probably change almost every time you change anything else! **KEEP CHECKING AND RESETTING IT!**

Repeat the above steps as necessary until the layout looks right and is at the correct scale.

6.3.2 Resizing the data frame in a layout

When you first change to layout view the area of the map that you see in the data frame will not necessarily be the area that you want to show. Changing the size of the data frame is easy, but can take a little experimentation. You will also need to look at this in conjunction with the instructions on changing paper size in the previous section.

Video Clip available in Minerva - Resizing the data frame in a layout.
Direct link: `http://bit.ly/2h2YQWp`

- Click once on the data frame (that is the main map area)
- When the data frame is selected you should be able to see that it is outlined by a dashed line with small turquoise boxes at the corners and on each side - see figure 6.3.
- Use the boxes as “handles” to resize the data frame by dragging
- Keep an eye on the scale dropdown! You may need to put this back to your required scale and then resize the data frame again
- Remember that you can use the pan tool on the layout toolbar to move your map within the data frame.
- Keep repeating this until the size/extent and scale of your map are correct

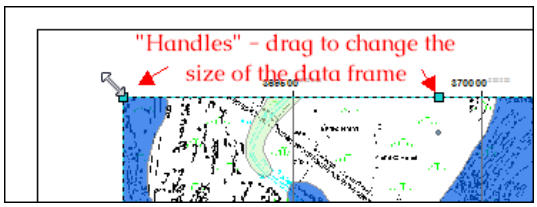


Figure 6.3: Using the “handles” to resize a data frame in layout view

Printing a map at the correct page size, area and scale
Printing a map at the correct page size, area and scale can be a bit like “juggling jelly”. You just have to keep trying and change it a little bit at a time until it looks right. • Start by setting the correct paper size • Then use the black arrow tool to set the data frame to the size you want compared to the paper size • Now check the scale of your map and change it if necessary • Check the coverage - does your map show the area you need? • keep repeating these steps (sometimes several times) until your map shows the right area at the right scale, and fits on the page!

Table 6.1: Printing a map at the correct page size, area and scale

6.3.3 Setting a fixed extent

It is possible to set the view to show a particular extent, but be warned that if you do this it then becomes impossible to change the scale of your map in either map or layout view, and you won't be able to resize the data frame in layout view or pan your map in map view. If you've been asked to produce a map at a particular scale this won't be a good idea!

- Go to Data Frame Properties > Data Frame
- Under **Extent** use the dropdown box to select Fixed Extent
- Enter the coordinates you require in the boxes or click on Specify Extent... to choose a layer or view.
- Apply > OK
- If you wish to undo this just set Extent back to Automatic

It is also possible to set the dropdown to Fixed Scale, which can be useful, but does mean that if you are still working on your map it isn't possible to zoom in and work on details.

6.4 Adding elements to a layout

The information below includes details on adding many different elements to a layout. Not all of these will be appropriate to every layout, it is up to you to decide which elements to use depending on the purpose and audience of your map and any guidelines specified for assessments or reports.

Remember that **Arc Desktop Help** will provide you with plenty of extra information on how to add map elements to a layout.

Most elements are added to a layout in a similar way to each other using the Insert menu. In most cases you'll then be presented with a properties dialog which allows you to make changes to the element.

Once they have been inserted you can move the elements around. If you need to change properties then double-click on an element.

Video Clip available in Minerva - Adding a scalebar, title and text to a layout. Direct link: `http://bit.ly/2s9iMYO`

6.4.1 Scale bar and text

Some indication of scale should always be added to both printed and screen maps. A scale bar is a useful convention for both. Scale text (e.g. 1:50 000 or 1cm = 1km) is only relevant for printed maps, not for maps on screen where someone can zoom to any scale.

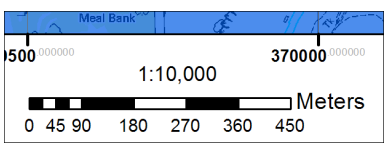


Figure 6.4: Scale bar and scale text on a map layout

6.4.2 Title and text

Adding a title

Maps need an informative title so that people looking at them know what they are supposed to show. You can add a title by going to Insert > Title. This gives you a dialog in which to add the title which will then appear on your map. If you want to change the font size etc double-click on the title then click on Change Symbol... . Doing it this way sets the title in the **Map Document Properties** for the whole map - change the title text by going to File > Map Document Properties.

Adding text

You should use the insert text command to add further text, such as your name (or for an assessment your student ID) as creator of the map, a copyright statement, acknowledgements, and further explanation.

Copyright acknowledgements Copyright is important. Remember that most data providers ask you to sign up to conditions that include an obligation to add a copyright acknowledgement to your map. Check what that copyright statement is and add it.

e.g. when you signed up to use the Digimap collections you agreed to add copyright acknowledgements whenever you created a map with the data. These do change from time to time so it's worth knowing how to check it for yourself.

- To find these copyright acknowledgements go to the **Digimap Resource Centre** (**Resources** at the top of the main Digimap page)
- Look for a link to **Digimap Licence Agreements** and click on it.
- Click on the End User or Sub-licence agreement for the data that you've used
- then look for the information under **In return, you must:** - that gives you the acknowledgement text.

For example, as of April 2019 when you use Ordnance Survey data obtained from Digimap you are expected to add the following text to your map.

> ***© Crown copyright and database rights*** `year`***. Ordnance Survey (100025252).***

Where *year* is replaced by the current year.

Remember that you do have to acknowledge each different dataset that you use and will have signed up to that when you registered.

If you are *not* using U.K. Ordnance Survey data this is **not** the correct copyright acknowledgement to use, for example if you are using data for Spain or the United States, or indeed UK data that you haven't downloaded from Digimap. You'll need to find the correct copyright acknowledgement for yourself. The web page[1] at `http://bit.ly/1ZSifnd` gives some information about how to cite GIS materials - including the software as well as the data. Have a look at that and follow the suggestions to cite non-Digimap data.

Advice on citing Digimap data, as opposed to the copyright acknowledgement is at `https://digimap.edina.ac.uk/webhelp/resources/citation/services.html`

If you want to add formatted text try adding it via a Word document using the instructions in section 6.4.9 on page 80.

[1] Last viewed: 18th September 2018

Adding the copyright symbol to your text
To add the **copyright symbol** - ©- to your text • check that the Num lock is on on the keyboard • hold down the Alt key • use the number pad to type 0 + 1 + 6 + 9 • release the Alt key

Table 6.2: Adding the copyright symbol to your text

6.4.3 Adding a key / legend to your layout

You'll have added various data to your map, and it is necessary for you to explain to anyone looking at your map what those layers and symbols show. To do this you'll need to add a legend or key.

Start by using the default options to create a legend. Once you have the basic legend it is possible to make alterations later

Video Clip available in Minerva - Adding and editing a map legend. Direct link: `http://bit.ly/2urgYuF`

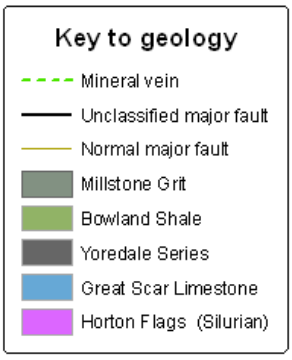


Figure 6.5: An example of a basic legend or key

- In layout view - Insert > Legend...
- The Legend Wizard should open. ArcMap will probably add all of your layers to the right-hand box automatically. Use the arrow buttons to remove and add layers and to order them as you want them to appear - referring back to the list that you just made.
- Next then change the legend title if you wish and click Next again
- Decide whether you want to add a background or border to your legend then Next > Next > Finish
- Move your legend to an appropriate position on your map.

You can double-click on the legend to change its properties and settings. At this stage if you make changes to the layers in the table of contents, those changes will automatically be reflected in the legend.

As an aside - the ESRI blog has a short discussion at `http://arcg.is/2eD2Kk2` about the use of singular and plural nouns for legend items which you might find informative.[2]

It is very likely that you will want to change the legend in some way to make it clearer. Once you have all the basic information in your legend you can convert it to a graphic and you will have more flexibility to rearrange items. Note that once you have converted a legend to a graphic it will no longer change automatically if you change symbology or layers on your map, you will have to generate a new legend. So leave this step until you are happy with everything else on your map.

Converting a legend into a graphic

- In Layout view use the **Select elements** tool (black arrow) to select the legend.
- Right-click on the legend Convert to Graphics.
- Right-click on the legend again Ungroup.
- Repeat the last step again

Now you should be able to select individual parts of your legend and move them around or delete them.

> ***For example if you have lines with symbols that have been added as points: in your legend move the point symbol so that it is positioned on top of the appropriate line then delete any text that was associated with the symbol.***

Use the tools on the **Draw** toolbar (figure 6.6) to add extra text.

Figure 6.6: The Draw toolbar

> ***The default legend styles in Arc will not necessarily group features in a way that is most helpful for your map. You can add headings yourself using the Text tool and then rearrange the entries under those headings manually.***

Make sure that your key covers all of the information that you have added to your map, but doesn't include any symbology that doesn't appear on your map. (Do you want a viewer to sit there wondering where that symbol is on your map?)

6.4.4 Adding a measured grid

Measured grids add labelled grid lines to a layout. If you are using Ordnance Survey or other UK data projected in British National Grid then you can easily add National Grid lines and numbers to your map. The O.S. raster tiff files already have grid lines marked, but adding a measured grid allows you to include coordinates around the edge of your map - making it possible to read grid references.

- View > Data Frame Properties > Grids > New Grid > Measured Grid

[2] Last viewed: 18th September 2018.

Video Clip available in Minerva - Adding a measured grid to a map. Direct link: `http://bit.ly/2uruf6q`

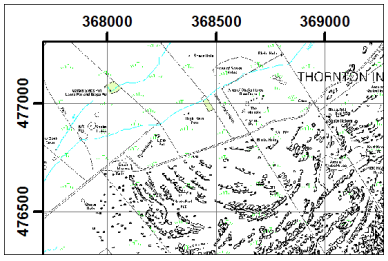


Figure 6.7: A map with a measured grid that shows British National Grid references on a 500 m grid

- Choose the style that you want. Check that the coordinate system is set to **Same as data frame**, and check that the intervals are suitable to the scale of the map, e.g. 500 meters for a 1:10 000 scale map. *Note that being able to set this relies on having the correct coordinate system set for your data frame.*
- Next > Next > Finish > OK

Once you have set the grid up you can make further changes to the properties by going to View > Data Frame Properties > Grids and double-clicking on the grid that you have already created.

Note that the grid that Arc adds is fully numeric, you may be more used to seeing grid letters for 100 km grid squares, e.g. our current grid reference is similar to SE 2934 3444, our current grid coordinates are similar to 42934 43444. It is the latter that will appear on a measured grid generated by Arc. For more information on this and a diagram to help you to change from one to the other, see section **??** on page **??**.

6.4.5 Adding north arrows

Before adding a north arrow to your layout stop and think about how you need to indicate north on your map. If you look at the technical information on an Ordnance Survey Landranger (1:50 000) map you'll see a diagram showing Grid north, True north and Magnetic north. The information given there shows how to plot the difference of magnetic north from grid north. Adding this to your own maps can also be useful.

If you are taking strike and dip measurements in the field you should have corrected your compass-clino for declination (the horizontal angular difference between true north and magnetic north) anyway. When you plot the measurements on your map it isn't worth worrying too much about whether you are plotting against grid or true north as the difference on any grid, not just the British National Grid, is unlikely to be that big. Figure 6.8 shows the different types of north and the declination.

If you add north arrows to your layout do remember to label them in some way which shows which version of north each one is showing.

Video Clip available in Minerva - Adding north arrows to a layout. Direct link: `http://bit.ly/2hohEQa`

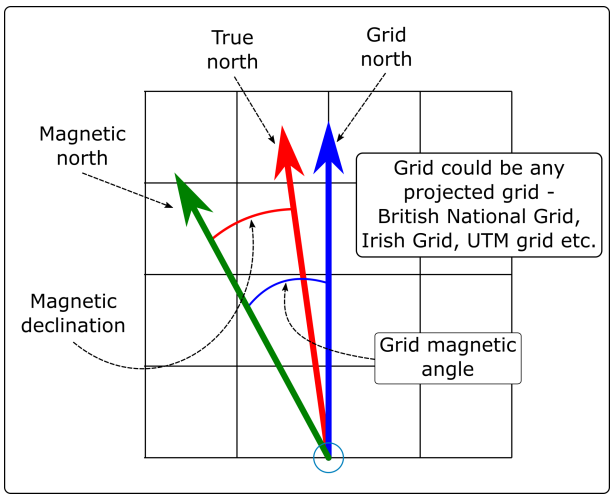


Figure 6.8: The different types of North that you'll find on a map set to a projected coordinate system, such as British National Grid

North arrow: Grid north

If a map is in a projected coordinate system ArcMap will automatically lay it out aligned with the grid. So for example, any map set to British National Grid will be aligned to grid north.

In this case it isn't strictly necessary to add a north arrow to show grid north if you also include a measured grid on your map, but it doesn't hurt.

In layout view:

- Insert » North Arrow...
- select an arrow style (it's usually better not to go for something too fancy!)
- Click on Properties... and check that **Align To:** is set to **Data Frame Rotation**
- OK » OK

If you check this against your measured grid lines you should find that it matches exactly.

North arrow: True north

True north is the direction from the area of your map to the North Pole. In the east/west centre of a grid, such as that set for the British National Grid, it may well be the same as grid north, e.g. in Leeds the difference is extremely slight. As you go further east or west towards the edges of an area covered by a grid the difference becomes more noticeable, e.g. at Lands End in Cornwall, or in Norfolk.

In layout view:

- Insert » North Arrow...
- select an arrow style (it's usually better not to go for something too fancy!)
- Click on Properties... and check that **Align To:** is set to **True North**
- OK » OK

If you check this north arrow against your measured grid lines you may well find that the north arrow is slightly tilted.

North arrow: Magnetic north

Magnetic north is the direction from the area of your map to the magnetic North Pole. This changes with time so the first thing you need to do is to find out what the **declination** is in your area at the moment[3]. To do this you can use the page provided by the BGS Geomagnetism Group at `http://bit.ly/2uGMfdp`[4]

Use the map to select your area and click to retrieve the data. Make a note of the figure shown as **degrees east** and round it to the nearest whole number. The key to the table you are given is underneath the map.

In layout view:

- Insert > North Arrow...
- select an arrow style (it's usually better not to go for something too fancy!)
- Click on Properties... and check that **Align To:** is set to **True North**
- Set the **Calibration Angle** to the figure you found above. The arrow on the preview should change to reflect this (see figure 6.9).
- OK > OK

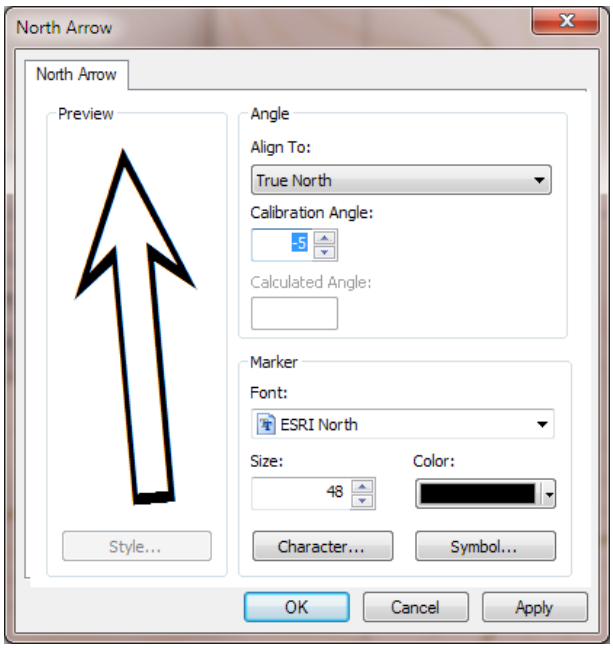


Figure 6.9: The properties for a north arrow to show magnetic north

This magnetic north arrow should now appear tilted the appropriate number of degrees from the true north arrow that you added above. It would be useful to also add text to your layout (Insert > Text...) showing the date that you added magnetic north, and the declination figure.

[3] **Declination** is the angle between true north and magnetic north at a particular location. **Grid Magnetic Angle** is the angle between north on the grid and magnetic north. To find Grid magnetic angle for Great Britain use the calculator at `http://www.geomag.bgs.ac.uk/data_service/models_compass/gma_calc.html` on the BGS pages. This is the number that is given on the corner of OS maps and the one you need for setting your compass-clino in the field so it would be worth making a note of this on your map too.

[4] This should work for anywhere in the world.

6.4.6 Adding extra data frames

It can be very useful to be able to place more than one map or map view on a single layout, either so that you can show a different area, or a different zoom level for the same area. You can also use this to set up an automatic extent indicator which marks your study area on a larger map. To do all of this you need to add extra data frames.

Video Clip available in Minerva - Adding extra data frames to a layout.
Direct link: `http://bit.ly/2spjXqZ`

Create a new data frame

- In either data or layout view Insert > Data frame
- A new data frame should appear in your table of contents and the map area will become blank if you are in data view, or show a new data frame on the page if you are in layout view (see figure 6.10). If the new data frame doesn't appear in layout view, use the cursor to drag the data frame title from the table of contents to the layout.
- Make sure that the data frame title in the table of contents is bold - that means that it is **active** (see figure 6.11). If you need to make a data frame active right-click on it and select **Activate**.

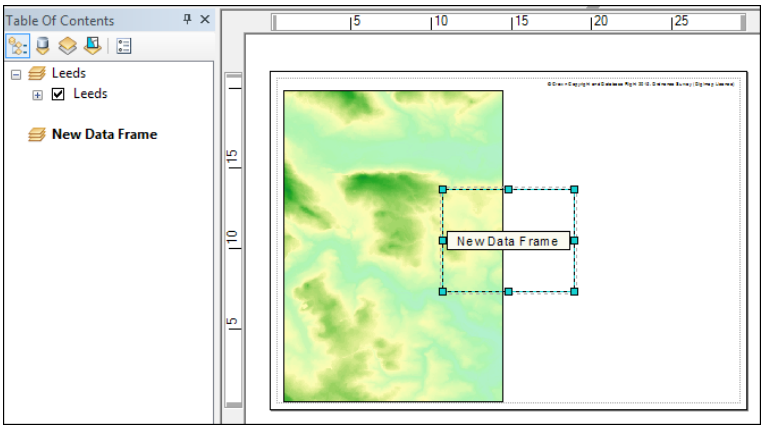


Figure 6.10: Layout view showing the newly added data frame. You can now move and resize this as you wish, and add data to it as required

Add data and set the projection

- Add map data to the new data frame, either by adding it from the Catalog, or by dragging and dropping it from an existing data frame.[5]
- You may need to alter the data frame properties to set the Coordinate System - don't forget to check that it has been set correctly! Note that it is possible for data frames within the same map to have different coordinate systems.
  - Right-click on the data frame title (probably **New data frame**) in the table of contents

[5] Occasionally if you are dragging and dropping from another data frame Arc will lose the link to some layers and you'll see the dreaded red exclamation mark. If this happens just follow the instructions in table 4.3 on page 38 to repair the links.

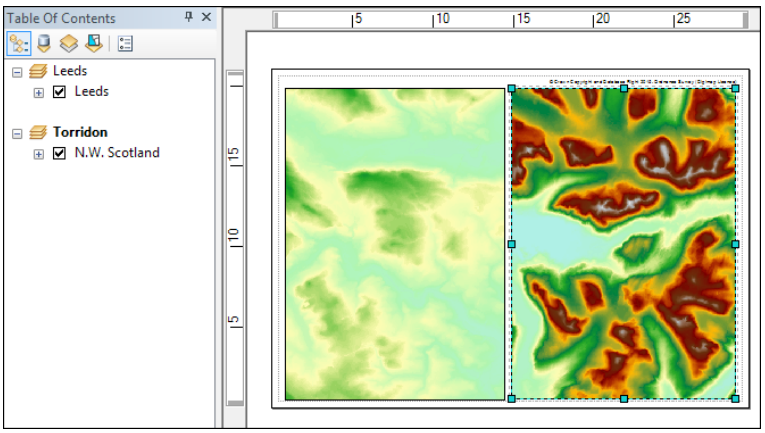


Figure 6.11: Layout view showing the activated data frame - note the data frame title in bold in the table of contents, and the selection lines around the data frame on the layout

– If it hasn't already been set, set the coordinate system as required by your map, e.g. for British National Grid - Properties... > Coordinate System > Projected Coordinate Systems > National Grids > Europe > British National Grid > OK

6.4.7 Adding an extent indicator

For some maps, particularly large scale maps of very small areas, it is useful to show a small scale map of the general area with the area of the main map marked (see figure 6.12). To do this you need to obtain small scale data and then add it to a second data frame in ArcMap. For Great Britain investigate the more general scale basemaps from Digimap, such as MiniScale or GB Overview, or use the national outlines from the boundary layers. It's up to you to select data which is readable/clear at the scale you are going to display it.

For areas outside of Great Britain you may need to search for suitable data, or use data from Natural Earth[6].

Note that using a screenshot from Google Maps or Google Earth (or similar) with a marker on it doesn't look good, and should be avoided.

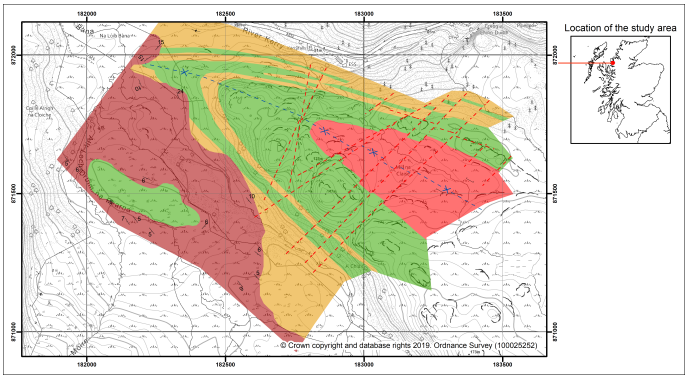


Figure 6.12: An extent indicator on a layout: using a smaller map to show the general area of the main map

Start by adding a new data frame to your map as shown in section 6.4.6 on page 78 and add your choice of map layers to the new data frame.

[6]Download from `https://www.naturalearthdata.com/` Last visited: 16th May 2019.

Set up the extent indicator

- Resize and relocate the data frame and set it to an appropriate scale (e.g. start with 1:1 000 000) and the area around the location of your main map.
- Right-click on the data frame title in the table of contents Properties > Extent Indicators add the main data frame (probably called "**layers**" to the right-hand box and tick the **Show Leader** box then click OK.

You should now have a map with a red box showing the outline of the area covered by your main map and with a line leading to it as in figure 6.12 on page 79.

Try moving and rescaling both maps - the box should resize and relocate to reflect your changes.

You can change the style of the box and the leader line by going back into the **data frame properties**.

6.4.8 Showing a profile on a layout

If you have created a profile graph for your map you may wish to include it in the final layout.

- If the profile that you created earlier is still open:
  - Right-click on the graph Add to Layout
- If the profile is closed - whilst in layout view:
  - Views > Graphs > Manage... right-click on your graph in the list Add to layout
- Once your profile graph is on the layout:
  - Move the graph to the required permission
  - Change properties by selecting the graph, right-clicking and going to **Properties**

6.4.9 Adding sections, diagrams and photographs to a map layout

You will probably want to add extra items to your map layout, in particular cross sections and diagrams created in vector drawing packages such as Inkscape, CorelDraw or Adobe Illustrator and maybe some photographs.

When it comes to creating a full map presentation, such as the Geological Sciences A0 dissertation map, which includes elements other than just a map, you have a choice:

- You can either use ArcMap to set up the full layout by importing photographs and also sections, diagrams, etc created in other programs such as Inkscape or CorelDraw - **instructions for importing elements from other programs are in this section**.
- *or* you can export your completed map (and other map elements) from ArcMap and import them into Inkscape, CorelDraw or a similar vector package. (Word, Powerpoint etc are **not** recommended for creating a full layout.) **In this case go to section 6.6.3 on page 84 and look at the instructions for exporting a layout from ArcMap.**

Video Clip available in Minerva - Adding diagrams, images and formatted text to a layout. Direct link: `http://bit.ly/2t8CHbs`

Adding objects: CorelDraw diagrams and Word documents

You should use these instructions to include any text and CorelDraw diagrams that you need to include in your layout. These instructions also work for Excel spreadsheets. Inkscape diagrams should be exported to png and then imported to ArcMap as images - see section 28 below.

Note that CorelDraw files may not display correctly if you have gradient fills. You may find that you have to export images from CorelDraw as png (Portable Network Graphics format) and then insert them into Arc as images - see section 28 below.

- In Layout view - Insert > Object... to open the dialog (figure 6.13)
- Click to **Create from File** and browse to find the file that you want to insert
- Check that Display as icon isn't checked
- then click OK
- Move and resize the file on the page as required.
- If you wish you can right-click on the object to get a dialog that allows you to add a background or border.

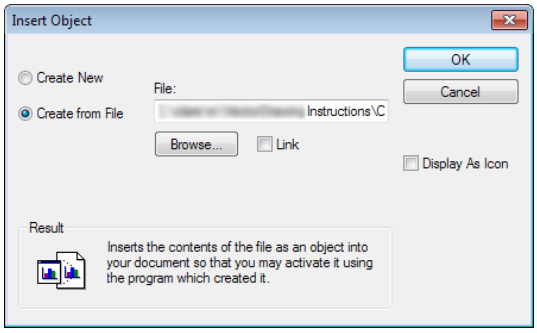


Figure 6.13: Inserting an object such as a CorelDraw file into a layout

If you are likely to want to make changes to your diagram or document later then you can click so that you **link** the file rather than insert it, but that does mean that you need to keep it in the same location relative to your Arc mxd file. This is particularly useful if you want to add formatted text as the tools are so limited in Arc. Write your text in Word and then include it as an object and you can still edit it by double-clicking on the object in Arc.

Inserting photographs and images

Very similar to above but use this method for including jpg, bmp, png etc files in your layout.

Following some experimentation I would recommend that if you are including diagrams produced in either CorelDraw or Inkscape you **export/save as...** your diagram as **png** format and then insert the result into Arc. It may not look quite right on screen (gradients can be a bit odd and the image can look very pixelated/blurry) but looks fine when actually printed. Jpg files tended to have problems with colours changing when they are exported from CorelDraw.

- In Layout view... Insert > Picture... and browse for the image you require OK
- Move the image as required. Try not to resize it unless you absolutely have to. You'll get better quality if you resize vector images in Inkscape/CorelDraw before you export them, rather than resizing them in Arc once they've been saved as rasters.

Remember, if the image doesn't look quite right, try exporting to pdf or printing a copy before you worry about it (see section 6.5.1 on page 82). What you see on screen isn't always how the final result will look.

NOTE: double-check that images inserted in this way print! If they don't then, if all else fails, it is possible to add them to a Word document then insert the Word document as an object - see section 28 above.

6.5 Checking your map

A very important stage but one that can easily be forgotten if you are in a hurry!

In addition to the points below have a look at Darkes (2017) which gives lots of quick tips on map layout and presentation. On pages 92 and 93 Darkes includes a section with quick wins for improving your map before publication if you have 5, 15 or 50 minutes. In addition, check the reading list for other references - there is plenty of information available to help you to present better maps.

- ***Check spelling. Even better - get a helpful (and reliable!) friend to proof-read your text for spelling mistakes. It's very easy to miss something obvious in your own work. In particular check geological and geographical names and any technical terms.***
- ***Check that you have included everything that you need to include - if this is an assignment reread the instructions and check that you haven't forgotten to do anything.***
- ***Check that your map doesn't include anything that you don't want to include! Did you add some experimental polygons when you were editing, then forgot to delete them? Have you clicked on the Add text button too many times, but then not removed the resulting text?***
- ***Look at the article on the ESRI blog at*** `http://bit.ly/SZyDiC` [a]***. Read about what makes a map great, then click on the link to the checklist and use the questions there to evaluate your own map. Have you included everything you need to include, or do you have a good reason if something is not on your map? Have you taken care with your presentation?***

[a] Last viewed: 18th September 2018

6.5.1 Printing a copy to pdf to check

Inevitably you'll notice something not quite right with your map after you have printed it. To minimize the chances of this happening when the (expensive) big version is printed it is a good idea to print your map at A3 and have a close look at it first! (This isn't such an issue if your map is only A3 or A4 when full size.)

- Export your map as a pdf file following the instructions in section 6.6.2 on page 83.
- Open your pdf map file in Acrobat reader, or your usual pdf program (instructions below are for Acrobat).
- File > Print...
- Choose your printer and use the printer properties to set the paper size to A3 then choose to print in colour.

- In the **Page Handling** section set **Page Scaling** to **Fit to Printable Area**. In Acrobat this should show you a small preview of how your file will print.
- When you are happy with the settings - OK

6.6 Printing and exporting maps from ArcMap

When you have finished creating your map in ArcGIS you will usually need to export it to pdf for printing. The following instructions should help to ensure that your map is the correct size and scale.

6.6.1 Printing a map from ArcMap

The best quality output is obtained by printing directly from ArcMap, though this isn't always possible. If it is, print as follows:

- Start by checking that the page size and scale are correct in **Page and Print Setup...** (section 6.3 on page 68)
- Whilst in Layout view - File > Print...
- Select your printer with the Setup... button and choose paper size and colour printing as you usually would (this is system specific so I can't include exact instructions here)
- Set **Output Image Quality** to **Best**
- Click on OK to print

6.6.2 Exporting a map for printing

These instructions show you how to export the map to pdf - the format that is usually required by print shops etc. There are other options in the dropdown list if you need to export an image or another format and the instructions are very similar.

- From within layout view - File > Export Map...
- Select **PDF(*.pdf)** in the **Save as** type. **(Do not select the 'Production PDF' option, if you have it - it causes all sorts of problems.)**
- Set the resolution - minimum 300dpi for printing. Higher is better, but too high and it will be impossible to export the file, particularly if it is a large map.
- Set **Output Image Quality** to **Best**.
- Give your file a name and choose where to save it (checking first that you have enough disk space - some exported maps can be very large[7]).
- Save - be patient! For a large map this can take a long time.

Important note on printing your final copy

If you are printing your final copy from pdf double-check that the **Page Scaling** or **Zoom** is set to **Actual Size...** or **None** (the actual terminology depends on which pdf application you are printing from). This is important to ensure that your map is printed at the scale at which you intend it to be printed. Major problems can be caused by the tiny amount that your map will be reduced by otherwise.

[7] If you think that you may be short of disk space you can save the export to the c: drive or the desktop of the computer in the first place, but do make sure that you then move the file to your m: drive or a USB stick. Forget and you'll lose it.

6.6.3 Exporting a map to import to other programs

As explained in section 6.4.9 on page 80 you can either import items into an ArcMap layout, or export the ArcMap layout to include in programs such as Inkscape, CorelDraw, Word or Powerpoint. The instructions here show how to do the latter.

- To start with set up your ArcMap layout as required
  - check that the page size, and the scale/size of the data frame are correct - you'll lose quality if you resize them outside of Arc
  - If you want to include a legend in the final layout it is a good idea to create it in Arc and export it with the map as then the colours and sizes of the symbols will match the map.
  - add a measured grid and a scale bar
  - optionally add an automatically generated extent diagram
- File > Export Map...
- Choose the appropriate output format (see below) and set the resolution - to **600 dpi** if you have the disk space
- Choose a location then Save

If you basically want a good quality image to import into Word, Powerpoint, CorelDraw, Inkscape etc, then **png** or **jpg** are both fine. Be aware that if you import png or jpg and then resize them you are likely to end up with blurred final result - double-check before printing.

You can also import **pdf** or **svg** into Inkscape and CorelDraw and do some limited further editing.

Whichever format you choose, if your map is going to be part of a bigger presentation where scale is important, such as the Geological Sciences final dissertation map, import to either Inkscape or CorelDraw without changing scale/size/proportions (check instructions for those programs) and then double-check the scale of the main map by drawing a horizontal line of known length and checking it against the lines of the measured grid. For example, for a map at 1:10 000, a line of 10 cm will be the same length as the space between the 1000 m (1 km) grid lines.

6.7 Recommended reading: layout and presentation

The module reading list[8] includes a full section on layout and presentation. In particular have a look at "Designing better maps" by Cynthia Brewer, but for a quick overview look at the article by Frye (2001) or the small book by Darkes and Spence (2017). For examples and ideas look at Brewer (2008) and the ESRI Map Book Gallery.

[8] Reading list available from Minerva and from the module catalogue at `http://webprod3.leeds.ac.uk/banner/dynmodules.asp?M=SOEE-2650`

Chapter 7

Creating data for GIS: Digitising

7.1 Introduction

Digitising or tracing data manually in Arc involves having a background map which shows the locations that you wish to digitise, and then using the editing tools to draw vector polygons, lines and points. In this exercise you will produce a map of Chancellors Court showing the outlines of the buildings, the paths, and other features such as seats and signposts.

Even if you never actually need to digitise a map it is extremely useful to know how to set up your own feature classes and how to add features by editing. Sometimes you just need to outline your study area, or add a point to show where something specific is, or as input to one of the tools provided in Arc.

This is a very brief overview of the tools for digitising in ArcMap as we are limited for time - if you need to do anything more complex then you should be able to find plenty more information in the ArcGIS Desktop Help.

Video Clip available - If you feel that you are still not clear about the difference between **raster** and **vector** GIS data it would be worth having a look at the video "Learn more about raster and vector map data" by the Ordnance Survey which is available at `https://youtu.be/hb0Gp51nYGI`

7.2 Obtaining the background data

- Download the `Chapter06_digitising_data.7z` file from Minerva.
- Unzip it to your GIS working folder

You should have a folder containing an ArcMap file. Open the `.mxd` file in ArcMap, check that data links in the table of contents are not broken[1] and that you have an aerial view of the University[2], then follow the instructions below to prepare to digitise data.

[1] If data links are broken follow the instructions in table 4.3 on page 38 to repair them.

[2] This is aerial data from Digimap. Unfortunately the imagery covering the University was created in 2000 so is rather out of date. Most noticeably for us, the north building of the School of Earth and Environment hadn't yet been built. This doesn't affect the exercise you'll be following, though.

7.3 Setting up a geodatabase to store your data

A geodatabase is a container that holds lots of other datasets or feature classes. You'll set one up and then use it to store the data that you create by digitising features.

Note that we will be using the Catalog panel in ArcMap for these steps, but all will work in ArcCatalog too.

Video Clip available - The YouTube video at `http://bit.ly/1zR2WBY` shows the process of creating a geodatabase, feature dataset and feature class. It also carries on to show how to add data to a feature class - we'll cover this later. (This video has sound)

- In the catalog panel on the right-hand side of ArcMap select the folder in which you want to set up your file geodatabase.
- Right-click on the folder New > File Geodatabase.
- Give your geodatabase a name, e.g. **Leeds**.

Things to check if you have problems setting up geodatabases
• Make sure that you are in a folder, not directly on the root of a drive, e.g. in the C: drive. • Check your disk space!

Table 7.1: Things to check if you have problems setting up geodatabases

You should end up with a new entry in the catalog that has an icon like a small grey tin (figure 7.1).

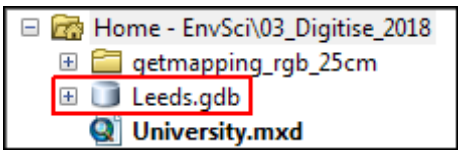


Figure 7.1: A file geodatabase in the catalog panel

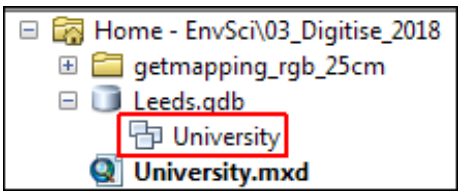


Figure 7.2: The file geodatabase now includes a feature dataset

7.3.1 Set up a feature dataset

Still in the catalog panel or ArcCatalog

- Right-click on your geodatabase
- New > Feature Dataset...

- Enter a name that describes the information that it will contain, in this example it could be **University**.
- Click Next.
- Set your projection - in this case British National Grid so select Projected Coordinate Systems › National Grids › Europe › British National Grid.
- Next › Next › Finish.

Getting around problems with adding feature datasets and feature classes to a geodatabase
Sometimes when you try to add feature datasets or feature classes to a geodatabase you'll get an error message saying that the database is already in use or is locked. This will prevent you adding anything else. The first thing to check is that you are not in an edit session. If you are sure that you are not and it still isn't working, try the following. • If you are using the Catalog Panel in ArcMap then close ArcMap completely. • Open ArcCatalog and, in the table of contents, go to the geodatabse to which you want to add a feature dataset or feature class. • Right-click and add the feature dataset or feature class here If you are having problems with creating feature datasets and feature classes in ArcCatalog, then do the reverse - close ArcCatalog, Open ArcMap, and use the Catalog panel to add new datasets or classes.

Table 7.2: Getting around problems with adding feature datasets and feature classes to a geodatabase

You should end up with a new entry in the catalog that has an icon like three small grey boxes (figure 7.2) (you may need to click on a + sign next to the geodatabase icon to see the feature dataset.)

7.3.2 Set up a feature class

Still in the catalog panel or ArcCatalog

- Right-click on the feature dataset in the geodatabase (e.g. in this example the feature dataset is **University**) New › Feature class...
- Give your feature class a name that describes what it's contents will be, e.g. **Buildings** and an alias, e.g. **University buildings**. The alias will be a readable name that will appear in ArcMap etc., so it can include spaces. Note that the name of the feature class should not contain any spaces or symbols.
- Select the type of feature class to be stored - for this class it will be **Polygon Features**.
- Next › Next.
- In the next dialog you can add extra fields to your feature class, in this case click in the first blank space in the **Field Name** column and type `Label` then check that the **Data Type** is `Text` and change the **Length** to `100`
- Finish

Arc should create the new feature class and add it to the current map. Note the icon for the Building feature class in the Catalog, this shows you that it holds polygon features (see figure 7.3).

In the same way, inside the feature dataset, create a feature class called Paths with a feature type of Line Features.

And create a feature class called Trees with a feature type of Point Features.

Note that if you forget to change the feature type when you are creating a feature class it can't be changed later. All you can do is delete the feature class and create a new one.

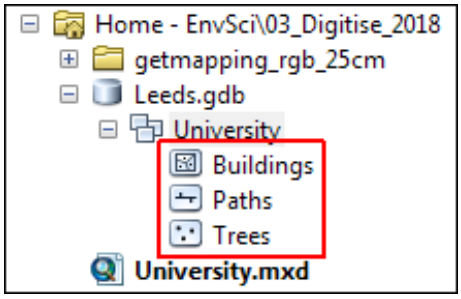


Figure 7.3: Examples of polygon, line and point feature classes within a feature dataset in a geodatabase.

Arc should have automatically added the new feature classes to your table of contents. If it hasn't add them now.

7.4 Digitising in ArcMap

You should already have an aerial view as a background for your map. For these exercises you'll be **digitising** polygons and lines by tracing over features on this view.

7.4.1 Open the Editor toolbar

All of your creating and editing will take place within an **Edit Session**. The drawing tools will create an **edit sketch** which will modify the feature in the feature class when you stop editing.

- Open the **Editor toolbar** (figure 7.4) (if it isn't already open) - Customize » Toolbars » Editor.

Figure 7.4: The Editor Toolbar

7.4.2 Check your features are available to edit

Sometimes when you create a feature class it appears in the table of contents, but doesn't appear in the list of layers that you can edit. Check that as follows -

- Start an edit session by right-clicking on the **Buildings** layer in the table of contents and selecting Edit Features » Start Editing
- The **Create Features** panel (figure 7.5) should open on the right-hand side of the window. If it doesn't, click on the right-most icon on the **Editor** toolbar to open it.

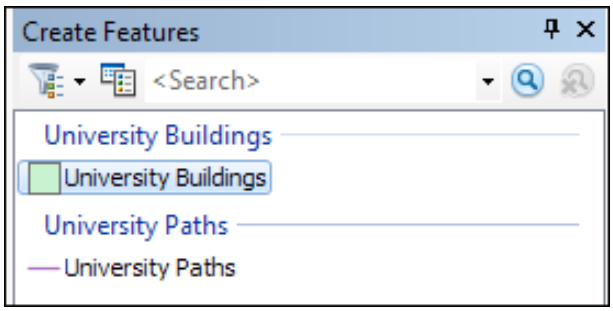


Figure 7.5: The Create Features panel with feature templates for two feature classes

If you created a feature class but it doesn't appear in the Create Features panel there are two things to check:

1. Have you selected the correct feature class? Stop editing (Editor > Stop Editing) and start editing again, being very careful to select the correct feature class.
2. If the feature class or feature still isn't visible you need to set up **feature templates** - see the next section.

7.4.3 Feature templates

If you can see the features that you want to edit, don't worry about carrying out the instructions this section. It's worth reading this section, though, as being aware of feature templates may be useful to you in the future. Start following again from section 7.4.4 on page 90.

Feature templates show the symbology of the layers that you are editing. Usually they are created automatically when you add a layer, but in some circumstances they are not. In that case you need to create them manually.

Figure 7.6: The organize templates button

- Open an edit session and select the correct geodatabase or shapefile folder.
- Click on the Organize Templates button on the **Create Features** panel (figure 7.6).
- In the **Organize Feature Templates** dialog box click on **New Template**.
- Tick the check boxes next to the layers that you need to create templates for Finish.
- There should be a symbol for each of the layers that were missing. Click to Close.

Your feature classes or features should now appear in the **Create Features** list and you should be able to select that layer to edit.

If you have set symbology categories for a layer, you can also add the symbology as templates in exactly the same way and select them directly when you are editing and creating data.

Video Clip available in Minerva - Digitising in ArcMap Part 1: Starting and finishing, and creating polygon features. Direct link: `http://bit.ly/2gNhDVw`

7.4.4 Digitizing a polygon

We'll digitise the School of Earth and Environment (SEE) building by drawing a polygon around the outline.

- If you haven't already, start an edit session by right-clicking on the **Building** layer Edit Features > Start Editing.
- In the **Create Features** area which should open to the right of your window, make sure that the **Building** layer is selected.
- In the area below select the correct **Construction Tool**, e.g. **polygon**.

Figure 7.7: Straight Segment tool

- The **Straight Segment** tool (figure 7.7) should automatically select on the Editor toolbar, if it doesn't then click on it now. Alternatively you can select another tool at this stage.
- Click on the map to start drawing a polygon. Trace along the edges of the SEE building by clicking each time you want to change direction.
- Each click creates a **vertex**, which is similar to a node in a drawing package such as CorelDraw.
- If you want to **undo** the last vertex that you drew, press Ctrl + z.
- Double-click when you finish your polygon, or press F2. If you don't do this you will find that your polygon just disappears when you start doing something else.

You can easily delete features within an edit session, so just have a go and don't worry if your shapes don't work the first time.

- **IMPORTANT:** Save your edits at regular intervals - Editor > Save Edits.
- To stop editing - Editor > Stop Editing.

You should have created a solid polygon which covers the School of Earth and Environment (figure 7.8).

Stop and think about the digitizing that you have just done. Can you think of any potential issues with the data that you have created in this way?

- ***What scale did you digitize at? What effect will this have on the amount of detail that you included? What recommendation would you make about viewing the data on a map?***
- ***How accurate were you when you were placing the vertices?***
- ***How clear were the edges of the building that you were digitizing? What did you do when there were trees overlapping? What about shadows?***

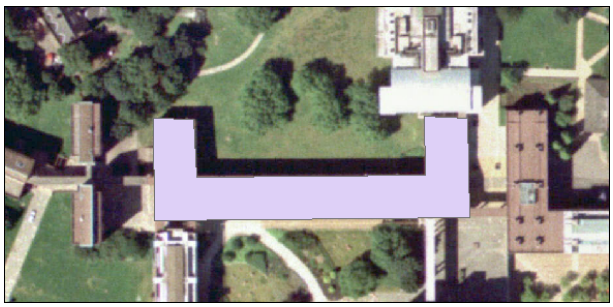


Figure 7.8: The digitised School of Earth and Environment (yours probably won't be the same colour as mine)

7.4.5 Editing features

If you want to edit a polygon or line to change it once you have created it, start by using the black arrow, i.e. the **edit tool**, from the Editor Toolbar to select the feature that you want to edit...

Video Clip available in Minerva - Selection tools and stopping layers from being selectable. It can be useful to prevent other layers from being selectable as if more than one feature is selected you won't be able to make the changes. Direct link `http://bit.ly/2fbGgee`

Video Clip available in Minerva - Digitising in ArcMap Part 4: Editing features after creation. Direct link: `http://bit.ly/2gNddyO` (watch Digitising in ArcMap Part 1 for general information about digitising.)

Figure 7.9: Edit Vertices button

- click on the **Edit Vertices** (figure 7.9) button on the Editor toolbar.
- You can then move the existing vertices, or use the small toolbar that appears to add or remove a vertex.
- You'll be editing the **Edit sketch**, not the actual line or edge, so the feature itself won't change until you finish editing by clicking F2 on your keyboard.

7.4.6 Transparency

Don't forget that you can make layers transparent. As you draw your building polygons you'll gradually be covering up the layers underneath and it can be useful to see through the top layers. Instructions for transparency are in section 1.4.5 on page 7.

7.4.7 Adding feature attributes to a feature class

Next you'll add some extra information to your new feature. It would be useful to be able to label the SEE building with its name so we'll add that to the feature class.

(Note: if you didn't create a text field called **Label** when you were setting up your buildings feature class then do so now by following the instructions in section 12.7.2 on page 173.)

- Start an edit session
- Click on the **attributes** button on the Editor toolbar (see figure 7.10). This will open the **Attributes** panel.
- Use the black arrow on the Editor toolbar to click on the digitised building and select it, the attributes panel will show the current layer and the fields (properties) available - figure 7.11.
- Enter an appropriate label in the **Label** field that you've set up. In this case enter **School of Earth & Environment**. Later we'll set this up so that it shows on the map.
- Save your edit and stop editing.

Figure 7.10: The attributes button

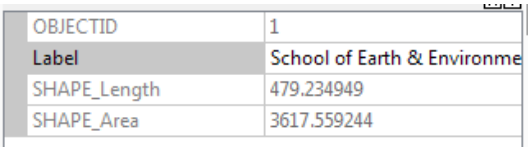


Figure 7.11: The attributes panel

7.4.8 Labelling features

Now that you have label text in your attribute table you can label the features on your map.

- Right-click on the **Building** layer in the table of contents Properties › Labels
- Click to put a tick in the **Label features in this layer** box and set the **Label** field to Label
- If you wish to, change the text symbol and colour.
- Apply to see what it looks like and OK when you are happy with your label.

The name of the building should appear on top of the polygon.

Video Clip available in Minerva - How to add labels to layers in Arc. Direct link: `http://bit.ly/2h2vtDs`

Digitise the other buildings that surround Chancellors Court. The Roger Stephens to the south east; Garstang Building to the south; and Priestley Building to the the west. Give labels to all of the buildings.

7.4.9 Digitising line features

Digitising line features is very similar to digitising polygons, except you don't have to "close" a line.

You should already have the paths layer added to your map.

- Open an edit session and select this layer to edit.
- Add lines for the paths across Chancellors Court
- save your edits and end the edit session

You don't need to add any labels for the lines layer in this case.

Video Clip available in Minerva - Digitising in ArcMap Part 2: Creating line features. Direct link: `http://bit.ly/2gNchJY` (watch Digitising in ArcMap Part 1 for general information about digitising.)

Again, think about the problems that you encounter as you edit. Do you draw the edges of the paths, or just the centre line? How can you be sure of what happens underneath trees? How easy is it to be accurate with the drawing tools? Think about the implications for future use of the map at different scales.

7.4.10 Digitising point features

Again, digitising point features is very similar to digitising lines, except you only have to click once for each feature.

You should already have the trees layer added to your map.

- Open an edit session and select this layer to edit.
- Add points for the trees that you can see in Chancellors Court by clicking once for each one
- then save your edits and end the edit session.

You don't need to add any labels for the points layer in this case.

Video Clip available in Minerva - Digitising in ArcMap Part 3: Creating point features. Direct link: `http://bit.ly/2gNlHoI` (watch Digitising in ArcMap Part 1 for general information about digitising.)

Again, think about the problems that you encounter as you edit. How easy is it to decide where you should add a point to represent a tree? How easy is it to be accurate with the drawing tools? Think about the implications for future use of the map at different scales.

7.5 Finally...

Finish digitising the buildings around Chancellors Court and the paths across it. Check that all of the layers that you have created - the points, lines and polygons, have all been symbolised appropriately and are labelled where necessary.

Then create a layout showing all of your data without the background imagery layer. Add any extra content that you think your map needs, such as a scale bar, a key, a measured grid and a title. This map isn't assessed, but this is good practice for when you need to produce a map for a report or exercise, though the layout chapter (chapter 6) does cover this in much more detail.

Your map should look different from the possible layout in figure 7.12, but this will give you an idea of what it could look like. You will have made different decisions when digitising and symbolising data.

7.6 Recommended reading: digitising

For more detailed information have a look at the following references from the module reading list[3].

Chang (2016), Section 5.4. on creating new data includes information on various ways of digitising.

Kennedy, M. (2013), Chapter 5 includes information and exercises which look at data storage structures and digitising.

For help with specific tools don't forget to search in Arc Desktop Help - there is a lot of helpful information in there.

There are a lot of videos on YouTube which may help you - just do a search on **digitising**. For example, have a look at the video at `http://bit.ly/1CasAjt`

[3] Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

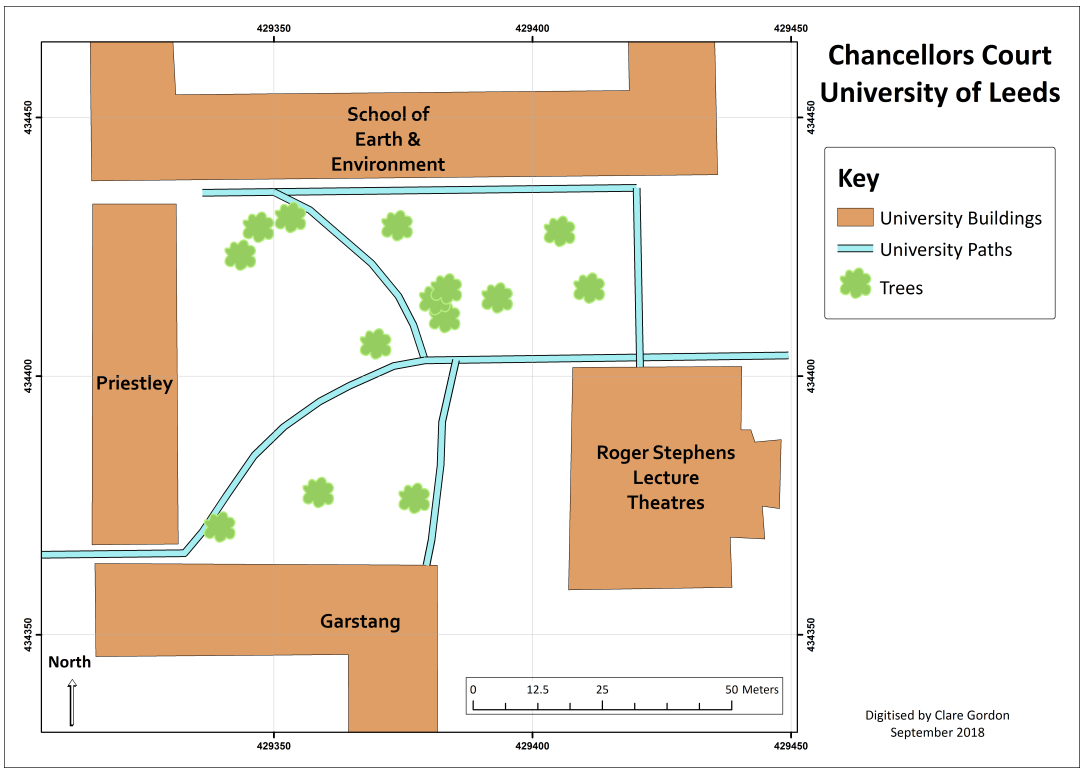


Figure 7.12: Possible final layout for digitised map of Chancellors Court

Data preparation for chapter 8: Elevation model exercises

Being able to find, download and prepare your own data is an essential part of using GIS. For the exercises in the next class you will need to download several datasets. While these should not take too long to download and prepare, don't leave it until the last minute. Websites can become unavailable either permanently or temporarily, or computers can crash.

If there are problems with a website then try again later. If the problems persist please get in touch with me (c.e.gordon@leeds.ac.uk) and I will try to contact the site or find an alternative source of data.

Data required

Download the following U.K. data from the web before the next class. Instructions on how to find the downloads are below the summary box.

Summary of data required

- ***Height data will be a DTM file - or Digital Terrain Model[a]. This can be downloaded from Digimap.***
- ***Tiff file for background mapping. You'll also download this from Digimap.***
- ***Shapefile of National Park boundaries from Natural England.***
- ***An Excel file containing points and data for hill summits in the UK from the Database of British and Irish Hills.***

[a] Sometimes called a DEM or Digital Elevation Model.

Data to download from Digimap

In Digimap **OS Download** select data by drawing a box around the Lake District - see figure 7.13 for the approximate area. (See section 5.4.2 on page 57 for a reminder on how to use Digimap OS Download.)

- From Digimap - 1:50 000 Raster - TIFF
- From Digimap - OS Terrain 50 DTM - ASC

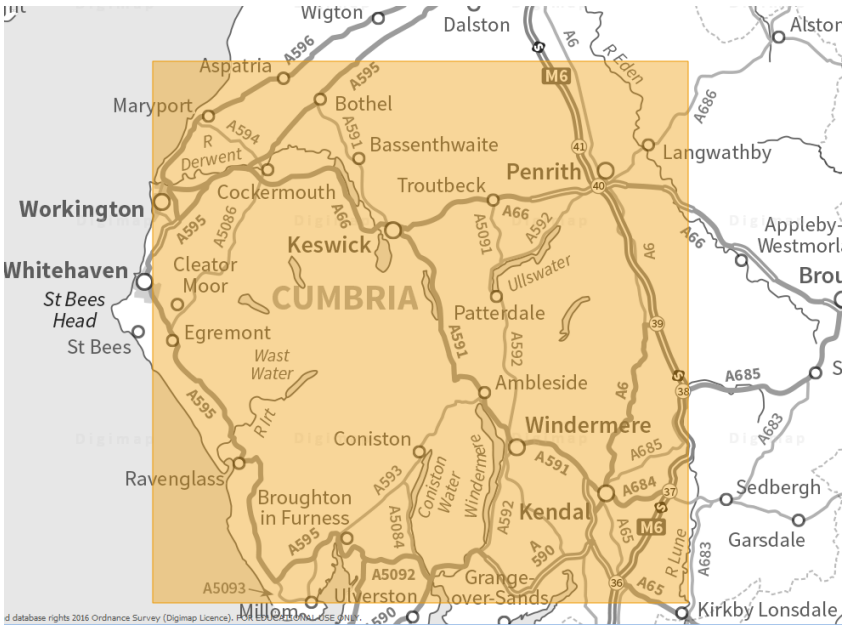


Figure 7.13: Area for which to download data for the Lake District

Database of British and Irish Hills

Start by having a look at the home page for the Database at

`http://www.hills-database.co.uk/`

Check how the data has been collected, and what information is included in the database.

Download a zip file containing an Excel file for British hills from the **Downloads** page and unzip it to your gis folder -

`http://www.hills-database.co.uk/downloads.html`

National Park boundaries

Go to the Natural England GIS page at

`http://naturalengland-defra.opendata.arcgis.com/`

- On that page enter **National Parks** in the box that says `Enter dataset name`
- From the list of results click on **National Parks (England)**
- You'll get a page which shows what the dataset looks like and which also has a **Download** link on the right-hand side. Click on that and select to download **shapefile**
- You'll download a zip file which you'll need to move to your gis folder and unzip

Make sure that you have all of the data that you have downloaded ready to use in the practical.

Chapter 8

Elevation models: the shape of the land

8.1 Learning outcomes

When you have completed this section you should be able to

- describe and identify raster formats of height data used in GIS and show an awareness of vector formats
- convert downloaded height data to an appropriate format to use in GIS
- use raster models to analyse surfaces
- describe appropriate applications of height data in environmental projects

8.2 Raster elevation models: DEM/DTM

Note that you do only need to mosaic the dtm files by following the instructions below. The other raster files that you downloaded (1:50 000 raster, VectorMap District raster, or VectorMap Local raster, or similar) are simply background images and will not be used for further analysis. They are basically there as a picture. If you do try to mosaic these don't worry if you end up with a very odd end result! With experience you will become used to the different file formats/purposes in GIS.

Raster elevation models are based on pixels or grids and can include various file formats, such as ascii or tiff. They have the advantages of being easy to store and manipulate and integrate easily with other raster formats. They are the best solution for continuous surfaces as they give a smoother and more natural appearance to terrains. The main disadvantage is that the grid size is set and it isn't possible to vary it to reflect different complexity of relief.

You will use raster elevation models for the rest of the exercises in this chapter. There is a little more information and some suggested readings on vector elevation models in section **??** on page **??**.

You should already have downloaded data for this exercise as detailed in the section on **Data preparation for raster elevation models** on page 96. If you haven't, follow the instructions there now.

8.2.1 Preparing the DTM data

The DTM files that you have downloaded are raster files in ascii text format with a file extension of **.asc** (though there are other files with extensions such as xml and gml in the same folder - just ignore

Video Clip available - If you feel that you are still not clear about the difference between **raster** and **vector** GIS data it would be worth having a look at the video "Learn more about raster and vector map data" by the Ordnance Survey which is available at `https://youtu.be/hbOGp51nYGI`

those). Try opening one of the **.asc** files in a text editor (on the University system right-click and select to open with **Notepad++**), but don't change anything!. The example in figure 8.1 is the NY03 tile from the OS Terrain50 DTM dataset.

Note that dtm/dem files may also be delivered as **.tif** or **.jpg** files. You can mosaic those in exactly the same way, but won't be able to open them in a text editor.

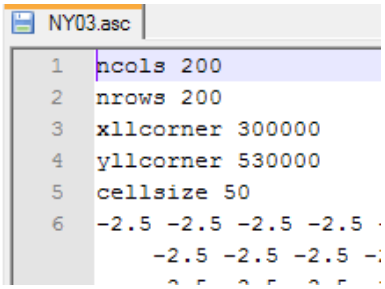


Figure 8.1: Ascii format DTM file in a text editor (Notepad++)

The five heading rows give ArcMap information about the data contained in the rest of the file -

1. number of columns - in this case 200
2. number of rows - in this case 200
3. x coordinate of the lower left corner - in this case 300000 on the British National Grid
4. y coordinate of the lower left corner - in this case 530000 on the British National Grid
5. actual size of each cell in map units - in this case 50 meters

You then have a screen full of numbers effectively in rows and columns, which each refer to the measurement at that particular grid point, or cell, in the file. When you view the file in ArcMap each of those points will be coloured according to that measurement.

Don't forget that it's a good idea to check the properties of your data in the Arc Catalog window before you start processing it too. See section 2.6.3 on page 25 for a reminder. For example, for Terrain 50 dtm data you'll find it useful to know what the coordinate system is, but also the Cell Size and the Pixel Type and Depth.

8.2.2 Producing "seamless" datasets from more than one tile of dtm data

If you are using more than one tile of dtm data follow the instructions below to combine the multiple files into one "seamless" dataset, a process that involves creating a mosaic. This will make it possible to use the files as a continuous surface in maps and 3D scenes. During this process we will also convert the multiple ascii or tiff files into one single **Grid** file.

This will work with various formats of dtm files including tiff and asc.[1]

On the University system be VERY CAREFUL that you add your files by navigating from the M:/ drive (your username) rather than via My Documents (your full name). The mosaic will almost inevitably fail if you use the wrong path.

[1] Otherwise, if you have downloaded a single dtm file, use the Toolbox to convert the file to a Grid without needing to mosaic (Toolbox > Conversion Tools > To Raster > Raster to Other Format (multiple)).

Video Clip available in Minerva - Creating a seamless mosaic from multiple DEM tiles. Direct link: `http://bit.ly/2stVzQn`

- If ArcMap isn't already open, open it now.
- Ensure that the Spatial Analyst extension is installed by going to Customize » Extensions... and checking that **Spatial Analyst** has a tick next to it. If it doesn't, then tick it.
- Now set the extent for carrying out geoprocessing operations - Geoprocessing » Environments... » Processing Extent set to Union of Inputs » OK.
- Then use the toolbox to open the correct tool - ArcToolbox » Data Management » Raster » Raster Dataset » Mosaic to New Raster.

Fill in the dialog that opens as shown in figure 8.2.

- Select all of your ascii dtm tiles under **Input Rasters** (you may need to look for them in more than one folder if your area covers parts of more than one 100km grid square)
- The **Output Location** is a folder or a geodatabase NOT a file name.
- Under **Raster Dataset Name with Extension** enter a file name without an extension to create an ESRI grid. Make sure you call it something that means something to you, e.g. *mosaicdtm*.
- Set the **Spatial Reference for Raster** to the one that applies to the original files using the button to the right of the field. (You can check this in the properties of one of the original files if you need to). If your final map needs to be a different coordinate system you will set this later - see section 8.2.3 on page 100.
- **Pixel Type** should be set to the same as the original files - have a look at the properties if you need to check
  - For properties right-click on a file in either the Catalog or the Table of Contents and select Properties....
    * From the Catalog the information you need will be on the **General** tab.
    * From the Table of Contents it will be on the **Source** tab.
    * You need to make a note of the **Pixel Type** and the **Pixel Depth**
  - For OS Terrain 5 and OS Terrain 50 files from Digimap this should work out as **32_BIT_FLOAT** from the list under **Pixel Type** in the tool.
  - Even though this is labelled optional, it isn't!
- Cellsize can be left blank, alternatively check this in the properties for your data.
- **Number of Bands** should be **1** to create a monochrome raster.
- OK

ArcToolbox should process your tiles, then add the result to your map. You should have a single tile which is coloured continuously rather than as a separate section for each individual tile (figure 8.3 - yours will look different to this one).

8.2.3 Define spatial reference for output mosaic

If you set the spatial reference when merging your files **then you can ignore this section**, otherwise you need to define the spatial reference of the output before you go any further. It is probably worth checking that your output mosaic does have a spatial reference - check in the properties.

If the spatial reference is **Undefined**:

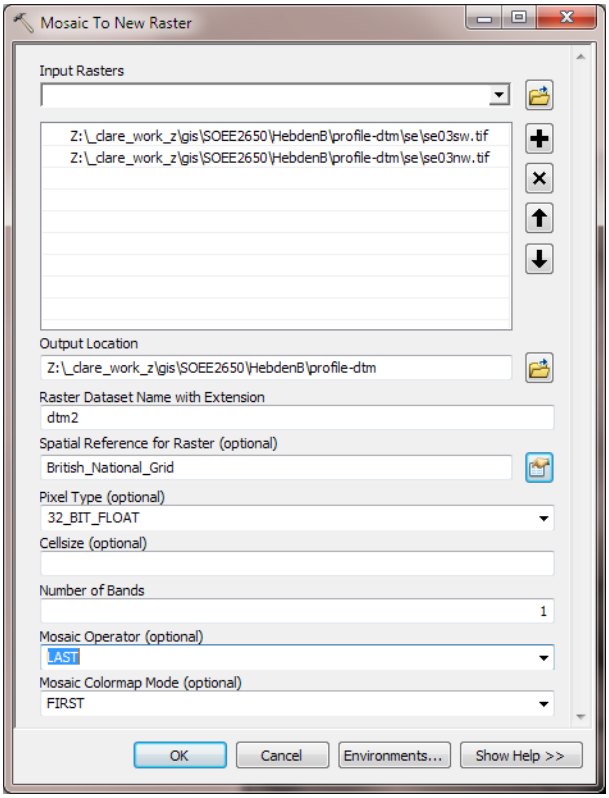


Figure 8.2: The Mosaic to New Raster tool. Note that the details for your data may be different to those shown here.

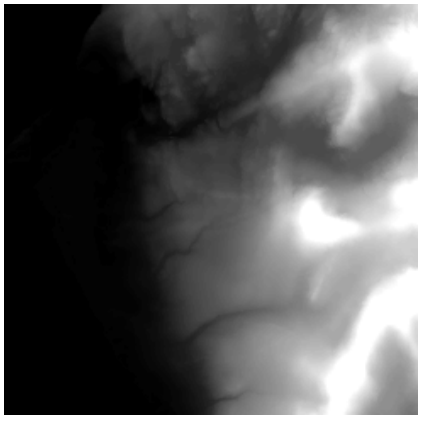


Figure 8.3: Grid file mosaic made by combining smaller tiles

- Open the toolbox and select Toolbox > Data Management Tools > Projections and Transformations > Define Projection
- Add the mosaic (you can drag it from the catalog into the appropriate box on the dialog)
- Select... and choose the coordinate system that your original data was in.

8.2.4 Changing spatial reference for output mosaic

If the spatial reference of your original files is not the same as your map project then you need to change the coordinate system.

- Open the toolbox and select Toolbox > Data Management Tools > Projections and Transformations > Raster > Project Raster
- Add the mosaic (you can drag it from the catalog into the appropriate box on the dialog)
- Select... and choose the coordinate system that your final map project needs to be in, e.g. British National Grid.
- Arc will probably set the **Transformation** automatically if necessary, but if it doesn't select one from the drop-down list. e.g. WGS84 to British National Grid is usually **OSGB_1936_To_WGS_1984_Petroleu**

8.2.5 Symbolising a dtm

You should now have a map with a black and white elevation model of the Lake District. If you look at the properties the layer is symbolised by a **Stretched color ramp** which shows a continuous surface

from low to high.

> ***To increase the contrast go to the symbology properties and change the stretch type from Standard Deviation to Minimum-Maximum.***
>
> ***If you wish try a different color ramp. Right-clicking on the color ramp allows you to deselect graphic view and then select color ramps by name. Look for Elevation 1.***

8.3 3D Analyst

3D Analyst is an ArcGIS extension. It provides tools for working with data with a height component, such as the DTM files that you have just opened in ArcMap. It runs within ArcMap and ArcScene (which you'll explore later) but it may be necessary to enable it before you can use it.

- Customize » Extensions... then tick the box next to **3D Analyst** and Close
- Now open the 3D Analyst toolbar - Customize » Toolbars » 3D Analyst

8.4 Restricting processing extent

Before we start running analysis tools on our terrain it makes sense to limit the size of the area on which those analyses will take place - we'll do that using **Geoprocessing Environments**. If you are working with a very large dataset this can make an enormous difference to the amount of time and computer processing power that you need. You'll find out more about these settings later in the workbook but for now we'll just use them to restrict the area.

To set the processing area globally for this project go to:

- Geoprocessing » Environments...
- Click on **Processing Extent** and drop down the **Extent** list.

You'll see that this gives you a lot of options, some of which are generic and some of which are the layers in your map. If you had a layer which defined, for example, the outline of the Lake District National Park, then you could select that to restrict processing.

In this case we'll enter coordinates manually to restrict the area.

- Click on **As Specified From Below** from the list of choices
- Enter the coordinates as shown in figure 8.4
  - **Top:** 541500
  - **Left:** 303200
  - **Right:** 356700
  - **Bottom:** 477900
- Click OK

Once you've completed section 8.6.4 on page 109 and have a shapefile containing the outline of the Lake District National Park you could use that to set the geoprocessing extent more accurately by going to Geoprocessing » Environments... » Processing Extent and selecting **Same as layer LakeDistOutline** (or what ever you called your shapefile).

When you run the tools below you may find that the output isn't much smaller than the original terrain layer, but in some cases this can make a much bigger difference.

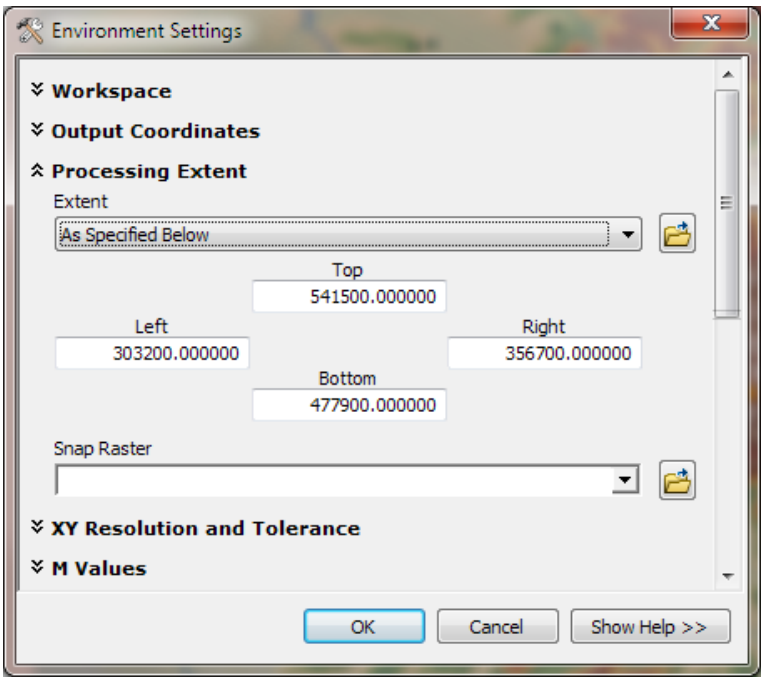


Figure 8.4: Manually entering coordinates in the Geoprocessing Environment Settings dialog

8.5 Working with surfaces

One of the sets of tools in 3D Analyst deal with raster surfaces, so raster "images" which show properties of the surface of the dtm. The exercises below show you how to use some of the tools, but don't cover creating contours from a dem. Once you've used the tools below, try out the other tools in the Raster Surface toolbox and see what they do.

Video Clip available in Minerva - 3D Analyst: hillshade, slope and aspect.
Direct link: `http://bit.ly/2ts2UnZ`

8.5.1 Hillshade

The DTM as it is now gives you a reasonable idea of the topography of an area, but if you want a clearer view for including in a layout, or want to give an idea of the topography on top of another map, then you can create a hillshade layer with 3D Analyst.

- Toolbox > 3D Analyst Tools > Raster Surface > Hillshade
- Fill in the dialog with your dtm layer as the input. Select where you want to save the output and give it a name (don't just accept the default location or the tool will almost inevitably fail to run). Leave the other fields as they are for now. See figure 8.5. Then click OK

The tool should run and add a new hillshade layer to your map. Zoom in and have a closer look at it. Try making it transparent so that the DTM shows through.

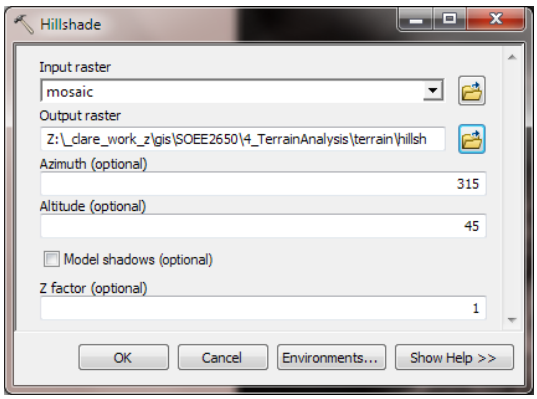


Figure 8.5: Filling in the Hillshade dialog

Add to your map the 1:50 000 raster tif files that you downloaded. Put them underneath the hillshade layer but above the dtm. Adjust the transparency of the hillshade layer so that you can see the raster map, but the hillshading is still visible.

Note that for this exercise you don't need to worry about the warning about projections. Just check that these files appear in what looks like the correct place in relation to the rest of the data in your map and don't try reprojecting them.

8.5.2 Slope

For this exercise you are setting up a study of a particular plant which prefers to grow on south facing slopes (that is, it has a south-facing aspect). For safety reasons the study area should not be more than a 15% slope. We'll use 3D Analyst **slope** and **aspect** tools to generate two separate raster files showing possible areas.

The slope tool returns a raster where each pixel shows rate of maximum change in z-value from each cell.

- Toolbox > 3D Analyst Tools > Raster Surface > Slope
- Fill in the dialog with your dtm file (double-check that you aren't using the hillshade by mistake) and give a name to the output raster
- Select **DEGREE** for the **Output measurement** then click OK.

The resulting layer will be a raster file with each pixel having a degree measurement (check the table of contents to see what each colour shows). Try using the **Identify** tool to click around the map and compare the results with the table of contents (make sure you select to identify the slope layer).

8.5.3 Reclassifying a raster

The layer doesn't show you clearly which areas have a slope of below 15 degrees, but you can **reclassify** the layer to show it more clearly.

- Go to the **Symbology** tab of the slope layer properties
- The layer should already be symbolised as classified, if it isn't change that.
- Look for the button on the right that says Classify and click on it.

Video Clip available in Minerva - Reclassifying rasters: by changing symbology. Direct link: `http://bit.ly/2h2PQ3q`

- You'll get a dialog similar to figure 8.6. Change the number of **Classes** to **2** and then change the first **Break Value** to the number of degrees - **15** - by clicking on it and typing.
- OK then OK on the symbology tab.

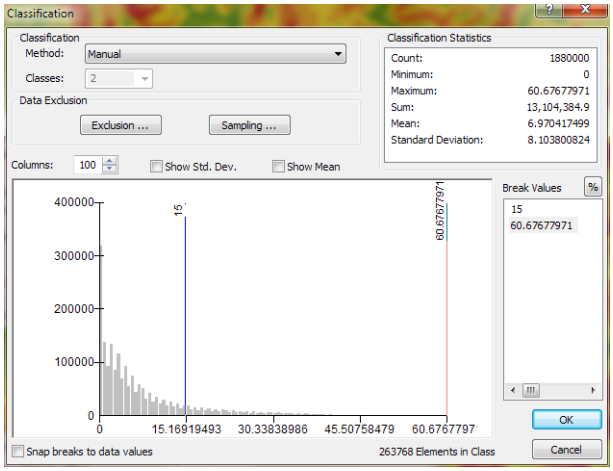


Figure 8.6: Changing the classification of a stretched layer

Now you should have a raster that shows you just two colours. Try making the raster transparent so that you can see the layers below. Compare it with the contours on the 50k raster tiles and see what you think.

8.5.4 Aspect

Aspect works in a very similar way to slope, but this time you'll finish with a raster coloured according to the direction that the slope faces - from north, round 360 degrees back to north. Remember that you are particularly looking for south-facing slopes.

- Toolbox > 3D Analyst Tools > Raster Surface > Aspect

> ***Have a look at the result and have a go at symbolising it so that only the slopes that face South are symbolised.***

For these analyses to be most useful in finding a possible site to study this particular plant you would need to combine them together. We'll look at this in more detail later in the course when we look at environmental decision making.

8.6 Line of sight analysis

You are going for a walk in the Lake District and are intending to park your car in the car park in Threlkeld (GR 331811 525630) and climb Hallsfell Top. Can you see your car from Hallsfell Top? What about if it was in the car park in Birkett Mire (GR 332007 524586)?

This type of question is called **line of sight analysis**.

Video Clip available in Minerva - Line of Sight in ArcMap. Direct link: `http://bit.ly/2h2X47v`

8.6.1 Adding xy data to a map

You should have downloaded an Excel file containing a list of summits of British and Irish hills. This Excel file is a form of **xyz** file in that for each record it includes *x* and *y* data in the form of eastings and northings of the British National Grid. This means that this data can be imported to Arc and mapped.

Video Clip available in Minerva - Importing points from Excel or csv to ArcMap. Direct link: `http://bit.ly/2hk1ffk`

Start by opening the unzipped .xls file of the Database of British and Irish Hills in Excel.

To be able to use this data in Arc you'll need to make some minor changes. Most notably the column headings need to be short (8 characters or less) and to have no punctuation or spaces in them. So start by changing headings such as **Parent (SMC)** and **Section name**.

If you want to, you could delete a lot of the columns as you'll only actually need a few of them for this exercise. If you do this, make sure that you **keep** the following columns (all of which fit the naming conventions anyway):

- Number
- Name
- Metres
- Xcoord
- Ycoord

Converting .xls or csv to a feature class

In the Catalog panel in ArcMap:

For an Excel spreadsheet (if you are using a csv file use the instructions below) -

- click on the plus sign next to the Excel file to show the contents (figure 8.7)
- You should be able to see a layer with a name which ends with with a **$** sign.
- right-click on that layer (if you can see more than one use the first in this case) and click to Create Feature Class > From XY Table... (figure 8.8)

- Fill in the X and Y Fields using the spreadsheet columns which show the coordinates in British National Grid
- Click on Coordinate System of Input Coordinates... and select **British National Grid**
- Choose a location and name for the output, then OK

This also works for csv (**c**omma-**s**eparated **v**alue) files. Indeed, **if you are having trouble loading an Excel file**, try saving it as csv in Excel[2], then import it to Arc using the instructions below. It often works much better than the Excel file.

For a csv file -

- just right-click on the file name, it won't have a plus sign like the Excel file does
- select Create Feature Class > From XY Table...
- Fill in the X and Y Fields using the spreadsheet columns which show the coordinates in British National Grid
- Click on Coordinate System of Input Coordinates... and select **British National Grid**
- Choose a location and name for the output, then OK

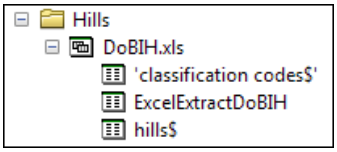


Figure 8.7: Excel file in Catalog opened out to show contents

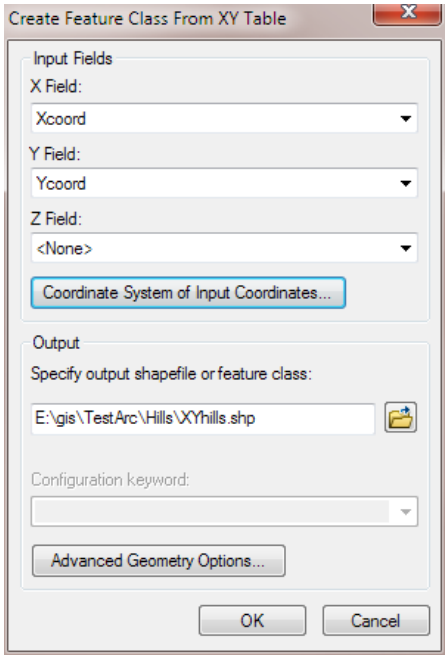


Figure 8.8: Creating a feature class from an XY Table (your field and file names probably won't be the same as this)

The output shapefile should appear in Catalog in the location that you chose to save it. Add it to your map in the usual way.

It is worth checking the attribute table of your new feature class to see that it does match the original table.

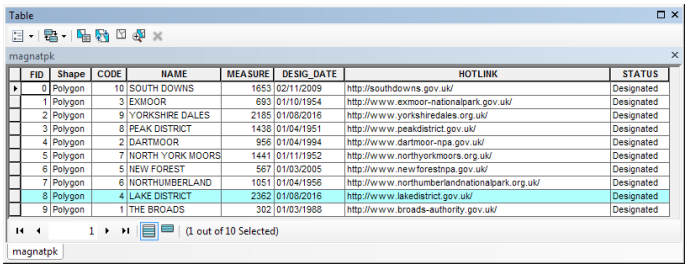
[2]Save from Excel to csv as follows: File > Save As choose a location then under **Save as type:** choose **CSV (Comma delimited) (*.csv)**.

Check your location by doing zoom to layer, if when you do that you are taken to a map with nothing except the new points, then you may have got the 100 km grid numbers wrong. Go back to the previous section and check that you have added the correct numbers for your 100 km grid square and have eastings and northings or x and y the right way round.

8.6.2 Selecting data in the attribute table

Add the National Park shapefile to your map and zoom to layer. This shapefile contains polygons for all UK National Parks so it will be a good idea to extract the Lake District National Park and remove the rest from your map. It will save confusion later.

- Right-click on the layer containing the National Parks in the table of contents and Open Attribute Table
- In the attribute table click on the little grey box on the left-hand side of the row for the **LAKE DISTRICT** to select it
- The Lake District National Park polygon should be picked out in turquoise in the attribute table (see figure 8.9) but also on the map.



FID	Shape	CODE	NAME	MEASURE	DESIG_DATE	HOTLINK	STATUS
0	Polygon	10	SOUTH DOWNS	1653	02/11/2009	http://southdowns.gov.uk/	Designated
1	Polygon	3	EXMOOR	693	01/10/1954	http://www.exmoor-nationalpark.gov.uk/	Designated
2	Polygon	9	YORKSHIRE DALES	2185	01/08/2016	http://www.yorkshiredales.org.uk/	Designated
3	Polygon	8	PEAK DISTRICT	1438	01/04/1951	http://www.peakdistrict.gov.uk/	Designated
4	Polygon	2	DARTMOOR	956	01/04/1994	http://www.dartmoor-npa.gov.uk/	Designated
5	Polygon	7	NORTH YORK MOORS	1441	01/11/1952	http://www.northyorkmoors.org.uk/	Designated
6	Polygon	5	NEW FOREST	567	01/03/2005	http://www.newforestnpa.gov.uk/	Designated
7	Polygon	6	NORTHUMBERLAND	1051	01/04/1956	http://www.northumberlandnationalpark.org.uk/	Designated
8	Polygon	4	LAKE DISTRICT	2362	01/08/2016	http://www.lakedistrict.gov.uk/	Designated
9	Polygon	1	THE BROADS	302	01/03/1988	http://www.broads-authority.gov.uk/	Designated

Figure 8.9: Selecting a feature in the attribute table

8.6.3 Exporting selections to a new shapefile or geodatabase

Once you have selected a subset of a layer, you can export that selection to a new feature class for use in further analysis.

- Right-click on the layer that contains the selected features - the national parks layer in this case
- Data > Export Data...
  - Choose to Export: Selected Features
  - Choose where to save the new file to, and the name that you want
  - Click OK
- Choose to have the new layer added to your map.

Once you have done that remove the original layer to keep things tidy.

Clear Selected Features

It's a good idea at this point to clear all selections -

- Selection > Clear Selected Features

8.6.4 Select by location

Now it would be useful to restrict the summit points to only those within the Lake District National Park. This will save disk space and time spent watching the screen redraw. To restrict the points you will need to use **Select by location** as you did in section 1.9 on page 13.

- Make sure that you don't have any features from any other layers selected by clicking on the **Clear Selected Features** button on the toolbar or Selection > Clear Selected Features. If there isn't anything selected anyway this will be greyed out.
- Selection > Select by location then fill in the dialog as shown in figure 8.10.

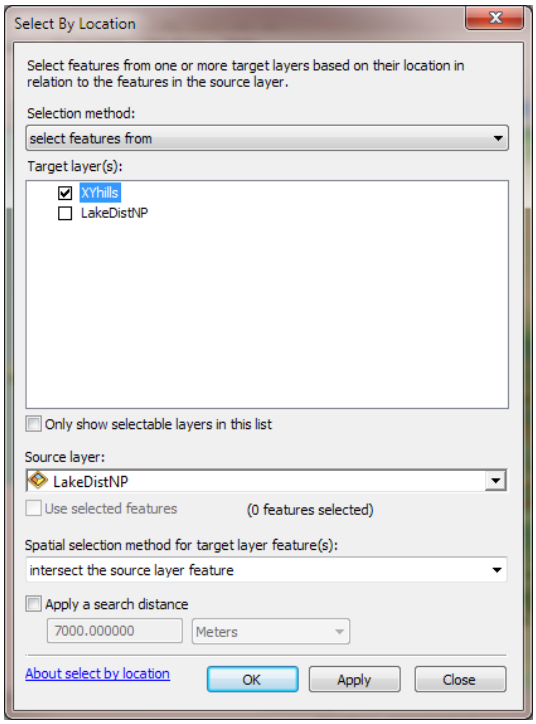


Figure 8.10: Select features by location within the Lake District National Park

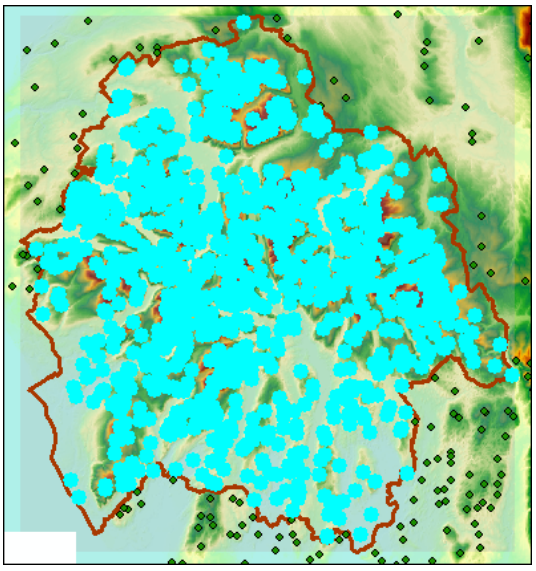


Figure 8.11: Points selected after running "Select by Location"

Once you click on OK you should have all of the points within the National Park selected - they should appear as turquoise blobs as in figure 8.11.

Once you have the points selected, you should export to a new feature class to save the selection in the same way that you did in section 8.6.3 on page 108. Make sure that you add the new layer to your map and remove the old one.

8.6.5 Running line of sight analysis

Now that you have all of the data prepared you can run the analysis:

Use **Find** from the toolbar[3] to find Blencathra - Hallsfell Top from the Lake District summits shapefile. Right-click on it in the list of results and **Zoom to** that point. You may also need to select it to make it obvious which point it is!

[3] You tried this tool out in table 1.2 on page 2.

- Make sure that your dtm layer is selected in the layer dropdown on the 3D Analyst toolbar (see figure 8.12)
- Click on the **Line of sight** button
- Now click on the point where the observer is standing - in this case the point at the top of Hallsfell Top.
- Finally click on the target point - the car park in Threlkeld.
- Note that it is possible to change the height of both the observer and the target using the offsets in the box that opens when you click on the button. The **Z units** are the same as map units. Try changing this and see what difference it makes.

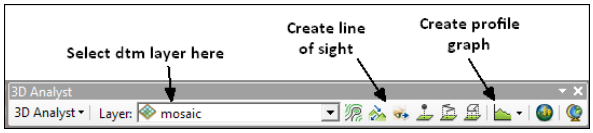


Figure 8.12: The 3D Analyst toolbar

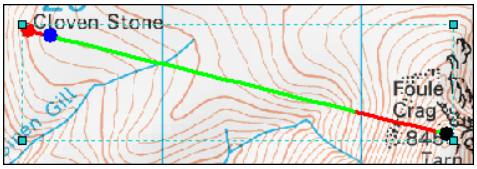


Figure 8.13: Line of Sight on map

You should find that you have a coloured line with some dots (figure 8.13).

- the black dot shows the observer
- the red or green dot shows the target - green if it is visible, red if not.
- the blue dot shows the obstruction blocking the target
- the coloured segments of line show which parts are visible to the observer - green for visible, red for not.

Question 8.1. Is the car park at Threlkeld visible from Hallsfell Top? Try the car park at Birkett Mire on the other side of the river instead. Would your car be visible there?

Once you have a line showing the line of sight it is easy to create a profile. Select both of the lines that you have created using the **Select elements** tool (the black arrow on the tools toolbar)

- Click on the **Create profile graph** button on the 3D Analyst toolbar (you may have to drop down the arrow next to the point profile button to find it)

The profile should make it easier to see what is causing the obstruction to the line of sight. You can double-click on the profile and make changes to the title, axes, legends etc to smarten it up a bit and make it more informative. You can also resize it by dragging the edges of the box. See the example of a profile in figure 8.14.

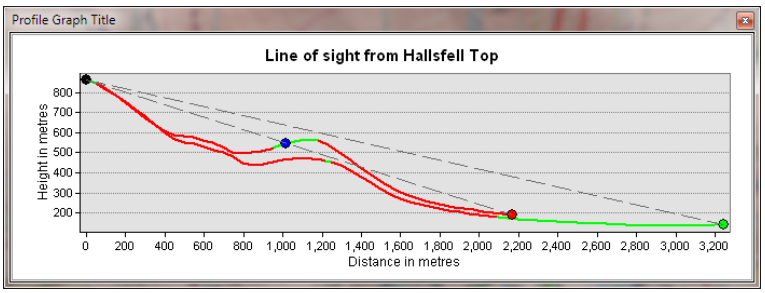


Figure 8.14: Line of Sight profile graph

8.7 Viewshed analysis

Julia Bradbury is also out and about with her copy of Wainwright and has reached the top of Blencathra. She's trying to work out how many other Lake District summits it is possible to see from the summit of Blencathra. If only she'd asked you! Using **viewshed analysis** in a GIS it is possible to work out which places are visible from any particular point without having to climb the hill yourself. Let's have a look at which summits are visible from Blencathra - Hallsfell Top. You've already loaded the height and summit data that you need for this section.

Video Clip available in Minerva - Viewshed analysis in ArcMap. Direct link: `http://bit.ly/2tsu669`

8.7.1 Adding an offset - the height of the observer

The first thing to do is think about **offsetting** the height of the observer above the base heights provided by the dem. If no offset is entered the default assumed by the tool is 1 map unit - in this case 1 meter. Most of us are taller than 1 meter - a little research via Google shows that Julia Bradbury is apparently **1.75 m** tall.

To use an observer offset you have to add it to the attribute table so to add an offset of 1.75 m to the height of each hill do the following:

- Clear selections (Selection > Clear Selected Features) so that changes to the attribute table will apply to all records
- Add a new field to the table for Lake District hills - see section 12.7.2 on page 173 if you need a reminder on how to do this. This field MUST be called **OFFSETA** and MUST be of type **Float**
- In the attribute table right-click on the grey heading at the top of the new OFFSETA column and select the **Field Calculator**
- Type the required offset in the box as shown in figure 8.15 and click OK

Arc should add 1.75 to every field. If it doesn't check that you have followed the instructions carefully. The most likely problem is that you forgot to clear all selections.

Note that it is also possible to offset the height of the target - so if your target is a tower 8m high, add a field called **OFFSETB** to your attribute table and enter the offset there. ArcGIS help has more information on this - search for **Using Viewshed and Observer Points for visibility analysis**.

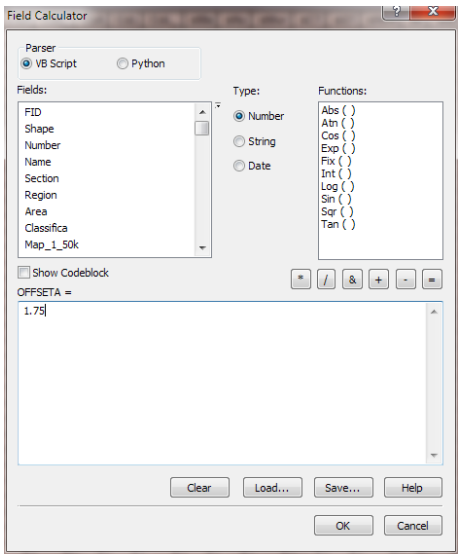


Figure 8.15: Using the Field Calculator

8.7.2 Selecting the observer point and running the viewshed tool

Now the next thing to do is make sure that the point for Hallsfell Top is selected otherwise the viewshed analysis will run on all of the points together.

- To be safe start by clearing all selections and then select **Hallsfell Top** using the **Find** tool (there is a video clip in Minerva demonstrating how to use the Find tool if you need a reminder).
- Once Hallsfell Top is selected: Toolbox » 3D Analyst Tools » Visibility » Viewshed
- Fill in the dialog in a similar way to figure 8.16. The input raster will be your dtm and the input point file will be the shapefile with the Lake District summits.
- OK

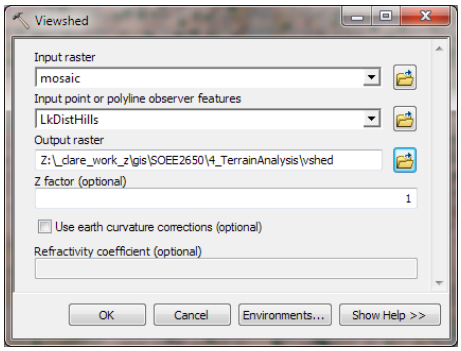


Figure 8.16: Filling in the viewshed tool

Once the tool has run you should find a raster layer in your map with just two colours - one indicating areas that are not visible, the other areas that are. Check the table of contents to see which is which. This is useful, but you still need to work out how many of the summits are in the area that is visible. You could sit and count them, but it would be better to make Arc do the work!

8.7.3 How many summits?

This is one of those times when you have to start breaking down exactly what you are trying to do. Somehow you need to work out which points are in the area which is visible - you have points in a

vector file and a raster file with two different symbols.

Have a close look at the raster viewshed layer. Use the Identify tool[a] to click on pixels in both the visible and not visible areas.

Question 8.2. What information can you use to differentiate the two areas?

[a] You tried this tool out in table 1.2 on page 2.

For the next few steps you need to

1. change the raster file to a vector file so that you can compare data of similar types
2. then delete the areas from the vector file that are not visible
3. then create a new point file containing just the points which intersect the visible areas

As with many GIS tasks there is probably more than one way of doing this, but follow the instructions below to see one way.

Convert raster file to vector polygons

Start by converting the raster file to vector polygons.

- Toolbox > Conversion Tools > From Raster > Raster to Polygon
- Fill in the dialog as in figure 8.17 with the **input raster** being the viewshed layer, and the **Field** being **VALUE** then OK

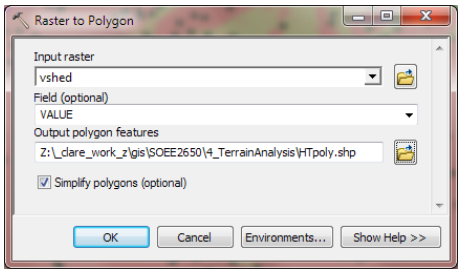


Figure 8.17: Converting Raster to Polygon

The new polygon feature class will be symbolised as just one colour, but you should be able to see outlines around the separate polygons. The next step is to get rid of the polygons that you don't need - in this case the **not visible** areas.

Question 8.3. Have a look at the attribute table for the new layer - which field do you think separates visible from not visible areas now and which attribute shows that it is not visible?

Selecting and deleting multiple features

To delete all of the not visible areas quickly the easiest way is to select them by an attribute first, then delete.

Video Clip available in Minerva - Select by attributes. Direct link: `http://bit.ly/2faQQC3`

- Start by clearing all selections. If there are selections in more than one layer you won't be able to delete anything.
- Open the attribute table for the vector polygons
- **Attribute table options** (button at top left of attribute table) then Select by Attributes
- Using the field that you picked above and the attribute that you think indicates not visible, you want to **Create a new selection** where that field equals that attribute.
- Apply

Once you have the features selected that are **not visible** you need to open an edit session for that layer (see section 7.4.2 on page 88 for a reminder) and then just click on Delete selected at the top of the attribute table (remember that hovering over buttons gives you a tool tip). Remember to save edits and stop editing.

If you can't delete anything remember to check that you don't have any selections on any other layer.

Now you should have a vector shapefile that just contains polygons for the areas that are visible from Hallsfell Top.

Intersect

Finally we can create a shapefile which contains only those summits which **intersect** with the visible areas.

- First check that all selections have been cleared
- Toolbox > Analysis Tools > Overlay > Intersect
- Fill in the dialog as in figure 8.18 with the input features being your shapefile of Lake District summits and the shapefile with the polygons of the visible areas. Change the Output Type to **POINT**
- OK

Finally you should have a feature class that just contains the summits that are visible from the top of Hallsfell Top on Blencathra. Open the attribute table to see how many summit records the feature class contains.

Question 8.4. How many Lake District summits are visible from Hallsfell Top?

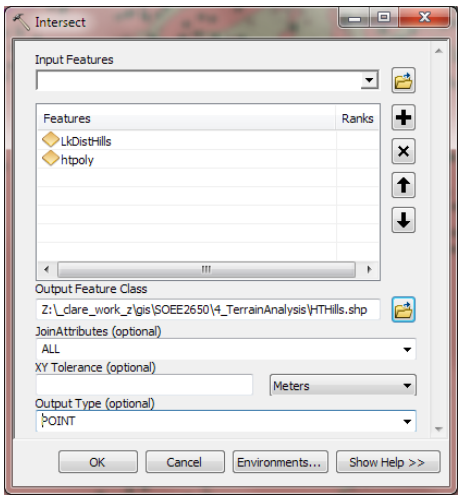


Figure 8.18: Filling in the Intersect tool

Repeat the process, this time starting with the point for the summit of Helvellyn.
Question 8.5. How many summits are visible from Helvellyn?

In a future chapter you'll see how it is possible to use a **model** run a process multiple times without having to do all of the work manually.

8.8 Suggested layout

The final step of any analysis is to display your results. Try creating a layout that shows which Lake District summits are visible from Helvellyn and from Hallsfell Top on Blencathra. Don't forget to include copyright information for both the data that you downloaded from Digimap (see section 12 on page 16 if you need a reminder of the details) and for the Database of British and Irish Hills (check their website for their requirements).

8.9 Save your data

To save yourself time later, make sure that you save the data that you have used for this chapter as you will need to use the same data in a future exercise.

8.10 Recommended reading: Raster elevation models

For more detailed information about using raster elevation models in your own work have a look at the following references from the module reading list[4].

Kennedy, K.H. (2010), Chapter 6.

Chang (2016), Chapter 13 covers raster and vector terrain analysis.

[4]Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

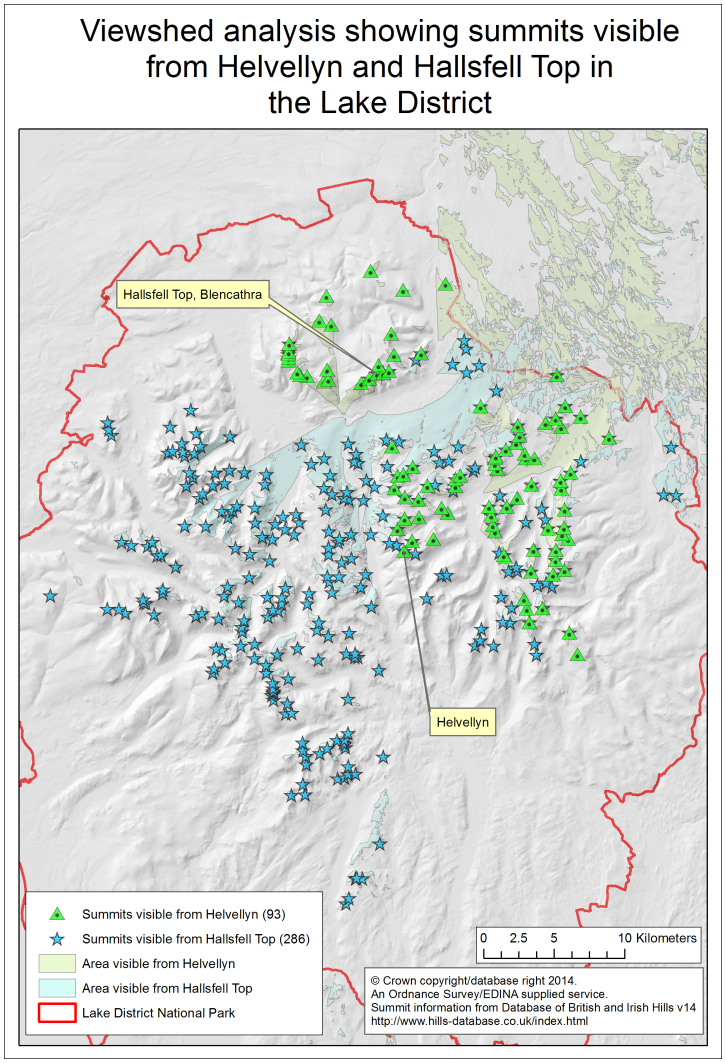


Figure 8.19: Possible final layout for a map of visible summits from Hallsfell Top and Helvellyn

Chapter 9

Model builder: making repetition easy

In chapter 8 you were able to tell Julia Bradbury how many Lake District summits she could see from the top of Blencathra - and even provide a list of their names. But now she would like to know the same information for several other summits. You'll need to go through the whole process again for each summit and it's rather long-winded. Luckily ArcGIS provides the **model builder** - a way of linking several processes and tools together to automate tasks.

9.1 Learning outcomes

When you have completed this section you should be able to

- explain the use of the model builder in ArcGIS
- analyse a task and build a model to produce the required output
- describe when parameters are required and how to set them

9.2 Data for this exercise

You should still have your Lake District map from the previous chapter and can also use this to work through the exercises in this chapter. If you would prefer a "clean" copy of the map you can download a map package from Minerva - `LakeDistrict.mpk`[1]

9.3 Planning a model

The first stage is to plan your model. One advantage of the model builder is that you can run a model and then easily go back and alter it before running it again, but if you plan in advance it makes it much quicker to get the right result.

Chapter 8 has already shown you the process that you want to automate in this model, and when you come to put a model together for yourself it's a good idea to start by making sure that you can achieve the desired outcome manually first. Refer back to that chapter to answer the questions in the next two boxes.

Question 9.1. What data do you need to start with?

[1] Instructions on using a map package are in section 4.2 on page 34.

Question 9.2. What processes or tools do you need to run on that data?

9.4 Building a model

To open the Model Builder click on the button on the tools toolbar (figure 9.1).

Figure 9.1: Button to open Model Builder window

You'll have opened a blank window (figure 9.2) and will build the model graphically in this window. Have a look at the tools that are available to you on the toolbar in the model builder (figure 9.3

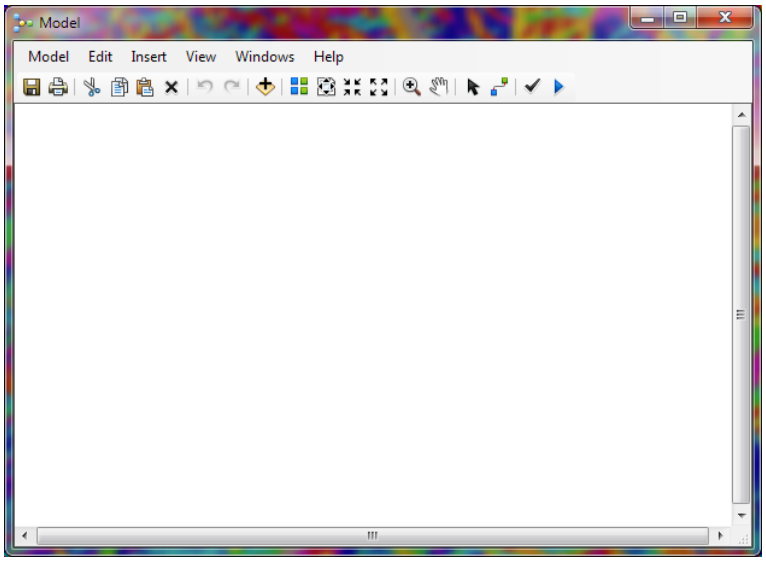


Figure 9.2: The blank Model Builder window

Video Clip available in Minerva - ArcMap Model Builder: Making repetition easy. Direct link: `http://bit.ly/2su07pX`

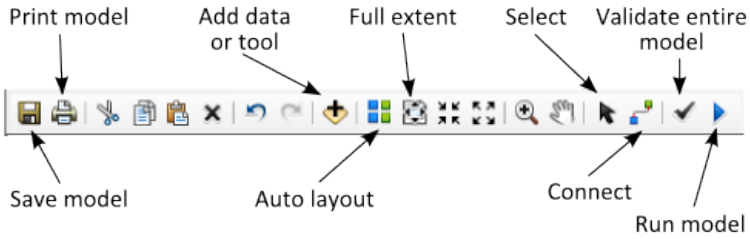


Figure 9.3: Model Builder Toolbar

9.4.1 Adding data to a model

Start by making sure that the two data files that you hopefully listed in the box above are added to your map in ArcMap. You'll need the **dtm mosaic** as height data, and the shapefile containing the list of **Lake District summits** as observer points.

To add data to a model:

- **drag and drop** both of the layers from the table of contents into the model builder window - it should look something like figure 9.4 though your file names may be different
- if that doesn't work you can also drag and drop directly from the Catalog or add files by going to the Add button on the model builder toolbar.

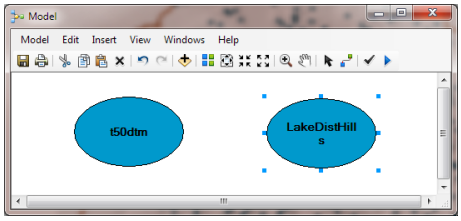


Figure 9.4: The model builder window with the height data and point shapefile.

9.4.2 Saving a model for later use

It's a good idea to **Save** your model frequently whilst you are working on it.

- Click on Save then click on the button to create a New Toolbox. Give this a general name and save it to your GIS folder.
- Now double-click on the new toolbox and save your model inside it - with a name that will tell you what it does in the future, e.g. **ViewShedHill**. Make sure that the **Save as** type is **Tools**
- Save

Once you have saved your model to a toolbox for the first time, you'll just have to click Model > Save next time.

Then, when you close it, you should be able to find your model again using **Catalog**.

- To run your model directly right-click on it and select Open
- To edit your model again right-click on it and select Edit

9.4.3 Adding tools to a model

Now that your data is in the model you need to start adding the tools for the analysis.

Viewshed tool

From **ArcToolbox** find the following tool and drag and drop it into the model -

- Viewshed - 3D Analyst Tools » Visibility » Viewshed

Your model builder window should look something like figure 9.5.

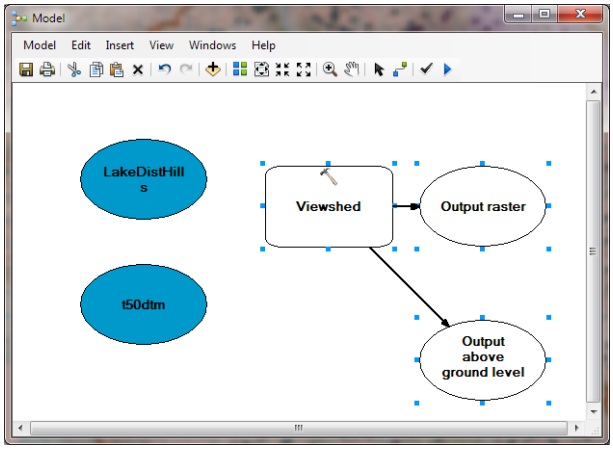


Figure 9.5: The model builder window with the Viewshed tool added.

Linking data to tools in a model

Now you need to link the data with the tools. Select the **Connect** button on the model builder toolbar (see figure 9.3 on page 119).

- Use the Connect tool (as shown in figure 9.3) to click on the shape for the mosaic input, then click on the **Viewshed** tool. A short menu should open (maybe after a short pause!), click on **Input Raster**.
- Repeat with the shape for the Lake District Hills input, and this time select the **Input point or polyline observer features** option.

If it has worked the connected shapes should fill with colour, as in figure 9.6, to show that the model is valid so far (there may be another short pause while Arc thinks about it). You don't need to worry about the **Output above ground level** item.

9.4.4 Renaming output

I have found that the model builder crashes Arc whenever I run a model if it is trying to save the output to its default location - your default geodatabase. To get around this you'll need to rename and relocate the output.

In addition, have a look at your model and stop and think about the file management rules for a moment. Can you see any potential problems here? Have a look at the default output name for the tool - you may need to open the tool by double-clicking on it to see what the default name is.

To rename the output file,

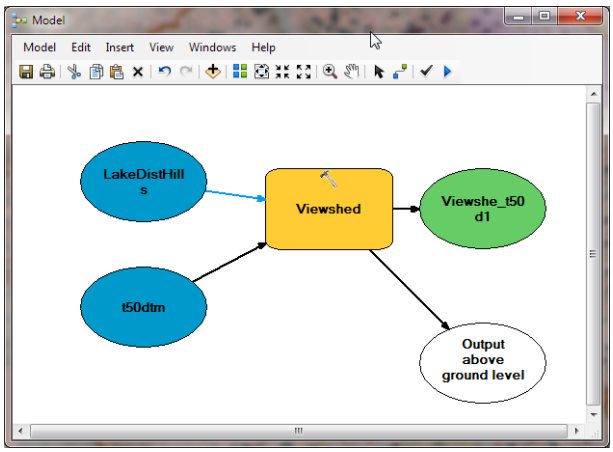


Figure 9.6: Linking the data to the Viewshed tool

- double-click on the Viewshed tool
- click on the folder symbol after the **Output raster** box and change the path and file name appropriately - see just below

I would suggest creating a new folder (with a short name and no spaces in the name, e.g. **op** for output) for the resulting output of the model and saving all of the files into that. Do check that you're not trying to save into the default geodatabase.

In addition if you are working on a University cluster machine make sure that you are navigating via your M: drive directly rather than through Home. Your file names should look something like figure 9.7 rather than 9.8. Both lead to the same location on the University network, but the first is much shorter and doesn't have more path "hidden" behind the scenes.

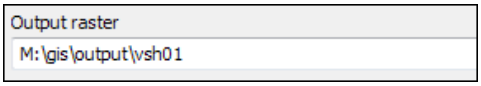


Figure 9.7: The correct way to link output file paths

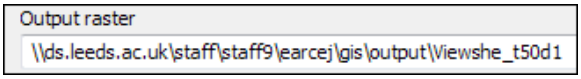


Figure 9.8: The wrong way to link output file paths

9.4.5 Running the model to check it

It is an extremely good idea to run your model at every stage of building it. This gives you a chance to sort out problems while you can still remember what you have just done, and is essential if you are adding a lot of tools or data.

- Clear all selections in your map,
- select a single summit from the attribute table for the Lake District Hills - it doesn't matter which one, but if you start with Hallsfell Top or Helvellyn you can check the result against the map you produced in the previous chapter.
- You should still have the model open so to run it click on Model > Run Entire Model.
- If you don't have the model open find it in Catalog, right-click and Edit... then Model > Run Entire Model. It can take a while for the model to run!

Note: If the model runs *really* slowly it probably means that you've forgotten to select a single hill and Arc is trying to calculate the viewshed for every Lake District summit at once. Cancel, make sure that you've selected a single summit and start it again.

If it runs successfully and either adds a raster file to your map or to your catalog showing the viewshed then make sure you have a look at the file to check that it looks as you would expect it to.

If it is fine, just delete the new raster file by using the catalog, then carry on with the next step.

If there is something wrong, go back and check that you have followed the previous instructions correctly. The most likely problem is probably the way you have named your output file.

9.4.6 Adding more tools

Raster to Polygon tool

To add the Raster to Polygon tool do the following.

- Toolbox » Conversion Tools » From Raster » Raster to Polygon

To link to the tool for **Raster to Polygon** do exactly the same thing as you did before, but using the viewshed output from **Viewshed** as the input for the next tool.[2] The result should be something like figure 9.9. Don't forget to check the name and path for the output and change those again.

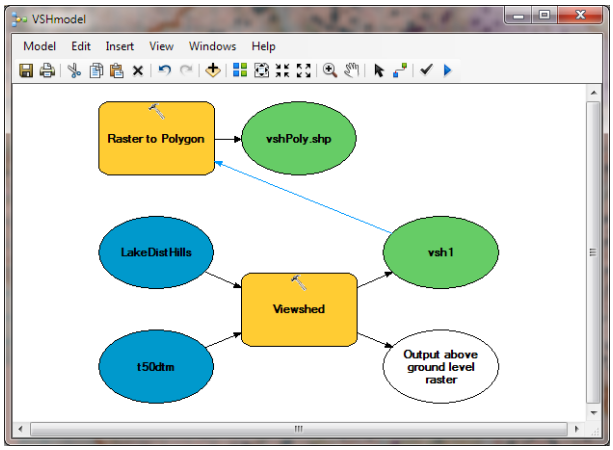


Figure 9.9: Linking the output from the Viewshed tool to the Raster To Polygon tool

Again, run the model (section 9.4.5 on page 121) and check that it works so far.

Select tool

Add the **Select** tool as follows:

- Toolbox » Analysis Tools » Extract » Select

The select tool needs to be set so that it only selects the records that you need - last time you had to select the hills that *weren't* visible, this time, though, you're selecting the records for **visible** hills rather than those that are not visible.

[2] Notice that the Viewshed tool also has output called **Output above ground** - just ignore this as it isn't necessary for this exercise, but can't be deleted.

- Right-click on the box for **Select** and Open (or double-click on it)
- The dialog box will have automatically filled in your input and output (though do check them), you need to enter the **Expression**. In this example you need to enter **"GRIDCODE" = 1** - you can click on the sql button for some assistance.
- OK

and again link the output from the **Raster to Polygon** tool to the **Select** tool. The result should be something like figure 9.10

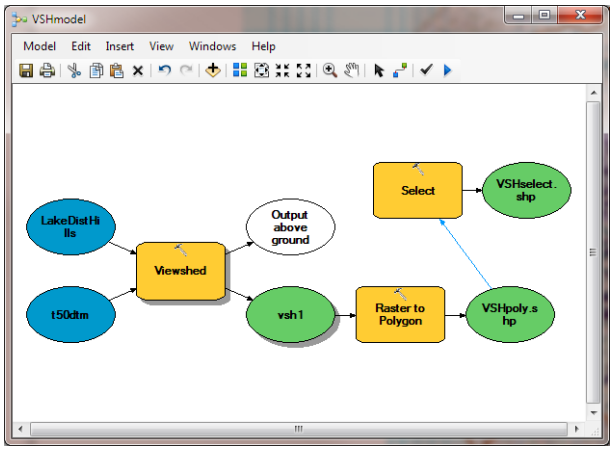


Figure 9.10: Linking the output from the Raster to Polygon tool to the Select tool

Once again, run the model (section 9.4.5 on page 121) and check that it works so far.

Select Layer by Attribute

Before you link to the **Intersect** tool you need to make sure that none of the records in the Lake District Hills feature class are selected as otherwise the operation will only happen on the selection. Remember, though, that you will need to have selected a single summit before you run the model, so at this point you need to unselect that.

Add the **Select Layer by Attribute** tool as follows:

- Toolbox » Data Management Tools » Layers and Table Views » Select Layer by Attribute

Then you need to set it up to unselect any existing selections.

- Start by adding another copy of Lake District Hills to your model - just drag and drop it from the table of contents again.
- then link that copy to **Select Layer By Attribute**
- Now you need to tell Arc what selection you want (or don't want), so right-click on the box for **Select Layer By Attribute** and click on Open...
- Make sure that your input layer is in the top box, drop down the choices in the second box and choose **CLEAR_SELECTION** as in figure 9.11 then click OK.

The output is basically still the same file, just with no selections, so you don't need to give it a name at this stage.

Your model should now look something like figure 9.12 - note that the selection doesn't yet link to anything else.

Don't worry about running your model at this stage, but carry on to the next tool.

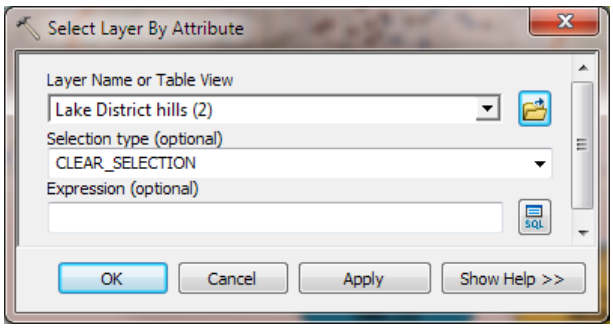


Figure 9.11: Model building: Select Layer By Attribute

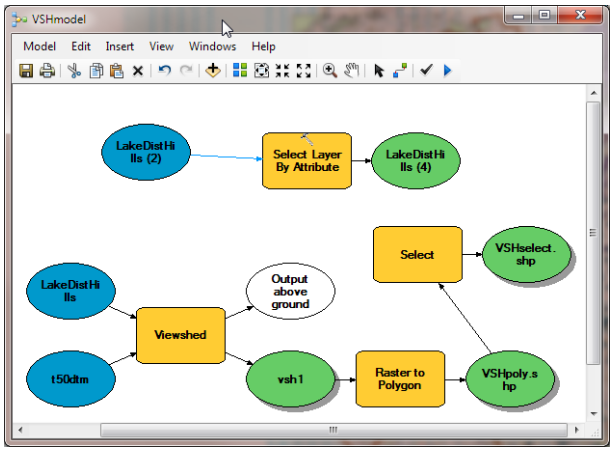


Figure 9.12: Clearing selections on the Lake District Hills layer

Intersect tool

For the final step add the **Intersect tool** as follows:

- Toolbox » Analysis Tools » Overlay » Intersect

Now feed the output from both the **Select** and **Select Layer By Attribute** tools in to the **Intersect** tool by using the connect button. The end result should be something like figure 9.14.

Open the Intersect tool by double-clicking on it

- Don't forget to change the path and name for the **Output Feature Class** to something shorter
- The output from the Intersect tool should be a feature class containing the points for all of the summits visible from the summit of whichever hill was selected so open the **Intersect** tool and change the **Output Type** to **POINT**.

The other fields should be fine as the defaults - see figure 9.13

9.4.7 Tidying up the model

At this stage you can tidy up your model by clicking on the Auto Layout button on the toolbar, and again on the Full Extent button.

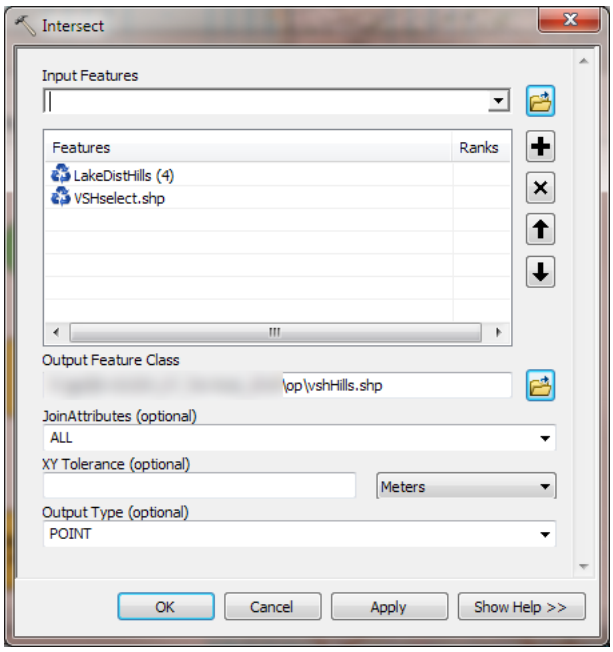


Figure 9.13: Settings for the Intersect tool

If you find that you are running out of space enlarge the window and then use the Full Extent button to fill the space. The end result should be something like figure 9.14 (but not necessarily arranged in the same way).

Don't forget to **Save** your model which should look similar to figure 9.14 by now. The full instructions are in section 9.4.2 on page 119 if you need reminding, but you should just need to press Model > Save this time.

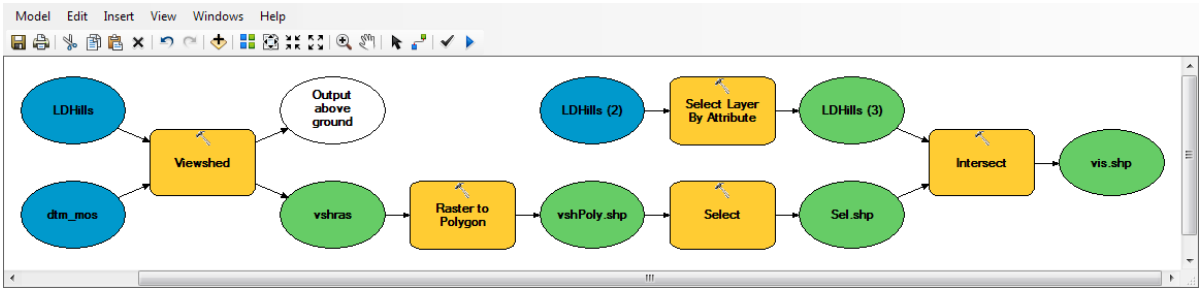


Figure 9.14: Your completed model

Remember, when you close it, you should be able to find your model again using **Catalog**.

- To run your model directly right-click on it and select Open or double-click on it.
- To edit your model again right-click on it and select Edit.

9.4.8 Running the final model

Clear all selections in your map[3], then select a single summit from the attribute table for the Lake District Hills - start with Scafell Pike.

Check that you have deleted from the Catalog any output from previous runs of the model.

[3] See section 8.6.3 on page 108 for a reminder

- You should still have the model open so to run it click on Model > Run Entire Model.
- If you don't have the model open find it in Catalog, right-click and Edit...
- then Model > Run Entire Model.

Note: If it runs *really* slowly it probably means that you've forgotten to select a single hill and Arc is trying to calculate the viewshed for every Lake District summit at once. Cancel, make sure that you've selected a single summit and start it again.

Does your model run without problems? Is the output a point file and is it automatically added to your map? Are any other layers added to your map? Check in catalog - what layers have been created? Add some of them to your map and have a look at them.

If you are not happy with your model or if there is a problem with it you can go back and edit it and run it again - though you will need to either delete all previous outputs or change some of the output names. This is one of the advantages of models - you are able to "tweak" it without having to start from scratch each time.

Video Clip available - ModelBuilder Introduction by Don Boyes is available from `http://bit.ly/1P1YiWH` (this video has sound). This covers the techniques outlined above.

9.5 Using parameters in a model

Once you are happy that your model is working:

- Close your model (making sure that you have saved it first)
- Select a different hill in the Lake District hills layer, e.g. Catbells
- Now open your model by finding it in Catalog and double-clicking on it.
- When you see a window that says **This tool has no parameters** just click on OK

What happens on this run? Does Arc add a new layer to your map? Where is the final output layer that has just been created? Do you still have the output of the previous run?

You should have found that Arc overwrote the previous output, and didn't add the output to the map - you had to add it yourself. This is where parameters are useful. You can tell Arc to give you the opportunity to rename output files on each run, and also to add output to the current map.

- Open up your model for editing again - right-click on it in Catalog and select Edit...
- Right-click on the output from Viewshed and select Model Parameter
- Do the same with the outputs from Raster to Polygon, Select, and Intersect. A "P" should appear next to each output that you do this for - figure 9.15.
- In addition right-click and select Add to display for those outputs that you would like to add to your map - probably only the final output from Intersect.
- Some outputs will probably have Intermediate selected - these will be deleted from the Catalog when the model finishes, so if you want to keep them, unselect Intermediate
- Save the model and close it. Then run it again by double-clicking on the model in the Catalog.

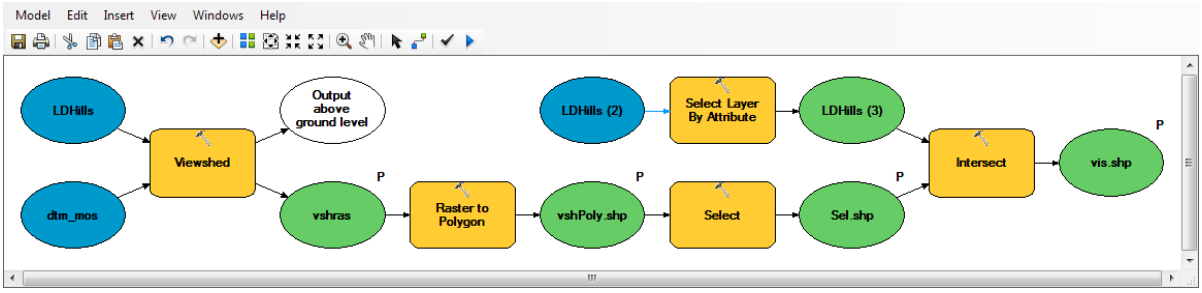


Figure 9.15: Your completed model with parameters set

This time, instead of a window saying that your model has no parameters you should be presented with a box that allows you to choose a location and file name for each output - figure 9.16.

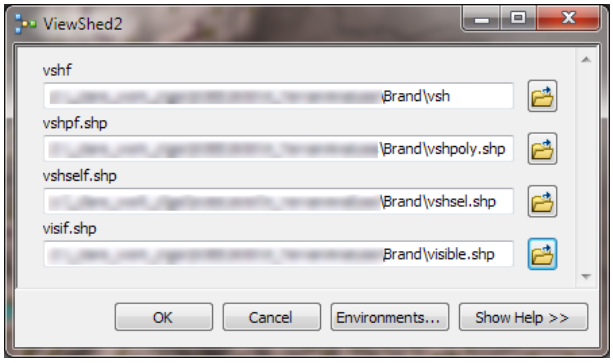


Figure 9.16: Entering new file names into the Model Builder

Fill in the parameters - setting up a new folder to contain the files from this run - maybe with the name of the hill that you selected. Now click OK and run the model again.

I find that all of the intermediate output files are added to my map, so once you have run the model successfully remove the files that you don't need and make sure that it is clear what the final output is - e.g. Change the layer heading in the table of contents to "Visible from Scafell Pike".

Now, finally, you can look at the attribute table for the final output and say how many hills are visible from Scafell Pike!

Although setting up the model has taken quite a bit of effort, if you are going to need to run it many times with very similar input, or with minor changes, you could save a lot of time.

Run the model at least eight times further (you should already have a total for Helvellyn), selecting a different hill each time. Try to choose hills that are spread across the National Park. List the numbers of other Lake District hills visible from each viewpoint in table 9.1.

Table 9.1: Lake District Hills - visible summits

Run no.	View point	No. of visible hills
1	Scafell Pike	
2	Helvellyn	
3		
4		
5		
6		
7		
8		
9		
10		

9.6 Model specific tools: Iteration, variables etc

The model that you have created here is a good start. It makes running a sequence of tools quicker and reduces the chance of making a mistake. It is always a good idea to start by creating a simple model and making sure that it runs successfully, but then think about how you could develop it further.

For example, at the moment you have to select a new summit each time, then use the parameters to change the name of the output files, how can you automate these steps?

- firstly, you could **iterate**, or loop, through a list of summits - maybe a subset of the existing feature class
- secondly, you could use **variables** to change the output file names based on the input

Try and improve your model one step at a time and make sure that it still works after each step. In addition, each time you get a step to work, save a copy of your model so that you can go back to it if things go wrong.

The Insert menu in Model Builder provides a lot of tools. Come up with some potential ways to make your model more effective and then explore the tools available.

Arc Desktop Help gives a lot of useful information about Model Builder, including some of the more advanced techniques - `http://arcg.is/2bE5lNs`

Use this as a starting point and look at the information suggested in the reading list too (section 9.8 on page 129 gives specific suggestions). As usual YouTube videos can be really useful - try the suggestions in section 9.8.1 on page 130.

When building your own models just remember:

- **Start simple**
- **Add functionality one step at a time**
- **Each time you get a step to work properly, save a separate copy of your model so you can go back to it if necessary**
- **Don't be afraid to get things wrong - experiment and learn!**
- **Use Arc Help, the reading list and YouTube to find answers**

In assessment 2 you will need to build a model so that we can see how you produced your output. A simple model that works will earn you good marks, but this will be an opportunity to show how much further you can go to earn extra. As preparation have a go at extending the model you've built in this chapter and see if you can **iterate** or **loop** through a list of hills, and then use **variables** to save the output. Just don't forget, though, that you still need to balance your workload with other modules - it can be easy to loose track of time when you are trying to get a model to work!

9.7 Final map

As the final result of this exercise put together a layout that shows the Lake District National Park. Mark on the map the summits that you have chosen to use to run the model, including Scafell Pike. For each of those summits mark the number of other summits that are visible. Aim for a clear presentation that shows your results to a viewer without them having to do too much interpretation.

Print out your final layout and bring it to the next class. I will try to speak to all of you individually during the practical and give you feedback on your maps.

Your final map could look something like figure 9.17. It is unlikely to look identical as you should make your own decisions about where to place elements and how to display your map.

9.8 Recommended reading: model builder

For more detailed information about building models in GIS have a look at the following references from the module reading list[4].

Kennedy, M. (2013), exercise 7-6 in the step-by-step section of chapter 7 covers building a model in ArcGIS.

Chang (2016), includes a chapter which covers model building in great depth. It's worth having a look at this for some ideas about what is possible.

[4]Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

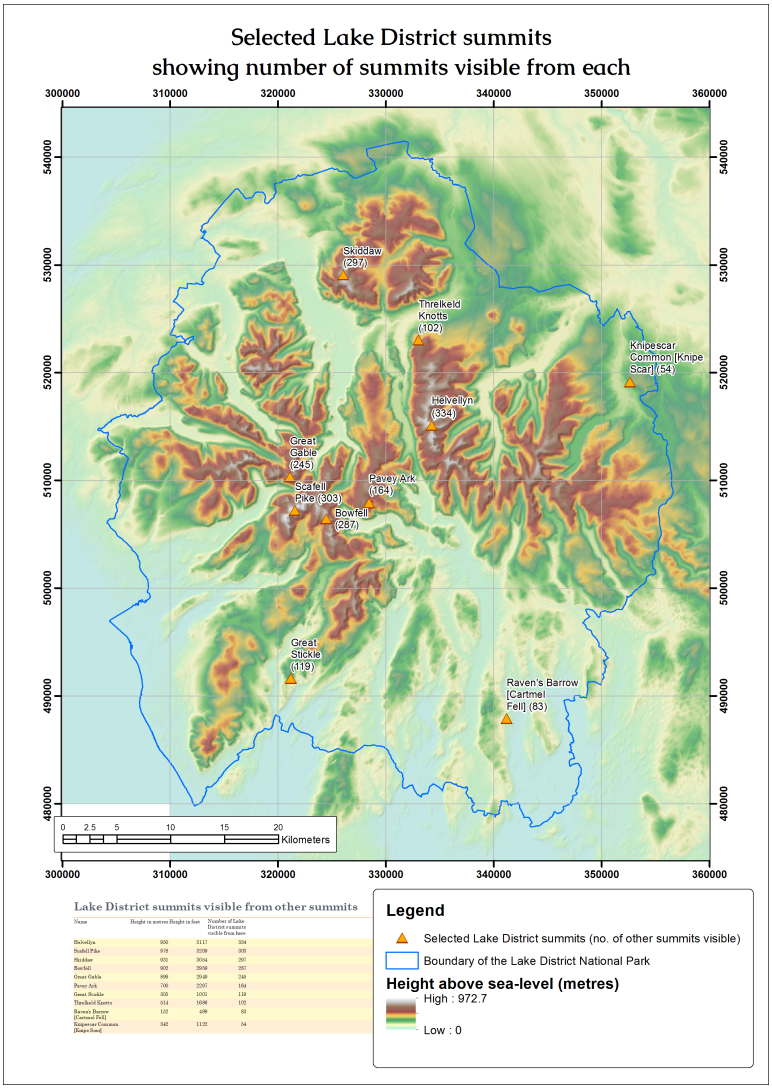


Figure 9.17: Possible layout for the map of summits in the Lake District

9.8.1 Videos online

The series of video clips by Shea O'Neill at `https://youtu.be/DoIkV2y0pEc` starts with a useful overview of all of the **iteration tools** and then moves on to a detailed look at some of the tools. He also includes useful comments to help you to understand models further, including **variables**.

By the way, don't just assume you can use the first tool he discusses - listen to his explanations and think through what you are trying to do yourself!

Further relevant video clips for models by Shea O'Neill are at `https://youtu.be/SDlfwZVNz_g` and `https://youtu.be/VJ2b6cjimYY`

Data preparation for chapter 10: raster analysis exercises

Being able to find, download and prepare your own data is an essential part of using GIS. For the exercises in the next class you will need to download several datasets. While these should not take too long to download and prepare, don't leave it until the last minute. Websites can become unavailable either permanently or temporarily, or computers can crash.

If there are problems with a website then try again later. If the problems persist please get in touch with me (c.e.gordon@leeds.ac.uk) and I will try to contact the site or find an alternative source of data.

Data required

Download the following data:

- From Digimap (for the approximate area shown as selected in figure 9.18)[5]
  - Background mapping - Vector Map District Raster
  - Height data - OS Terrain 5 DTM - asc (ascii text) format
- From Minerva
  - Rainfall data for 2016 [6] This is in the `Chapter10_Data.7z` zip file.

Preparing the data

Add the Background mapping (Vector Map District Raster) and the Terrain 5 DTM tiles to a new map.

Mosaic the asc tiles for the Terrain 5 DTM layer (you'll probably have asc files in two subfolders remember to add all asc files from both) so that you are running processes on a single tile of data (instructions are in section 8.2.2 on page 99). Make sure that you save the resulting mosaic as a Grid file - i.e. don't add a file extension to the output file[7]. Don't delete the original asc files - you will also need these during the practical.

Note for mosaic dialog:

Arc doesn't always seem to set the Pixel Type to the correct setting for the original data. For Terrain 5 DTM tiles make sure that it says **32_BIT_FLOAT** or you will lose some data.

Use the **Hillshade** tool (instructions in section 8.5.1 on page 103) to create a hillshade layer based on the mosaic DTM and add it to your map. Set the transparency on this layer to approximately 70%.

Save your map and bring it to the next practical. It should contain the following data:

[5] for a reminder of how to download O.S. data from Digimap see section 5.4.2 on page 57

[6] Extracted from data downloaded from `http://data.ceda.ac.uk/badc/ukcp09`. Registration is required. Once you have permission to download data there are a wide variety of datasets covering UK historical climate and weather.

[7] You will find out more about raster data formats and properties in the practical

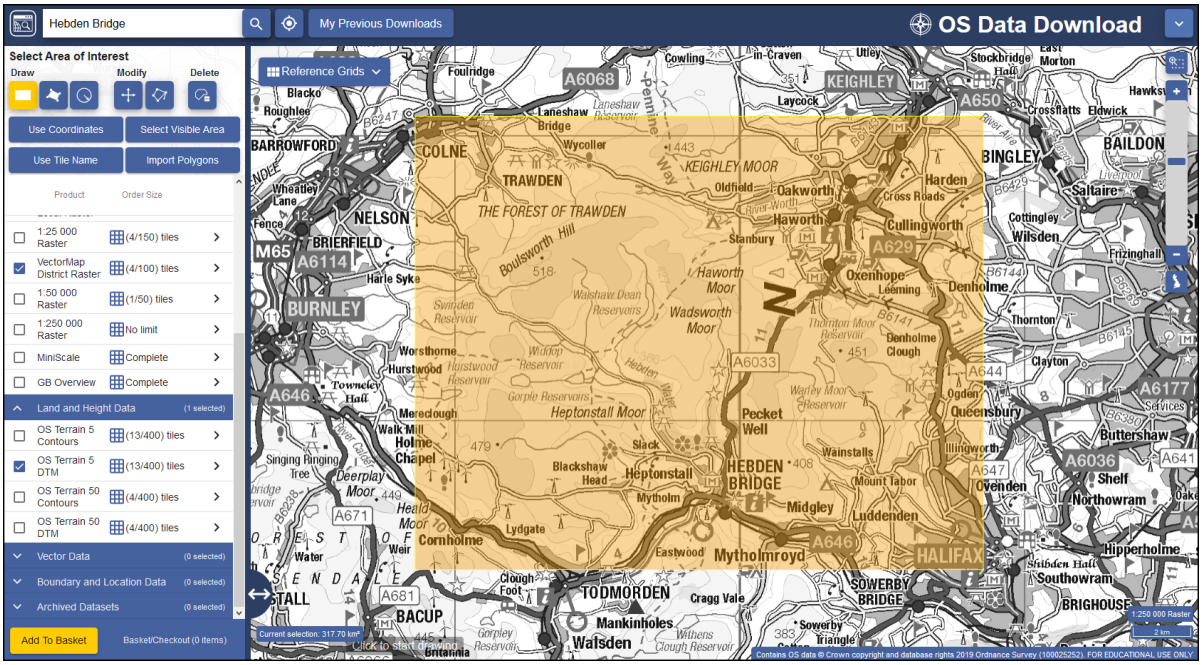


Figure 9.18: Minimum area for which to download data from Digimap for the Hebden Bridge exercise

- a background map for the Hebden Bridge area - VectorMap District Raster
- a mosaic dtm
- a hillshade layer

Chapter 10

Raster analysis I

10.1 Learning outcomes

When you have completed this section you should be able to

- demonstrate how to convert between raster and vector file types and show an awareness of the problems of conversion
- use the raster calculator to build expressions in order to analyse raster layers
- select appropriate tools to carry out geoprocessing tasks

10.2 Introduction

Raster analysis is a way of taking existing raster datasets and using them to generate new locational information. Analysis can show how locations are associated with one another based on properties and spatial relationships.

Virtually all of the analysis that we will be doing on raster data can also be done on vector data, but due to the differences in the data models the analysis often works in a very different way.

You have already seen examples of raster analysis in the sessions on using elevation data. This chapter will build on that and introduce you in detail to more of the tools for processing raster-based data.

The first exercise will look at the Hebden Bridge area of West Yorkshire. In 2012 Hebden Bridge and nearby towns suffered two major flooding events within a few weeks of each other. Cloud-bursts on the moors caused heavy run-off. Sediment quickly blocked drains and shops and houses were flooded.[1]

In this chapter and the next you will investigate the catchment area of the River Hebden/Hebden Water, combining dtm data with rainfall data and data on the population of the catchment.

10.3 Data

You should already have downloaded and prepared data for this exercise as detailed in the section on **Data preparation for raster analysis** on page 131. If you haven't, follow the instructions there now.

0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	1	0
0	1	1	1	1	1	0	0	0	0
0	1	1	1	1	1	1	0	0	0
0	0	1	1	1	1	1	1	0	0
0	0	0	0	1	1	1	0	0	0
0	0	1	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	0
0	0	0	0	1	1	0	0	0	0

Figure 10.1: Example of raster structure. Note cells containing one value each.

```
10,10,1
0,0,0,0,0,0,0,0,0,0
0,0,1,0,0,0,0,0,1,0
0,1,1,1,1,1,0,0,0,0
0,1,1,1,1,1,1,0,0,0
0,0,1,1,1,1,1,1,0,0
0,0,0,0,1,1,1,0,0,0
0,0,1,0,1,0,0,0,0,0
0,0,1,0,0,0,0,0,1,0
0,0,0,1,0,0,0,0,0,0
0,0,0,0,1,1,0,0,0,0
```

Figure 10.2: Example of raster file in text editor. Top row tells Arc how many cells *x* and *y* and location of origin.

10.4 What is raster data?

You should already have discovered that raster files show data in a grid. Each cell in that grid gives one value. Information in the raster file tells Arc the location of each grid cell, allowing Arc to display the data in the correct location and to run processing tasks on multiple files.

ArcGIS prefers to use a raster format which it calls a **Grid**. You'll have come across these already - in many cases you've converted raster files to a GRID by not entering a file extension in a dialog. To find more information about this file type search for **Esri Grid format** in ArcGIS Desktop Help.

10.4.1 Raster properties

You have already been adding raster datasets to maps and using geoprocessing tools to analyse them, but now lets have a closer look at them.

Video Clip available in Minerva - Raster file properties and information.
Direct link: `http://bit.ly/2h30YgC`

Question 10.1. Using Catalog have a look at the properties for the following files (refer back to section 2.6.3 on page 25 if necessary) and fill in table 10.1 for both of the files.

- ***One of the original OS Terrain 5 DTM ascii files (NOT the mosaic)***
- ***The Hillshade layer***

There is a lot of useful information here, but what does it all mean? Make sure that your DTM mosaic is open in ArcMap and that you have at least one tile of the original DTM ascii files open.

Columns and rows and cell size

Columns and rows show how many cells there are in your file and how they are arranged. **Cell size** shows how large each individual cell or pixel is in map units. Remember you can check the map units by looking at the **General** tab of the **Data Frame Properties**.

[1] See the news story at `http://www.bbc.co.uk/news/uk-england-leeds-18768291`

Table 10.1: Raster file properties

Property	OS Terrain 5 DTM ascii	Hillshade layer
Data type		
Columns & Rows		
Number of Bands		
Cell size (X,Y)		
Format		
Pixel Type		
Pixel Depth		
Colour Map		
Pyramids		
Spatial Reference		

Question 10.2. Given the cell size of a single downloaded tile of the ascii DTM, what is the coverage of the tile in square metres?

Number of bands

Number of bands refers to the bands of data in the image. In this case *one band* shows that the image data is held in one band with different values converted on screen to a black and white image. Colour images often have three bands, one each for red, green and blue.

Pixel type

Pixel type shows how the data is stored.

- **Floating point** is data with a decimal point, e.g. 12.45
- **Integer** rasters store whole numbers. *Unsigned* integers will represent only non-negative values, *signed* integers will represent negative and positive values.

It is possible to convert from one to the other, but data can easily be lost. When converting from floating point to integer types the numbers after the decimal points are merely truncated rather than rounded.

Floating point rasters tend to be used for **continuous** data. Values can change gradually over an area, such as in a rainfall raster.

Integer rasters are more likely to be useful for categorised data. For example, a land-cover raster could contain values such as 1 for forest, 2 for farm land, 3 for scrub, etc.

Making sure that the original ascii DTM and the hillshade layer are both visible in your map, use the **Identify** tool to click on a point that is covered by both. Check that **Identify from: Visible Layers** is selected - click again if you need to so that both layers appear in the top panel - figure 10.3. Then look at the result in the Indentify window and select the value of each layer in turn. Can you see the difference between the pixel values in the two files? They will be different numbers anyway, but the floating point layer should have decimal points, the integer layer won't.

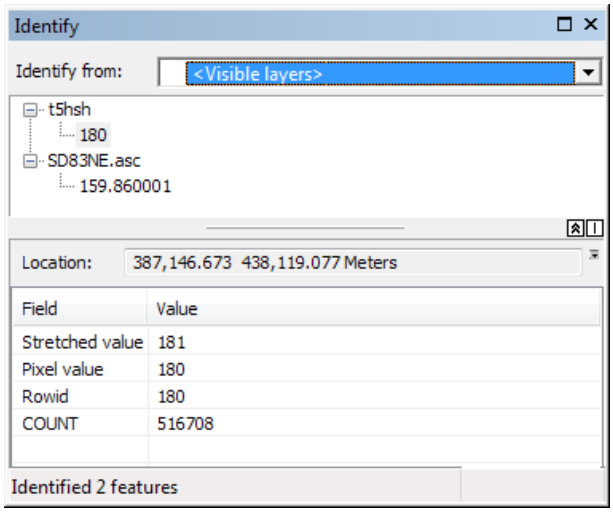


Figure 10.3: Identifying the content of two raster files at a single location

Question 10.3. Now try to look at the attribute table of both the dtm and hillshade raster files in the table of contents. What is the difference?

It should become obvious that the floating point raster does not have an attribute table while the integer raster does.

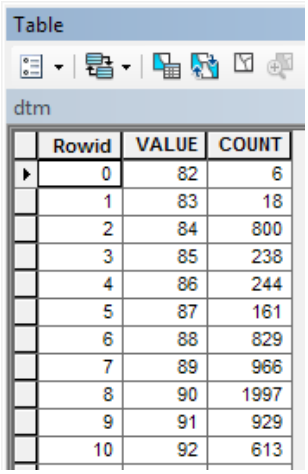
The attribute table for the integer raster is not the same as the attribute table for a vector file, though. The example in figure 10.4 shows the attribute table for the hillshade layer.

- Each row has a unique ID - Rowid in this case
- The **VALUE** field lists each unique cell value in the dataset
- The **COUNT** field shows the number of cells in the dataset with that value. Cells with no value are not calculated.

So in the attribute table in figure 10.4 tells you that, for example, there are **18** cells which have a value of **83**.

You can find more information about these attribute tables by searching for **Raster dataset attribute tables** in Arc Desktop Help.

Try selecting one of the values in the attribute table (preferably one with a high count - maybe 5 figures) and have a look at the effect on your map. You should be able to see that all of the cells with that value have been selected and are highlighted in turquoise.



Rowid	VALUE	COUNT
0	82	6
1	83	18
2	84	800
3	85	238
4	86	244
5	87	161
6	88	829
7	89	966
8	90	1997
9	91	929
10	92	613

Figure 10.4: The attribute table for an integer raster

10.5 Raster statistics

You may have already come across raster statistics. When you change the symbology of a layer from Stretched to Classified, if the raster does not already have statistics calculated you may have to run the **Calculate Statistics** tool if Arc doesn't offer you the opportunity to do that automatically.

As a reminder, or in case you haven't had to do it already, if you are told that it is necessary to Calculate Statistics. . . or Compute the Histogram

- Either go to Toolbox > Data Management Tools > Raster > Raster Properties > Calculate Statistics
- or right-click on the file in Catalog and select Calculate Statistics

If the option is available when you right-click on the layer and you haven't had the opportunity to do this automatically, do this now for your mosaic dtm layer.

Once you have calculated the statistics have a look at the result by going to the layer or file properties and scrolling down the information that is given in the **Source** tab. If you weren't able to calculate the statistics have a look anyway - it probably means that they are already available.

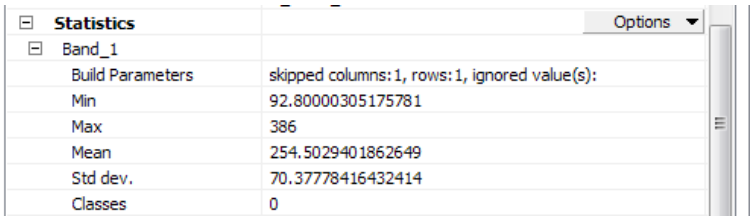


Figure 10.5: Raster statistics

Now you have potentially useful information, such as minimum, maximum and mean values, available as well as being able to symbolise the data by classification.

10.6 Geoprocessing environments

You'll be running a lot of tools to create new datasets. To save you having to enter key information over and over again Arc allows you to set up **Geoprocessing environments** which apply to all processes.

To set geoprocessing environments globally go to

Video Clip available in Minerva - Setting global geoprocessing environments. Direct link: `http://bit.ly/2h38qbV`

- Geoprocessing > Environments...

Have a look at the options available and set the following environments:

- Set **Current** and **Scratch workspaces** to your folder for this project. This stops Arc from trying (and often failing!) to put everything in the default geodatabase.
- Set **Processing Extent** to the same as your mosaic DTM. This will mean that all processes are run on that area, and any data outside of that area will not be included.
- Under **Raster Analysis** set **Cellsize** to the cellsize of your mosaic DTM. This will ensure that all of your output datasets will have the same cellsize and will be useful for further processing.

Click OK to save your settings.

10.7 Creating an interpolated surface from point data

10.7.1 Preparing your rainfall data

You should have downloaded from Minerva a csv file containing rainfall data for the U.K. for 2016 by month[2]. Open the file in Excel or a text editor (such as Notepad++ - right-click on the file in My Computer and select **Edit with Notepad++** or similar) and have a look at the data. This covers the whole of the UK and the first two columns give you locations in British National Grid eastings and northings.

You will want to use the *total rainfall* for 2016 rather than monthly.

- Use Excel to add a new column to the csv file by using a function to sum the total of the month fields for each location.
- Once you have this extra column close Excel - saving your csv file.
- Add this data to your map of the Hebden Bridge area in the same way that you added an Excel spreadsheet to the Lake District map (*hint:* you're adding xy data. Try to remember how to do this yourself, but if you need a reminder look at section 8.6.1 on page 106)

You should end up with a grid of points at 5000 metre intervals. If you don't, check that you have added the file correctly - in particular, that you have chosen the correct columns to use for the x and y data.

- **Zoom to layer** on the Rainfall layer - you should find that you have data for the whole UK.
- Use **Zoom to layer** to zoom back in to your mosaic dtm
- Now zoom out slightly from the layers that you already have in there (e.g. to about 1:200 000 scale)
- right-click on the rainfall layer and use the Data > Export Data... command to export **All features in view extent** to a new shapefile and make sure that it gets added to your map.
- **Remove** the full rainfall layer - you won't need it again

If you didn't add a total field to the csv file it is possible to do the same thing in Arc by adding a new field with the type **float** to the attribute table of your new shapefile and using the field calculator to add the total of the month fields for each location. This is sometimes a bit of a challenge to get to work, though, and if you can plan in advance and use Excel before you import the data it can be much quicker.

[2] Data downloaded from `http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/index.html` and altered to show only data for 2016. May 2019.

10.7.2 Interpolating your data

This shapefile shows the total rainfall at each particular point. What do you do if you want to know the rainfall at any other point between those points, or over an area? Arc gives you the tools to **interpolate** point data and calculate *z* values for the spaces between the points. Inevitably the accuracy of the surface will increase if you have more data points in a particular area, but it still works if your points are widely spaced.

Question 10.4. Think about the potential issues to do with interpolation. How reliable do you think the results are likely to be? How can this be affected by the original data?

There are several different methods of interpolation available in Arc. The instructions below use Spline as an example, but try Inverse Distance Weighted, Kriging and Natural Neighbour too, and have a look at the differences. Different methods work best for different data.

Video Clip available in Minerva - Interpolating surfaces from point data.
Direct link: `http://bit.ly/2h39mN9`

There is more information in ArcGIS Desktop Help - search for **Raster Interpolation**. Also see ArcUser for a useful article freely available online[3] -

`http://www.esri.com/news/arcuser/0704/files/interpolating.pdf`

- From the toolbox select 3D Analyst Tools » Raster Interpolation » Spline
- Fill in the dialog box, selecting the field that shows the total rainfall for 2016 as your Z value field (figure 10.6)

ArcMap will interpolate a **surface** from your data points and add it to the map. You should end up with something similar, but probably not identical, to figure 10.7

10.7.3 Change the symbology of the surface

The surface is divided into discrete units at the moment.

Use the Identify tool to click on various points within one colour band.
Question 10.5. What do you notice about the readings for the interpolated layer?

[3] Last visited: 18th September 2018

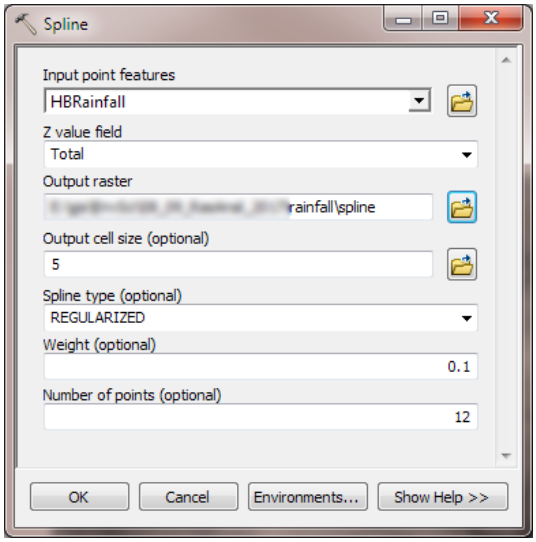


Figure 10.6: The Spline interpolation dialog

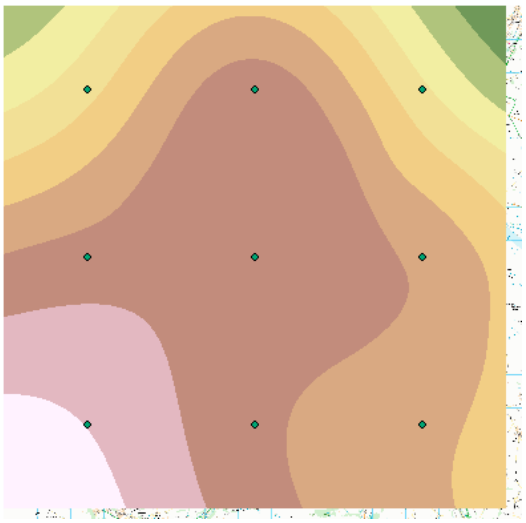


Figure 10.7: Spline interpolation of total rainfall

Hopefully you have spotted that different points within one colour band actually have different readings, and that the readings are floating point. The automatically generated symbology is not the best for this data and should be changed so that the colours are **stretched**.

- Open the layer properties symbology tab and set **Show** to **Stretched**
- Right-click on the **Color Ramp drop-down** and click **Graphic View** so that you have a list of names instead of colour ramps. From the list select a suitable colour ramp, e.g. **Spectrum - full bright**. Click on the **Invert** tick box to reverse the colour order so that low is blue and high is red. This is the "standard" direction which is usually expected. Now click Apply. The result should look something like the example shown on the suggested layout in figure 10.15 on page 146.
- Use **Transparency** (section 1.4.5 on page 7) to allow the Vector map raster layer to be visible through the rainfall layer.

10.7.4 Comparing types of interpolation surfaces

Repeat section 10.7 three times more. This time select the following tools so that you have four different interpolated layers on your map:

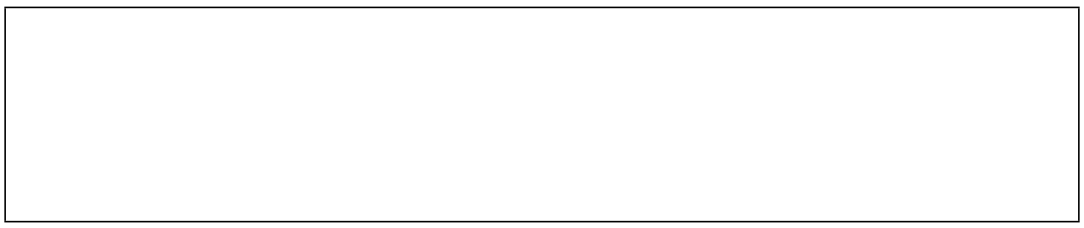
1. IDW (Inverse Distance Weighted)
2. Kriging
3. Natural Neighbour

Have a look at each layer and look at the information in Desktop Help and in the article at

`http://www.esri.com/news/arcuser/0704/files/interpolating.pdf`

Question 10.6. Which surface do you think is the most appropriate for this data and why? Make notes below, then keep your preferred surface on your map and remove the rest.[a]

[a] The **Swipe** tool on the **Effects** toolbar can be useful for comparing layers. Once you've clicked on it and selected the top layer hold down the mouse cursor on the map to drag the selected layer up and down or across.



10.8 Watershed delineation

Watershed boundaries are often used for environmental analysis. Generating your own watersheds from a DEM is not difficult, but does involve several stages. Once you have delineated a watershed you can use the boundary with other datasets.

Start by turning off all of the layers in your map except the dem.

You will be using a series of tools from the **Hydrology** tools which is part of **Spatial Analyst Tools**.

Important: Each time you run one of these tools you will generate output. Make sure that you give each output layer a name that will allow you to identify it later so that you can be sure to add the correct *input* to further tools.

10.8.1 Fill in depressions in DEM

The first step is to ensure that there are no depressions in the DTM that you are using as otherwise they can cause problems later in the process.

- Spatial Analyst Tools » Hydrology » Fill
- Select your dtm as the input, and check where the output will be saved, and give it a short filename.
- Run the tool.

The result of filling should be another dtm that may well look identical to your original one. If you check the values of both your original and the new dtm you may find that the lowest value has increased - if it hasn't it should just mean that your original dtm didn't have any depressions.

From now on you will be working with the new dtm, NOT the original one. So if you want to keep your map tidy it would be worth **Removing** the original DEM. This is good practice for preventing confusion!

10.8.2 Flow direction

- Next open the Flow direction tool from the hydrology toolset.
- The **input** will be the filled dtm from the previous step
- as usual give the **output** a name which makes sense to you.

This works out which direction is downhill for each individual cell. The output from this tool looks rather a mess, but each cell is coded according to the direction of flow - see figure 10.8. In effect, this raster layer is showing which direction water would flow if it was dropped onto any point on the dtm. Despite the rather odd look of this layer it should be possible to see the general drainage patterns (figure 10.9).

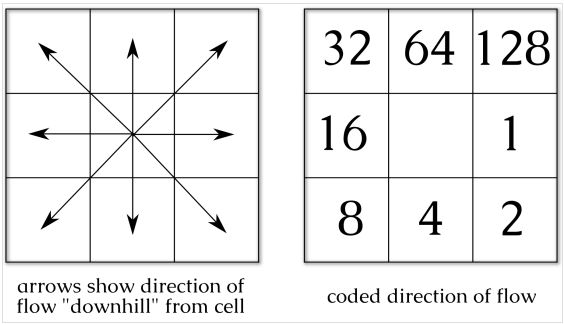


Figure 10.8: Coded flow direction

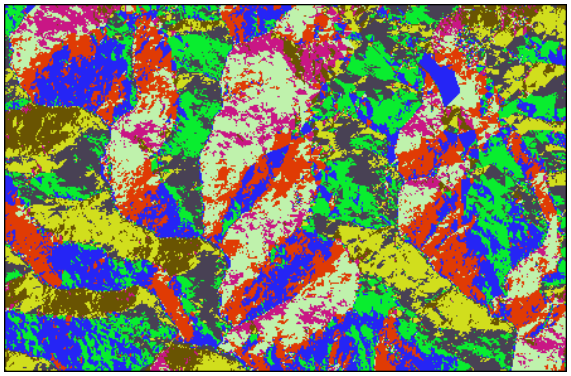


Figure 10.9: The symbolised output from the Flow Direction tool

Video Clip available in Minerva - Watersheds: classifying a flow accumulation raster to show water courses. Direct link: `http://bit.ly/2u6THPA`

10.8.3 Flow accumulation

- The next tool to run is the Flow Accumulation tool, again from the hydrology toolset.
- The **input** for this will be the flow direction raster from section 10.8.2.
- as usual give the **output** a name which makes sense to you.

Suddenly everything could go black! The flow accumulation tool enters a value in each cell that shows how many cells there are upstream from that cell. Cells with higher values will usually be drainage channels, or close to them, rather than hills or ridges.

You can't see much on this raster at the moment except, maybe, a vague white line or two (figure 10.10). To make the cells with high flow visible you need to alter the legend for the raster.

Figure 10.10: The output of the Flow Accumulation tool **before** reclassification. If you look very carefully you can just about see a thin white line.

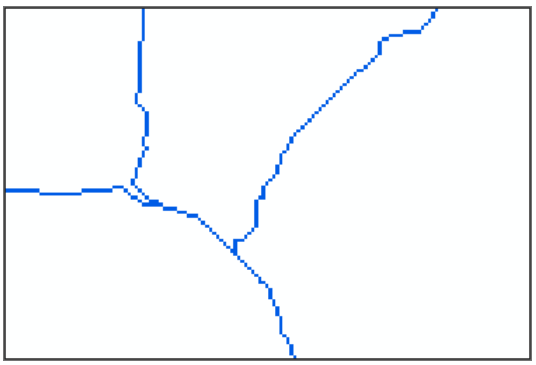


Figure 10.11: The output of the Flow Accumulation tool **after** reclassification. Now you should be able to see "streams"

- Change the symbology method to **Classified**

- Set the number of classes to two.
- Click on the Classify... button and alter the break value for the first class to **5000**
- Change the symbology for the two classes so that 0-5000 is no colour and over 5000 is blue.

Your flow accumulation layer should now look something like figure 10.11.

Question 10.7. The cells in blue all have the flow of at least 5000 upstream cells flowing through them. Given that cell size of the input raster is 5 m (so the area of a single cell is 25 m^2) what is the minimum area that each of the blue cells is draining?

- Turn off all layers except the flow accumulation and turn on the Vector Map District raster layer (or add it to your map if you haven't done so already)

You should be able to compare the streams that you have "created" with the hydrology tools with the streams that the Ordnance Survey have mapped. They are unlikely to be identical but you should be able to see that they are fairly similar. You may need to zoom in pretty close to see the flow accumulation streams.

Zoom in close and use the **Identify** tool to click on several points on one of the blue flow accumulation lines - it should be possible to tell which direction the stream is flowing by looking at the values. Upstream points will have lower accumulation values; downstream points will have higher accumulation values.

10.8.4 Create pour points

Pour points are a particular point that the flow from that watershed will all drain through. It is important that you place pour points completely within cells of high cumulative flow - that is in one of the blue areas of the flow accumulation raster.

Video Clip available in Minerva - Watersheds: accurately locating a pour point. Direct link: `http://bit.ly/2spdHj7`

- Create a new point shapefile called `pour_points` as follows:
  - Create a shapefile in Catalog by right-clicking on the folder in which you want to create it
  - select New > Shapefile
  - Give your shapefile a name and check that the **Feature type** is **Point**
  - Click on the button that says Edit... to set the coordinate system
  - then click OK and check that the shapefile has been added to your map as a new layer
- Find grid reference **399081 427155** - this should be the point where Hebden Water flows into the River Calder. You can use the **Go to XY** tool to find a specific grid reference -
  - Click on the Go to XY button on the standard toolbar

  - On the dialog that opens click the little black arrow at the end of the toolbar
  - Set the units to **Meters**
  - Type your grid reference into the **X:** and **Y:** boxes
  - Now the other buttons should have become available so you can choose to pan to the location, zoom to it, make it flash, or put a marker onto it. If you add a point note that this is only "drawn" on top of the map and can't be used for analysis. If you want to delete it use the black arrow on the standard toolbar to select it.

- Edit the pour points layer[4] and place a dot within the blue line of the Hebden Water just before it joins the main river (figure 10.12). You'll need to zoom well in to do this as you need to be **really** sure that the point is within the blue line.
- Save your edit and stop editing.

Everything upstream of this point will define a single watershed - that of Hebden Water in this case. It is possible to add multiple pour points at once and generate watersheds for more than one stream, and it is possible to generate "nested" watersheds. If you do add more than one pour point to your feature class make sure that you alter the ID values for each point in the attribute table - each point must have a unique ID.

This would be a good time to check that you have set the geoprocessing environments correctly - the extent and cell size should both be the same as either the original dtm or the filled dtm (which should be the same extent and cell size anyway). See section 10.6 on page 137 for a reminder of how to set these.

Figure 10.12: Placing a pour point - at high zoom level

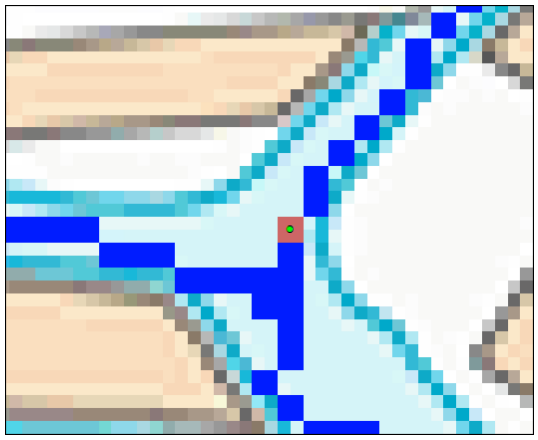


Figure 10.13: Raster pour point overlying high flow pathway

10.8.5 Convert the vector points to a grid

You can miss this step and move straight on to the watershed tool in section 10.8.6, but that does depend on your pour points being very accurate.

If there is a problem when you run the watershed tool try converting the vector file to a raster grid. There are a choice of tools to do this.

- Either Spatial Analyst Tools » Hydrology » Snap Pour Point which is probably the best to use
- or Conversion Tools » To Raster » Point to Raster

Once you have converted the layer zoom in close and check that your new pour point cell directly overlies the high flow pathway - figure 10.13. This is important - if it doesn't the watershed tool won't work.

[4] see section 7 on page 85 for a reminder on how to edit

10.8.6 The watershed tool

Finally it is time to run the watershed tool!

- Spatial Analyst Tools > Hydrology > Watershed
- Fill in the dialog box, the first input will be your flow direction raster layer
- for the **Input raster or feature pour point data** make sure that you select the **raster** pour point layer if you created it, not the feature class.
- Click OK to run the tool.

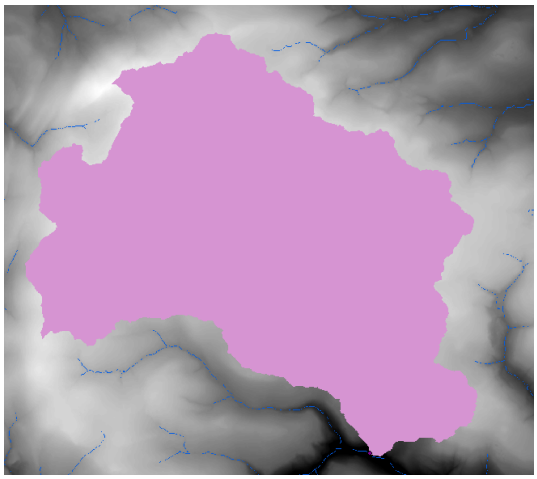


Figure 10.14: Hebden Water watershed

You should end up with something similar to the shape in figure 10.14. If your watershed ended up extremely small it will be because your pour point was located outside of a high-flow pathway or the original input dtm was not filled. Correct these problems, convert the vector pour point to a raster using the instructions in section 10.8.5 and try the whole process again using the raster pour point.

Look at the resulting watershed layer closely. Use the **Identify** tool to click inside and outside of the watershed. Have a look at the attribute table for the raster layer.

Question 10.8. What value(s) delineate the watershed? Use the attribute table to work out the area of the watershed in metres and write it in the box below (tip: you may need to widen the width of the COUNT column to see all the figures).

10.8.7 Raster to vector conversion

We will be using this watershed for further analysis, but for some of that it will be necessary for the layer to be a vector feature class rather than a grid. To convert it use the Raster to Polygon tool.

- Conversion Tools > From Raster > Raster to Polygon

10.9 Suggested layout

Use the layers that you have created to layout a map similar to the one in figure 10.15. Include your chosen interpolated surface, a hillshade layer, and the outline of the watershed for Hebden Water. Don't forget to include the usual map elements, such as title, key, scalebar etc.

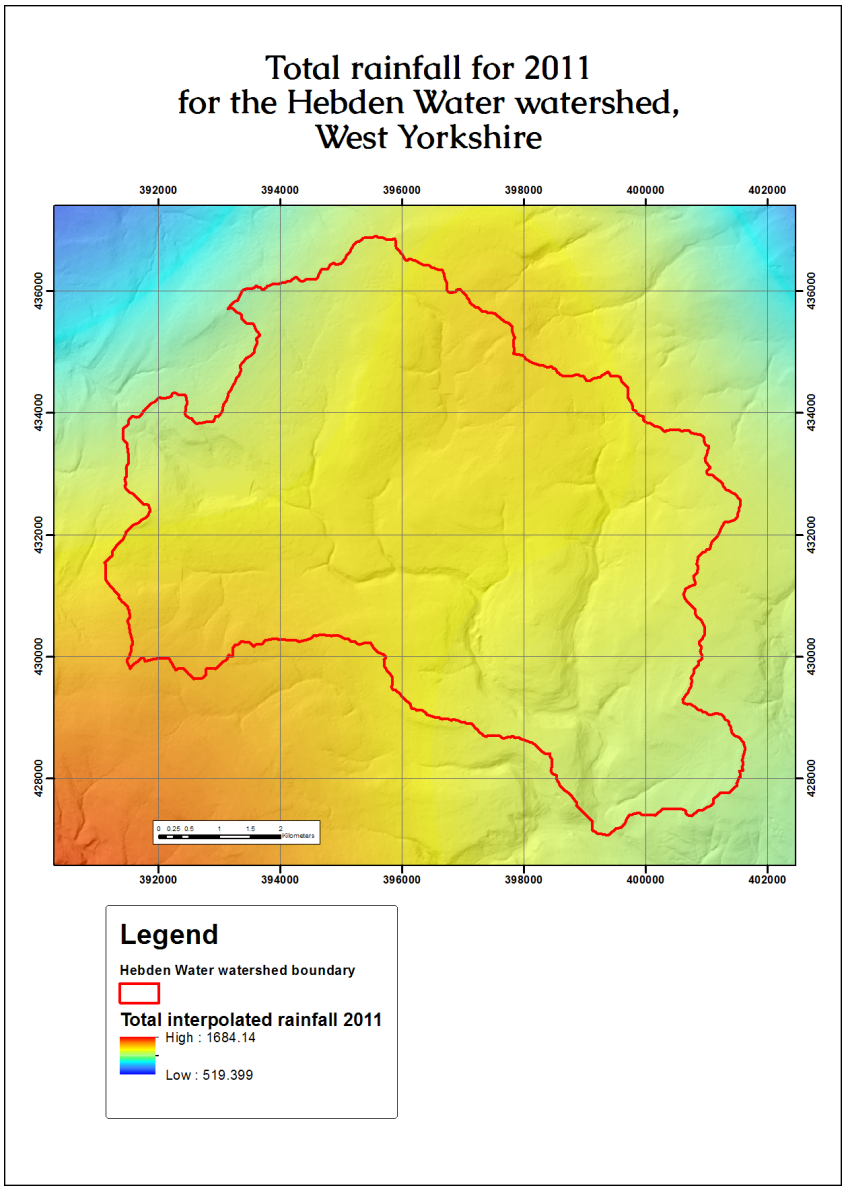


Figure 10.15: Example map of the Hebden Water watershed with total annual rainfall for 2016

10.10 Next practical

Please note that the next chapter is raster analysis part two. You will need the output and project from the exercises here to complete the exercises in part two, so make sure that you keep it all. Try to make sure that you remember where you have stored the files, and what you have called them.

10.11 Recommended Reading: raster analysis

Full references are in the module reading list[5].

Chang (2016), Chapter 12: Raster Data Analysis, p.248-267 and Chapter 14, section 4 - Watershed analysis, p.297-311.

Heywood (2011), Chapter 6, p.198-217. Sections on Spatial Interpolation and Analysis of Surfaces.

Longley (2011), Section 15.3. p.386-393. Analysis of Surfaces.

[5] Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

Data preparation for chapter 11: raster analysis exercises 2

Being able to find, download and prepare your own data is an essential part of using GIS. For the exercises in the next class you will need to download several datasets. While these should not take too long to download and prepare, don't leave it until the last minute. Websites can become unavailable either permanently or temporarily, or computers can crash.

If there are problems with a website then try again later. If the problems persist please get in touch with me (c.e.gordon@leeds.ac.uk) and I will try to contact the site or find an alternative source of data.

Data required

For the exercises in this chapter you will need the project that you worked on in the previous chapter - including the output that you created.

In addition download the following from the 2011 Census for England and Wales following the instructions below.

- ***Population data from the 2011 census for output areas for Calderdale District (West Yorkshire).***
- ***England and Wales boundary data layers in shapefile format***

Obtaining census data for England and Wales

The Census is a tremendous source of data about the population of Great Britain, but it is not always easy to find what you need. The census takes place every 10 years, the latest one being in 2011, and collects data from every person resident in the UK on a particular date in that year. Very general data is released first, with more detail being made available later, though the full personal data is only made available after 100 years.[6]

A lot of the data is based around social identifiers, such as type of house, or occupation, but the Office of National Statistics also provide key sets of data which can also be combined with physical data to allow useful analysis. For example, in conjunction with viewshed analysis, population data can be used to find out how many people live within sight of a proposed wind farm or would be affected by other types of development.

[6] Find more information about the census on the website of the Office for National Statistics at `http://www.ons.gov.uk/ons/guide-method/index.html`

Downloading UK Census Data

As a member of UK Higher Education you have access to data via the UK Data Service and UKBorders.

InFuse includes 2011 data, but only for England and Wales. The instructions in this section show how to use InFuse. The data available from InFuse needs to be joined with boundary data from **UKBorders**. The following sections show you how to do this.

Video Clip available - See a video on YouTube about How to access census aggregate data in InFuse (note that the data downloaded is different to the data required in this chapter) - `https://youtu.be/AzK04BOFd_s`

Data from the Scottish census of 2011 is available from their **Census Data Explorer** which is available at `http://www.scotlandscensus.gov.uk/`

Logging in to the UK Data Service for the first time

You'll need to start by logging in to the UK Data Service and signing for "Special Conditions" so that you have permission to use all of the data that you will need.

- Go to `http://census.ukdataservice.ac.uk/`
- Click to **LOGIN** and login via the **UK Data Service** - you'll be logging in via University of Leeds using your usual username and password.
- Review and agree to all **Special Conditions**
- **Close all browser windows**. If you try and carry straight on you'll probably find later that the services don't acknowledge that you have signed up to the special conditions and you'll have trouble downloading the data.

Infuse: 2011 data for England and Wales

For the purposes of this exercise we will aim to download data on the population of *output areas* for Calderdale District (West Yorkshire) for 2011. There are, of course, a lot of other census data sets available and it is worth exploring and thinking about what could be of use to to you in the future.

- Go to `http://census.ukdataservice.ac.uk/`
- Click to **LOGIN** and login via the **UK Data Service** - you'll be logging in via University of Leeds using your usual username and password.
- Click to go to the **UK Data Service**
- Get data » Key data » Census Data » Census Aggregate Data » InFuse then choose whether you want data from the 2001 or 2011 census - in this case choose **2011 Census Data**.
- then click to go to **Topics** - the original InFuse interface.

You'll be presented with a screen full of possible data choices (figure 10.16). The topics in the list on the left allow you to filter the choices in the boxes in the main area.

- For now click to select **Age** in the left-hand list.

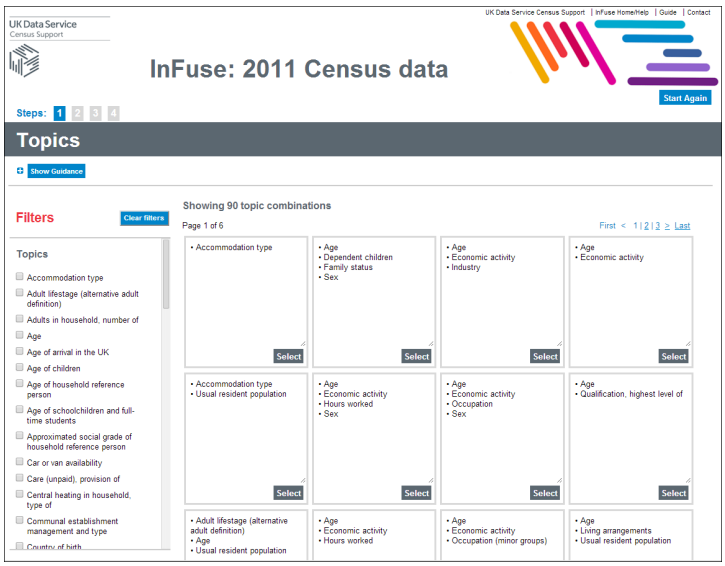


Figure 10.16: The InFuse selection screen

- Now click on the Select button in the **Age** box on the right. You'll get a bit of information about the topic.
- Click **Next**

This time you'll be presented with a list of options.

- Click to tick the box next to Age > Total: Age at the top of the list.
- Go to the bottom of the page and under Unit select **Persons** by ticking in the box next to it - this means that the data you download will show the number of people in each area.
- then click Add so that your choices show in the box at the bottom - **167 - Age : Total: Age - Unit : Persons**.
- Click Next to start selecting the geographic units that you want.

The **geographic units** used for the census are rather complex and you need to be careful about the level of detail that you pick. Have a look at the page at `http://census.ukdataservice.ac.uk/use-data/guides/boundary-data.aspx` for more detailed information.

- Click on the plus sign next to **Local Authorities** to open out the list
- click on the plus sign next to **Calderdale** (be careful not to put a tick in the box at this stage!)
- then put a tick in the box next to **Output Areas and Small Areas**
- next go to the bottom of the page and click to Add your selection to the box at the bottom of the page. At this point the text in the box should say something like **All Output Areas and Small Areas (668 areas) in Local Authorities (404 areas) - Calderdale** (figure 10.17).
- Click Next
- Check your selections and then Get the Data
- Once the orange/pink button appears Download Data and save the data to your local drive. You may want to rename the file so that it's clear what you've just downloaded.
- If you want to download any further data click on Start Again at the top of the page.

Figure 10.17: Choice of data to download

Once you have unzipped the resulting download you should find yourself with two csv (comma separated value) files. Open the one with the name beginning with **Data_** (it should open in Excel or a text editor) and have a look at the contents. You should end up with something similar to figure 10.18 which includes columns for information about the output areas and then columns containing the age data that you selected. The **All categories** column should include the total population of that output area.

	A	B	C	D	E	F	G	H	I
1	CDU_ID	GEO_CODE	GEO_LABEL	GEO_TYPE	GEO_TYP2	F167			
2						Age : All categories: Age - Unit : Persons			
3	113654	E00054810	E00054810	Output Areas and Small Areas	OASA	320			
4	113655	E00054811	E00054811	Output Areas and Small Areas	OASA	245			
5	113656	E00054812	E00054812	Output Areas and Small Areas	OASA	268			
6	113657	E00054813	E00054813	Output Areas and Small Areas	OASA	262			

Figure 10.18: Census data for Age in output areas in Calderdale

Also have a look at the other csv file - the one with the file name that starts with **Meta_**. This gives information about the data in the other file, including what each column contains.

To be able to display this data in ArcMap you need some way of showing the geographic units - the output areas - in their correct places. The next section will show you how to download the extra data that you need to be able to do that.

Downloading UK Boundary data

If you have downloaded a csv file containing census data you will need to associate it with the correct geographic boundaries.

Note that this is where it becomes important that you signed up to the **Special conditions** earlier. If you didn't you will have to do so now.

The data for the geographic boundaries can be downloaded as follows:

- Go to the UK Data Service Census Support at `https://borders.ukdataservice.ac.uk/`
- Login via UK Federation and select **Boundary Data Selector**
- Select Country - **England**
- Select Geography - **Census**

- Select Dates - **2011 and later** [7]
- Click on Find

A list of boundary datasets should appear below. Select the set that you need.

- In this example, you've downloaded the population data for output areas, so select the **English Census Output Areas with OAC, 2011**
- Click on List Areas. Scroll down the resulting list and select **Calderdale**.
- Click to Extract Boundary Data

You may need to wait a short while but eventually you can download the resulting file following the instructions on the page and save it to your disk. You'll need to unzip the file that you downloaded and should find that it contains a shapefile.

Copyright and source acknowledgement

Information about the required acknowledgement for the data we downloaded above is available on the web at

`https://census.ukdataservice.ac.uk/use-data/citing-data`

Make sure that you check the requirements for each dataset you download. If you have used boundary data you will need to reference that as well as the census data itself.

Adding census data to ArcMap

If you download a csv text file (also known as attribute data) from Infuse, and separate boundary data, you need to tell ArcGIS how to link the attribute data in the csv file to the boundaries. To do this you will **join** the data.

Video Clip available in Minerva - Joining a data table to a feature class.
Direct link: `http://bit.ly/2h2QoXb`

Start by cleaning up the csv file so that it will work in ArcMap.

- Open the file in either Excel or a text editor
- Check that the data is as expected
- Check column headers - for import to Arc it is best to use headers that are 8 characters or less, start with a letter, and don't contain spaces. So rename the column headers appropriately if necessary. Unfortunately Arc seems to rename the headers when the join is made so it's also a good idea to make a note of which number column contains which data.
- Make sure that there isn't a second header line - Infuse often does this. Delete it if present!
- Save the file either as CSV (Comma-separated Value) or Excel.

[7] Note that administrative boundaries do tend to change between each census so you do need to make sure that you download the right set for your census data.

Then you are ready to open ArcMap and start adding data.

- Add both the boundary shapefile and the csv/Excel file to Arc. The attribute data file (the csv file) won't show on your map.
- you may find that the coordinate system of the data frame is not set automatically - if it isn't then set it to British National Grid now. See section 4.2.3 on page 36 for a reminder of how to do this.

Joining data

To join the data you need to have fields in each source file that match. So have a look at both files now.

Which fields in the shapefile and csv file contain matching data that can be used to join them? (The fields will probably have different names in each file, but should contain very similar data.)

Join the attribute data to the shapefile as follows

- Right-click on the shapefile in the table of contents and select Joins and Relates › Join...
- Fill in the dialog as in figure 10.19 though if you have downloaded boundaries for the whole country you can save space by clicking to **Keep only matching records**. Try both options and see what you think.
- Validate Join and if it works click OK

Open the attribute table of the boundary shapefile and you should now be able to see all of the data in one place. If Arc has renamed all of the fields you may find that you need to go back to the csv file and double check which column refers to which statistic.

Make the join permanent by exporting the shapefile to a new shapefile using **Export data**[8]. Add the resulting shapefile to your map and remove the other layers.

Make sure that you save your map and have it available for the next class.

More information about downloading census data

If you want more information about how to download census data, and about what is available the UK Data Service has some guides that you can look at:

The guide for **Census aggregrate data** includes a video showing how to download data from Infuse - `http://census.ukdataservice.ac.uk/use-data/guides/aggregate-data.aspx`

The **Boundary data** page has a lot of useful information and links to further tutorials - `http://census.ukdataservice.ac.uk/use-data/guides/boundary-data.aspx`

[8] instructions are on page 30

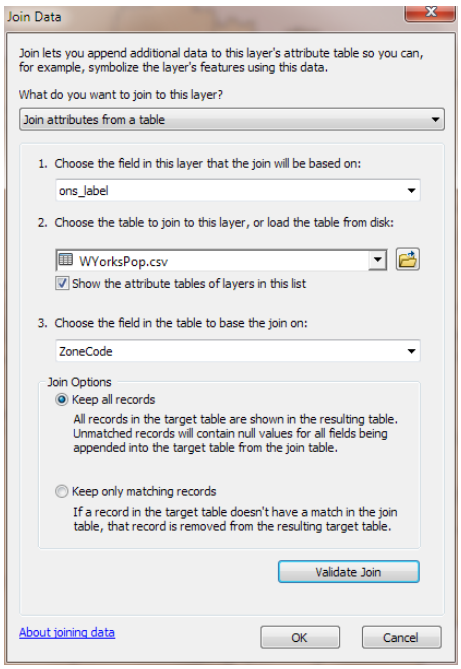


Figure 10.19: Joining census attribute data to boundary data

Chapter 11

Raster analysis II

11.1 Introduction

In Raster Analysis I you looked in more detail at the properties of rasters and how those make a difference to settings and usage. You ran some of the raster tools in the Spatial Analysis toolset to interpolate a Grid from point data, and to delineate a watershed or catchment area. In this chapter, Raster Analysis II, you'll do further raster processing using more advanced tools from the Spatial Analyst Toolset.

11.2 Data to download

For the exercises in this chapter you will need the project that you worked on in the previous chapter - including the output that you created.

In addition you should already have downloaded and prepared census data for this exercise as detailed in the section on **Data preparation for raster analysis 2** on page 148. If you haven't, follow the instructions there now.

11.3 Using masks

For the exercises in this chapter it would be useful to restrict further geoprocessing options to the area of the Hebden Water watershed.

Question 11.1. What do you think are the advantages of restricting your datasets and processing tasks to a smaller geographic area?

You need a raster layer where the cells outside of the area you wish to mask have **no value** and the cells within the area have a value. What that value is, is not important. Remember that zero counts as a value in GIS. Luckily we already have a layer that will do this job for us.

Video Clip available in Minerva - Setting a raster mask. Direct link: `http://bit.ly/2h2gnhs`

Use the Identify tool to have a look at the watershed raster that you created in the previous chapter.

Question 11.2. What value do the cells outside of the watershed have? What value do the cells inside the watershed have?

Outside watershed:

Inside watershed:

With luck the cells outside should have **no value** and the cells inside a value of **0**. So this layer is exactly the one you need.[1]

- Open the Geoprocessing Environment dialog Geoprocessing › Environments... › Raster Analysis
- In the **Mask** dropdown select your watershed raster file then click OK.

To check that this works try running the **Hillshade** tool and see what area the new hillshade layer is generated for.

11.4 Spatial Analyst tools

You should be realising by now that the Spatial Analyst toolbox provides a range of tools specifically for working with raster datasets. This section will explore more of those tools but there are plenty more. If you need to analyse a dataset try to think clearly about what you are trying to do, and then look and see whether there is a tool that will do that job for you. Remember that it is possible to search for tools in the toolbox -

- Use the **Search** window (Windows › Search if it isn't already showing).
- Click on the **Tools** link and then enter the name of a tool - for example **Mosaic to new raster**

If you are not sure what a tool does, or whether it is the right tool for the job you are trying to do, just have a go with it! If it fails, try different parameters, or try another tool. You have nothing to lose! You may need to go though your data in Catalog and delete extra layers occasionally, just to free up space. But as you try tools out the experience will increase your knowledge of gis and may give you other ideas of how you can use your data.

[1] Sometimes you may need to run the **Polygon to Raster** tool to convert a polygon outlining an area into a raster layer that you can use as a mask.

11.4.1 Raster Calculator

The Raster Calculator is available as part of the Spatial Analyst toolbox and is an essential interface for performing **map algebra**. Using the raster calculator you can perform an enormous number of calculations on raster layers. The exercises in this section will only give you a brief introduction to the possibilities. For some more information try searching for **Raster Calculator** and **Map Algebra** in ArcGIS Desktop Help.

- To open the raster calculator go to Spatial Analyst Tools > Map Algebra > Raster Calculator

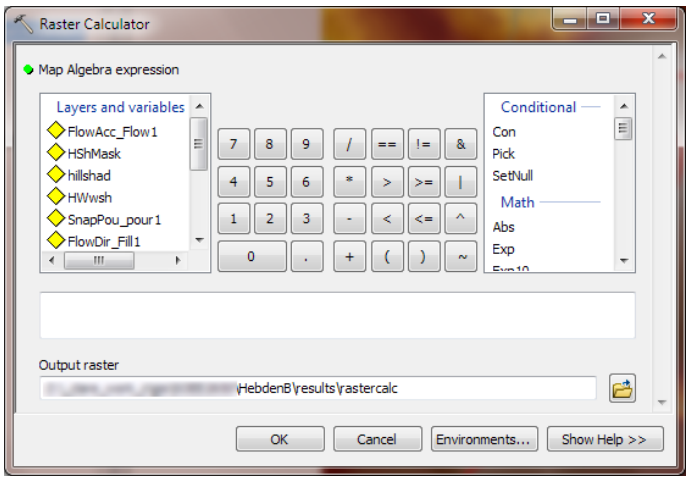


Figure 11.1: The raster calculator

11.4.2 Reclassifying rasters: setting cells to null

Video Clip available in Minerva - Reclassifying rasters: with the raster calculator. Direct link: `http://bit.ly/2h2Lkly`

The flow accumulation raster shows the stream network, and you have symbolised it using a classified symbology to show just the streams (in section 46 on page 142). Any cell outside of the high flow channels, that is which has a value of less than 5000, should have a **no color** symbol.

This is not a permanent change. If you took your raster and added it to a blank map the symbology would once again cover the whole of the raster area.

To make this change permanent it is necessary to **reclassify** the raster by changing any cell with a value below 5000 to **NULL** - that means that it will have no value. Note that this is different to having a value of zero.

The raster calculator provides the **SetNull** command which will do exactly this.

- Open the Raster Calculator
- Use the tools provided to enter the following statement exactly as it appears below (though with your flow accumulation layer replacing **FlowAcc**) in the window as for figure 11.2:

```
SetNull("FlowAcc" <= 5000,1)
```

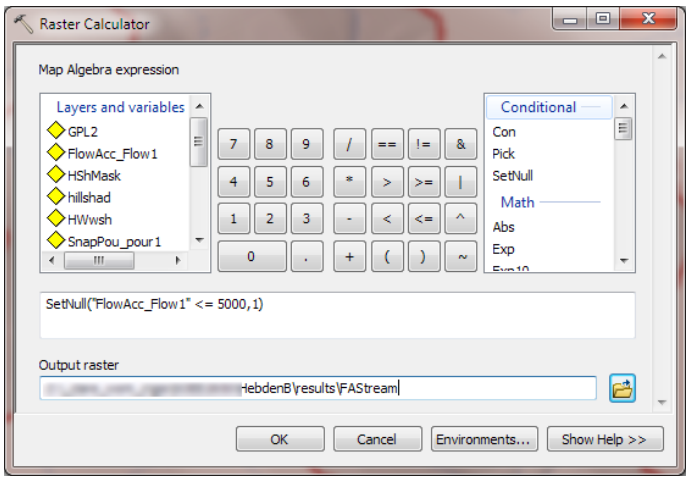


Figure 11.2: SetNull in the raster calculator

- Select a location to store the output and enter a **short** output file name then click OK

The statement that you have entered means "make a new grid where the cells that have a value of less than or equal to 5000 are made **null**; the remaining cells should be given a value of **1**".

The tool should run and then add a new raster layer to your map. Have a close look at the layer, both the attribute table and using the **Identify** tool.

Question 11.3. What are the differences between this and the original flow accumulation layer? What information has been lost for the high flow channels?

If you want to display on your map the streams that you have generated you will probably get a better result if you convert the raster to a feature class and then symbolise it. Try running Spatial Analyst tools > Hydrology > Stream to Feature.. The output from this tool adds information from the flow direction raster. Conversion Tools > From Raster > Raster to Polyline will also convert the raster to a feature class.

As well as running **SetNull** through the raster calculator there is a tool under Spatial Analyst Tools > Conditional > Set Null which you can use. In general the raster calculator provides more flexibility, but it can be useful to have an interface where you can enter your input and statements.

11.4.3 Proximity

Once you have a raster for the streams with only the high flow cells having a value, it is possible to use it to run other tools such as the **Euclidean Distance** tool. This allows you to answer such questions as which areas are within 500 m of a stream. This should hopefully be a familiar concept to you from the vector **Select by Location** tool[2]. For rasters **Euclidean distance** works in a different way, and you get a raster output rather than vector.

- Spatial Analyst Tools > Distance > Euclidean Distance

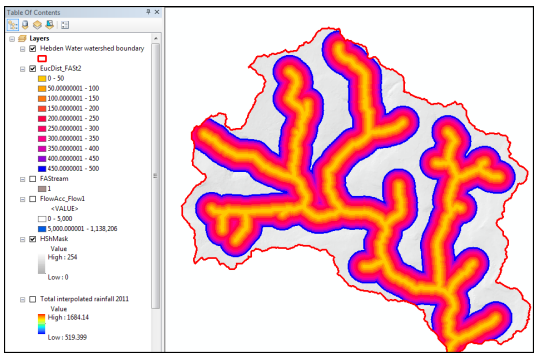


Figure 11.3: The result of the Euclidean Distance tool

- Enter your new stream raster as the input and fill in the output details as usual.
- Set the Maximum Distance to **500** - this is map units. Click OK

The output should look something like figure 11.3. As usual explore the output further using the **Identify** tool. You should find that the layer consists of cells with values according to their distance from the values in the source layer. Cells outside of the 500 m distance that you set should be null.

You should have noticed that there are other tools in the **Distance** toolset. We'll be exploring some of those further in the environmental decision making exercises in chapter 13.

11.4.4 Replacing values in a raster with values from another raster

As another example of how you can use the raster calculator how about using the interpolated rainfall surface to give values to the area of the watershed? Once you have those values you can then run a function called **Zonal statistics** to find out statistics for the new raster layer, for example, what was the total rainfall for 2011 in the catchment area of Hebden Water?

- Open the raster calculator and enter and run the following statement, using your file names for the watershed and rainfall layers.

```
SetNull("Watershed","Rainfall")
```

The statement means "make a new grid where the cells in the watershed raster that have no value are left/made **null**; the remaining cells should be given the value from the rainfall raster".

You should end up with a raster with the same values as your rainfall layer, but that only covers the area where the watershed has values, even if those values are `0`.

Again, explore the resulting raster with the **identify** tool.

11.4.5 Zonal statistics

Arc carries out three main categories of operation on rasters: Local; Neighbourhood and Zonal[3].

- Local operations are cell-by-cell - reclassification is an example of this.

[2] Section 1.9 on page 13

[3] For more detailed information on local, neighbourhood and zonal operations see Chang (2016) pp. 249 - 257

- Neighbourhood operations involve a focal cell and its surrounding cells - terrain analysis such as slope and aspect are examples of this.
- Zonal operations work with groups of cells with the same values or similar features - for example zonal statistics.

You have a raster showing the annual rainfall for the Hebden Water watershed, now how do you use that to calculate statistics for the area, such as the mean rainfall or the sum? We'll use the **Zonal Statistics as Table** tool as that puts the statistics in to a table that we can look at.

- Open the Zonal Statistics as Table tool from Spatial Analyst Tools > Zonal.
- Fill in the dialog as in figure 11.4 with the watershed layer (either the raster or the feature class in this case) as the **Input raster or feature zone data**, and the rainfall raster as the **Input value raster**.
- Give the **Output table** a location and name
- Optionally you can choose the type of statistics but in this case leave it as **ALL** so that you can see what is calculated.
- Click on OK

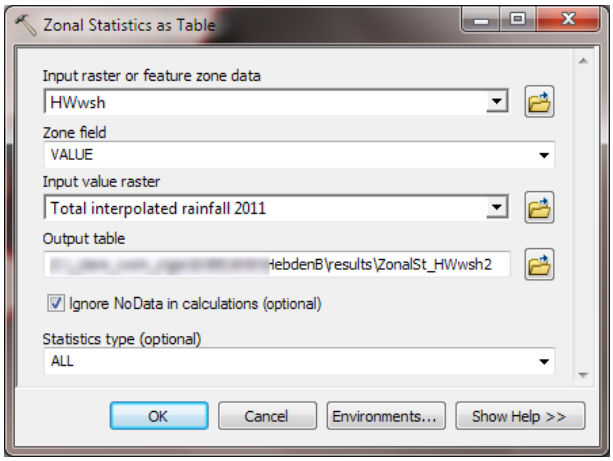


Figure 11.4: Zonal Statistics as Table tool

The table will be generated and added to Arc, but it won't show as part of your map. Use the icons at the top of the table of contents to go to **List by Source** (hover to see what the icons are if you need to). Find the table (if it isn't already highlighted), right-click and Open...

You should see that you have an attribute table with just one row (in this case) and statistics for the whole of the zone covered by the watershed (figure 11.5). Your results will probably be at least slightly different from the ones in the figure.

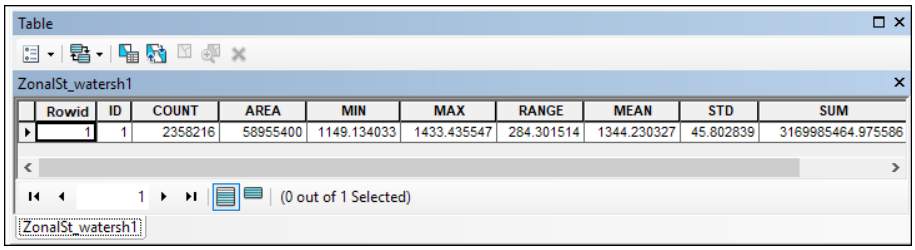


Figure 11.5: The Zonal Statistics table

In effect you have used the watershed to designate a **Zone** and used that to generate statistics for that zone based on the values in the rainfall raster.

Have a look at your zonal statistics table. Think about what each field is showing you - and what units of measurement each field uses. Make notes below.

11.4.6 "Flooding" a raster

You've already seen how to reclassify a raster using the raster calculator - that is what you are doing when you set some cells to a value and others to null. There is also a raster tool for reclassifying.

To try that out, imagine that there is a plan to build a 30 m dam where the Hebden Water runs into the Calder. You've already drawn the pour point and the watershed, so you can use that information to limit the "flood" to the valley above that point rather than covering the whole of the area of the DTM under that height (if you have a raster that goes down to sea-level that may not be so much of an issue).

Make a note of the height of the pour point that you have already drawn at grid reference 399081 427155. Use the Identify tool to find the height on the dtm.

Using the raster calculator

Have a go at using the raster calculator to reclassify the raster so that

- all cells with a value of more than 30.001 m above the height that you made a note of, are reclassified as **null**,
- and the cells with a value of 30 m or less above the height are reclassified as **1**.
- Refer back to section 11.4.2 on page 157 if you need a reminder of how to do this.

Question 11.4. What statement did you use to reclassify your raster?

If you get stuck on this don't forget that the answers to questions are at the back of the workbook - check the answer to this question on page 208.

If you have the geoprocessing mask[4] set to your watershed then you should get a raster with the area running up the valley filled in with a colour (figure 11.6). The raster cells outside of the coloured area should have a "value" of **NoData**.

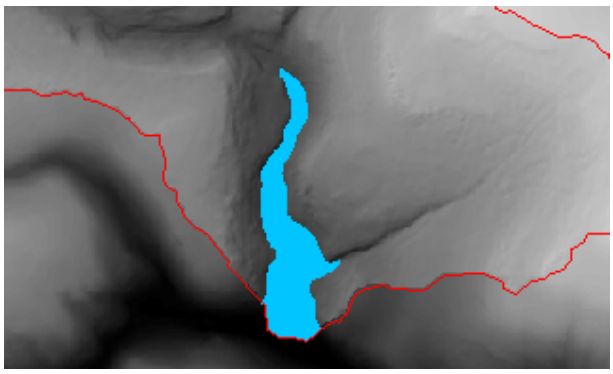


Figure 11.6: "Flooded" raster showing areas which have been reclassified as being below the height of flooding within your watershed. Areas outside of the flooded area are set to NoData.

Video Clip available in Minerva - Reclassifying rasters: with the Reclassify tool. Direct link: `http://bit.ly/2tEiA47`

Using the Reclassify tool

Now try the same process in the **Reclassify** tool as follows:

- Spatial Analyst Tools > Reclass > Reclassify
- Fill in the dialog as in figure 11.7 with the input being your filled dtm. Use the Classify button to set the classification. This should be familiar from the Symbology dialog.
- Tick to **Change missing values to NoData**
- Click OK to run the tool.

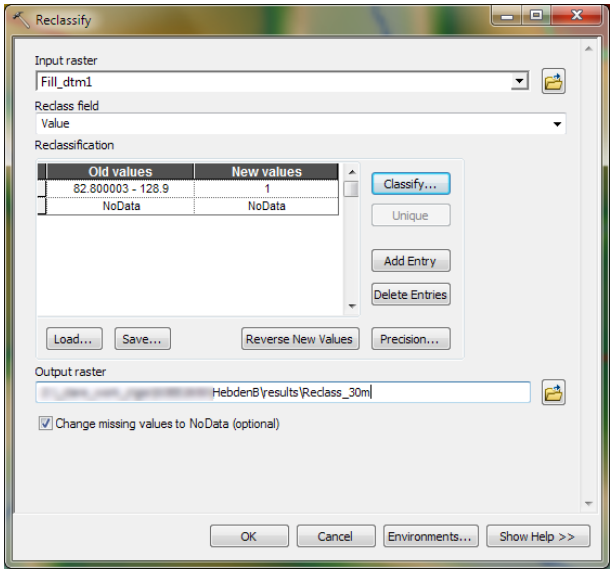


Figure 11.7: Using the Reclassify tool

[4] see section 11.3 on page 155

The Reclassify tool can look easier to use than the raster calculator, but it can also be less flexible to use. In effect, it limits the statements that you can enter.

11.4.7 What is the population of the flooded area?

Now the lower Hebden Water obviously (I hope!) isn't likely to be a good location for a dam. The resulting layer should show the area that would be flooded and if you turn on or add the Vector Map District layer it should be obvious that the local residents in Nutclough would not be happy. You should have downloaded the census data for this area - you can use that to work out how many people would be affected if the area was flooded.

- To be able to select the population for the output areas that intersect that area the flooded raster needs to be converted to a vector file so use the Conversion Tools > From Raster > Raster to Polygon to convert it.
- Then use Selection > Select by Location to select all output areas in the census data that **intersect** with the new output feature class[5].
- Export the selection as a new layer.
- To find out the total number of people in the output areas that you have exported.
  - Open the attribute for the new table
  - Right-click on the heading of the column that holds the population data
  - Select **Statistics** and you'll be given a summary of various statistics for the column (figure 11.8) which will include the total. Make a note of the total population in **your** statistics below.

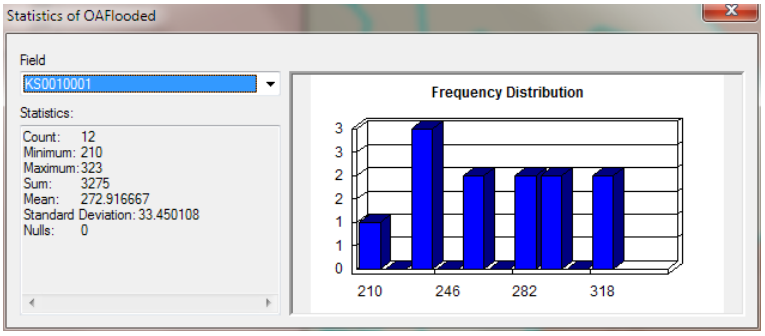


Figure 11.8: Attribute table column statistics

Question 11.5. Stop and think about the data that you have used. Output areas are the smallest unit that we can download for census population data. How do those match the area that we are analysing? How would you phrase the explanation of the figures that you have just produced to make it clear what the data showed?

[5] See section 1.9 on page 13 if you need a reminder about Select by Location

11.5 Suggested layout

Use the layers that you have created to layout a map similar to the one in figure 11.9. Include your chosen interpolated surface, a hillshade layer, and the outline of the watershed for Hebden Water. Don't forget to include the usual map elements, such as title, key, scalebar etc.

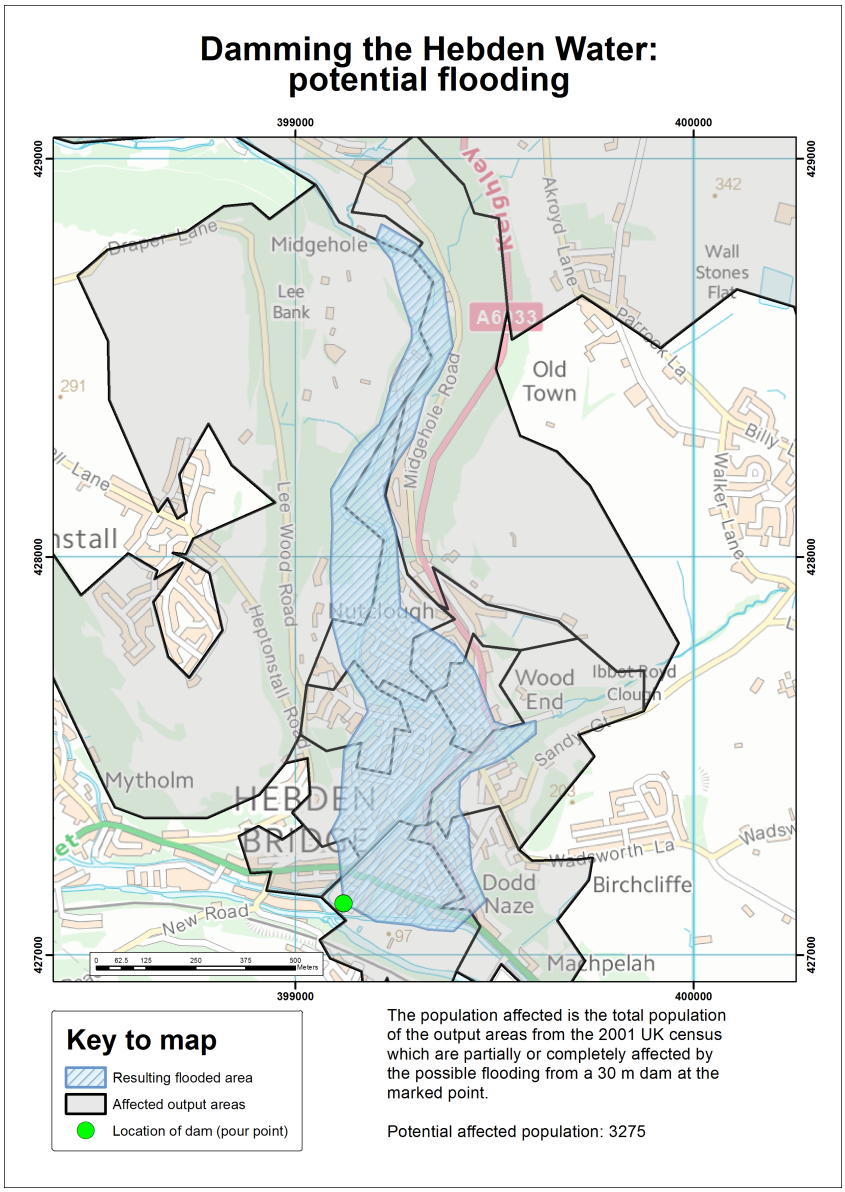


Figure 11.9: Example map of the result of damming the Hebden Water in Hebden Bridge

11.6 Recommended Reading: Raster analysis II

Full references are in the module reading list[6].

Chang (2016), Chapter 12: Raster Data Analysis, p.248-267.

[6]Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

Chapter 12

Creating data for GIS: Point data and GPS

12.1 Learning outcomes

When you have completed this section you should be able to

- collect your own spatial data for use in GIS
- discuss the problems that can affect data for GIS
- suggest ways in which to minimize error and uncertainty in spatial data

12.2 Introduction

The previous chapters should have given you some idea of the variety of data that is available for you to use, but there is nothing to replace going out and collecting your own data and it is very likely that you will be using GPS units for fieldwork at some point.

In this chapter you will collect waypoints using a GPS unit. Once you have collected waypoints you will look at how to import the data from the GPS units into ArcMap.

Waypoints collected using a GPS receiver can be downloaded and opened in ArcGIS in a variety of ways depending on the software provided with your receiver. Instructions in this section will of necessity be vague in places as it is impossible to know about every combination of hardware and software. You may need to use instruction booklets and help files provided with your setup.

If you are new to GPS and would like to find out more about the background and technology there are beginners guides at:

Garmin:

`http://www8.garmin.com/aboutGPS/index.html`[1]

Ordnance Survey:

`http://bit.ly/1cPJkCw`[2]

12.3 Prerequisites

- GPS receiver with cables to connect to computer
- **OR** GPS enabled mobile device either with cables to download data or wifi connection.
- Base map - these instructions will show you how to use ArcGIS Online as a base, but use the most suitable base map for your area.

[1] Last visited: 18th September 2018
[2] Last visited: 18th September 2018

12.4 Collecting data with a GPS

You will be divided into small groups. Each group will have a GPS unit (probably a Garmin eTrex 10), a brief quick start guide and a fieldslip (see section 12.12). The official Quick Start manual for the Garmin eTrex 10 is available online[3] at

`http://static.garmincdn.com/pumac/etrex_10_QSM_EN.pdf`

12.4.1 Setting up the GPS

This is best done once you are outside and the gps can find satellite signals. Wait for me at the location I tell you, and we will check that you all have a gps which works, and know how to do the basics before you continue with the exercise.

You will be given a quick reference sheet which you can take outside with you to use during the exercise.

Take a short while to familiarise yourself with the GPS and work out how to add waypoints (use the quick reference leaflet to see how to do the basics). Please ask if you can't work anything out.

- Start by turning the GPS on!
- Use the thumbstick to navigate the menu. Press it to select.
- Use the **Waypoint manager** to delete all existing waypoints (hint: use the **Menu** button!)
- Use the **Track manager** to clear the current track
- For this exercise go to Setup ⟩ Position Format and check that the format is as follows:
  - **Position format:** British Grid
  - **Map Datum:** Ord Srvy GB
  - **Map Spheroid:** Airy
- If the position format isn't correct, reset it.[4]
- Check that you know how to record a **Waypoint**

Now you should be ready to go.

12.4.2 Collecting data: warnings

Accuracy

It is possible check how many satellites your GPS receiver can see (**Satellite** in the initial menu). The more satellites there are within view, the more accurate your readings will be.

When you get outside, keep an eye on this from time to time.

[3] Last visited: 18th September 2018

[4] It is often best to have the coordinate system set to the same as a paper map that you are using in the field. If this isn't possible set the format to WGS84, which is a standard geographic coordinate system and can be **transformed** into another system later:

- **Position format:** hddd.ddddd degrees
- **Map Datum:** WGS84
- **Map Spheroid:** WGS84

Figure 12.1 shows the satellite information screen on the eTrex 10. In this case it is showing that it has picked up four of the satellites that it is expecting, although it only has a full-strength signal from three of them. The accuracy is +/- 34 m, hopefully yours will be better than that!

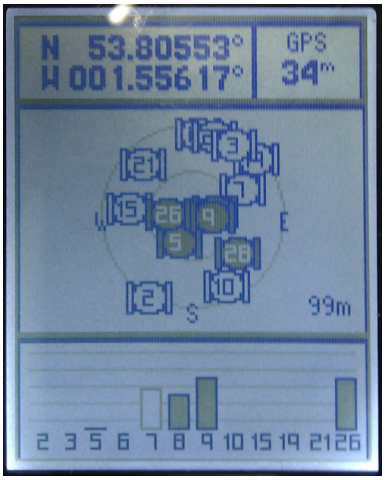


Figure 12.1: Garmin eTrex 10 satellite information screen

Make a note on your sheet of the number of satellites that there are in view when you first switch on the GPS and of the stated level of accuracy which should be in metres (ask for help if it is in feet).

The general advice is to turn on your GPS well in advance of starting to work, and leave it on for the whole of the working day. This gives it a chance to find and track the maximum number of satellites. Even under ideal conditions, when your receiver has found several satellites, due to the nature of the system accuracy still won't be 100%. Under **Satellite** you should be able to find out what the current level of accuracy is - it will be a measurement in metres. Be aware of this when using the readings. According to the O.S. website "Positional accuracy with a single receiver, to civilian users approximately equals 5 m to 10 m, 95% of the time." [5]

It is particularly worth noting that GPS data can give an *illusion* of extreme accuracy. The readings tend to show figures with lots of decimal points which could lead you to assume that a reading is accurate to 1 m or less. Given the statement above that is very unlikely to be the case.

For this reason it is still important to know how to locate yourself accurately on a paper map without the use of GPS, and most navigation experts will say that with practice you can be far more reliable and accurate than a GPS unit. Not least, you should have the intelligence to recognise when the point where you are standing is at the top of a cliff, not off it!

Elevation

Don't use elevation measurements from your GPS. For various reasons obtaining accurate height readings with GPS is much more difficult than obtaining accurate horizontal readings. The OS website has an explanation of how best to do this, but it involves specific equipment and readings taken over at least 24 hours.

[5] `http://bit.ly/1cPJkCw` [Last accessed: 18th September 2018]

12.4.3 Data to collect

Go out to the area indicated in the class (probably Chancellors Court or St Georges Fields) taking a copy of the data sheet or map with you and collect a series of point readings. You will be given a time limit - try quickly to collect points which are spread out across a fairly wide area. When you are doing field work you will collect data in your field notebook and/or on a field slip but for now mark items on the field slip provided.

Suggested features to take a reading for are: Trees; Seats; Rocks; Rubbish bins; Memorials; Sign posts; Planters; Maps. But add any other features that you think are appropriate.

Fill in the fieldslip with the number of the waypoint, and the type of feature, e.g. seat.[6]

Make sure that every member of the group has a turn with the GPS and try to work quickly and efficiently.

Once you have at least the recommended number of points, return to the computer cluster and continue following these instructions to download the data.

12.5 Downloading files from the GPS

Start from here once you get back into the cluster from collecting data.

To download data directly from the GPS unit you will have a USB lead (if you're in class you should sign one out from the demonstrator).

- Connect the USB lead to a USB port on the computer.
- Lift the "weather cap" from the port near the top of the back of the gps unit and plug the other end of the USB lead in to that
- The gps unit should appear as a removable drive in **My Computer**
- navigate to `Garmin`▸`GPX` and download the gpx (gps exchange format) file - `Waypoints_`*`current_date`*`.gpx`

You won't be able to open the file directly, but **copy it to your working folder** so that you don't lose it when you remove the gps.

Make sure that every member of your group has a copy of the gpx file on their own drive so that you can all work through the remaining exercises independently.

When you've finished make sure that the gps is turned off - the batteries are not rechargeable!

12.6 Converting gps files for ArcGIS

Before you start this exercise check that you have set the links from ArcMap to datafiles to relative - see section 4.3.1 on page 38 for a reminder on this and how to deal with broken links (the little red exclamation mark).

Video Clip available in Minerva - Converting gps files to display in ArcMap. Direct link:`http://bit.ly/2fY3bd7`

12.6.1 Converting with the Conversion tools

Methods of converting gpx files in Arc appear to change with each version. This method should work with version 10.4 and above. If it doesn't, or if you are on version 10.3 or another lower version try the instructions in section 12.6.2 on page 170 instead.

The simplest way to convert gpx to feature class is to use the **From GPS** tool.

- Open ArcMap and begin by having a look at the properties of the gpx file in the Catalog panel - right-click on the file and select Properties
- In particular check the XY Coordinate System and make a note of how it is set in the box below.

gpx file coordinate system:

If the XY coordinate system is `<unknown>`, which it probably is, you'll need to work out what the coordinate system actually is.

Open the gpx file in a text editor such as Notepad or Notepad++ (right-click on the file in the windows file explorer and Open with... . You may need to set the text to wrap around if the whole thing appears on a single line - in Notepad++ go to View > Word wrap.

It will look rather confusing - this is a form of xml - but don't panic! Look for a line that begins `<wpt lat= ...` (see figure 12.2). This line shows the **latitude** and **longitude** of a waypoint and demonstrates that, even if your gps unit was set to British National Grid, for example, a gps unit will still **store** the data in a coordinate system called **WGS84**.

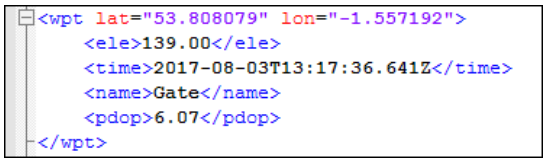


Figure 12.2: This is how a waypoint looks in Notepad++ - note the line beginning **<wpt lat=** . Also note that the coordinates will be in lat and long even if you had the GPS unit set to British National Grid.

Figure 12.3: This is the same file as figure 12.2 but with all of the data on one line. It's harder to see what is happening, but the information is the same. Just look for **<wpt lat =** still.

So if the coordinate system of your file was `<unknown>`, write **WGS84** in the box above where you wrote the gpx file coordinate system previously.

You'll use one of the tools in **ArcToolbox** to convert the gpx file. ArcToolbox gives you the opportunity to do a lot of very advanced processing tasks without needing to use a command-line interface.

[6] It is possible to use the GPS unit to add notes, such as the type of feature, to each waypoint, but the GPS doesn't have a touch keyboard and entering text is very long-winded and fiddly. It is much easier to collect the points on the GPS, make notes on paper, then add the notes to the data on computer.

- If the toolbox isn't already open find it by going to Geoprocessing > ArcToolbox. Be patient, it can be slow to open - it should look something like figure 12.4 once it does.
- Open Conversion Tools > From GPS and double-click on GPX to Features to open the tool (figure 12.5).
- Fill in your **Input GPX File** and then click on the folder symbol next to **Output Feature class** (remember - never try to save to the Default geodatabase - it almost always crashes)
- You can either just navigate to your folder and then type in a name such as `Waypoints` or you can add the data to an existing geodatabase
- Click Save > OK

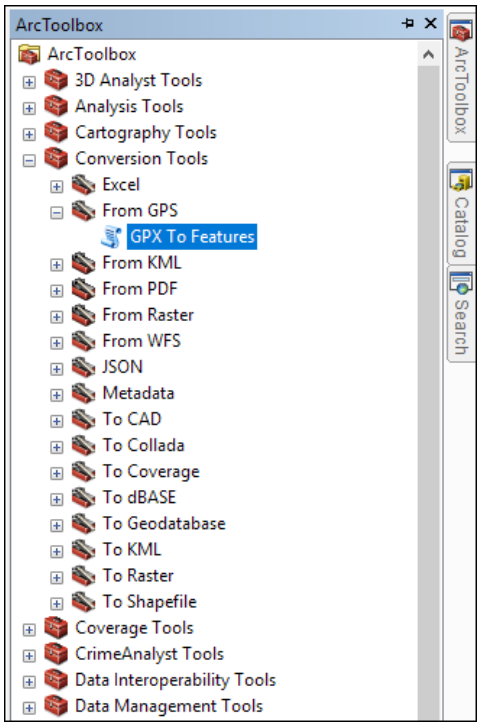


Figure 12.4: ArcToolbox - showing GPS to Features selected

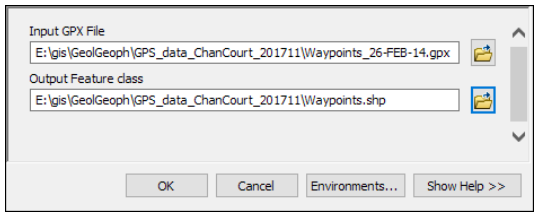


Figure 12.5: The filled in GPS To Features tool

The tool should run and add a point feature class to your blank map.

12.6.2 Converting with the Data Interoperability tools

If you have already converted your gpx files in section 12.6.1 on page 169 go straight to section 12.7 on page 172.

Methods of converting gpx files in Arc appear to change with each version. This method should work with version 10.3.1. If it doesn't, or if you are on version 10.4.1 try the instructions in section 12.6.1 on page 169 instead.

The simplest way to convert gpx to feature class is to use the **Data Interoperability Quick Import tool**.

- Open ArcMap and begin by having a look at the properties of the gpx file in the Catalog panel - right-click on the file and select Properties
- In particular check the XY Coordinate System and make a note of how it is set in the box below.

gpx file coordinate system:

NOTE: If the XY coordinate system is actually `<unknown>` you'll need to know the system that the gps was set to - in this case it should be **WGS1984**.

You'll use one of the tools in **ArcToolbox** to convert the gpx file. ArcToolbox gives you the opportunity to do a lot of very advanced processing tasks without needing to use a command-line interface.

- If the toolbox isn't already open find it by going to Geoprocessing > ArcToolbox
- Once in the toolbox double-click on Data Interoperability Tools > Quick Import
- Click on ... next to **Input Dataset:**
  - Set format to gpx by clicking on ... next to **Format** and searching for **gpx** in the box at the bottom left, then selecting **GPS eXchange Format(GPX)**.
  - Click on ... next to **Dataset:** to navigate to your gpx file and open it
  - Click on ... next to **Coord. System** to set it to WGS84 (or whatever coordinate system your gps was set to - see the note you made above) - For WGS84 look for Geographic Coordinate System > World > WGS1984
  - OK - see figure 12.6
- OK
- Now click on the folder symbol next to **Output Staging Database** to set where you want to save your data. **Don't save it to the default location as it will almost inevitably crash!**

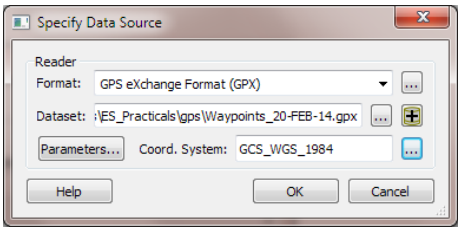


Figure 12.6: Selecting the data source to import

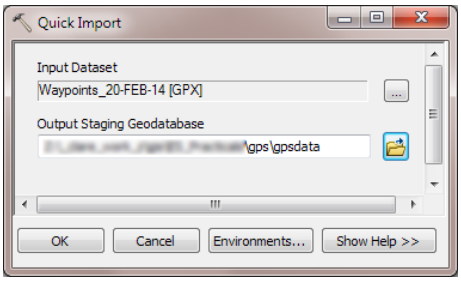


Figure 12.7: The Quick Import dialog

Your input dialog should look something like figure 12.7.

- Click OK to run the conversion.

Check in the Catalog panel to make sure that you have a new geodatabase with the name that you gave it under **Output Staging Database**, and which contains a feature class which will probably be called something like **Waypoints**.

12.7 Add waypoint data to ArcMap

Before adding your data to a map you need to stop and think about coordinate systems - the coordinate system of your data needs to match the coordinate system of your map.

If you followed the instructions for converting your gpx file with the Conversion tools or the Data Interoperability tools then the coordinate system will be **WGS1984** (you should have made a note of it in section 12.6.2 on page 170). We'll start by adding the data to a map with that coordinate system.

- Add your converted Waypoints feature class to the map, if it hasn't been added automatically.
- Check the coordinate system of the data frame (double-click on the data frame title (usually **Layers**) to open the properties, then go to the **Coordinate System** tab) - it should be WGS84. If it isn't, set it to that now (`Geographic Coordinate Systems▸World▸WGS84`)
- also check that the waypoints are set to WGS84 by going to the layer properties and looking for the **Geographic Coordinate System** heading under **Data Source**. If that says `<unknown>` you'll need to set the projection:
  - use the toolbox to **Define** the projection of the Waypoints feature class to WGS84. (Toolbox ▸ Data Management Tools ▸ Projections and Transformations ▸ Define Projection and set the **Coordinate System** to `Geographic Coordinate Systems▸World▸WGS84`)

12.7.1 Adding a background map from ArcGIS Online

As a quick way of setting up a background map we'll use a dataset provided by ArcGIS Online. There are a lot of maps available this way and although they have some limitations it can be a useful way of creating a map.

Warning: adding online data can slow Arc down significantly, or cause it to crash completely. If you are having trouble with a map try removing any online layers.

Video Clip available in Minerva - Adding data from ArcGIS Online. Direct link: `http://bit.ly/2sp41oY`

- File ▸ ArcGIS Online...
- Search for **Imagery** in the box at the top and from the layers that appear choose **World Imagery**. Make sure that you choose the layer package (see figure 12.8) - if the button for the layer says Open rather than Add then look for another similar layer! **Add** the layer to your map.

Be patient while the layer loads. If it won't load and complains of lack of memory you will need to close ArcMap and open it again - the previous operations will have been fairly memory intensive!

Because the map uses the coordinate system WGS84, which is also the coordinate system for data in ArcGIS Online, you shouldn't get any error messages or warnings.

Have a look at your map and zoom in and out a bit. Take particular note of where your gps points are. How accurate do you think the locations are? What problems can you spot based on your memory of collecting the data? How do you think you could increase accuracy of data collection?

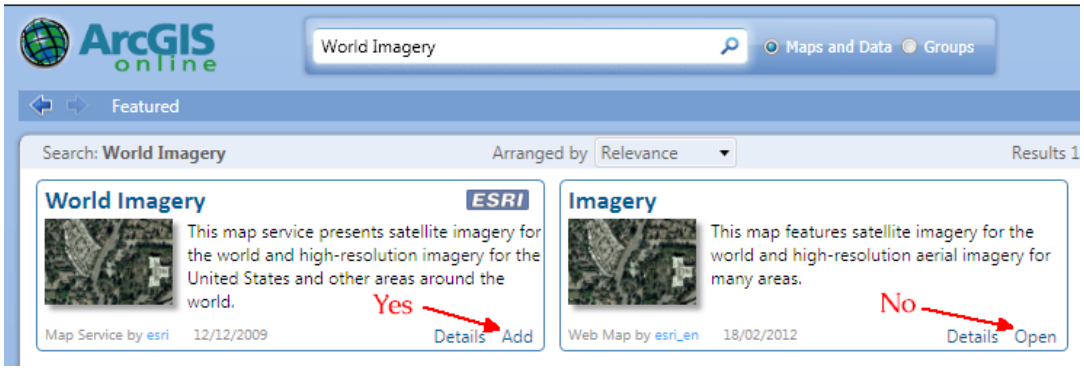
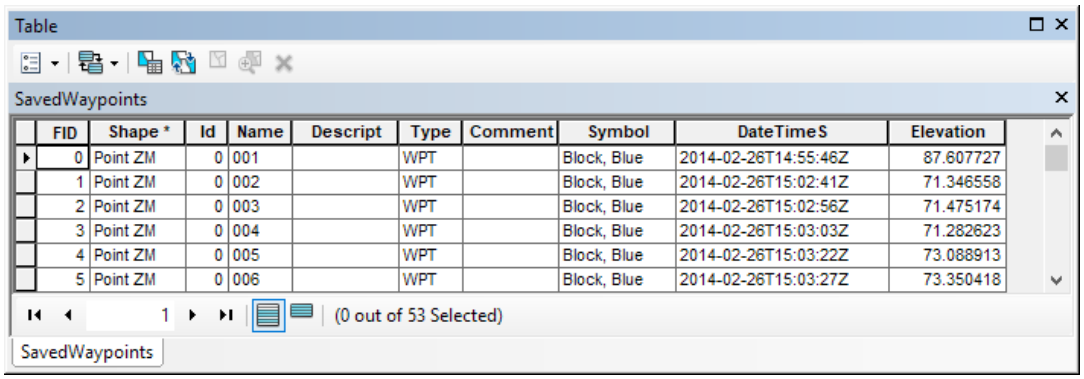


Figure 12.8: Adding imagery from an ArcGIS Online layer package

12.7.2 Adding extra data to feature classes

Have a look at the attribute table of the new layer

- right-click on the layer in the table of contents
- select Open Attribute Table. It should look something like figure 12.9



FID	Shape *	Id	Name	Descript	Type	Comment	Symbol	DateTimeS	Elevation
0	Point ZM	0	001		WPT		Block, Blue	2014-02-26T14:55:46Z	87.607727
1	Point ZM	0	002		WPT		Block, Blue	2014-02-26T15:02:41Z	71.346558
2	Point ZM	0	003		WPT		Block, Blue	2014-02-26T15:02:56Z	71.475174
3	Point ZM	0	004		WPT		Block, Blue	2014-02-26T15:03:03Z	71.282623
4	Point ZM	0	005		WPT		Block, Blue	2014-02-26T15:03:22Z	73.088913
5	Point ZM	0	006		WPT		Block, Blue	2014-02-26T15:03:27Z	73.350418

Figure 12.9: The attribute table for the converted gps data

Amongst many other attributes there should be one for **Name** which should include the label or name of each waypoint as stored by the GPS unit. There is a set of important information missing from this file, though. What do you think it is?

Hopefully you spotted that you still need to add the details of each feature to the shapefile, i.e. what type of feature it is, such as seat or signpost. You should still have a copy of this information. This is the point at which you add that information to the attribute table but first you need to add a new field.

Adding a new field to a feature class

This can also be referred to as adding a new column or a new attribute field.

Video Clip available in Minerva - Adding a new field to a feature class.
Direct link: `http://bit.ly/2fYVbZE`

- Within ArcMap, with editing off and ArcCatalog closed...
- Right-click on the layer title - e.g. **Waypoints**.
- Open Attribute Table click on the Table Options button in the top left of the attribute table window Add Field...
- Fill in the form (see figure 12.10) by typing **FType** in the **Name** field[7]; change the **Type** to **text**; change the **Length** to 75 OK
- Close the attribute table.

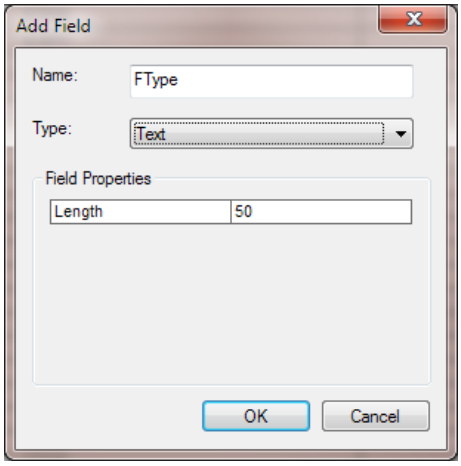


Figure 12.10: Add Field dialog

Problems with adding fields to feature classes crop up rather regularly, usually it is possible to get around them by using the tips in table 12.1 on page 175.

12.7.3 Adding feature attributes to a feature class

Now you're ready to add information, or **attributes**, to your new field.

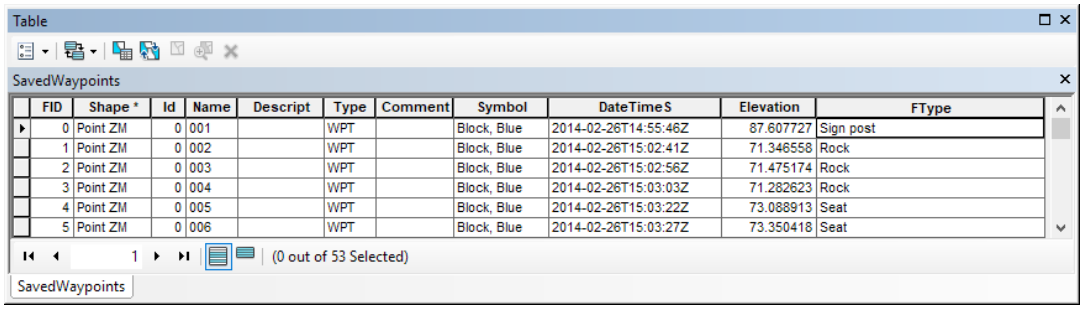
- Start an edit session by doing the following
  - open the Editor toolbar by going to Customize Toolbars and clicking so that there is a tick next to **Editor**
  - right-click on the waypoints layer in the Table of Contents and select Edit Features Start Editing
- Open the attribute table for the waypoints feature layer (right-click on the layer then Open Attribute Table)
- Click in the first box - check that the `Name` field matches the number in your notes, and add the type of feature. Try to be consistent, so all features of the same type have exactly the same text - check spelling and if you use upper case to start one, use it for all.

[7] Field names are restricted to 8 characters and cannot have any spaces. `FType` is a contraction of `Feature Type`

Getting around problems when adding fields to feature classes
Sometimes when you try to add a field to a feature class you'll get an error message saying that the field is already in use. This will prevent you adding a field. The first thing to check is that you are not in an edit session. If you are sure that you are not and it still isn't working, try the following: • If you are using the Catalog Panel in ArcMap then close ArcMap completely. • Open ArcCatalog and go to the feature class to which you want to add a field. • Right-click and open **Properties** • Go to the **Fields** tab. • Use the boxes there to add as many new fields as you need to add. If you are having problems with creating fields in ArcCatalog, then do the reverse - close ArcCatalog, Open ArcMap, and use the Catalog panel to add new fields.

Table 12.1: Getting around problems with adding fields to feature classes

- go through the list and add all the feature types, see figure 12.11.
- then save your edits and close the edit session - using the Editor toolbar Editor > Save Edits then Editor > Stop Editing.



FID	Shape *	Id	Name	Descript	Type	Comment	Symbol	DateTimeS	Elevation	FType
0	Point ZM	0	001		WPT		Block, Blue	2014-02-26T14:55:46Z	87.607727	Sign post
1	Point ZM	0	002		WPT		Block, Blue	2014-02-26T15:02:41Z	71.346558	Rock
2	Point ZM	0	003		WPT		Block, Blue	2014-02-26T15:02:56Z	71.475174	Rock
3	Point ZM	0	004		WPT		Block, Blue	2014-02-26T15:03:03Z	71.282623	Rock
4	Point ZM	0	005		WPT		Block, Blue	2014-02-26T15:03:22Z	73.088913	Seat
5	Point ZM	0	006		WPT		Block, Blue	2014-02-26T15:03:27Z	73.350418	Seat

Figure 12.11: The attribute table for the converted gps data with the feature type added manually

Video Clip available in Minerva - Adding feature attributes to a feature class. Direct link: `http://bit.ly/2fYFMZ5`

12.8 Symbolising a layer

So far you have a single coloured dot representing every point. Your map would be much more informative if each type of feature had it's own symbol.

Open the attribute table for your new point feature layer again and have another look at the data that it contains. In the previous section you created a column called **FType** or something similar and

added attributes to show what type of feature each record contained. In Arc it is easy to colour, or **symbolise** the features so that you can differentiate what they refer to.

- Close the attribute table.
- Right-click on your point layer and click on **Properties**
- Go to the **Symbology** tab

Video Clip available in Minerva - Symbolising a layer by categories in ArcMap. Direct link: `http://bit.ly/2ePRqVG`

At the moment the layer is symbolised as a single symbol - a single random colour which is used for all features.

- Select **Categories** in the list on the left of the properties dialog
- then select **Unique Values**
- in the **Value Field** box that appears select **FType** - or whatever you called the field that you added attributes to.
- click on Add All Values

You should find that you get a list of the values of FType to which Arc will have assigned random coloured symbols - figure 12.12.

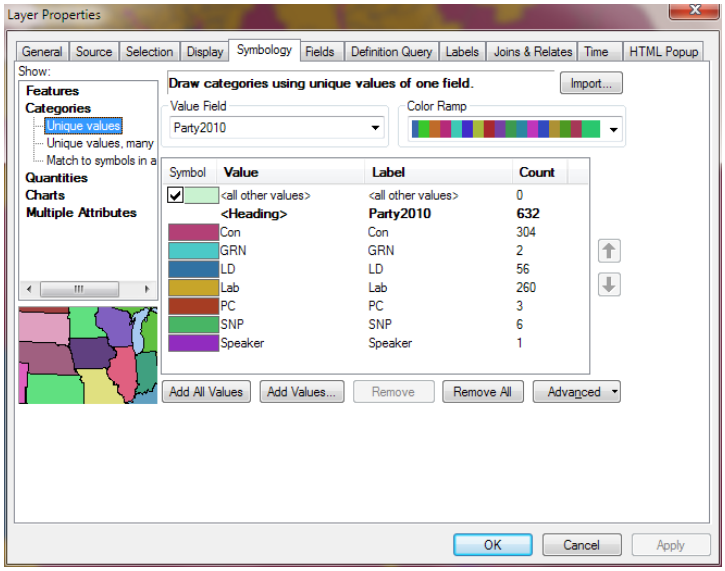


Figure 12.12: Setting symbols for a layer with multiple categories

- You can change the symbols by double-clicking on each symbol in turn - have a go now. If you search through the possible symbols in the symbol selector you may find appropriate symbols for rocks, plants etc.[8] Use the Style References button to add further selections of symbols.
- Click on Apply to see the result and OK when you are happy with it.
- You may find it easier to see what you are doing if you turn off the base map layers.

[8]Note that the search facility doesn't always work in cluster machines - you may have to browse the possibilities instead.

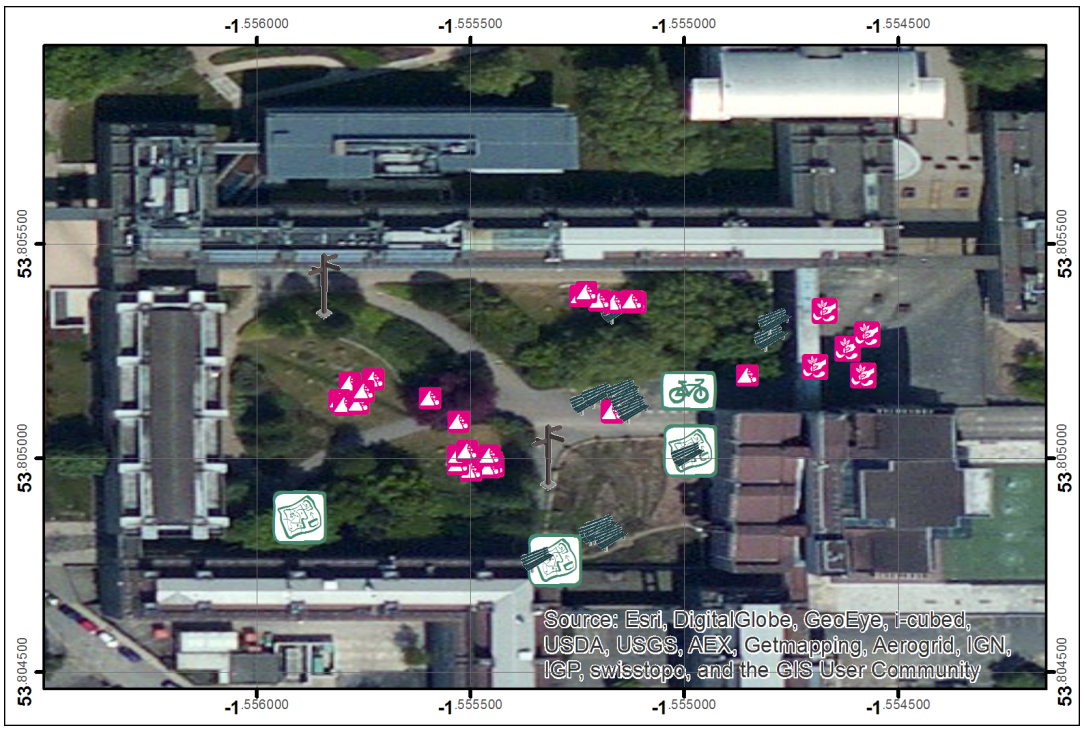


Figure 12.13: An example of symbolised waypoints for Chancellors Court (WGS84 coordinate system)

12.9 Data frame reference scale

When you print your map you will want the symbols and labels to be a particular size at a particular scale. If you set a **data frame reference scale** to the scale at which you are intending to print the map then you can set the size of the symbols and labels at this scale.

Question 12.1. Zoom in to 1:500 and then zoom out to 1:25 000. What happens to the size of the symbols you have just created when you zoom in very close or zoom out?

- Scale the map to the scale that you will be printing it at by using the **scale drop down** on the standard toolbar. In this case set the scale to **1:1 000** (you can just type **1000** into the box).
- Right-click on the **data frame title** (Layers) in the table of contents.
- Reference Scale > Set reference scale. Arc will set the reference scale to the current map scale.

Question 12.2. Zoom in to 1:500 again - what happens to the size of the labels now? And what happens to them when you zoom out to 1:25 000?

When you use the symbology settings to set the size of your symbols now, you will be setting the size that they print out at your reference scale. You may find that you do need to resize the symbols so that they don't look to crowded once you have set this.

- To remove the reference scale completely use Reference Scale > Clear Reference Scale.
- To change a reference scale set your map to the correct scale then use Reference Scale > Set Reference Scale again.

12.10 Changing the coordinate system of data

The GPS data that you have collected is in the WGS84 geographic coordinate system, but often you will need to use the data in a local projected coordinate system. The obvious example is if you are using Ordnance Survey maps from Digimap in the same project. This is the example that we'll use now, but the same situation can arise if you are, for example, mapping in Spain or Eire.[9]

- Open a new blank map in ArcMap and add the **LocationBNG** shapefile that you can download from Minerva as **Week06Data.zip**. Remember that the first layer that you add to a data frame automatically sets the coordinate system.
- Add the **se2934.tif** layer from the downloaded data to your map.
- Now try adding your **Waypoints** layer. What happens?

You should get a warning which looks something like figure 12.14.

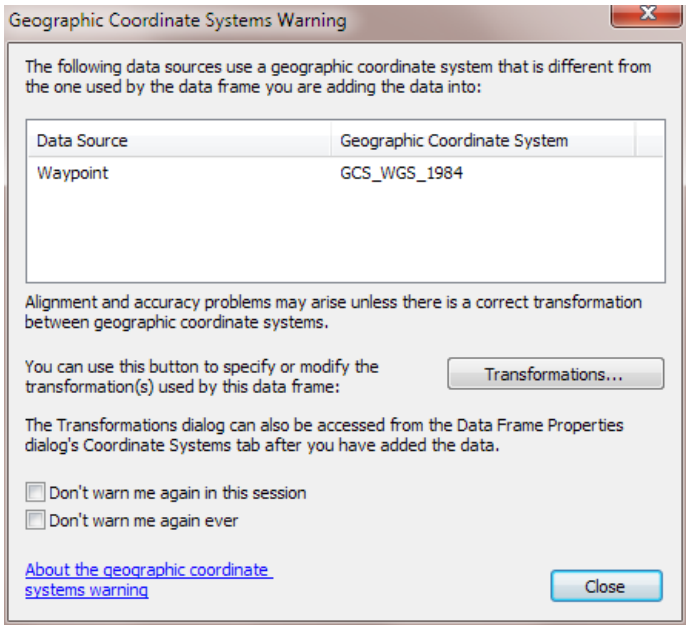


Figure 12.14: Geographic Coordinate System Warning

This is telling you that the data that you are adding to the map is not in the same coordinate system as your map, so Arc can't add it in the correct location without some extra information from you. You need to tell ArcGIS that you want to **project on-the-fly** so that the WGS layer appears in the same space as the map and data that has already been projected to British National Grid.

[9] If you want to find out more about coordinate systems and projections have a look at Heywood (2006) pp. 44-51 for a general introduction. The books in the Coordinate systems and projections section of the module reading list give more detailed information.

Video Clip available in Minerva - Transforming the projection of data "on-the-fly". Direct link: `http://bit.ly/2fYQtLg`

- Click on Transformations...
- Set the Transformations dialog so that your selections are as in figure 12.15 with the top box being the GCS to convert from[10].
  - **Convert from:** GCS_WGS_1984
  - **Into:** GCS_OSGB_1936
  - **Using:** OSGB_1936_To_WGS_1984_Petroleum
- OK > Close

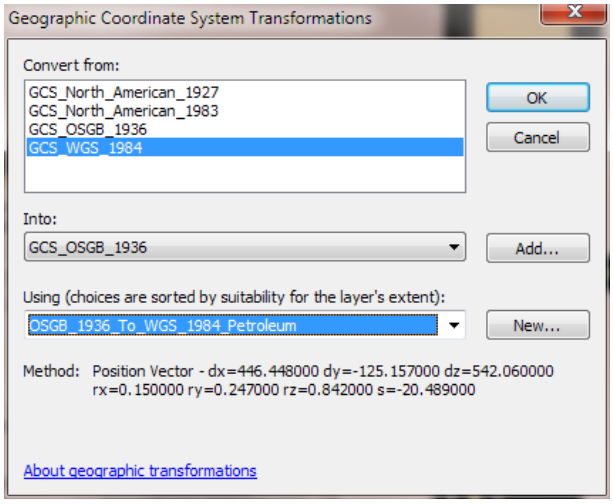


Figure 12.15: Transformations dialog

Even if you don't get a warning, don't assume that all is well! The **Location** feature class should outline an area around where you collected data. If it doesn't you need to check that transformations are set up correctly.

The layer should be added to your map and appear in the correct position. This method of projecting a layer is only temporary.

- Open the data frame properties
- Go to the **Coordinate System** tab and click on the Transformations... button
- from there select to transform WGS84 to OSGB1936 using the Petroleum option as in the previous instructions.

If you want to project a layer permanently, particularly if you want to do analysis on it, you have to use the **Project** tool which you find from Toolbox > Data Management Tools > Projections and Transformations. There are separate tools for feature classes and raster layers, in this case you would select Feature > Project

[10] If you want more information about what you are doing here try clicking on the **About geographic transformations** link at the bottom of the dialog.

Video Clip available in Minerva - Reprojecting a feature class with the toolbox. Direct link: `http://bit.ly/2fYCPYv`

12.10.1 Adding data from ArcGIS Online

Once again add an Imagery layer from ArcGIS Online as you did in section 12.7.1 on page 172. You should find that you get the Geographic Coordinate System warning again, and again you'll need to **Transform** the layer to British National Grid to be able to use it on your map.

Be aware that adding layers from ArcGIS Online can slow ArcGIS down a lot. If Arc crashes because of this all you can do is remove the ArcGIS Online layer. In this case - speak to staff or demonstrators to obtain an alternative dataset.

Look at both maps in turn and it should become obvious that changing the projection doesn't just have an effect on how your layers line up with each other, but also on the "shape" of your data.

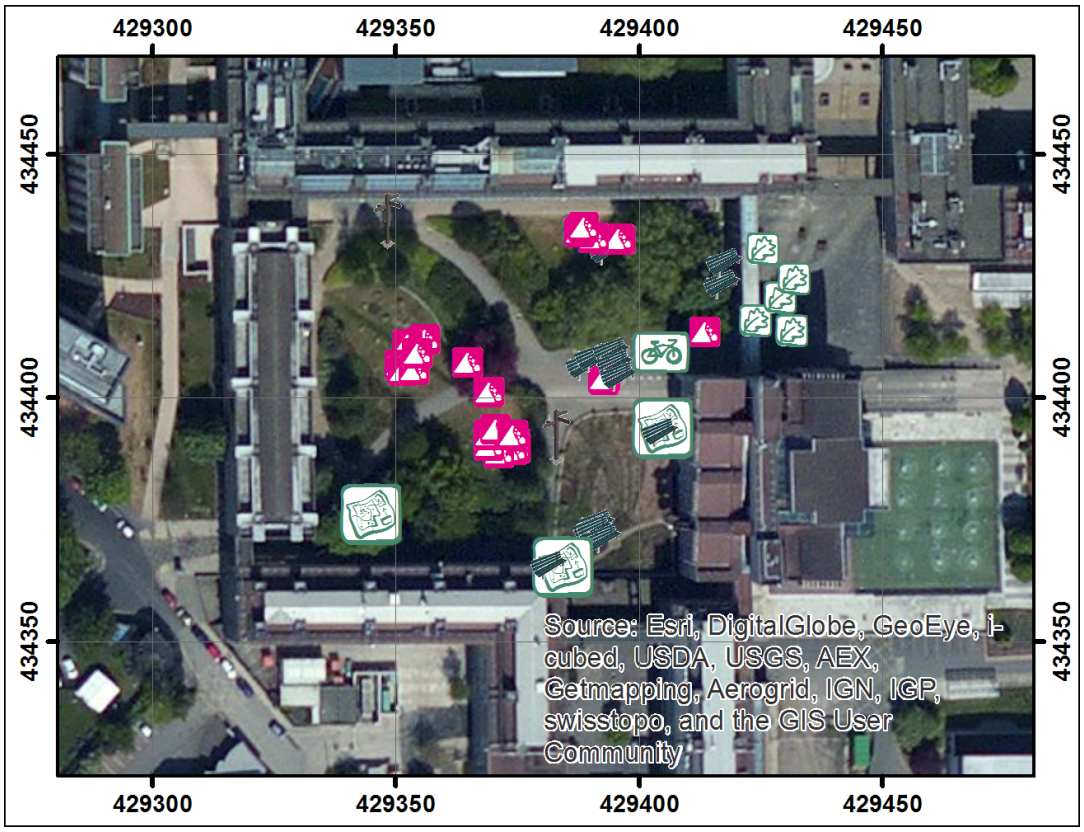
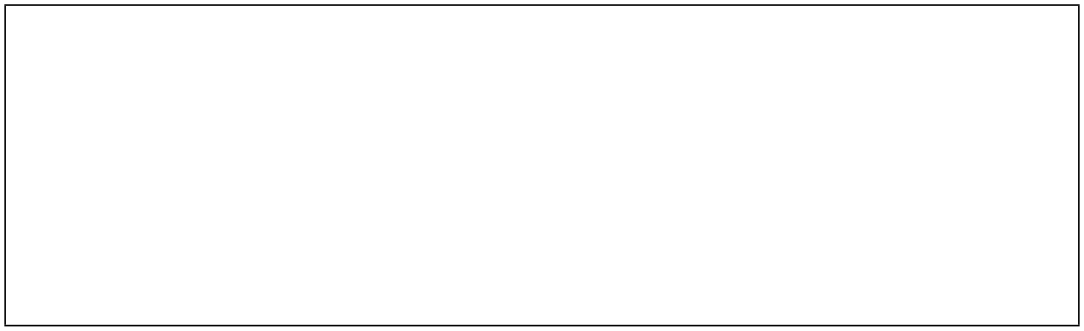


Figure 12.16: An example of symbolised waypoints for Chancellors Court (British National Grid coordinate system)

12.11 Finally...

Question 12.3. Have another close look at the gps layer. How accurate do you think the locations of the points are? What problems can you spot based on your memory of collecting the data? Compare the points you collected with the base imagery that you've added. How do you think that you could increase accuracy of data input?



When you are mapping in the field you can use a gps receiver to locate your measurements and keep a record in your field note book. But remember the issues with accuracy (section 12.4.2 on page 166) and make sure that you can also locate yourself accurately using a paper map. The advice of professional mappers is often to check the location given by your gps unit against a map every time that you take a reading!

12.12 Recommended reading: collecting data with GPS

For more detailed information have a look at the following references from the module reading list[11].

Chang (2016), Section 5.4. on creating new data includes information on GPS.

The Ordnance Survey has a lot of information about GPS on their website[12], including a Beginners Guide to GPS. Start at `http://bit.ly/1C5XMST`

Heywood, I. (2011), Chapter 10 covers data quality issues, including accuracy.

[11] Reading list available from Minerva and from the module catalogue at `http://webprod3.leeds.ac.uk/banner/dynmodules.asp?M=SOEE-2650`

[12] Last visited: 18th September 2018

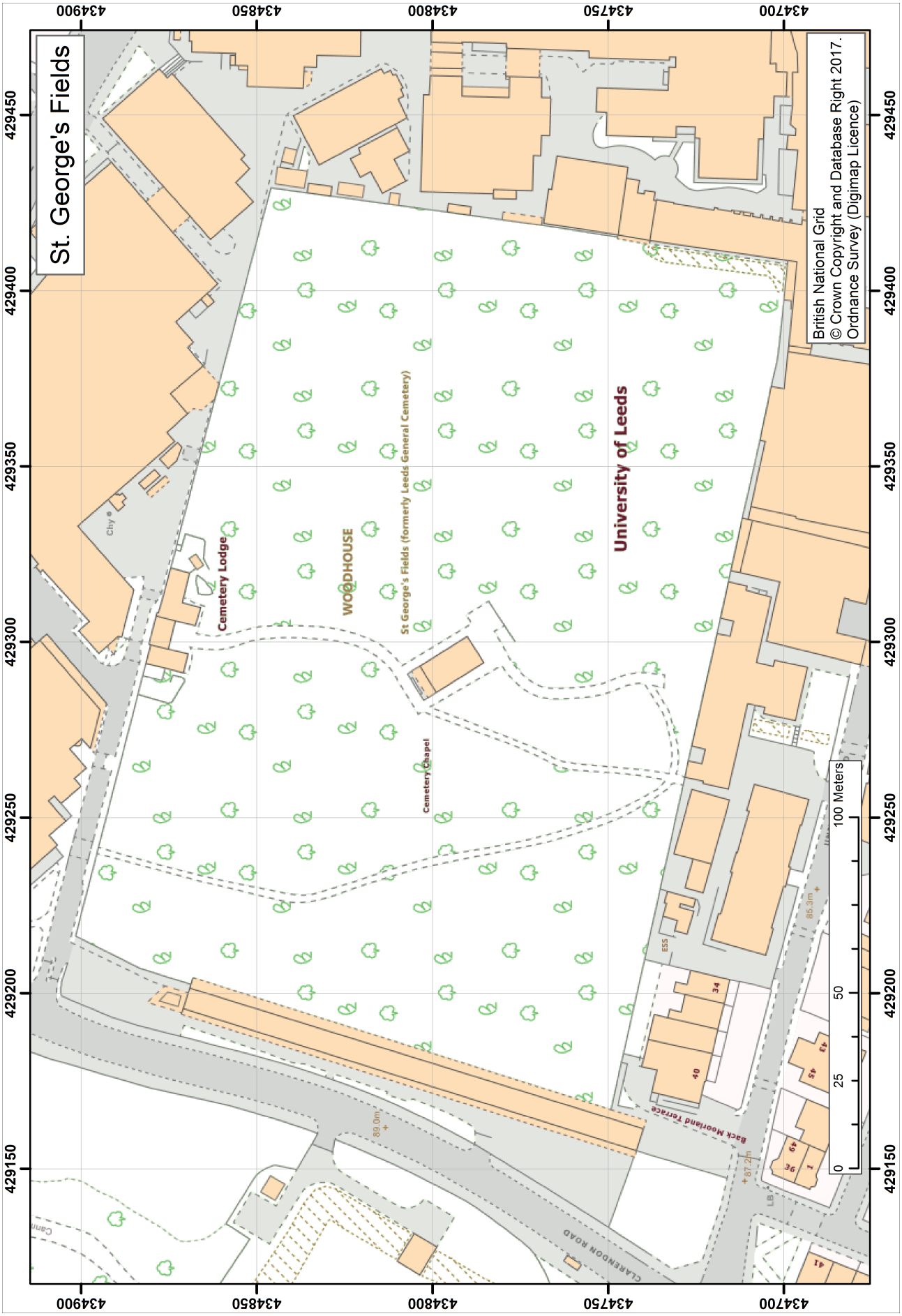


Figure 12.17: Field slip for St George's Fields

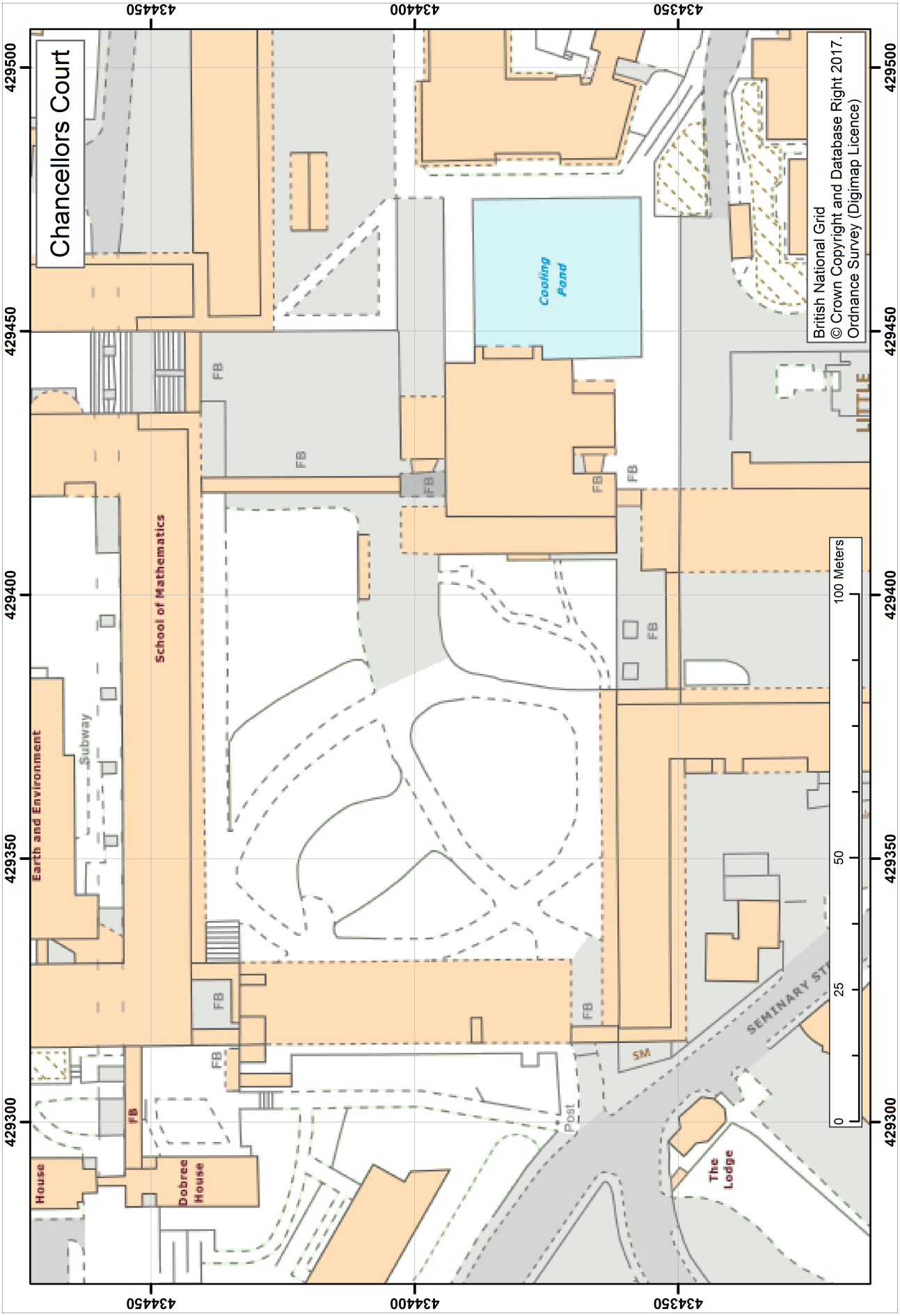


Figure 12.18: Field slip for Chancellors Court

Data preparation for chapter 13: environmental decision making exercises

Being able to find, download and prepare your own data is an essential part of using GIS. For the exercises in the next class you will need to download several datasets. While these should not take too long to download and prepare, don't leave it until the last minute. Websites can become unavailable either permanently or temporarily, or computers can crash.

If there are problems with a website then try again later. If the problems persist please get in touch with me (c.e.gordon@leeds.ac.uk) and I will try to contact the site or find an alternative source of data.

Data to download

Log in to Digimap and download the following datasets for the area around Horton in Ribblesdale in North Yorkshire that is shown in figure 12.19. Figure 12.20 shows the data to download from OS Download, and you'll need to go to Geology Download for the bedrock layers (figure 12.21).

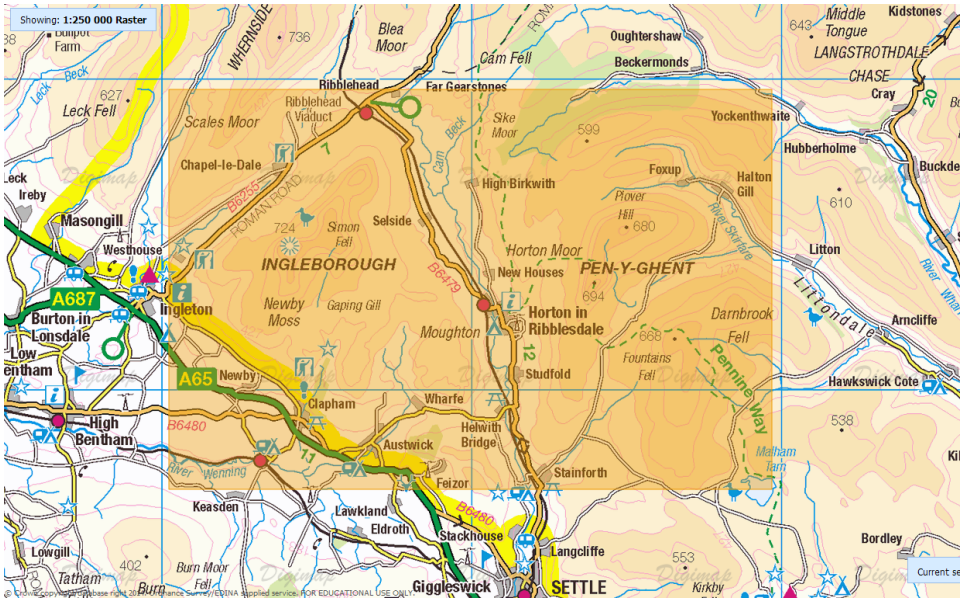


Figure 12.19: Minimum area around Horton in Ribblesdale for which to download data for environmental decision making exercises

- Ordnance Survey Terrain 50 DTM
- Ordnance Survey 1:50 000 raster background map
- Ordnance Survey VectorMap District vector dataset (NOT raster)
- British Geological Survey 1:50 000 bedrock and superficial geology shapefiles

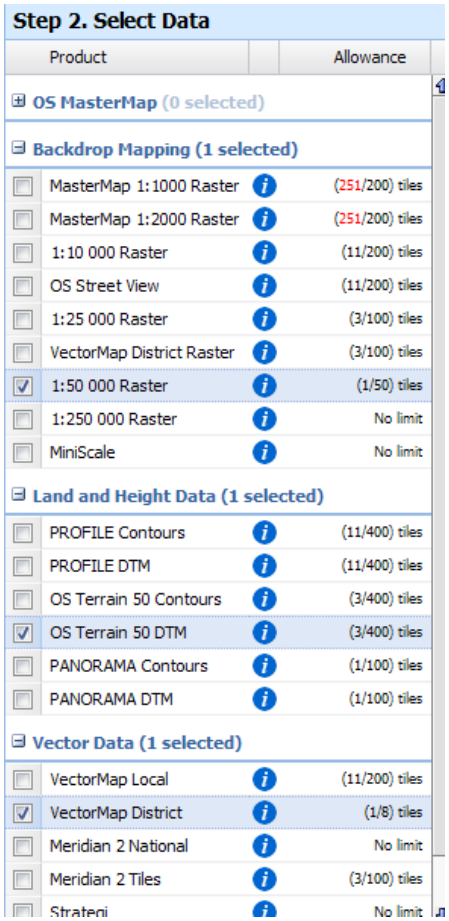


Figure 12.20: Datasets to download from Ordnance Survey Download

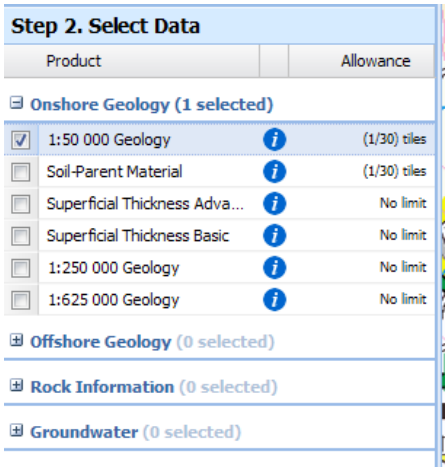


Figure 12.21: Datasets to download from Geology Download

Preparing data

Start by unzipping all of the data, putting it into a folder, and having a look at what you have downloaded. What formats are the data in, and do you have multiple tiles of data for any dataset that will need to be merged?

OS Terrain 50 DTM

You should have more than one tile of this DTM dataset. Follow the instructions in section 8.2.2 on page 99 to mosaic the tiles so that you have a seamless dataset. Don't forget to check the properties of the tiles before you mosaic them, e.g. what is the cell size? what are the pixel type and depth? what is the spatial reference?

Once you have set up a mosaic use it to generate two further layers for:

- slope - section 8.5.2 on page 104
- aspect - section 8.5.4 on page 105

OS Vector Map District

The OS Vector Map District dataset consists of multiple shapefiles. Look at the folder in Catalog and see what is available to you. For this exercise the only layer that you need is the **Road** layer, so if you need to save space on your disk you can delete the rest of the layers. Remember to do this using Catalog rather than My Computer.

BGS 1:50 000 geology

The geological data should have been downloaded as two tiles. Add the following layers to your map:

- `ew050_hawes_bedrock.lyr`
- `ew060_settle_bedrock.lyr`

These are **layer files** which reference the shapefiles. By adding these rather than the shapefiles you can see that the layers are symbolised for you.

You will need to **merge** the two shapefiles for the first exercise, do this as follows:

- Geoprocessing > Merge

This does mean that you lose the symbology but that isn't important for this exercise as the only information you will need is to know which areas are limestone.

Now repeat the steps above to merge the layers for the superficial deposits which you will need for the second exercise. The superficial deposits include anything lying on top of the bedrock such as peat, alluvium or glacial till.

The layers to merge are:

- `ew050_hawes_superficial.lyr`
- `ew060_settle_superficial.lyr`

Data from Minerva

You should also download `Chapter13_Data.7z` from Minerva and unzip it to your disk. The zip file should contain a personal geodatabase called **Horton.mdb**.

Chapter 13

Environmental Decision Making

13.1 Introduction

So far you've mainly been looking at a lot of techniques to process data which give you separate maps or layers for each feature or result. This still allows you to combine factors, e.g. windspeed and visibility, but not easily to present the final result.

In this chapter you'll be looking at how GIS can be used to analyse multiple criteria using overlay analysis techniques. You'll also look at how GIS can solve least cost pathway problems, in other words, show the "cheapest" route from a source to a destination.

ArcGIS provides the overlay analysis toolbox as part of the Spatial Analyst extension. Tools such as weighted overlay and weighted sum allow you to combine diverse datasets to arrive at an optimum answer.

For more detailed background information on these approaches search ArcGIS Desktop Help for **Understanding Overlay Analysis**.

13.2 Learning outcomes

When you have completed this section you should be able to

- use GIS to analyse multi-criteria models to provide answers to complex questions
- explain how to use least-cost pathways to suggest the optimum route from a source to a destination
- give examples of how these analysis techniques can be used to solve environmental questions.

13.3 Multi-criteria analysis

You have been asked to recommend suitable sites for investigating vegetation on limestone. The requirements that you have been given for the study area are as follows:

- The minimum size of the site should be 100 m^2
- The underlying geology must be limestone
- The study site should be on a south-facing slope
- The study site needs to be close to or adjacent to a road to enable the use of heavy equipment
- also, to enable the use of equipment, the slope should not be steep

13.3.1 Prepare data and create new layers

You should already have downloaded and prepared the data for this exercise as detailed on page 184. If you haven't, follow those instructions now before proceeding with the instructions below.

Before you do anything else check that the geoprocessing environments have been set (see section 10.6 on page 137 for a reminder of how to set these) so that the extent and the cell size are the same as the dtm mosaic, and the scratch and default workspaces are the folder in which you want to store your results rather than the default geodatabase (this can save you a lot of irritation during the course of a project).

Make sure that you have a map open in ArcMap which contains the following layers. If your map contains any other layers remove them before continuing.

- a mosaic dtm
- a slope layer generated from the mosaic dtm
- an aspect layer generated from the mosaic dtm
- a road layer from VectorMap District
- a merged geology layer

Distance to roads

Use the roads layer from VectorMap District to generate a raster that shows the proximity of each cell to a road.

- Run the **Euclidean Distance tool** (section 11.4.3 on page 158) to generate a new raster showing proximity to roads and add it to your map (example in figure 13.1). Use the vector Road layer from VectorMap District as the input.

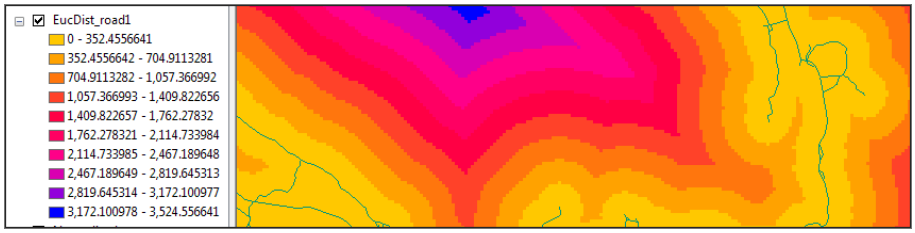


Figure 13.1: The result of running the Euclidean Distance tool on the roads layer. The key shows distance from nearest road in metres. The lines on the map are the roads.

Selecting the limestone areas

You should have a merged shapefile that shows the geology in your area. In order to pick the study area all you need to know is which areas are underlain by limestone so you don't need to keep the data for the other areas.

- If you look at the attribute table you will be able to see that there are a large number of different rock types included. Look for the **RCS_D** field - that is much more general. Use that field to select all the instances of **Limestone**
  - On the attribute table menu bar click on Select by Attributes

  - Use the dialog to construct a query that will select all limestone features - you should be able to build the query by double-clicking on the field name, then the equals sign, then click on the Get All Unique Values button and select **Limestone**.[1]
  - click on Apply to make the selection
- Once you have a selection export the selected data to a new feature class[2]. You should end up with something similar to figure 13.2.

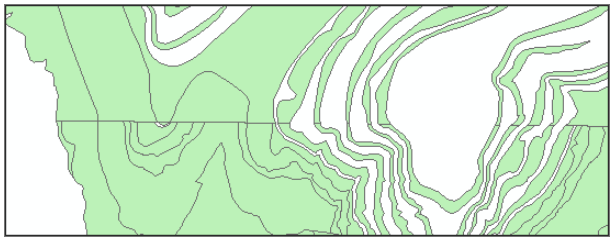


Figure 13.2: Part of the limestone features as extracted from the BGS geology shapefile.

For the purposes of the analysis this layer will need to be a raster so you need to convert the limestone areas using **Polygon to Raster**:

- Open the toolbox and click Conversion Tools > To Raster > Polygon to Raster
- Fill in the dialog using the limestone layer as the input.
- Set the Value Field to **RCS_D** and keep the other selections to the default
- Click OK to run the tool.

13.3.2 Normalising layers

Now you have all of the layers that you need for the analysis, but the layers that you will be using each use different units or ranges. For example, the slope raster may be in degrees from 0 to 48; the aspect raster is in degrees from 0 to 360; the "distance from roads" raster may be 0 to 3,500 m. How can these be compared?

So the first task that needs to be carried out is to convert all of the layers required for the analysis into the same scale, e.g. 0 to 1. In effect, the normalised factor will show which part of a raster is "good" - that is nearest to **1** and which are not so good - nearest to **0**.

Normalising with the raster calculator

We'll start by normalising the slope layer using the raster calculator.

- Open the raster calculator (see section 11.4.1 on page 157)
- in this case the least steep slopes are considered "good", so the slope that is closest to 0 degrees should have a normalised value closest to 1, and the slope closest to 48 degrees should have normalised value closes to 0.
- Enter the following expression in the raster calculator - using the file name of your slope raster. The **1-** at the start reverses the order. The **0** should be the minimum value of your slope (rounded down if it isn't 0), and the **48** should be replaced by the maximum value of your slope rounded up.

[1] You can find help on more complex queries by going to Arc Desktop help at `http://arcg.is/2atXj3I`

[2] Right-click on the layer and go to Data > Export Data... and make sure that you only export selected features.

- Give the output file a name that will differentiate it from the original so that you can recognise it later.

```
1-(("Slope" - 0) / 48)
```

You should end up with something similar to figure 13.3 where the shallowest slopes have a value close to 1 and are white, and the steepest a value close to 0 and are coloured black or dark grey. Compare the result with your original slope layer to check that it is correct.

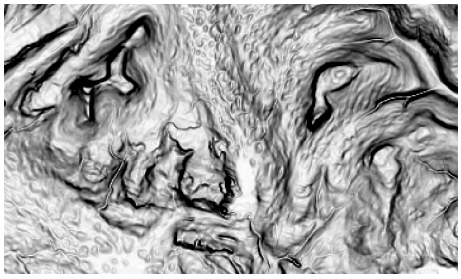


Figure 13.3: Normalised slope raster

Normalising with the Fuzzy Membership tool

Fuzzy membership converts an input raster to a 0 to 1 scale. We'll try this out with the distance from roads layer.

- Spatial Analyst Tools > Overlay > Fuzzy Membership
- fill in the dialog in the usual way (figure 13.4) using your road proximity raster as input. Set **Membership type** to **Linear**
- You want the areas closest to a road to have the values closest to **1**, this is the reverse of the minimum and maximum at the moment, so type your highest distance (rounded up to the nearest 100) into the minimum box, and the lowest distance (presumably 0) into the maximum.

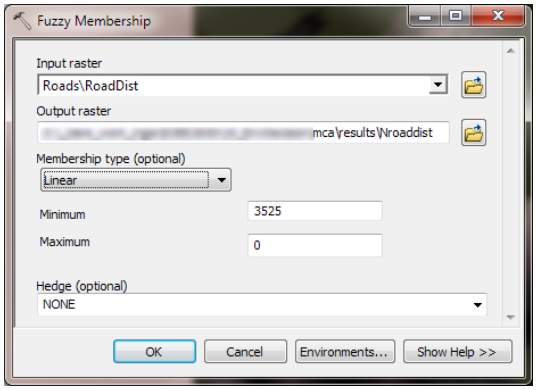


Figure 13.4: Filling in the Fuzzy Membership tool

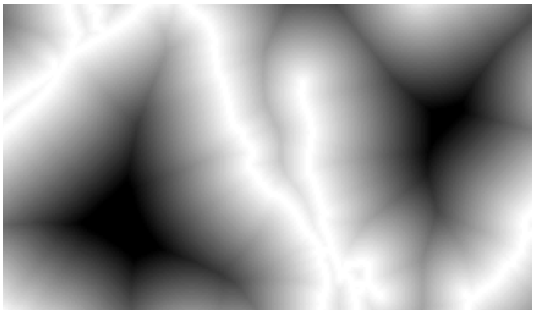


Figure 13.5: Normalised road proximity raster. Cells closer to the road have a value closest to 1 and are paler coloured.

You should end up with a layer similar to figure 13.5 where the cells closest to the roads have a value closest to 1, and the cells farthest from roads have a value closest to 0.

Normalisation of the aspect layer

Aspect is the only remaining layer that requires normalisation. This is a little more complex. Aspect ranges from 0°(north) to 180°(south) and back to 360°(north again). So this time a linear transformation won't work. Fortunately it is possible to use a different fuzzy membership transformation to normalise this layer.

- Open the Fuzzy Membership tool again
- Add your aspect layer as input
- Set Membership Type to **Gaussian**; Midpoint to **180** and Spread to **0.0001**
- OK

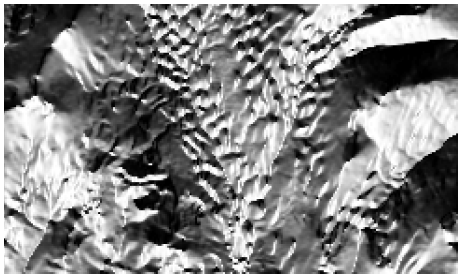


Figure 13.6: Normalised Aspect raster

This time the normalisation will set the closest angles to 180°as the closest value to 1, and the closest angles to 0 or 360 to 0. The result should look something like figure 13.6. Don't forget to check each time that the layer has been normalised in the way that you want it to be.

13.3.3 Determining weights for each factor

The final stage before running a model is to determine the relative weight of each factor. Which factor is the most important for the final research site? Which is the least important?

In a web browser go to

`http://bpmsg.com/academic/ahp.php`

AHP stands for the Analytical Hierarchy Process and is a method of **pairwise comparison**, meaning that you can enter multiple criteria, rank them, and then obtain a percentage for each item as the output[3].

- Start by clicking on the **AHP Priority Calculator** link
- We have 4 criteria so enter **4** next to **Input number and names (2-20)** then click Go
- Enter the criteria as shown in figure 13.7, and also a name for the project e.g. **Site selection** then click OK
- Once you've done that you should get a matrix showing each of your criteria paired which each of the others, in this case a total of 6 pairwise comparisons. For each comparison select which one is the most important (see list below) and then select how much more important you think it is. There is an example in figure 13.8

For this example

[3]Web page last visited: 17th September 2018. If this disappears try searching online for **pairwise comparison calculator** to find alternatives

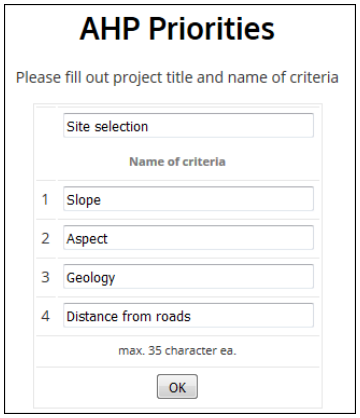


Figure 13.7: Entering criteria

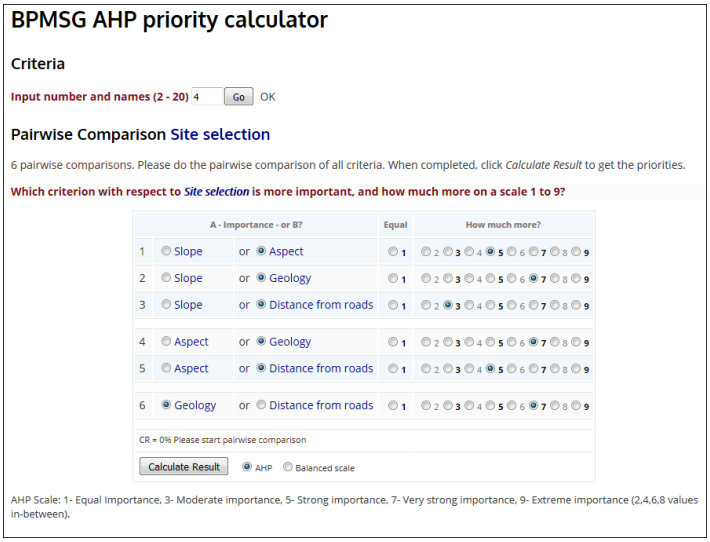


Figure 13.8: Setting the priority and importance for each pairwise comparison

- Geology is the most important criteria
- Aspect is more important than slope or distance from road
- Distance from road is more important than slope

Once you've selected the importance for each pair click on Calculate Result.

The form should now show you how you could make the priorities more consistent (figure 13.9). You don't have to accept these suggestions! Play around with the form until you are happy with the weightings.

In addition keep an eye on the **Priorities - resulting weights** table shown further down the page - figure 13.10. Keep checking that these priorities match the criteria above, e.g. geology should be the top priority.

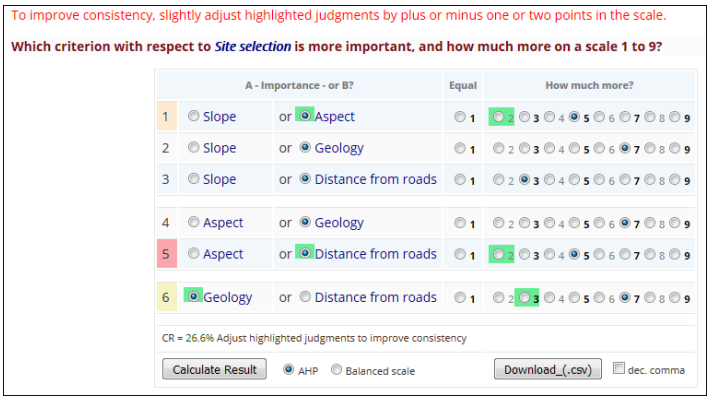


Figure 13.9: Suggestions for how to make the priorities more consistent

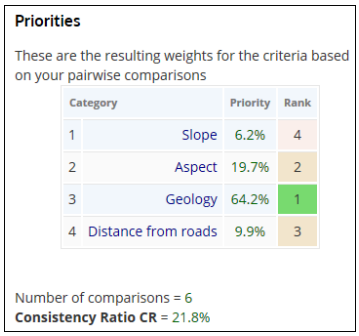


Figure 13.10: Priorities - Resulting weights: the output from your choices. Make a note of these percentages

Once you are happy with your result make a note of the percentages from the Priorities - resulting weights table (it doesn't matter if they are different to the percentages shown in figure 13.10, you are making your own choices):

- ***Slope =***
- ***Aspect =***
- ***Geology =***
- ***Distance from roads =***

13.3.4 Running the Weighted Sum tool

Finally it is time to run the weighted sum tool.

- Open the tool from Spatial Analyst Tools » Overlay » Weighted Sum
- Add your normalised raster layers for limestone; distance to roads; aspect and slope
- Fill in the weighting of each factor based on **your** percentages
- Give the output a location and name and then run the tool.

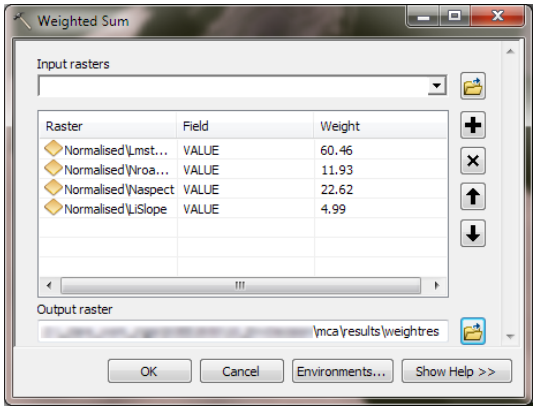


Figure 13.11: Using weights in the Weighted Sum tool

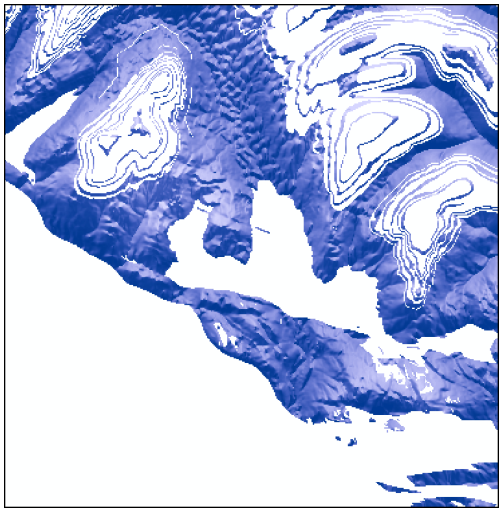


Figure 13.12: Output of the weighted sum tool

The output should look something like figure 13.12 but, of course, if you used different percentages your result will probably look different.

As with the normalised layers it is the highest value that is the most suitable for your purpose.

Have a close look at this new raster and examine what it is telling you. Experiment with symbology - would classified symbology give you a better idea of suitable locations than stretched?

How much difference does changing the balance between the four factors make? Try decreasing the importance of the geology and increasing the importance of something else (remembering that these are percentages so need to add up to 100!).

Try running the tool without the limestone layer - make aspect the most important factor and slope the least. How do the results compare?

Use the first weighted layer that you generated to create a map showing your recommended sites for studying the vegetation of a south-facing limestone slope. Pick sites measuring at least 100 m square and mark the boundaries on your map. Make sure that you include a base map and that it is visible underneath your weighted layer.

Your final map could look something like figure 13.13. It is unlikely to look identical as you should have made your own decisions about the relative importance of each criteria, and about the final location of the study site.

13.4 Least cost path analysis

You will use the same area of North Yorkshire around Horton-in-Ribblesdale for this next exercise. This time, imagine that a new farm has been built at GR 387000 476000 - outlined in the LPSource feature class, which is in the Horton geodatabase[4]. It needs to be linked to the national grid by a buried cable and your task is to suggest the optimum route based on a range of criteria. The LPDest feature class, which is also in the Horton geodatabase, shows an existing cable running close to the road across the map[5]. We'll be using a simplified range of criteria, but the exercise should give you an idea of how least-cost pathways work.

13.4.1 Criteria for the least-cost pathway

For this example we will use the following criteria to suggest the optimum route for the cable

- Distance - a longer cable will cost more to lay. Distance is an integral part of these calculations, so we will not need to add a specific layer to analyse this.
- Surface geology - it is easier to bury a cable when there is a thicker layer of soil above the rock surface, but this area includes a lot of peat, and the work needs to cause as little damage to the peat as possible.

[4] You should already have downloaded `Chapter13_Data.7z` from Minerva and unzipped it. The zip file contains the **Horton.mdb** personal geodatabase.

[5] Note that this existing cable is only given for the purposes of this exercise and is not real data.

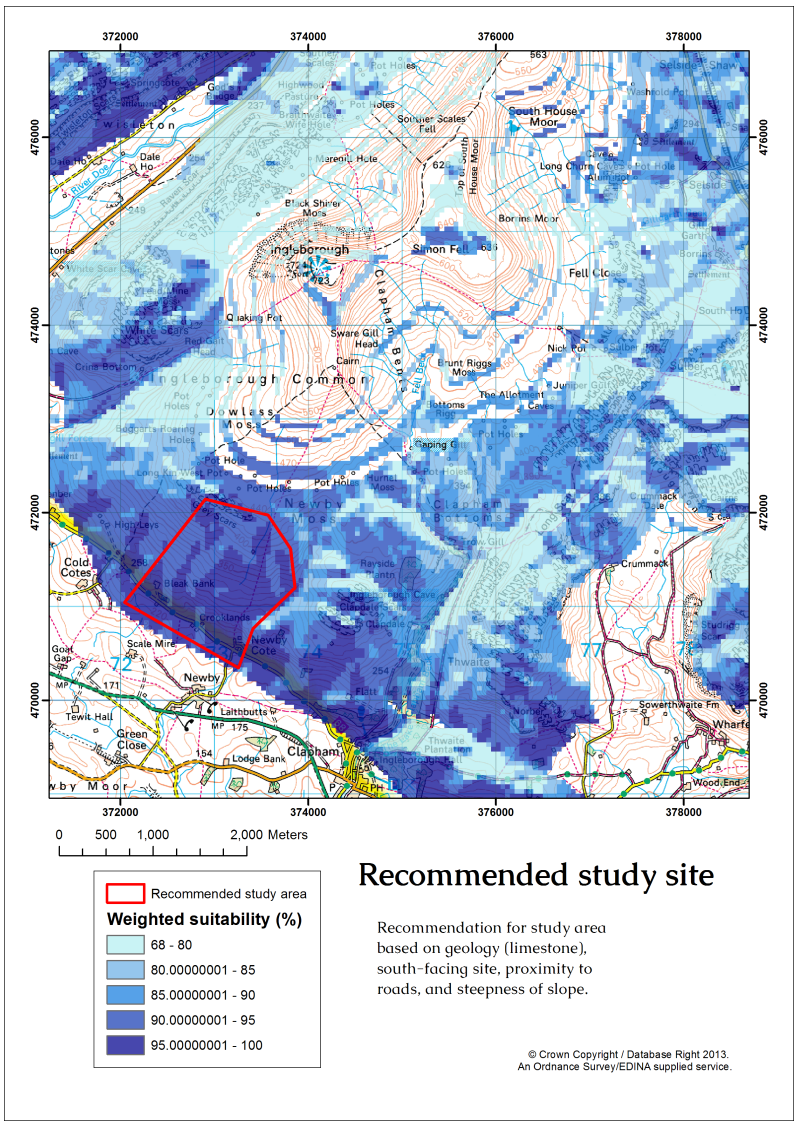


Figure 13.13: Possible layout for the map showing the recommended study site based on the criteria given

- The height of the land. The cable needs to follow a valley, or preferably not go straight over the top of a hill.

For each of these factors there is a "cost" involved. That cost isn't always directly financial (though the factors can have an effect on the financial cost of the project). For example, the requirement to avoid peat where ever possible is an environmental cost.

The idea of least-cost pathways is to find the route or pathway that has the lowest total cost associated with it. In other words, it is distance analysis, but unlike the Euclidean Distance tool which you have already used, the distance is not just a geographical distance, but can involve a wide range of factors. Euclidean distance basically gives you distance "as the crow flies". Least-cost pathways give you a result that is more closely related to the real world.

Least-cost pathways are another form of raster analysis. The vector equivalent is network analysis. This tends to be used for routing vehicles on roads, such as working out the most economic route for a delivery van to take to make multiple deliveries.

13.4.2 Overview of the process

As with multi-criteria analysis there are several steps to least-cost analysis - see the flow diagram in figure 13.14 on page 196 for an overview. You need to start by deciding on the input datasets and then work through the process using the output of each step as the input for the next.

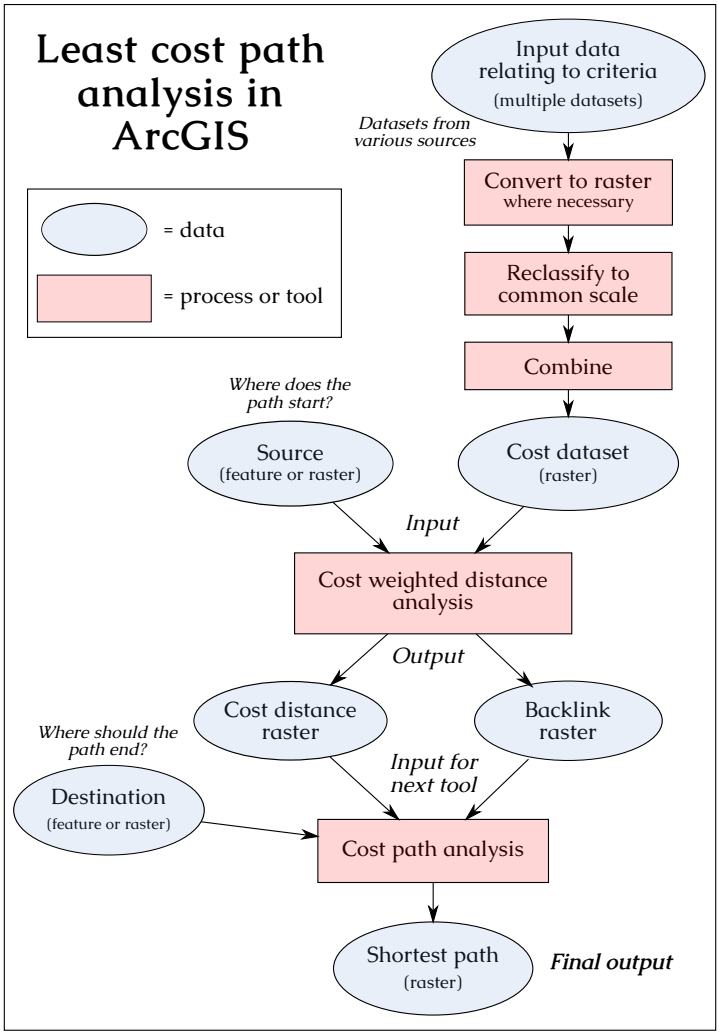


Figure 13.14: Flow diagram for least cost path analysis

13.4.3 Preparing a cost surface or dataset

The first step is to prepare a single cost surface or dataset that includes the total effect of all the factors. In effect, you can think of this as a surface that shows the **friction** for each cell and how easy or difficult it would be to traverse it. The ideal route will take the path with least total friction.

Question 13.1. So, looking at the criteria in section 13.4.1 what datasets need to be included on this friction or cost surface?

Each layer must be a raster and each layer then needs to be reclassified to a common scale so that the most costly factor has the highest classification. We are not going to prioritise the layers for this exercise, but within each layer there will be conditions that "cost" less than others, and conditions that "cost" more. Cost values are always calculated relative to a fixed base amount of **one**. So if a particular factor doubles the basic cost, then that factor will be assigned a value of **two**.

13.4.4 Data to include

You should already have downloaded and prepared the data for this exercise as detailed on page 184. If you haven't, follow those instructions now before proceeding with the instructions below. The extra data that you need has been included in the zip file that you downloaded from Minerva for this session. Add the following layers to a new map.

- The OS 1:50 000 raster tif files for the base map
- The dtm layer from the previous exercise
- A feature class containing the merged superficial geology tiles.
- A polygon shapefile containing the site of the new building - the *source* (**LPSource** from the Horton geodatabase)
- A line shapefile containing the powerline to which the cable needs to be connected - the *destination* (**LPDest** from the Horton geodatabase).

Prepare the layers as follows:

Height data - DTM

The dtm is already a raster file so does not need converting, but it does need to be reclassified before being added to the cost surface. As the brief is that the cable should follow the lower ground, the lowest areas of the raster should be reclassified as **1** and the highest as **10**.

- Spatial Analyst Tools > Reclass > Reclassify
- Add the dtm raster as the input and give your output a name
- Click on Classify and set the reclassification to **Equal Interval** with **10** classes.
- Click OK twice to run the tool.

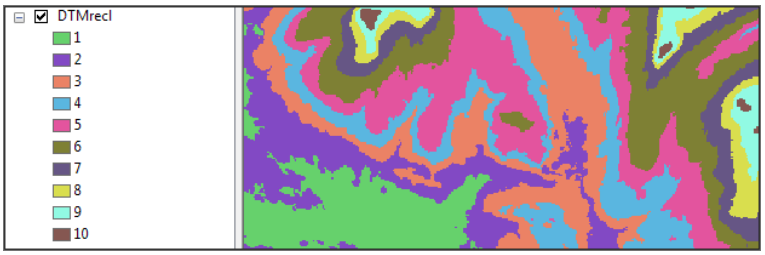


Figure 13.15: The reclassified DTM. 1 = the lowest ground, and 10 = the highest ground.

The resulting layer (figure 13.15) should have classes from 1 to 10, with 1 being the lowest elevations, and 10 being the highest.

Superficial Geology

The superficial geology should already have been merged from two tiles downloaded from Geology Digimap in the same way as the bedrock geology for the last exercise. This is a vector file so the first requirement is to convert the superficial geology to a raster file.

- Open Conversion Tools > To Raster > Polygon to Raster
- Fill in the dialog (figure 13.16) using the superficial geology layer as the input.
- Set the Value Field to **LEX_D** - this is the field that contains a description of the type of geology. Including this will make reclassifying your raster much simpler.
- Click OK to run the tool.

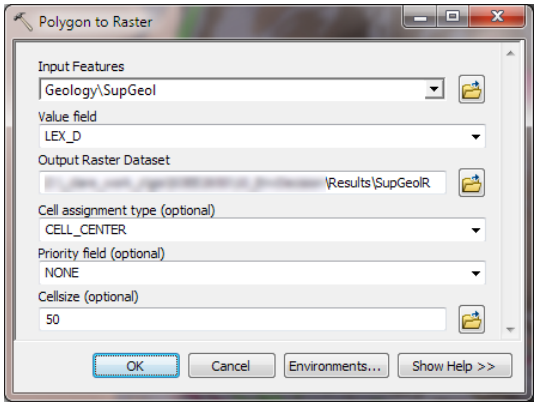


Figure 13.16: Converting the superficial geology feature class to a raster

The resulting raster should look like a pixelated version of the original vector feature class. Have a look at the attribute table to see what Arc has done with your chosen value field (figure 13.17).

Table

SupGeolR

Rowid	VALUE	COUNT	LEX_D
0	1	68920	TILL, DEVENSIAN
1	2	25	GLACIOFLUVIAL DEPOSITS
2	3	31225	PEAT
3	4	7600	ALLUVIUM
4	5	204	TALUS
5	6	181	ALLUVIAL FAN DEPOSITS
6	7	824	GLACIOFLUVIAL DEPOSITS, DEVENSIAN
7	8	876	RIVER TERRACE DEPOSITS (UNDIFFERENTIATED)
8	9	243	SUPERFICIAL DEPOSITS
9	10	167	HEAD

Figure 13.17: The attribute table of the rasterised superficial geology - the value field was set to LEX_D.

The next step is to **reclassify** the superficial geology raster in order to **weight** the different types of geology.

- Spatial Analyst Tools > Reclass > Reclassify
- Fill in the dialog (figure 13.18) using the raster superficial geology layer as input

Old values	New values
Peat	9
Till	3
Alluvium	3
Glacio-fluvial deposits	3
All other values	2
NoData	10

Table 13.1: Values to use when reclassifying the superficial geology raster

- Select **LEX_D** as the Reclass field - now you should be able to see why this was the value field to choose in the previous tool.
- Set the Reclassification values as shown in table 13.1 on page 199. Areas with **NoData** do not have superficial deposts and are likely to be rocky, this means that it will be more difficult to bury cables in those areas, so set them to a high value.
- Click OK to run the tool.

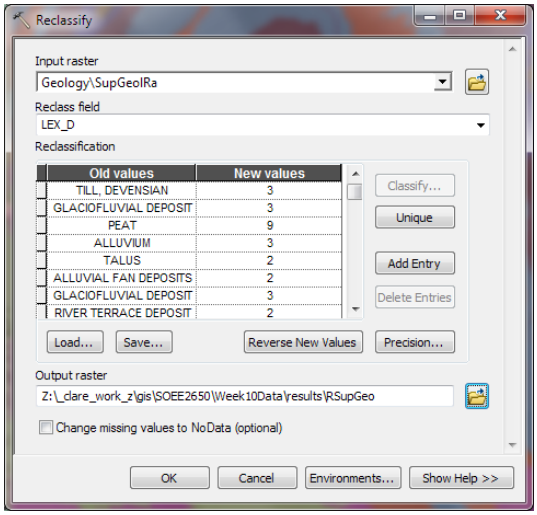


Figure 13.18: Reclassifying the superficial geology layer

The output raster should include only the new values listed above and should not include any areas of no data.

13.4.5 Combining the datasets

For this analysis we won't be prioritising the layers so combining the rasters for elevation and geology will be relatively simple.

- Open the raster calculator and run the following statement, using your reclassified dtm and superficial geology layers as the input.

```
"dtmRecl" + "SGeolRec"
```

Make sure that the result is added to your map. You should have a classified raster surface with the highest value being the total of the highest values in your input files, or slightly less. This is your **Cost raster**.

You can check that this has worked by using the **identify** tool. If you set it to **All layers** the value of the cost raster should be the total of the reclassified dtm and the reclassified superficial geology.

13.4.6 Calculating the cost distance

The next stage is to perform cost distance analysis.

- Spatial Analyst Tools > Distance > Cost Distance
- Fill in the dialog as in figure 13.19 with the source feature class as the input source data and the output of the previous step (your **cost raster**) as the Input cost raster.
- Give the Output distance raster a name and location
- Despite the Output backlink raster being labelled as optional, if you want to create a shortest path you **do** have to include this, so give that a name and location too.
- Click on OK to run the tool.

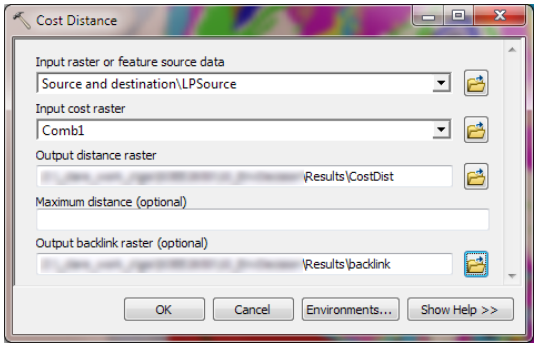


Figure 13.19: The Cost Distance tool

The output should be two files from this tool - the cost distance raster and the backlink raster. Check that they have been added to your map and have a closer look to see what these surfaces represent.

The **cost distance raster** uses your cost raster and **distance from the source** to work out the accumulated least cost value for that cell of travelling back to your source.

The **backlink raster** shows the *direction* of the least cost path from each cell back to the source.

13.4.7 Calculating the cost path

Finally you are in the position to calculate the shortest path from the source (the new building) to the destination (the existing power line).

- Spatial Analyst Tools > Distance > Cost Path
- Fill in the dialog as in figure 13.20 with the input destination data being the line feature class for the power line.
- The cost distance raster and the backlink rasters are the files produced in the previous step - note how importing careful file naming becomes!
- Set Path type to **BEST_SINGLE**
- Click on OK to run the tool.

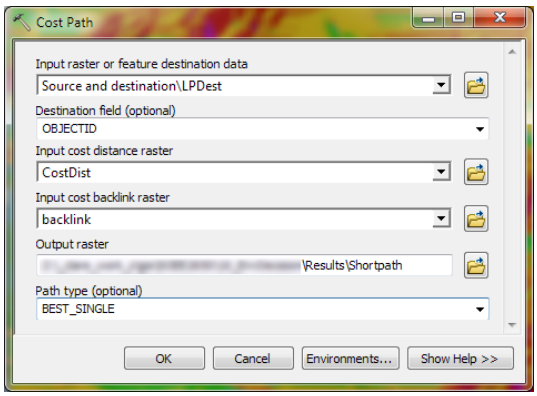


Figure 13.20: The Cost Path tool

This time the layer that is added to your map should show a single line of cells leading from the source to the destination. This is your least cost pathway.

If you find that the path does not appear, or only goes a very short way and doesn't join the destination line, check that you don't have *NoData* areas in your input rasters. These prevent the tool from crossing that area completely.

Have a close look at the least cost pathway and compare it with the original geology and terrain layers. Does it follow valleys? What geology does it cross?

Try running the tools again, this time giving a lower cost to the peat. Does it make any difference?

There are plenty of other data available which could be added to this model.

Question 13.2. What other layers do you think could be usefully added as criteria? Make a note of some below.

13.5 Final layout

Produce a layout to display your findings to the company that will be laying the cable. Convert the raster path to a vector for display - it will look better. Add it to your layout along with the background map, source and destination feature classes, a hillshade layer and the geology.

Think about how best to present all of this information. It can be difficult to balance the layers so that all are visible.

Your final map could look something like figure 13.21. It is unlikely to look identical as you should have made your own decisions about the relative importance of each criteria.

13.6 Recommended Reading: environmental decision making

Full references are in the module reading list[6].

[6]Reading list available from Minerva and from the library by searching for *SOEE2650* at `http://lib5.leeds.ac.uk/rlists/index.php`

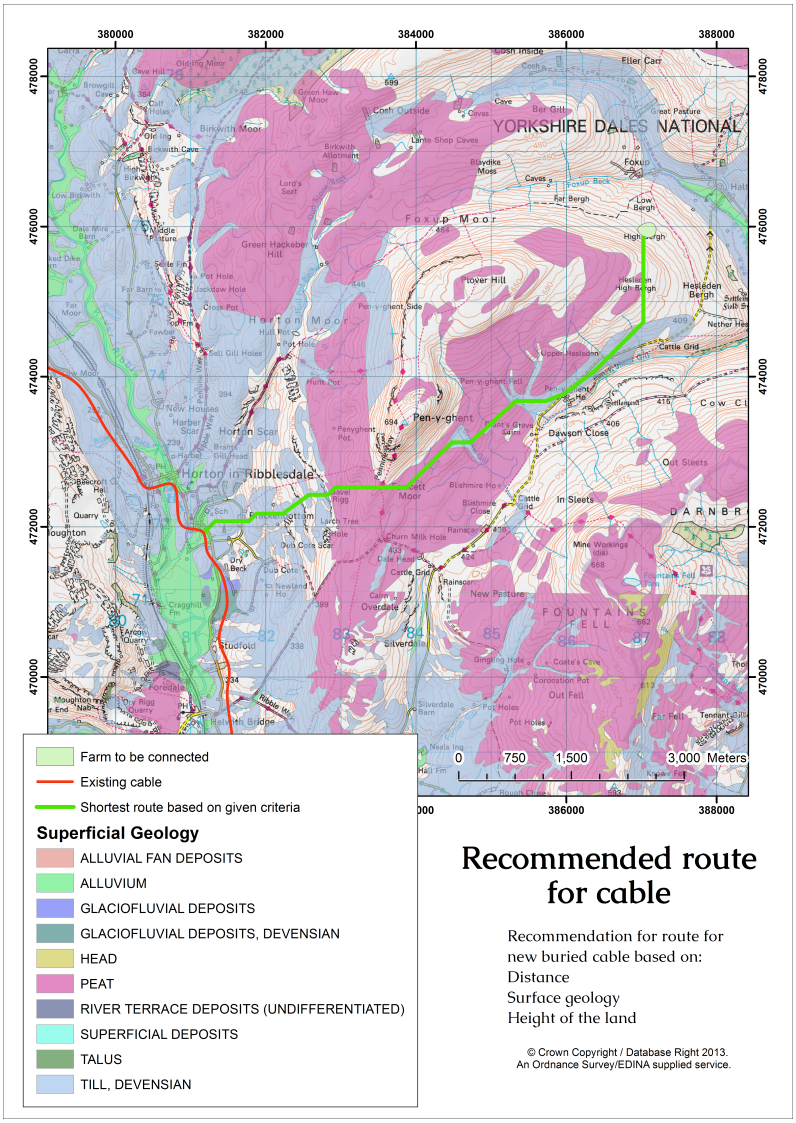


Figure 13.21: Possible layout for the map showing the recommended route for a new buried cable based on the criteria given

Heywood (2011) covers multi-criteria evaluation on pp. 244 - 247. (Their example of Fuzzy GIS on page 249 uses the fear of crime in Leeds as an example).

Longley (2011) has information on multicriteria methods, though they recommend different software - pp. 418 to 420.

Chang (2016) covers Least-cost path analysis in detail in chapter 17 (pp. 364 - 369) and also covers the vector equivalent - network analysis.

See case studies of the use of environmental analysis in **Scally (2006)**.

Appendix A

Answers to questions in text

These are suggested answers to the questions asked in the text. Check your answers against them but be aware that in many cases there is more than one correct answer. If you don't understand why a particular answer has been given please ask module staff or demonstrators for more information.

Chapter 1: Introduction to ArcMap

Question 1.1: Try out each tool in the tools toolbar in turn and see what it does.

Tool	What it does
Zoom in	*Moves the view closer in to the map so that you are viewing a smaller area in more detail*
Zoom out	*Moves the view out from the map so that you are viewing a larger area in less detail*
Full extent	*Zooms right out so that all of the data in your map is visible.*
Zoom to layer (this one isn't on the tools toolbar. Right-click on the title of a layer in the table of contents zoom to layer)	*Zooms to the extent of the data in the layer you clicked on*
Pan	*Move the area of the map that you are viewing by dragging it*
Select features	*Select particular features, or items from the selected layer*
Identify	*Find out more information about the features at a particular point on the map*
Find (try searching for **Cutting** in the **Feature** tab. Once you have a result, right-click a record and have a go with the commands from the menu, e.g. **Flash**)	*Search for features that match a particular term and view the features in the map*

Question 1.2: How has the bookmark affected the scale of the map?

The scale should have returned to the scale that had been set when you created the bookmark.

Question 1.3: What are the names of the other layers in the HS2 map?

*The other layers are **Wales; England and Scotland**.*

Question 1.4: What are the map units of the current map?

The map units should be set to meters[1]

Question 1.5: What is the difference between zooming with the tools in the layout toolbar and with the tools in the tools toolbar in layout view?

You should find that the zoom on the layout toolbar changes the zoom of the layout so that you are zooming on the "sheet of paper", while the zoom on the tools toolbar changes the zoom level of the map itself without changing the size of the paper.

Chapter 2: Introduction to the Catalog

Question 2.1: What is the main difference between the contents of the Constituencies folder in the catalog window in Arc, and the contents of the same folder in My Computer?

The main difference should be that in Arc you can only see one version of each file and that has a file extension of .shp. In My Computer there are multiple versions of each file with different file extensions.

These are examples of shapefiles. A specifically GIS format which can be read by many different GIS programs.

Question 2.2: What is the main difference between the contents of the HS2.gdb folder in the catalog window in Arc, and the contents of the same folder in My Computer?

The main difference should be that you can clearly see your individual layers in the Catalog view, but in My Computer there are lots of complicated extra files and you can't find your layers.

Question 2.3: What are the coordinate details for the HS2_route layer?

Your answers should be similar to the below:

Current coordinate system: British National Grid

Projection: Transverse Mercator

Linear unit: Meter (1.0)

Chapter 3: ArcGIS Desktop Help

Question 3.1: A possible definition of raster format.

A file format consisting of cells of data with each cell defined by x and y coordinates.

Question 3.2: A possible definition of vector format.

A file format consisting of paths and points which are located by x and y coordinates, and which can be joined to create lines and polygons.

Question 3.3: What types of geographic features can be stored in a shapefile? What is the file extension that shows you that this is the format of a file in Catalog?

The types of features are Polygon; Line (or polyline); and Point. The file extension is .shp.

Question 3.4: What is the name of the constituency at GR 437600 429689?

The constituency is Elmet and Rothwell Co Const

[1] The spelling of words such as metres and colour are Americanised in Arc.

Chapter 4: Finding and using spatial data: Coordinate systems, projections and transformations

Question 4.1: What is the coordinate system of this map? Is it a Geographic Coordinate System or a Projected Coordinate System and what makes you think that it is one or the other?

The coordinate system is GCS_WGS_1984. In "plain English" this is WGS 1984. It is a Geographic Coordinate System. That isn't completely obvious, but that is what the GCS at the beginning of the name stands for.

Question 4.2: What is the distance from London to Istanbul? What units are the measurement in?

2,500,721 Meters

Question 4.3: What do the different results tell you about different projections? How do distance and area compare?

Although on the ground the distance from London to Istanbul and the area of Algeria should remain constant, the results vary considerably between different projections on a flat map. Some projections are equal area and should give a reasonably accurate areal measurement, others are equal distance, and should give a reasonably accurate distance measurement. But all projections are mathematical methods of flattening the globe and none of them are perfect.

Question 4.4: What are the coordinate systems of the Miniscale and rivers layers?

Your answer should be similar to the entries below:

Table A.2: Projections for European region map

Layer	Projection
Miniscale map of the UK	Undefined
ArcGIS rivers layer	WGS_1984_Web_Mercator_Auxiliary_Sphere

Question 4.5: What is the coordinate system of the SRTM file?

The coordinate system is GCS_WGS_1984, and is a geographic coordinate system, so it is not projected.

Chapter 5: Digimap

Question 5.1: Name some other view and basemap combinations besides **Neighbourhood** >> **VML Streetview** that allow you to select content?

Possible combinations include the following:

- Street >> Vector Map Local
- Street >> VML Plan
- Detailed >> Full Colour
- District >> Mid-scale (2016)
- City >> Strategi (2016)

There are other combinations which also allow you select. Note that none of the basemaps marked as Raster allow you to select, neither do the most zoomed out Views.

Question 5.1: Use the Measure Distance tool to measure your route to the University. How far away do you live?

Of course, I can't tell you the answer to this one. Make sure that you include the units of the measurement in your answer - which should be either metres or kilometres.

Question 5.3: What is the area of Woodhouse Cemetery?

The area is approximately 36450 m^2

Question 5.4: What is the Tile Name at this location, and on what date was the aerial imagery at this location flown? As a bonus, what town is this point within?

*This point is in Aviemore (switch on Overlays - Road/Place Names to be able to see this) and the Tile Name is **nh8912**. The date that the imagery was obtained was **2015-10-01** (as of September 2019).*

Chapter 8: Elevation models: the shape of the land

Question 8.1: Is the car park at Threlkeld visible from Hallsfell Top? Would your car be visible if it were parked in the car park at Birkett Mire instead?

You should find that you can't see the car park at Threlkeld form the summit of Hallsfell Top, but you would be able to see your car if it were parked in the car park at Birkett Mire.

Question 8.2: What information can you use to differentiate the visible areas from the not visible?

You should find that the pixels in visible areas have Class values, Pixel values and Rowids of 1. Pixels in not visible areas have values of 0

Question 8.3: What information can you use to differentiate the visible areas from the not visible in the new vector layer?

You should have a column called GRIDCODE which contains values of 1 for visible polygons and 0 for not visible.

Question 8.4: How many Lake District summits are visible from Hallsfell Top?

Your answer should be similar to 286.

Question 8.5: How many Lake District summits are visible from Helvellyn?

Your answer should be similar to 93.

Chapter 9: Model builder: making repetition easy

Question 9.1: What data do you need to start building your model?

- dtm mosaic
- Lake District hills (with one selected...)

Question 9.2: What processes or tools do you need to run on that data?

Your answer to these two questions may be slightly different to mine. As long as you get the correct end result that is not a problem. You may have found alternative tools that do a similar job in a slightly different way or you may have thought of an alternative process. This is the example that is used for building the model in this exercise, but you can vary it if you think you would rather.

1. Select location to use as view point
2. Generate viewshed
3. convert the viewshed raster to a vector polygon file
4. select the polygons showing visible areas
5. intersect the full list of summits with the visible polygons
6. give number of summits that are visible

After each stage you output a file or layer which can then be fed back in to the next stage.

Chapter 10: Raster Analysis I

Question 10.1 *Your answers should be very similar to those in table A.3 on page 207:*

Table A.3: Raster file properties

Property	**OS Terrain 5 DTM ascii**	**Hillshade layer**
Data type	File system raster	File system raster
Columns & Rows	1000, 1000	2000, 2000 (depending on the no. of tiles in your mosaic)
Number of Bands	1	1
Cell size (X,Y)	5, 5	5, 5
Format	AAIGrid	GRID
Pixel Type	floating point	unsigned integer
Pixel Depth	32 bit	8 bit
Colour Map	absent	absent
Pyramids	absent	absent
Spatial Reference	British_National_Grid	British_National_Grid

Question 10.2: Given the cell size of a single downloaded tile of the ascii DTM what is the area of the tile?

Each cell should be 5 x 5 m and the tile is 1000 x 1000 cells, so the area is 25,000,000 square metres (25 square kilometres)

Question 10.3: What is the difference between the attribute tables of both raster files?

You should find that you can't open the attribute table for the DTM tile, but that you can open the attribute table for the hillshade.

Question 10.4: Think about the potential issues to do with interpolation. How reliable do you think the results are likely to be? How can this be affected by the original data?

The closer together your data points, the more reliable the interpolation because there is more data to base it on, i.e. fewer spaces to fill in

Question 10.5: What do you notice about the readings at various points within one colour band of the interpolated layer?

Despite the band showing as a single colour, the readings at different points should vary.

Question 10.6: Which surface do you think is the most appropriate for this data and why?

There is no one answer to this question. Make sure that you read the ArcUser article and think about how it applies to your data, also have a good look at the results of each of the above interpolation methods. Make sure that you have a reason for your choice!

Question 10.7: The cells in blue all have the flow of at least 5000 upstream cells flowing through them. Given that cell size is 5 x 5 m (so the area of a single cell is 25 m^2) what is the minimum area that each of the blue cells is draining?

The minimum area is 125,000 m^2

Question 10.8: What value(s) delineate the watershed? Use the attribute table to work out the area of the watershed in metres and write it in the box below.

The value of the cells inside the watershed are "0". According to the data in the attribute table the area of the watershed should be raster cell size (in this case 25 m^2) times COUNT of cells. So it should be something like 25 $\times$ 2361728 m^2

Chapter 11: Raster Analysis II

Question 11.1: What do you think are the advantages of restricting your datasets and processing tasks to a smaller geographic area?

The main advantages are that processing your data will take less time and processing power, particularly if you are working with large datasets. Quite apart from saving you time and stress, another outcome of this is that Arc is less likely to crash!

Question 11.2: What value do the cells outside of the watershed have? What value do the cells inside the watershed have?

The value of cells outside of the watershed should be "no value"

The value of cells inside the watershed should be "0" (zero)

Question 11.3: What are the differences between this and the original flow accumulation layer? What information has been lost for the high flow channels?

The original file doesn't have an attribute table. The new file has an attribute table with one row.

The high flow channels all now have a value of "1" so it is no longer possible to tell the direction of flow.

Question 11.4: What statement did you use in the raster calculator to reclassify the cells with a value of 30.001 m or less above the height of the pour point as 1?

*My pour point was at 98.9 m above sea level (I used the identify tool on the filled dtm mosaic to find that out) so I used the following statement in the raster calculator (where **"fill"** is the name of my filled raster)*

```
SetNull("fill">(98.9+30),1)
```

Question 11.5: Output areas are the smallest unit that we can download for census population data. How do those match the area that we are analysing? How would you phrase the explanation of the figures that you have just produced to make it clear what the data showed?

Your answer may vary, but it should include some of following ideas. The census output areas don't match either the watershed or the flooded area exactly so not every person who lives in an affected output area will actually be flooded. Any explanation of the data on a map needs to make that clear and also needs to say where the population data is taken from.

Chapter 12: Creating data for GIS: Point data and GPS

Question 12.1: What happens to the size of the symbols when you zoom in to 1:500 and then out to 1:25 000?

You should be able to see that the text and symbols stay the same size on the screen, which means as you zoom out they look larger in comparison to the rest of the map. This means that at a smaller scale the symbols overlap.

Question 12.2: Once you've set a data frame reference scale, what happens to the size of the symbols when you zoom in to 1:500 and then out to 1:25 000?

This time you should be able to see that the text and symbols become larger or smaller on the screen depending on the zoom, but they remain in the same proportion to each other - and don't overlap more at a smaller scale than they do at a larger.

Question 12.3: How accurate do you think the locations of the points are? What problems can you spot based on your memory of collecting the data? How do you think that you could increase the accuracy of data input?

Your results may be very different to mine, but based on the readings that I took I would say that the accuracy is variable. The data sheet should enable you to quantify this for each point. In relation to the base imagery my points vary between very accurate and up to a couple of meters away.

Ways to increase accuracy include using GPS in areas with a clear view of the sky, so away from buildings, trees, mountains, etc. Turn on your GPS well before you start to use it and give it plenty of time to connect to multiple satellites. Read the instructions for your GPS! Some models have additional ways of increasing accuracy.

Chapter 13: Environmental decision making

Question 13.1: Which datasets need to be included on the friction or cost surface?

The datasets should be the following:

- Height data - DTM
- Superficial geology
- The starting point for the cost distance - where is the farm?
- The destination for the cost distance - where is the national grid cable?

Question 13.2: What other layers do you think could be usefully added to extend the least cost path analysis?

The suggestions below are just to start you off, you may well have suggested others:

- How about access for laying the cable? So distance from roads could be useful.
- What about the machinery necessary - heavy machinery is often not able to work on steep slopes. You could generate a slope raster from the dtm.
- The suggested pathway goes close to some houses in Horton, how about finding a vector layer which shows buildings and adding that? (The VectorMap District dataset has a possible layer). You could use it in a similar way to the roads layer in section 13.3.1 on page 188 to generate a layer which gives you proximity to buildings.
- Are there any nature reserves or SSSIs (Sites of Special Scientific Interest) in the area? This data can be downloaded from Natural England[2]

[2] `http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp` You used this site to download data for

chapter 8

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