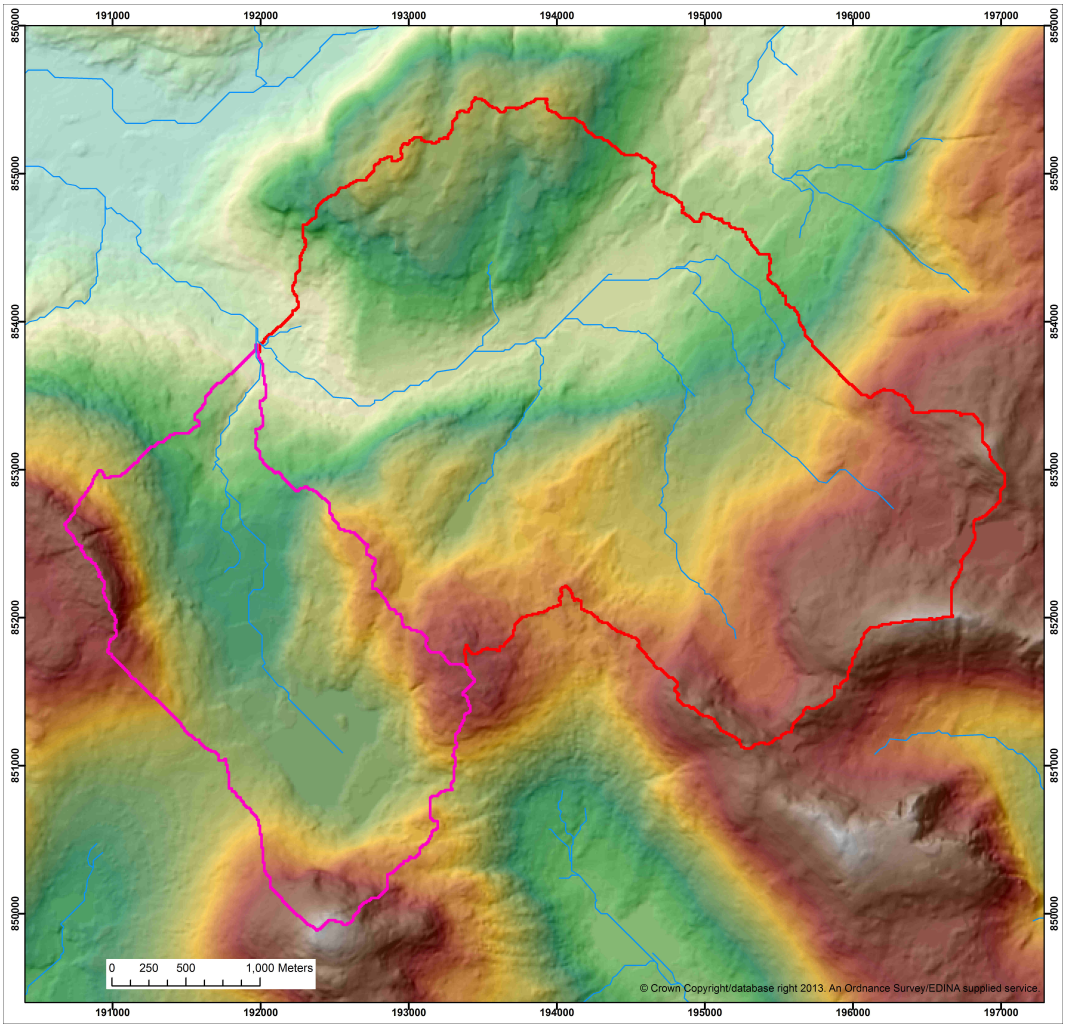
Introduction to GIS with ArcGIS

for Environmental Science



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For ArcGIS Pro version 2.4.0
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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. Most recent first.

Date of change	**Section no.**	**Summary of change**
10th October 2019	Section 6.7.5	Simplification of information on adding north arrows due to latest version of ArcGIS Pro.
25th September 2019	Section 5.5	Added information on controlling which layers are selectable.
Summer 2019	All chapters	Updating to use ArcGIS Pro instead of Desktop.

Chapter 1

Introduction to GIS with ArcGIS Pro

The background to GIS and an explanation of what it is will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

1.1 Learning outcomes

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

- demonstrate how to open a map project in ArcGIS
- select appropriate tools to navigate in a map document
- use layers to organise and display information on a map
- add information to a layout and prepare it for printing or display
- demonstrate different ways of finding help when using GIS

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 nature reserves and Sites of Special Scientific Interest (SSSIs) will be directly affected by the route. 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 a basic map of the HS2 route so that you can explore the GIS 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.

1.3 Obtaining and opening 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 **HS2.7z** file from Minerva and save it on your M:/ drive.

- Create a new folder called **gis** on your M:/ drive and **unzip** the downloaded file to that folder (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 it first - it won't work.**

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

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.

1.3.1 Open the sample map

- Open Arc by searching for **ArcGIS Pro** in the start menu of your computer and clicking on it. Be patient - Arc can open slowly!
- From the splash screen (figure 1.1) select to Open another project. If you don't have the splash screen use Project » Open....
- Navigate to the folder in which you unzipped the downloaded file and open **HS2.aprx**.

- Alternatively you can navigate to the folder to which you unzipped the downloaded data
- Go into the **HS2** folder and double-click on the **HS2.aprx** file - the map should open

Your ArcGIS window should look similar to figure 1.2.

1.4 The map ribbon

The menu ribbon at the top of the window (figure 1.3) gives you a variety of tools. Hover over the buttons to see the tooltips that explain what each button will do.

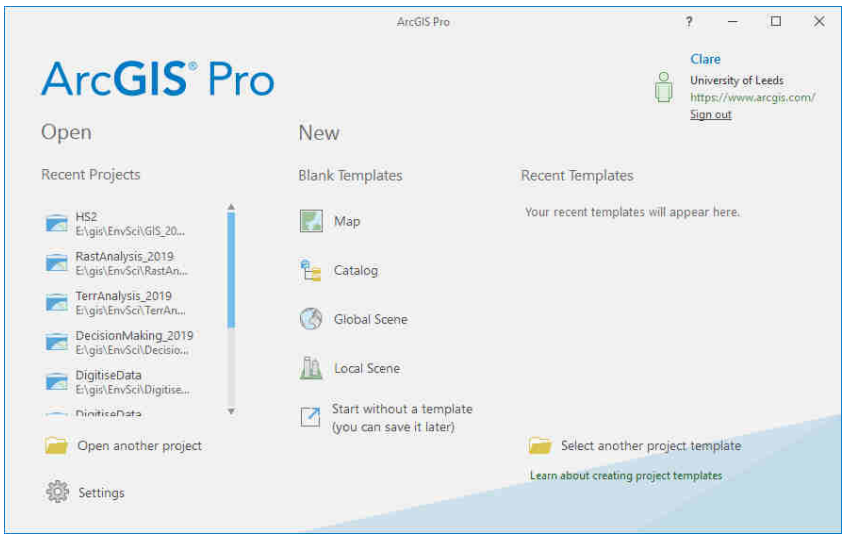


Figure 1.1: The ArcGIS Pro splash screen. If you have opened projects previously they will be available here. (Esri software graphical user interfaces are the intellectual property of Esri and are reproduced herein by permission. All rights reserved.)

Question 1.1. On the map ribbon look for each of the tools suggested in table 1.2 in turn and try them out to see what they do. Make notes for yourself in table 1.2 on page 3.

To see the basic navigation options hover over the Explore button on the ribbon.

(Remember that possible answers to questions in the workbook are given in appendix B starting on page 239)

Table 1.2: Map ribbon tools

Tool	**What it does**
Fixed zoom in - also try using the mouse wheel to zoom in and out	
Fixed zoom out	
Full extent	
Zoom to layer (this one isn't on the ribbon) Right-click on the title of the **HS2_route** layer in the contents pane Zoom To Layer[1]	
click the **Select** button then click and hold on the map, drag out a rectangle, and let go	
click the **Clear** button in the Selection group	

[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.

click on **Explore**, then click on one of the nature reserves on the map. Also try some of the options found by clicking on the down arrow under the **Explore** button	
click on **Locate**, the locate pane should open on the right of your map. Type **Sheffield** in the search box and select one of the results[2]	

1.4.1 Change scale

Instead of zooming with the mouse wheel you can change to a particular scale, e.g. 1:100 000, simply use the drop down box at the bottom of the window (figure 1.4) 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**.

1.5 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 showing the planned route near Leeds (figure 1.5).

- Bookmarks > HS2 Leeds.

To set up your own bookmarks

- Pan the map to a different location
- Bookmarks > New Bookmark... type a name for your bookmark OK.
- The bookmark should be visible as a thumbnail when you click on Bookmarks again.

Video Clip available in Minerva - Spatial bookmarks in Arc.

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?

[2] If nothing happens when you search, try the following: Click on the **Settings** tab above the search box. Click on **ArcGIS World Geocoding Service** - check it's Enabled, and move it to the top of the list (above XY provider). Go back to the **Locate** tab and hopefully the search will work now.

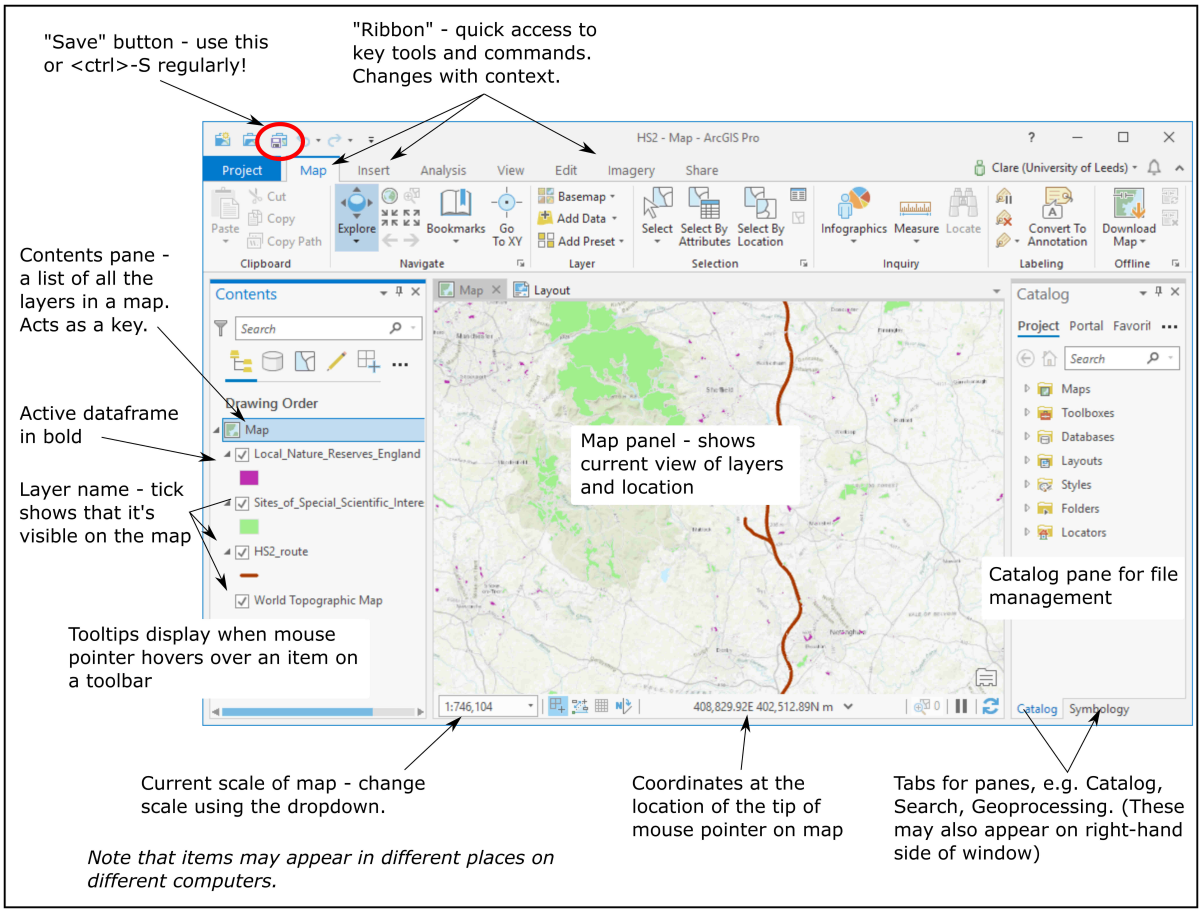


Figure 1.2: The ArcGIS Pro window (Esri software graphical user interfaces are the intellectual property of Esri and are reproduced herein by permission. All rights reserved.)

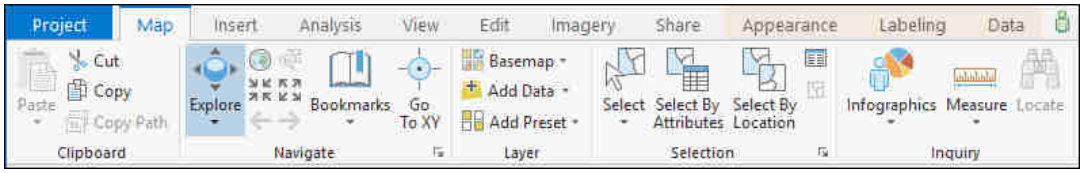


Figure 1.3: Part of the map “ribbon”

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.

1.6 Catalog pane

The Catalog pane allows you to explore and find out more information about your data.

- If the catalog pane isn’t visible on the right of the window already, go to View > Catalog Pane on the ribbon to open it.

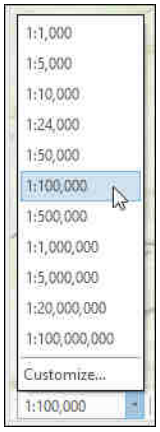


Figure 1.4: Scale dropdown box

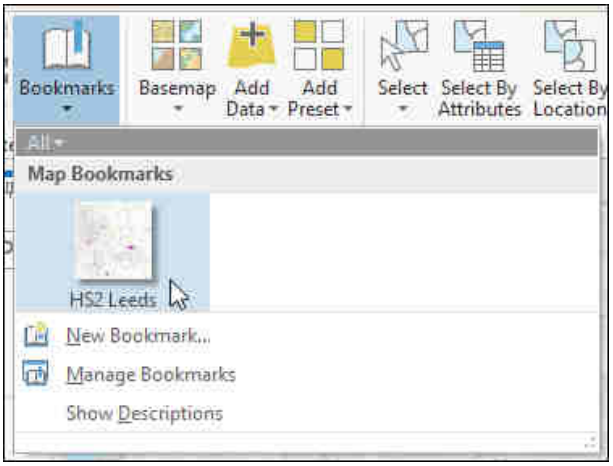


Figure 1.5: The bookmark menu showing the HS2 Leeds bookmark

- Explore the tree in the Catalog pane by opening out all of the subheadings (click on the small arrows). You should end up with something like figure 1.6

The view that you've been working in shows a **Map** and this is available under the **Maps** heading in the Catalog. If you close it you can reopen it from here.

The **Layouts** heading shows any print layouts that have been set up. You should already be able to see one, just called "Layout".

The heading for **Databases** shows the geodatabase which contains most of the information which makes up the map. If you open out the geodatabase **HS2.gdb** you can see the layers.

There is another subheading for **Folders**. This has a "home" folder for this project - **HS2**. You can also add other folders here so that you can add data from outside of your project. See the tip box in table 1.3 on page 10 for how to do this.

1.7 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

- Local_Nature_Reserves_England
- and HS2_route

Question 1.3. What is the name of the other layer in the HS2 map?

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

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

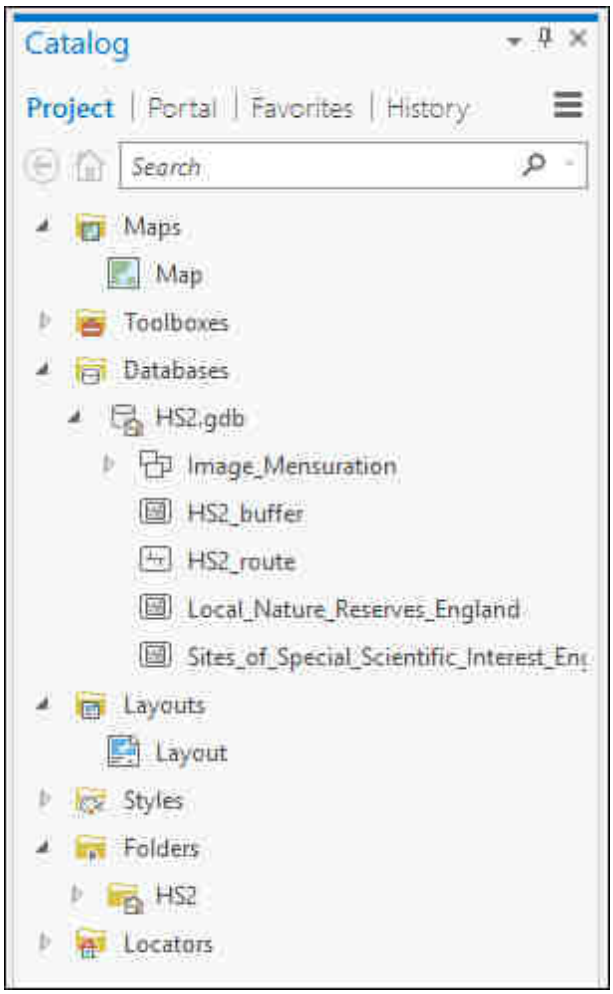


Figure 1.6: The Catalog pane with subheadings opened out to show contents of the project

Video Clip available in Minerva - Working with layers in Arc.

1.7.1 Viewing contents of layers

In the contents pane:

- Click on the small arrow next to a layer to open and close the layer contents.
- The contents pane also acts as a key to your map and shows the symbols for map features.

1.7.2 Renaming layers in the contents pane

You can make the layer names more useful by changing them in the contents pane. 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 Arc.

- Select **Local_Nature_Reserves_England** in the contents pane and press F2 on the keyboard, or double-click slowly on the layer name.
- Type the new name, e.g. **Local Nature Reserves in England** and then press Enter

1.7.3 Turn layers on and off

Once a layer is in the contents pane you can turn the layer on and off to view or work with other data without removing it completely.

- Click in the box next to the **Local Nature Reserves** layer title to turn the reserves off on the map.
- Turn other layers on and off and see what the map looks like but finish with all of the current layers visible.

1.7.4 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 Arc and Add Folder Connection

Add data command

- Map ribbon › Add data… navigate to the folder in which you unzipped the map - you'll need to start by going into `Folders` in the browse dialog, then go to the `HS2 ▸ Miniscale` folder and add **MiniScale_mono_R19.tif**.
- When you add tif or jpg files to Arc as a layer for the first time it sometimes asks you whether you want to create **pyramids**. It's your choice, but usual advice is to create them. 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.[3]
- If you can't find the folder in order to add the image follow the instructions in the **Add Folder Connection** tip box (table 1.3).

Miniscale data is a general basemap of the whole of the UK. Zoom in closer and you'll be able to see more detail (if you can't see the layer make sure that it is above **Topographic** in the contents pane - you can change the order by dragging layers around in the pane).

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

Drag and drop

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

- The Catalog pane should be visible to the right of your map. If it isn't click the **View** tab on the ribbon and click on **Catalog pane** - see figure 1.7
- In the Catalog pane go to the **Folders** section, go into the `HS2▸Miniscale` folder and drag and drop **MiniScale_standard_R19.tif** on to your map. If you drag it over to the contents pane 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 data follow the instructions in the **Connecting to a folder** tip box (table 1.3).

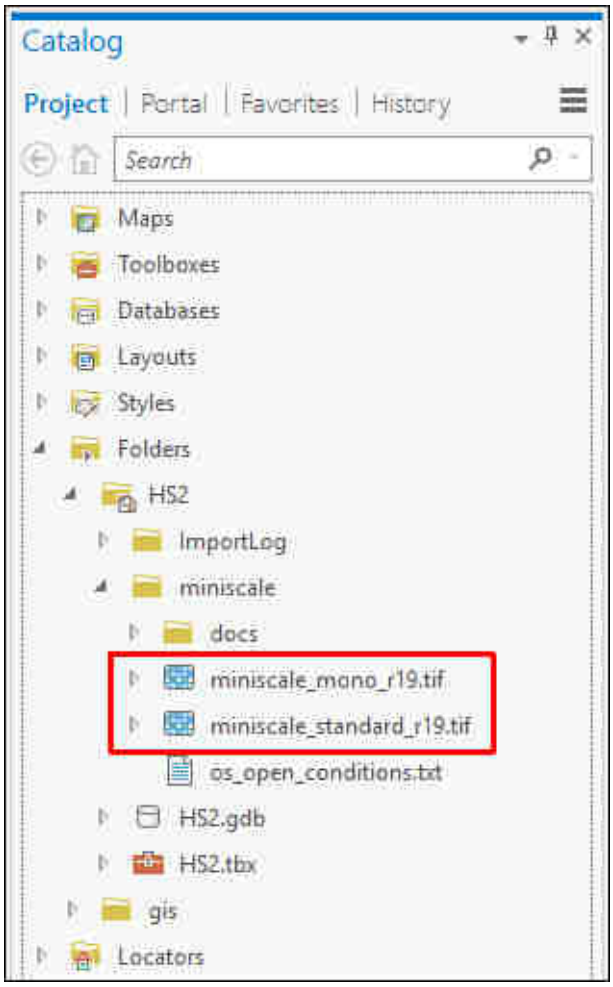


Figure 1.7: Finding the Minimap layers in the Catalog

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

Add your M: drive to the Folders heading using the Add folder connection command now to check that you can do it.

Adding a folder connection in the Catalog pane
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**. • Right-click on the **Folders** subheading in the Catalog panel • **Add Folder Connection** (figure 1.8) and select your top level gis folder, or your M: drive then click OK. If you select the drive that you want, rather than navigating right to the file, you'll be able to navigate to any files within it. • 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: Adding a folder connection in the Catalog pane

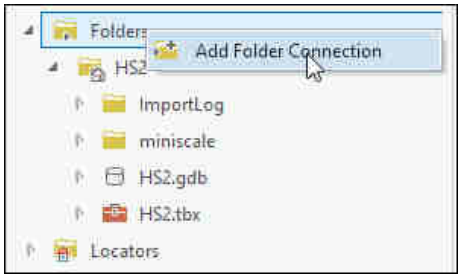


Figure 1.8: Add Folder Connection - found by right-clicking on the Folders subheading in Catalog

Video Clip available in Minerva - Add Folder Connection

1.7.5 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 contents pane. So the layers towards the top will cover up the layers lower down.

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

You should find that the miniscale layer covers up the local nature reserves layer so that it is no longer visible.

- Move the **Local Nature Reserves** layer back up above the miniscale layers so that you can see it again.

1.7.6 Make layers transparent

Zoom in close to one of the Local Nature Reserves on your map. You should be able to see that the polygons making up the reserves 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 contents pane.

- Start by making sure that you have the Local Nature Reserves layer switched on and the miniscale layers off so that the basemap is visible, then select the Local Nature Reserves layer in the contents pane. Try to have your contents pane looking something like figure 1.9
- Click to open the **Appearance** tab on the ribbon. The **Effects** group contains a slider to control transparency and a box showing percentage - see figure 1.10.
- 0% is fully opaque, 100% is fully transparent. Try several steps between 30 and 60% and see what difference it makes.

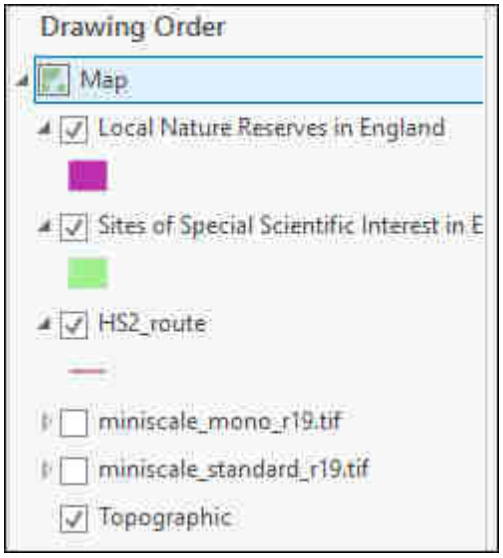


Figure 1.9: Arrange your contents pane so that it looks like this before setting transparency for this exercise

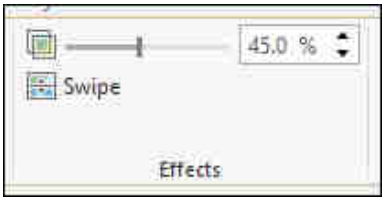


Figure 1.10: The Effects group on the Appearance tab of the ribbon. The slider and percentage show that the selected layer is set to 45% transparency.

Using the above instructions move the layers around in the contents pane and change transparency for various layers, just to see what the possibilities are.

1.7.7 Grouping layers

The Local Nature Reserves and SSSI 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 reserve layers on and off together.

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

1.7.8 Remove layers

Perhaps we don't need the **Miniscale** layers in our map after all.

- Right-click on the Miniscale layers in the contents pane 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. Check this in the Catalog pane - the layers should both still be available if you want to add them back in again.

1.7.9 Using Basemaps

The lowest layer on your map is probably called something like **Topographic**. If you look at the **Source** for this by double-clicking on the layer and choosing the **Source** heading, you'll see that it's **Data Type** is listed as **ArcGIS Map Service** - figure 1.11

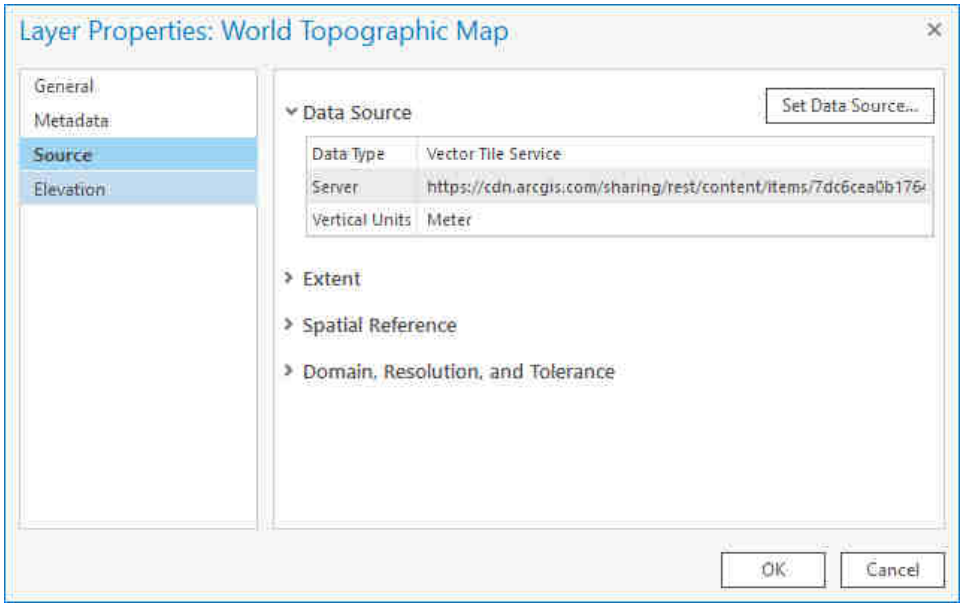


Figure 1.11: The Source information for the World Topographic Map layer - note the Data Type

When you create a new map in ArcGIS Pro you are automatically given a basemap of this type. It's useful as it gives you some idea of where you are. These layers are also very convenient as background maps, and it is possible to change the basemap that your map uses.

- On the **Map** tab of the ribbon click on the down arrow under **Basemap**
- from the list of alternatives click on **Imagery Hybrid** (this has the imagery with labels, roads, borders etc added)

You do have to wait a bit for these layers to load sometimes, but they can be really useful.

> ***Have a look at the Imagery Hybrid layer, then try out some of the others. When you've investigated them select one to use as the basemap for your current map.***

Video Clip available in Minerva - Working with attribute tables in Arc.

1.8 Viewing an attribute table

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

- Right-click on the **HS2_route** layer in the contents pane and click on Attribute Table.

A pane similar to that in figure 1.12 should open at the bottom of your map window.

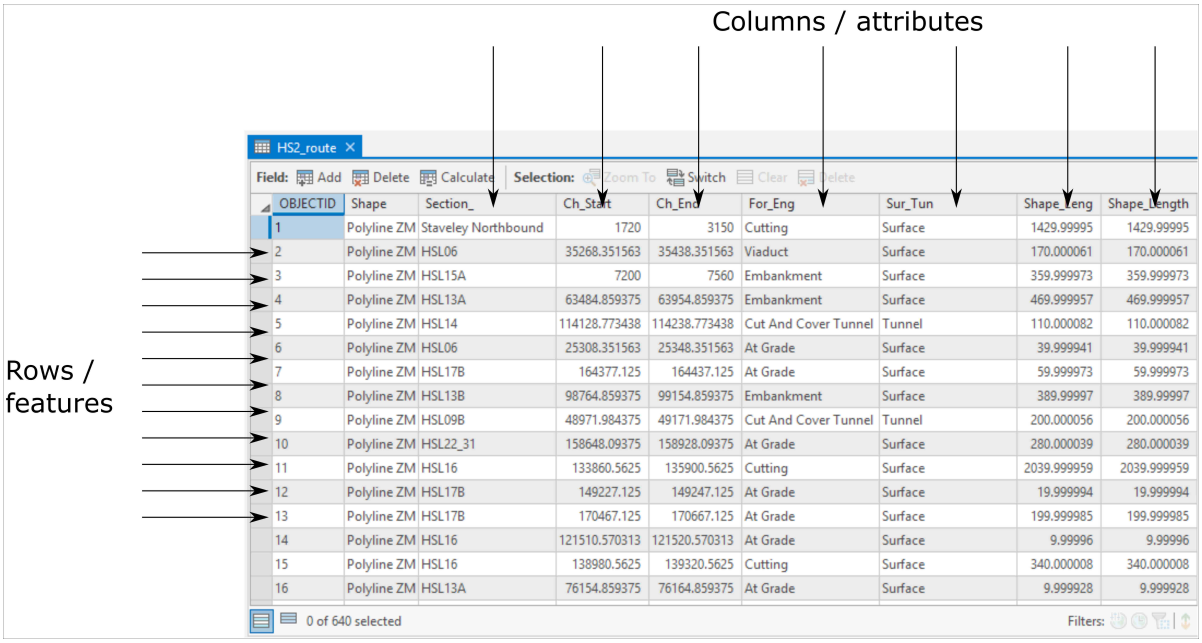


Figure 1.12: The attribute table for the HS2 Route feature class

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[4] 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 right-clicking on **Map** (the title of the map frame) in the contents pane and going to Properties. Under **General** look at **Map units**

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

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.

1.8.1 Selecting features in the attribute table

Video Clip available in Minerva - Select by attributes in ArcGIS Pro

- In the attribute table click on the little grey area to the left of the one of the records (see figure 1.13). The feature will be selected in the table, and will also be selected 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. Selected features are marked in a bright turquoise colour both in the attribute table and on the map.
- Use the **Select** tool from the Map tab of the ribbon 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 in the grey area next to the first of the features that you can see. 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. ⇧ will also work.
- To view only your selections click on the Show selected records button at the bottom left of the attribute table pane. 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 Clear button either on the attribute table top bar (figure 1.14), or on in the **Selection** group on the ribbon (figure 1.15).
- 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 feature, so the shortest at the top.

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

When you've finished, clear all selections by clicking on **Clear** in the Selection group of the Map ribbon then **close** the attribute table pane by clicking on the cross on the tab at the top of it.

1.9 Finding help for ArcGIS

I've been throwing a lot of new terms at you here. Don't worry - most of them will become more familiar as the course goes on. Don't forget you will be able to look back at this workbook - and that there is an index in the back which will hopefully help you to find what you're looking for.

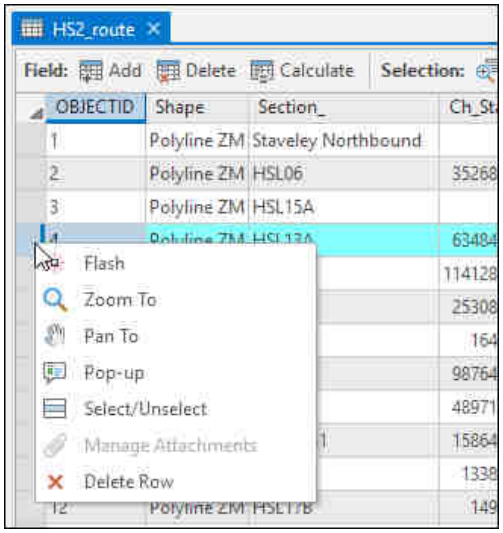


Figure 1.13: Selecting a feature in the attribute table - the "little grey area"

Figure 1.14: The "clear" button on the attribute table menu

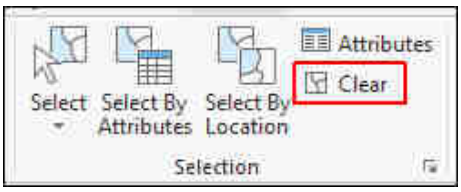


Figure 1.15: The "clear" button in the Selection group on the ribbon

In addition you can make use of some resources provided by ESRI, the company who produce ArcGIS.

ArcGIS Pro help is available at `https://pro.arcgis.com/en/pro-app/help/` You'll find this useful when you start using more advanced tools in Arc, but if you're not sure of something it's worth searching in the help.

In addition if you want to explore further ways to use GIS there are lots of lessons available at `https://learn.arcgis.com/en/`

1.9.1 ESRI GIS Dictionary

The Dictionary can be useful if you need to remember what a particular term means.

- Go to `https://support.esri.com/en/other-resources/gis-dictionary/`
- Type **attribute table** in the search box and press ↵
- The answer should match what you've already learnt in section 1.8 on page 13.

Practice using the dictionary by completing the exercises below.

"Raster" and "Vector" are the two main types of data structure used in ArcGIS and you will come across these many times during this course.

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 1.5. Raster:

Question 1.6. Vector:

1.10 Saving a map

IMPORTANT: Develop the habit of saving your map projects at regular intervals. Arc 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.

To save your project:

- Either Project > Save or the save icon on the quick access toolbar
- or use Ctrl + S on the keyboard

1.11 Symbolising a layer

At the moment all of the layers in the HS2 map are symbolised as a single colour. By using multiple colours, or classes, you can make your map much more informative.

- Open the attribute table for the **HS2_route** layer and have a look at the data that it contains. The column headed **For_Eng** contains information on what type of engineering will be necessary for each section. Make a note of the field name.
- Close the attribute table.
- Right-click on the **HS2_route** layer and click on Symbology

The **Symbology** pane should open to the right of the map window. At the moment the layer is symbolised as a single symbol - a single random colour which is used for all polygons in the layer. See figure 1.16.

Video Clip available in Minerva - Symbolising a layer by unique values in ArcGIS Pro

To symbolise the layer as multiple colours by engineering type:

- Select **Unique Values** in the dropdown box at the top of the Symbology pane
- in the **Field 1** box that appears select **For_Eng** - the field we were looking at earlier.

You should find that you get a list of the values of For_Eng to which Arc will have assigned random colours - figure 1.17.

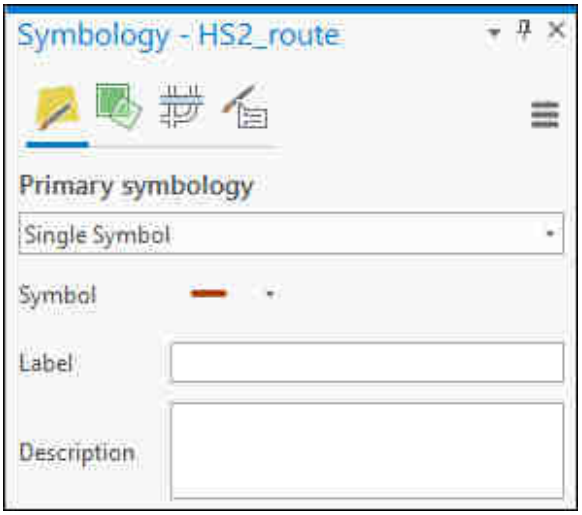


Figure 1.16: The Symbology pane showing single symbology for the HS2 route

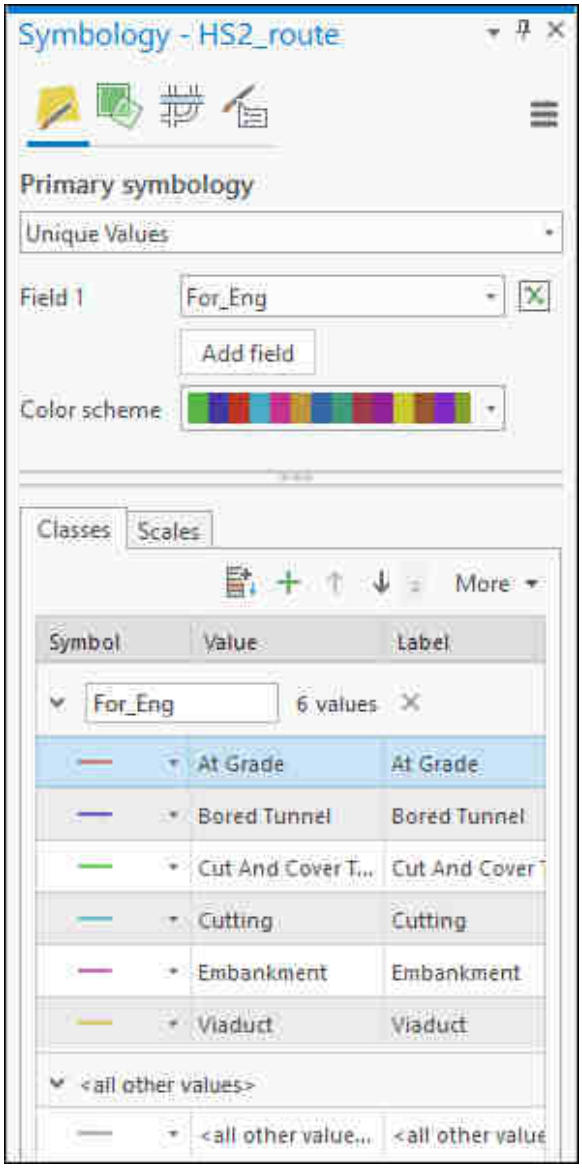


Figure 1.17: Setting symbols for a layer with unique values - or multiple categories

- You can change the colours and thicknesses of the lines by clicking on each symbol in turn - click on the line symbol next to **At Grade** now.
  - If you click on the **Gallery** heading you'll get a choice of preset styles - click on one of them now, e.g. **Highway**. You should see the new symbol appear for some of the features on your map [5]
  - In the **Properties** heading you can set up your own styles. Click on this heading and try making some of the line widths thicker, and change the colour of the symbol.
- This time you'll need to click on Apply to see the result on your map
- Click on the back arrow at the top of the pane to go back to the full list and try setting the other symbols too.

[5] If you find the selection of symbols available rather limiting, it is possible to add more styles from the ESRI Gallery - see table 12.1 on page 210 for more details.

- You may find it easier to see what you are doing if you turn off all of the other layers in the contents pane.

1.12 Intersecting two different layers

Now that you have your data in a GIS, why not take advantage of its power? You can use GIS to select features which are within a certain distance of features in another layer. For example, which nature reserves will be directly affected by the HS2 line?

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

Make sure that both the HS2 route and the Local Nature Reserves layers are visible in your map.

Video Clip available in Minerva - Select by location.

- From the **Map** tab of the ribbon click on the button to Select by Location
- The dialog should open in the Geoprocessing pane on the right. Fill it in following figure 1.18
  - **Input Features** should be the layer which contains the features that you wish to select, in this case the nature reserves
  - **Relationship** should be set to **Intersect** (but have a look at the other options which are available)
  - **Selecting Features** is the layer that indicates the location you want to select against, so the HS2 route.
  - We'll also add a small margin so that nature reserves which have parts within 1 km of the route will also be selected, so enter the **Search distance** as **1000** meters.
  - **Selection type** should be **New selection**
- Click on Run at the bottom of the pane

Now your map should show the nature reserves 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. You may need to zoom in a bit to see them properly!

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

- Right-click on the layer containing the selection - the nature reserves layer
- Data > Export features
- Choose to save the new Output feature class in the project geodatabase (HS2.gdb) - see figure 1.19 and give your output a name - then Run
- The new layer should be automatically added to your map

Now **remove** the original local nature reserves layer and you should be left with just those reserves which you had selected. Try symbolising the reserves as a single, green symbol.

Repeat the process with the Sites of Special Scientific Interest layer and symbolise in a different colour.

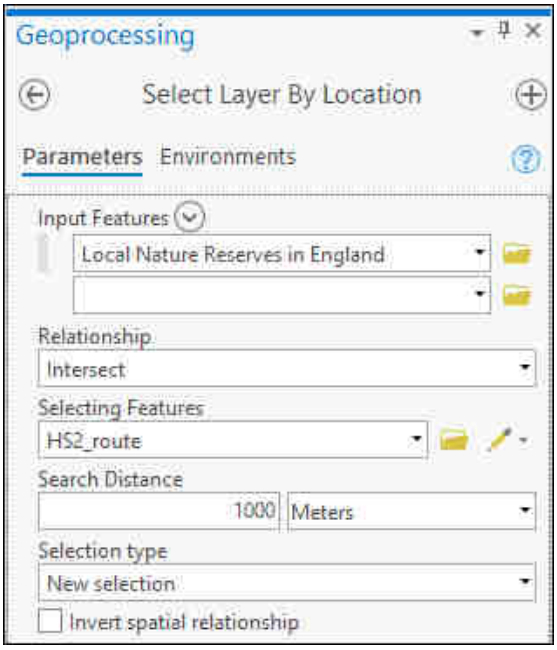


Figure 1.18: Filling in the Select by location dialog

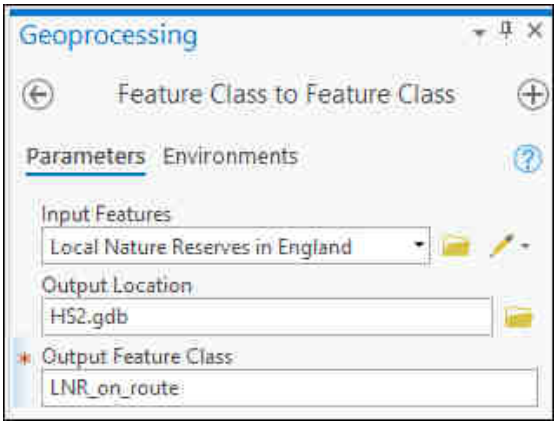


Figure 1.19: Exporting a selection to a new feature class. I haven't shown the whole tool panel - the defaults are fine in this case

Question 1.7. How many features are there in the new layers showing only the reserves and SSSIs within 1000 meters of the route? You should be able to tell by opening the attribute table for each layer.

Local Nature Reserves:

Sites of Special Scientific Interest:

1.13 Some simple analysis: Buffering

ArcGIS provides a wide range of tools with which to analyse data and this is one of the big strengths of GIS. 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 HS2 route.

- Right-click on the **HS2_route** layer in the contents pane and **Zoom to Layer**
- From the **Analysis** tab on the ribbon select Tools to open the **Geoprocessing** pane
- In the pane search for **Buffer**
- In the results click on **Buffer (Analysis Tools)**
- Fill in the fields as shown in figure 1.20[6]

[6] If you want more help on a field when you're entering your requirements, try hovering the mouse pointer over the little `i` information symbol that pops up.

- To add **HS2_route** as the input click on the down arrow next to the **Input Features** box
- Click on the browse button next to **Output Feature Class** and choose where you want to save the output. The best place will be in the geodatabase associated with this project - **HS2.gdb**. Don't forget to give your output a sensible name, in this case make it clear that the output will be a buffer.
- Set the **Linear Unit** as **Kilometers** and the **Distance** as **10**
- Set the **Dissolve Type** to **Dissolve all output feature into a single feature** - this means that the buffer will be calculated for all records as a whole, rather than for each one individually.

• Click Run at the bottom of the pane.

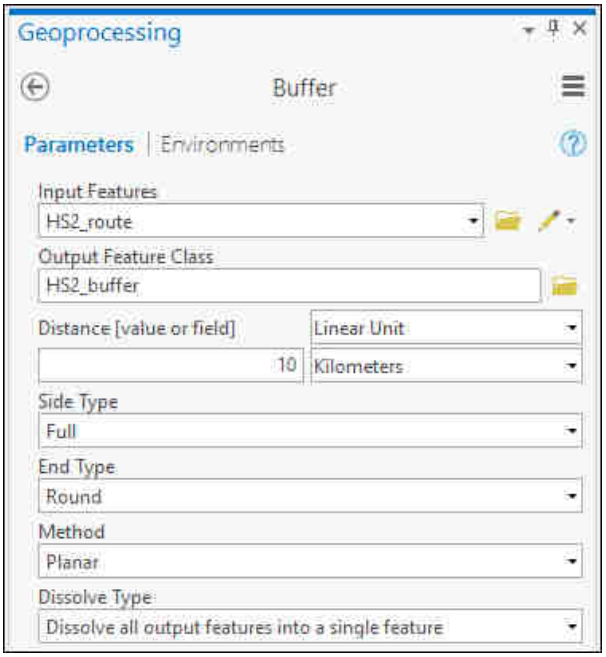


Figure 1.20: Filling in the Buffer tool

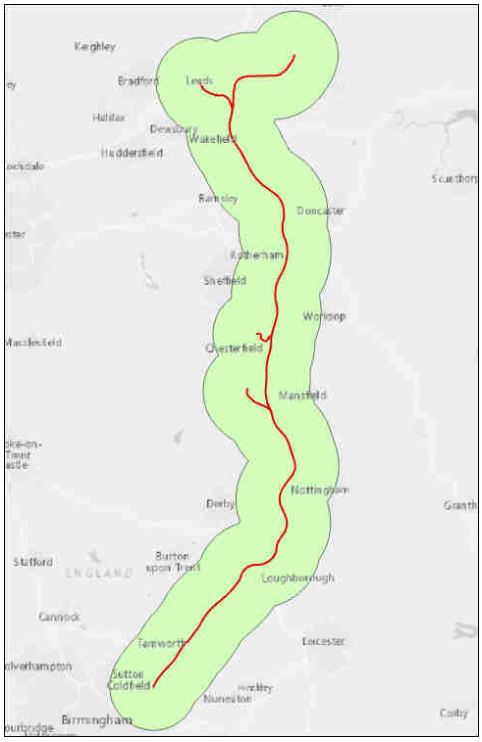


Figure 1.21: Map showing a 10 km buffer around the proposed route of HS2

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 1.7.6 on page 10) it should make it possible to see the places and layers underneath it.

1.14 Layout - laying out a map for print or export

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

• In the Catalog pane open out the **Layouts** subheading and double-click on the **Layout**

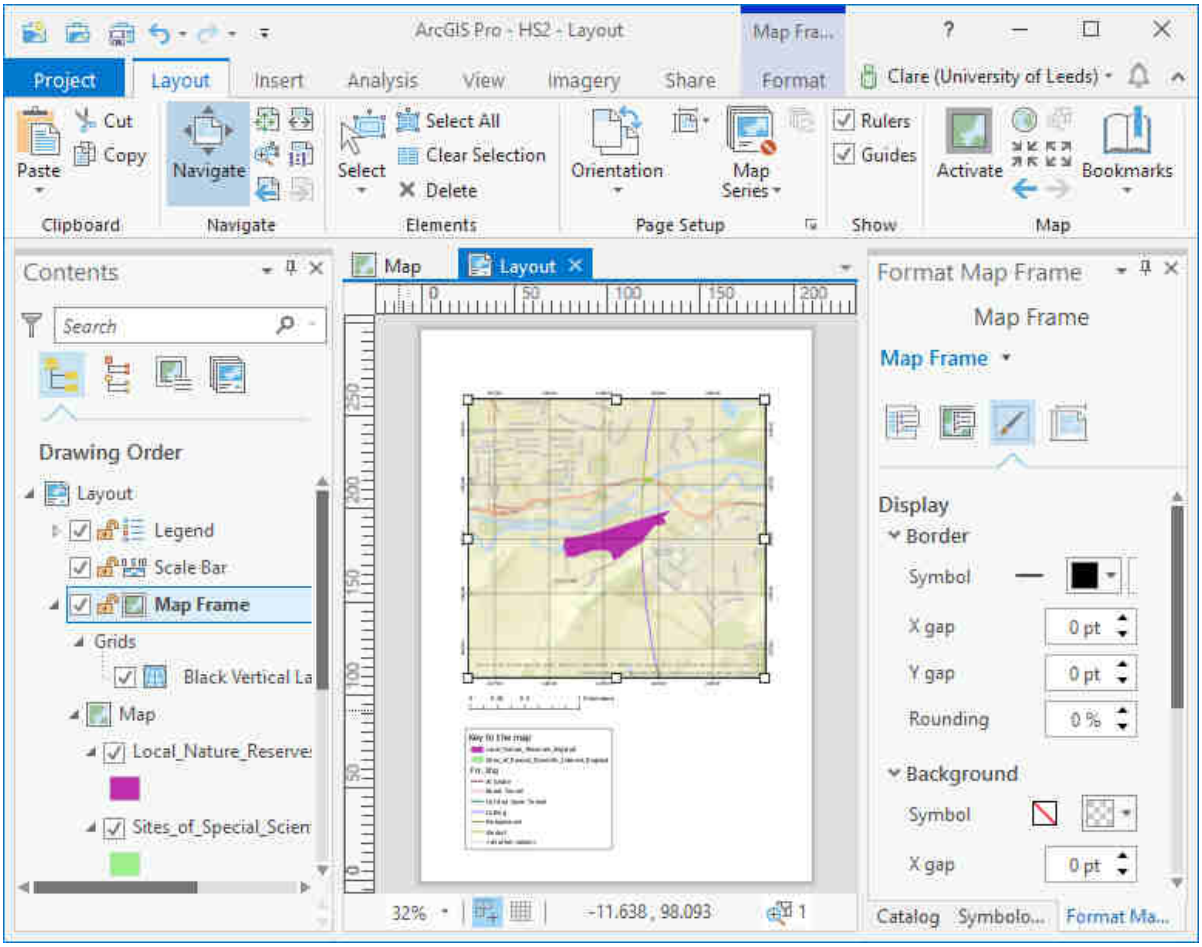


Figure 1.22: Layout view in ArcGIS Pro showing a layout with a single map frame.

The layout window (shown in figure 1.22) looks similar to the map window, but shows the layout as it will appear when printed. You still have the contents pane on the left of the screen and the ribbon at the top, but the ribbon will offer some different options.

- On the ribbon go to the **Layout** tab. Use the buttons in the **Navigate** group to zoom in and out of the layout and move around it.
- Try the tools in the **Map** group on the **Layout** tab in this view too.
- In addition you can open out the contents of the Map Frame in the Contents and **Zoom to Layer** on any of the layers just as you did in Map view (section 1.4 on page 2)
- To move the actual map, rather than the layout, you need to click on the **Activate** button in the Map group on the Layout tab. Once you've done that you can pan and zoom the area of the map using the mouse. Once you've finished click on the back arrow at the top of the Layout window to get back to the usual Layout view.

Question 1.8. What is the difference between zooming with the tools in the Navigate group of the Layout tab and with the tools in the Map group in layout view?

To get back to the original view use the **bookmarks** just as you did in section 1.5 on page 4. There should be a bookmark called **Denaby Wetlands** that you can click on. This shows a Local Nature Reserve that straddles the planned route.

1.14.1 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. I've already added a measured grid, a scale bar and a legend to this layout. You'll add a title and copyright text to this map but you'll learn more about layout in a later chapter.

Video Clip available in Minerva - Adding a scalebar, title and text to a layout.

To add text

To add text to your layout:

- Go to the **Insert** tab on the ribbon
- In the **Text** group click on **Text** then select the top option - **Text**
- Click on the layout somewhere close to where you want the text to appear (you can move it later!)
- Type the text that you want to add - for now type the text below as a title - then click elsewhere to come out of the text box.

> ***Denaby Wetlands Local Nature***
> ***Reserve and HS2 planned route***

Formatting text You're likely to want to change the default text option. There are books about cartography on the reading list which give more information about font choices, but for now use the instructions below to play around with the options.

- If you select the text that you've just added a **Format Text** pane should open on the right of the window.
- Click on **Text Symbol** to get options to change the text appearance.
- As with symbology the **Gallery** gives you preset choices, or go to **Properties** to set your own.
- Investigate the options to set the text that you've just added as a title at the top of the page.
- You can see what the style will look like at the bottom of the pane. Once you're happy with it click Apply to change the style of your text.

Copyright acknowledgement is important! Always check the terms and conditions for any data that you use. Most will tell you the wording that you should use - though it can take a bit of finding sometimes! The HS2 route and nature reserves data is under the Open Government Licence[7]. So add the text below to your layout. If you are using an ESRI basemap the acknowledgement for that will automatically be added to your map.

> ***Contains public sector information licensed under the Open Government Licence v3.0.***

There is more information about adding text and copyright acknowledgements in section 6.7.2 on page 89.

1.15 Printing or exporting a map

To **print** your layout:

- If you need to change the paper size and orientation use the tools on the **Layout** ribbon **Page Setup** group.
- To print go to the **Share** tab on the ribbon and click on the printer button in the **Print** group.
- Set up the printer as you would usually then click to Print.

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

- If you need to change the paper size and orientation use the tools on the **Layout** ribbon **Page Setup** group.
- To export go to the **Share** tab on the ribbon and click on the green arrow in the **Export** group.
- 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 Export

1.15.1 Suggested layout

Your final map could look something like figure 1.23. 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 next practical and will give you feedback on this exercise. If you have any questions about what you have done you can ask them at any time during the session.

1.16 Recommended reading: Introduction to GIS

Many of the books in the reading list[8] have a general introduction to GIS which explain what it is and how it is used. Suggestions include the following:

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

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

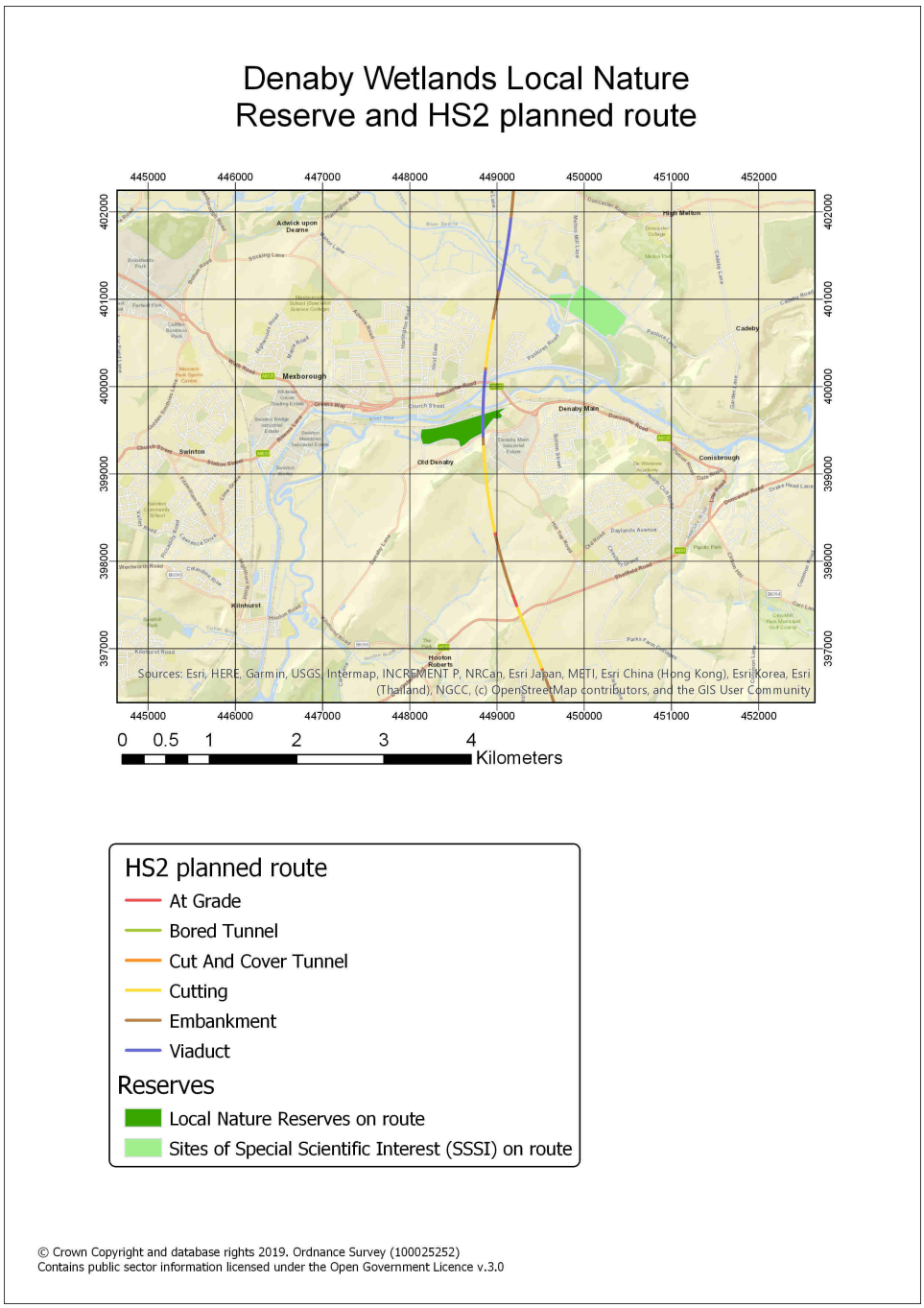


Figure 1.23: Possible layout for HS2 map. Your map probably won't look identical to this as you should make your own decisions about how to lay it out.

- 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 Arc 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.

1.16.1 Videos online

If you find videos helpful then search online for specific tasks in Arc. Make sure that you are viewing videos for ArcGIS Professional rather than Desktop, though.

Examples include:

Navigating ArcGIS Pro: The Basics Part 1 - `https://youtu.be/WDlUoDXQ_-o` - and other videos in the playlist from the University of Toronto Library

`https://youtu.be/soBtBP6aZ60` - quick start tutorials from ESRI which start with this video.

Data preparation for Chapter 2: 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 and prepare the following data before the next class. Full instructions are in the sections below.

- ***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 `CoordSystems.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.

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).

Shapefiles are a form of vector data storage. We'll mainly use geodatabases (more later…) for data that we create, but if you download data it is often delivered in shapefile format as that will work in most GIS software, not just ArcGIS. There are limitations on the format, which is why we're mainly using geodatabases, but the main one to remember is that a single shapefile actually consists of multiple files on disk with extensions such as `.shp`, `.dbf`, `.prj`, `.sbn` etc. If you're dealing with shapefiles make sure that you keep all of those files together or you won't be able to open the data in GIS.

Ordnance Survey Miniscale map of the UK

You will also use a general map of the UK which you can find in the `CoordSystems.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://on.doi.gov/2V1Af4x` 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 via Digimap and Open Government sources, 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 1.24 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 1.24 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.

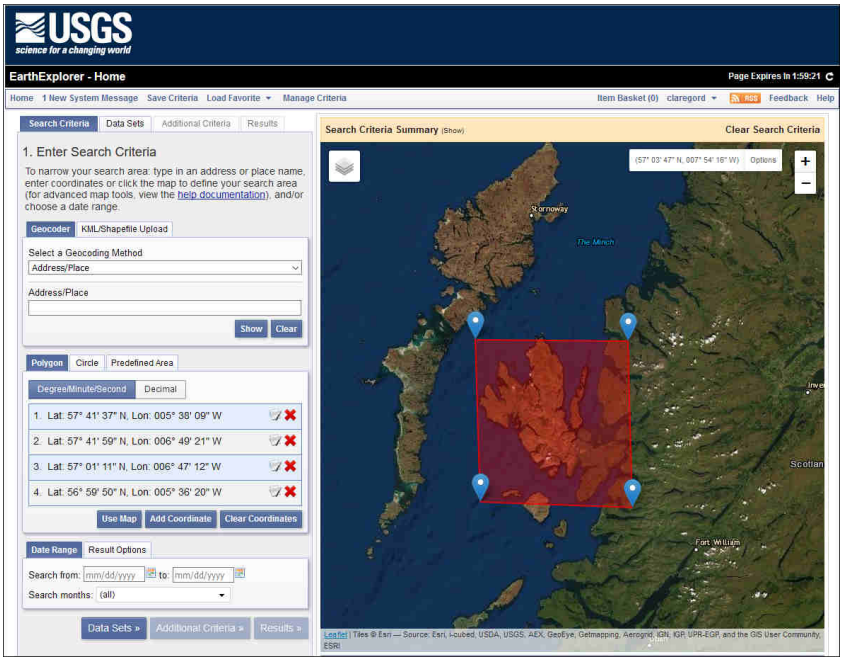


Figure 1.24: Selecting data in Earth Explorer - the area to enter to search for data for Skye

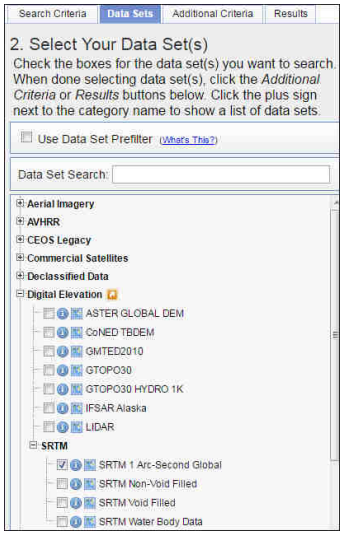


Figure 1.25: Selecting data in Earth Explorer - SRTM data choices

- For this exercise select **SRTM 1 Arc-Second Global** by putting a tick in the box next to it.
- 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 1.26 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 one tile of data covering Skye as shown in figure 1.26 and save it to use in the exercises in this chapter.

If you need to do multiple searches then click on **Clear Search Criteria** above the map. This doesn't always work, if it doesn't you have to close the browser completely and start again from scratch.

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

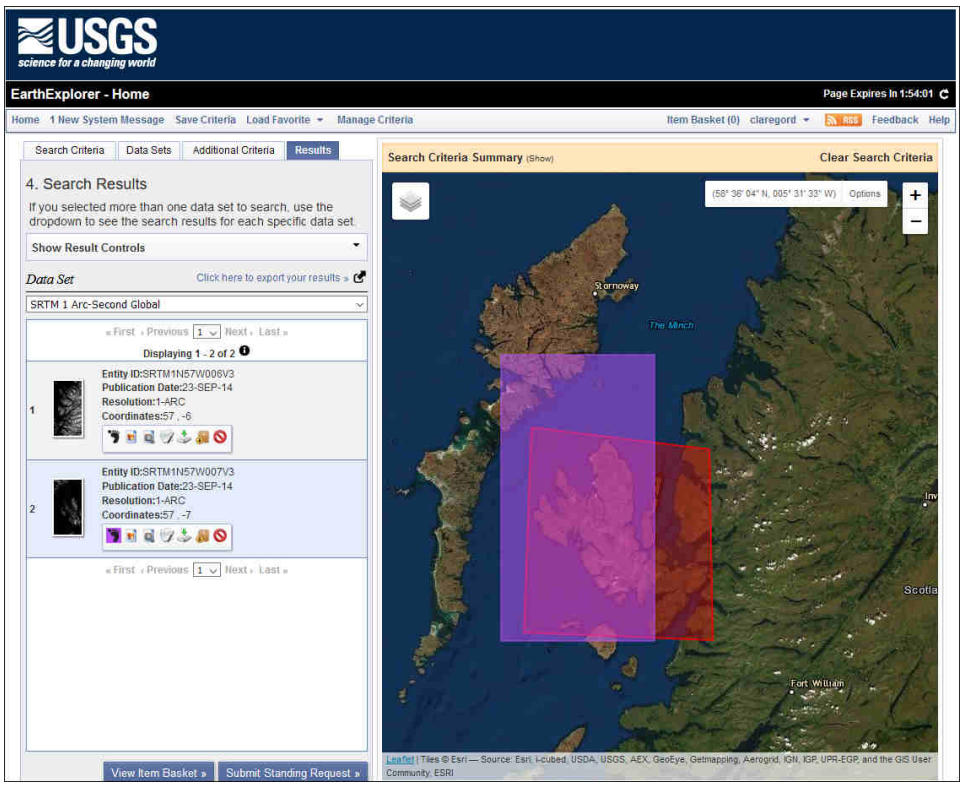


Figure 1.26: The SRTM results screen - showing the footprint of the SRTM tile to download for the Isle of Skye

Chapter 2

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

2.1 Learning outcomes

The background to coordinate systems and projections will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

When you have completed this chapter 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

2.2 Experimenting with coordinate systems

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

- You should already have downloaded `CoordSystems.7z` from Minerva and unzipped it. If not, do so now (instructions in table 1.1 on page 2).
- The folder in the unzipped data should also be called `CoordSystems`. This is an ArcGIS Pro project. Open the `CoordSystems` map in the same way that you opened the sample map for chapter one in section 1.3 on page 1

You should find that you have a map of the World open in Arc that looks like figure 2.1.

If you find that your map doesn't show, and that you have the red exclamation marks next to the data as in figure 2.2, follow the instructions in table 2.1 to repair the data links.

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

[1] URL last visited 29/8/19

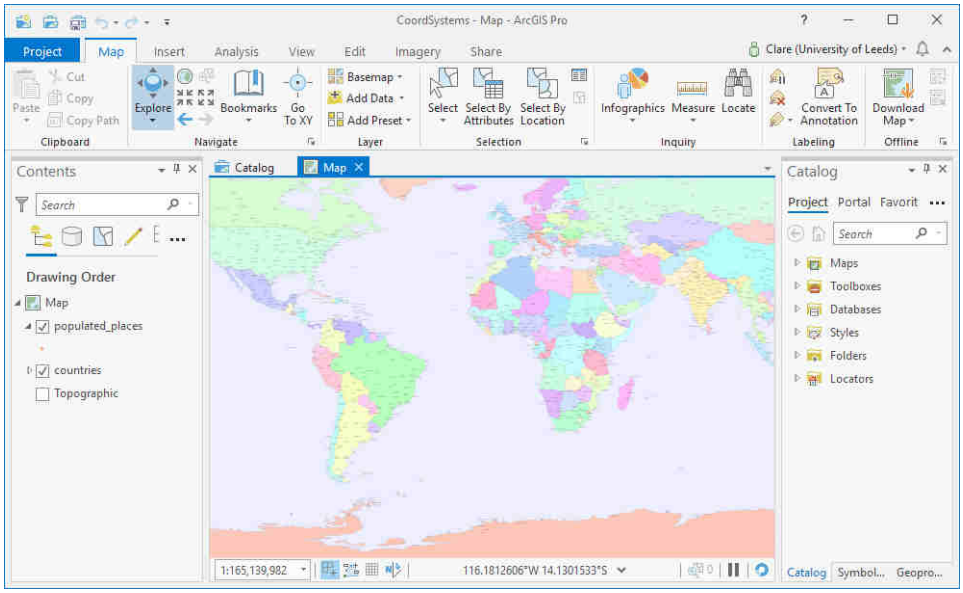


Figure 2.1: The map for the first exercise in chapter 2

Repairing broken file links

If you use absolute file paths and you have to move the files from one location to another, or if you have a project folder set up by someone else, you may find that the broken links are marked by a red exclamation mark next to the layer name (as in figure 2.2). This can also happen if you are adding .lyr files for symbology.
To check the name of the file that you'll need to locate:

- Open the layer properties and go to the Source tab
- Under **Data Source** you will see which file Arc is looking for - see figure 2.3

Once you know where the file you need is located, do the following to repair the link:

- From the layer properties source tab
- Set Data Source...
- Navigate to the file that you need OK > OK.

If you're lucky all of the missing layers will appear, but if you're not you'll need to repeat the process for each layer.

Table 2.1: Repairing broken file links

2.2.1 Finding out the map 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 **Map properties**.

- Right-click on the **Map** subheading in the contents pane
- Select **Properties**
- Click **Coordinate Systems** on the left of the properties panel - see figure 2.4

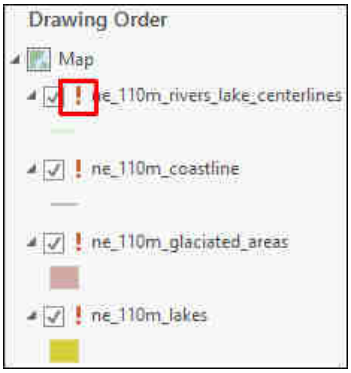


Figure 2.2: The red exclamation mark showing that the links to the data for these layers is broken

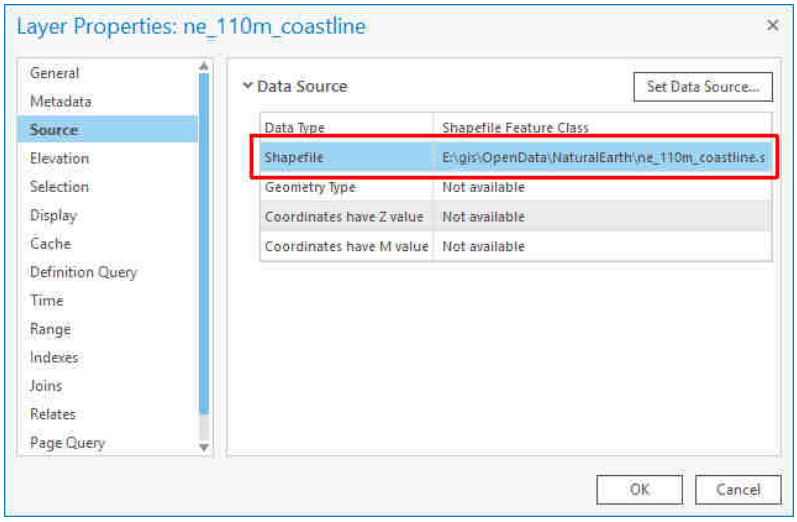


Figure 2.3: The Layer Properties for the missing layer, showing where Arc is actually looking for the data. Note the file name - this is what you need to look for in your file system.

Video Clip available in Minerva - Repairing broken file links.

The Coordinate System tab gives you information about the current setting, including its name. It also shows the coordinate systems of the layers in the map. In this project the layers called **populated_places** and **countries** both have the same coordinate system as the map. The layer **Topographic** is in **WGS 1984 Web Mercator Auxiliary Sphere**.

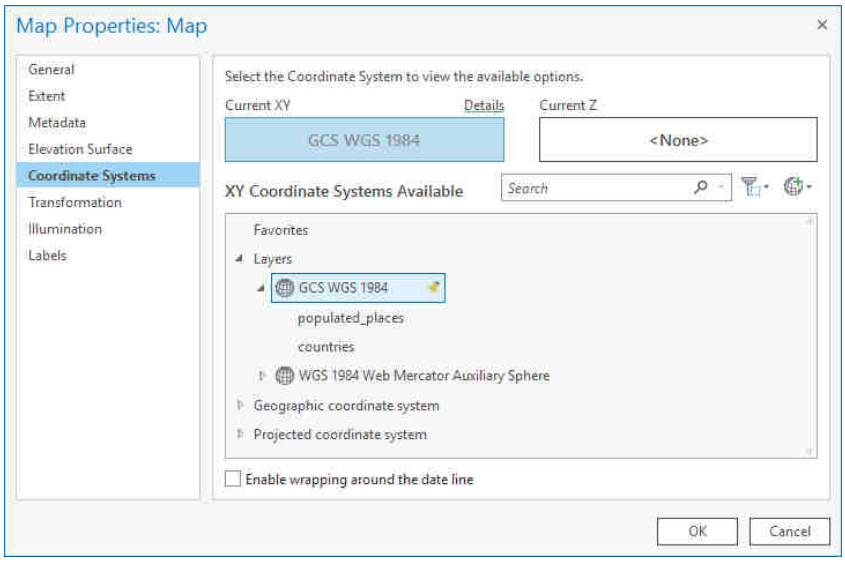


Figure 2.4: The coordinate systems information in the map properties

Question 2.1. What is the coordinate system of this map? Write it below. Do you think that it is a Geographic Coordinate System or Projected Coordinate System, and what makes you think that it is one or the other?

- Click OK to close the properties box for now.

2.2.2 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 in the **Inquiry** group on the **Map** tab of the ribbon.

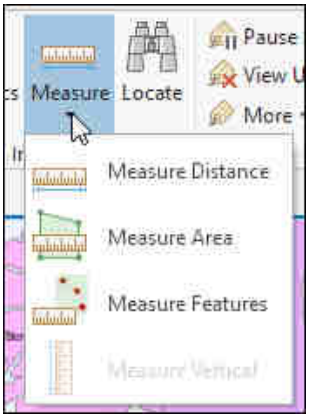


Figure 2.5: The measure tool on the ribbon

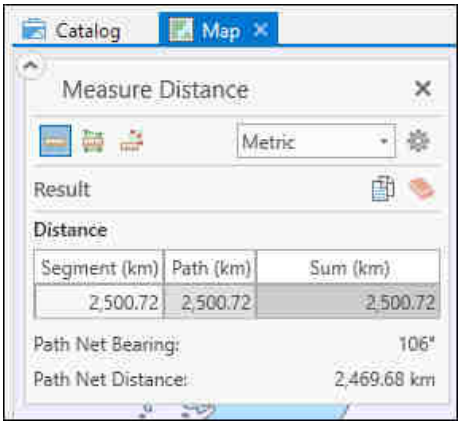


Figure 2.6: The options after you've started to measure a line distance

The tool gives you a choice between measuring distance, area or a particular feature. Once you click on the down arrow underneath tool you get an option box so that you can change the unit measurement, and clear the previous measurement - figure 2.6. This box also shows the results of your measurement.

Video Clip available in Minerva - Using the Measure Tool in Arc.

Zoom in to the map until you can see city names. Use the Measure Distance tool to measure the distance from London to Istanbul (figure 2.7), double-clicking to finish your measurement.

Question 2.2. Write the distance that you come up with in the box below. What units have been used for the measurement? You may need to go into the options to find out.

Figure 2.7: London to Istanbul - using the measure tool

- Click on the **Clear results** button on the options box.

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.

2.2.3 Changing the map coordinate system

To change a coordinate system

- Right-click on the map title (right at the top of the table of contents - it's probably called **Map**) and select Properties
- Select the **Coordinate System** tab
- Browse to the required coordinate system in the **XY Coordinate Systems Available** box, for example browse to `Projected Coordinate Systems` ▸ `World` ▸ `Azimuthal Equidistant (world)` then click OK
- Zoom to **Full extent**[2] to have a look at the map, then zoom back in to make the suggested measurements

Fill in table 2.2 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 Features tool). Don't forget to include the units that you are using - check the selections in the Measure tool window.

[2]Remember this is a button on the Map tab of the ribbon.

Table 2.2: Distance and area measurements in various projections

Projection	London to Istanbul	Area of Algeria
Azimuthal Equidistant (world) - `Projected Coordinate Systems▸World`		
Cassini - `Projected Coordinate Systems▸World`		
Aitoff (sphere) - `Projected Coordinate Systems ▸ World (Sphere-based)`		
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 so look rather odd for other areas, e.g. the British National Grid for Great Britain.

Question 2.3. Looking at the results in table 2.2 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[3] 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.

When you've finished this section close ArcGIS completely.

2.3 Using coordinate systems: Setting up your project

For this next exercise you will be using the data that you downloaded before the class and exploring what you need to do when your layers have different projections to each other - a situation that is very likely to occur. This exercise should show the importance of understanding coordinate systems and how they work in ArcGIS.

2.3.1 Starting a project from scratch

For this exercise you'll need to set up the project for yourself from scratch.

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

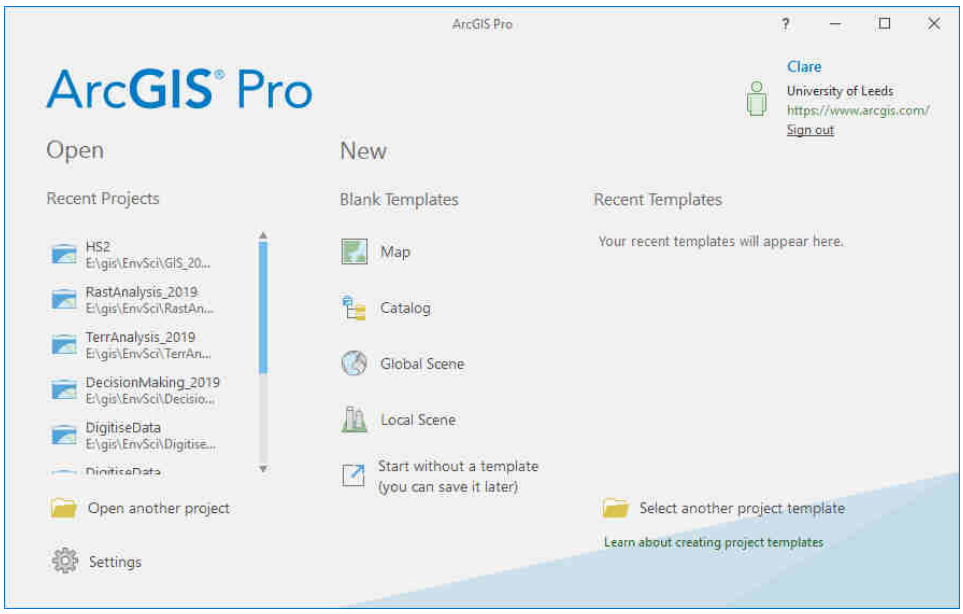


Figure 2.8: The start screen when you open ArcGIS Pro

- Open ArcGIS Pro by searching for it in the Windows start menu. Make sure that you open **ArcGIS Pro**, not any other version of Arc!
- You should get a start screen which looks something like figure 2.8. Though your recent projects will be different.
- Under **Blank Templates** pane click on Map
- You'll get a dialog box which you should fill in as follows:
  - For the name enter the name of the project - so in this case something like **Projections**
  - For the location navigate to the folder where you want to store the project. You can use the default setting if you want to or click on the folder icon to navigate to another location
  - Check that **Create a new folder for this project** is ticked
  - Click OK to create your new project

ArcGIS Pro creates the new project folder and sets up the component parts automatically. As you are working on your projects make sure that you save all of your data into the project folder so that it all stays together even if you move the project to another drive, e.g. by backing it up to a USB stick.

Open out some of the subheadings in the Catalog pane. You should see that Arc has created some empty content for you. Most notably a geodatabase for data storage with the same name as your project, e.g. Projections.gdb. This geodatabase will have a little house icon on it to show that it's the "home" geodatabase.

You should find yourself with a familiar screen. Arc will have set up a map view and added a topographic basemap, which will show a default area.

2.3.2 Adding your downloaded layers to the map

Add the three layers that you've already prepared in section 1.16.1 on page 26 to the map that you've just created, by dragging and dropping them from the Catalog pane[4] to the contents pane in the order below.

You may need to **Add a Folder Connection** to be able to find the files - remember instructions for this are in table 1.3 on page 10.

Add the following layers in the order shown below:

1. European River Catchments
2. SRTM height data for Skye, off the West coast of Scotland
3. Ordnance Survey miniscale map of the UK - this may not show up when you add it, don't worry about that for the moment

We'll worry about storing these layers in your project folder later.

2.3.3 Map layers from the ESRI Portal

ESRI Portal is a fantastic resource of maps and data that you can add to your own maps. Follow the instructions below to download the additional data that you need for this exercise, but it's also worth having a look at what else is available to you.

- Go to the **Catalog** pane on the right of the window (if it isn't visible you need to go to View › Catalog pane on the ribbon to open it).
- Click on the **Portal** heading, then click on the button for **All Portal** - remember there are tool tips if you hover over buttons
- Search for **rivers Europe** in the search box. If you can't find it under All Portal try clicking on **Living Atlas** and searching again.

You are looking for a layer with yellow symbol - see the layer under the mouse pointer in figure 2.9. 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** which should appear a short way down the results.

- You can see more information about the layer and a preview by hovering over it.
- Right-click on the title to **Add to current map**. (If you don't already have one open you can click to **Add to new map**.)

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.

[4] If the Catalog pane isn't visible you need to go to View › Catalog pane on the ribbon to open it.

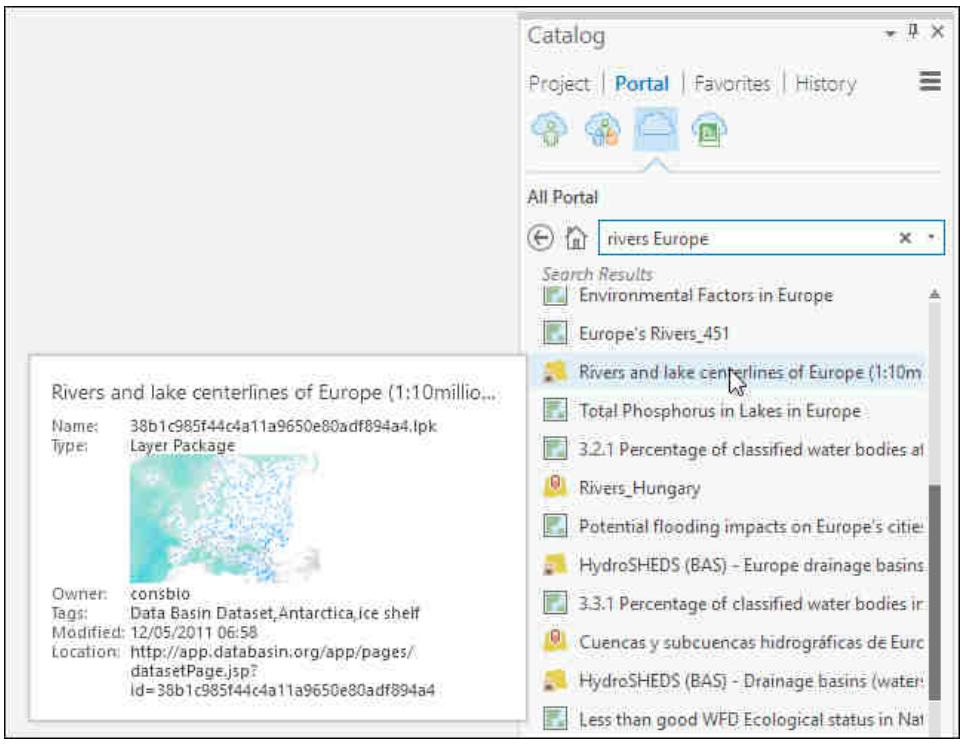


Figure 2.9: Searching for data in ESRI Portal

2.3.4 Export a vector layer to your project folder

To export a vector layer to a location and format of your choice, so that all of your data is in one place and within the project:

- Right-click on the rivers and lake centerlines layer in the table of contents then Data > Export Features and the **Geoprocessing** pane should open on the right of the window - see figure 2.10
- the input features should be set automatically to the layer that you right-clicked on, or select it using the buttons on the right
- select a location to save the new feature class by clicking on the folder icon next to **Output Feature Class** and navigating to the geodatabase that has the same name as your project, but an extension of `.gdb`
- Give your output feature class a name, e.g. **RiversEurope** - note no spaces or unusual characters.
- Run

Arc should add your new layer to your map. It's good practice to **Remove** [5] the original version of the layer to keep your contents tidy.

Repeat this with the **European River Catchments** layer. This and the Rivers layer are both **vector** layers and are best stored in a geodatabase.

2.3.5 Export a raster layer to your project folder

To export a raster layer to a location and format of your choice, so that all of your data is in one place and within the project:

[5] section 1.7.8 on page 12 if you need a reminder of how to do this

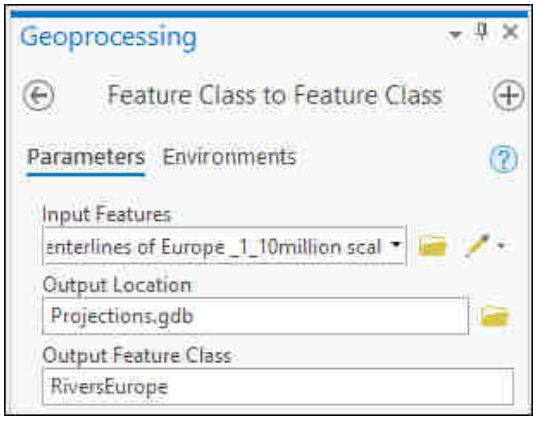


Figure 2.10: Exporting or copying features from one feature class to another

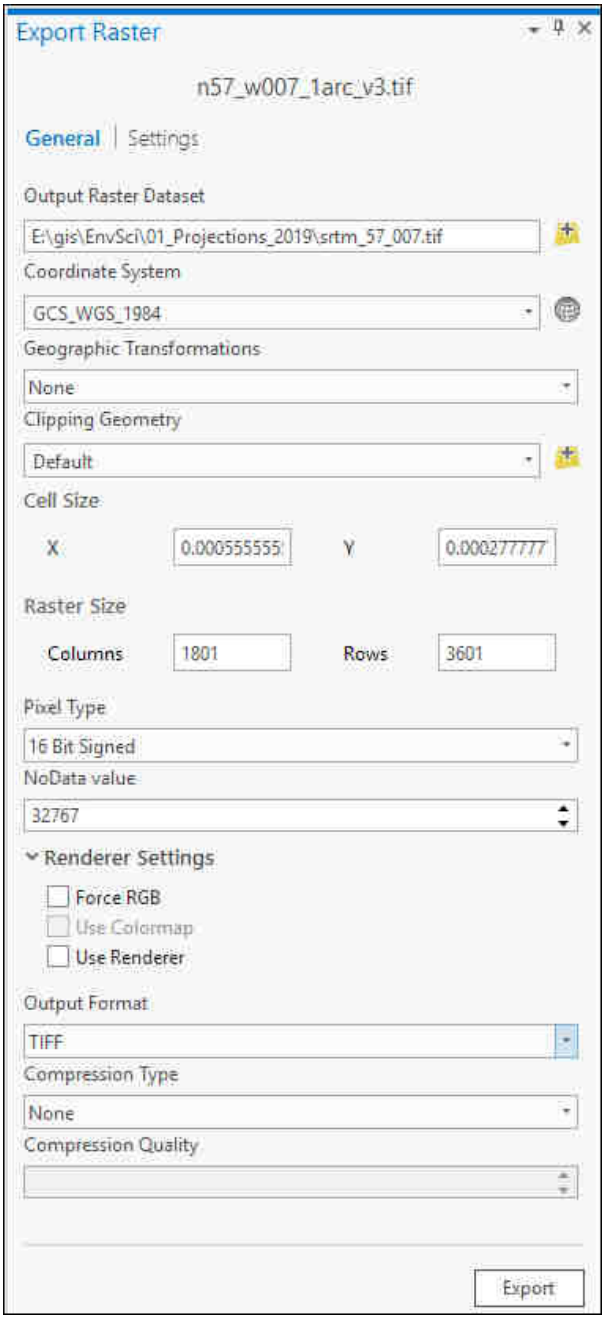


Figure 2.11: Geoprocessing panel for Export Raster

The dialogs for the **raster** files are a bit more complex.

- Right-click on the SRTM layer in the Contents pane then Data > Export Raster and the **Geoprocessing** pane should open to the right of the window - see figure 2.11
- select a location to save the new raster by clicking on the folder next to **Output Raster Dataset**. This doesn't have to be in the geodatabase but can just be in the project folder.
- Check that the other settings match the figure, though the defaults should be fine in this case. You can check settings like cell size and Pixel Type by looking at the **Properties** of the original layer.

- Click Export

Arc should add your new layer to your map. **Remove** [6] the original version of the layer to keep your contents tidy.

2.3.6 Copy a raster layer to your project folder

The Miniscale layer is basically a coloured background raster rather than a layer used for processing. In this case the simplest way to get it into your project successfully is to use the Catalog pane to copy and paste the file from the original folder to your project folder then add the copy to your map.

Once you are sure that you have all of the data you need safely stored within your project, you can go ahead and delete the original data from the default location, or wherever you saved it, to save space. Space can become an issue as you do more GIS!

2.4 Working with coordinate systems in Arc

The data frame is set to the coordinate system of the first layer to be added, which in this case will have been the original **European River Catchments** layer. If the coordinate systems don't match Arc will try to project the subsequent layers "on the fly". This usually looks fine - your layers should line up - but isn't ideal if you are going to do analysis or measurements and in this case you'll need to decide what coordinate system you need to work in and change all of your data to that.

Start by deciding what coordinate system you want your final map to appear in - in this case we'll aim for:

British National Grid

To check the coordinate system for the current map go to the **Properties** by right-clicking on the **Map** heading in the Contents pane, going to the **Coordinate systems** tab and checking the **Current XY** box.

Write the coordinate system of the map in the box below:

Arc sets the map to the coordinate system of the first layer to be added to the map. So in this case it should be set to **ETRS 1989 LAEAS L52 M10**, not British National Grid.

Check the coordinate system for each layer by looking at each layer properties and make a note of each one in the table 2.3.

To find the coordinate system in the layer properties:

- right-click on the layer
- go to **Properties**
- click to look at **Source** and scroll down and expand the **Spatial Reference** heading.

Question 2.4. Write the coordinate system of each layer in the table below.

[6] section 1.7.8 on page 12 if you need a reminder of how to do this

Table 2.3: Projections for European region map

Layer	Projected coordinate system	Geographic coordinate system
Miniscale map of the UK		
ArcGIS portal rivers layer		
European river catchments		
SRTM height layer		

The full answer is in the appendix at the end of the workbook, but you should find that each layer has a different coordinate system, and that not all are projected, but one layer, the Miniscale layer, has spatial reference as **Unknown**

The layers that have a proper spatial reference should all appear in the correct location with regard to each other - thanks to Arc's "on-the-fly" reprojection, but **Zoom to layer** on the Miniscale layer - because the spatial reference is **unknown** this layer has ended up at latitude **0**, longitude **0**, somewhere close to Africa.

Given that you need to be able to display all of your layers correctly, **and** in future exercises will need to use data for analysis, the rest of this chapter will look at how to project and reproject data from one coordinate system to another.

2.4.1 Defining projections

You should have found that the projection of the Miniscale layer is **Undefined**. To be able to display it and use it with other data you need to use the **Define projection** tool to project it. The challenge here is that you need to know what the original projection was - you can't just project it to anything. This can take a bit of detective work.

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

- Open the toolboxes by clicking on the **Analysis** tab of the ribbon, and then on **Tools**. The toolbox should open in the right-hand panel. You may need to click on the **Toolboxes** tab to see the full list (figure 2.12).
- Data Management Tools > Projections and Transformations > Define Projection
- If you know what tool you want to use you can type it's name into the **Find Tools** search box instead.
- Select the Miniscale file for the **Input Dataset**

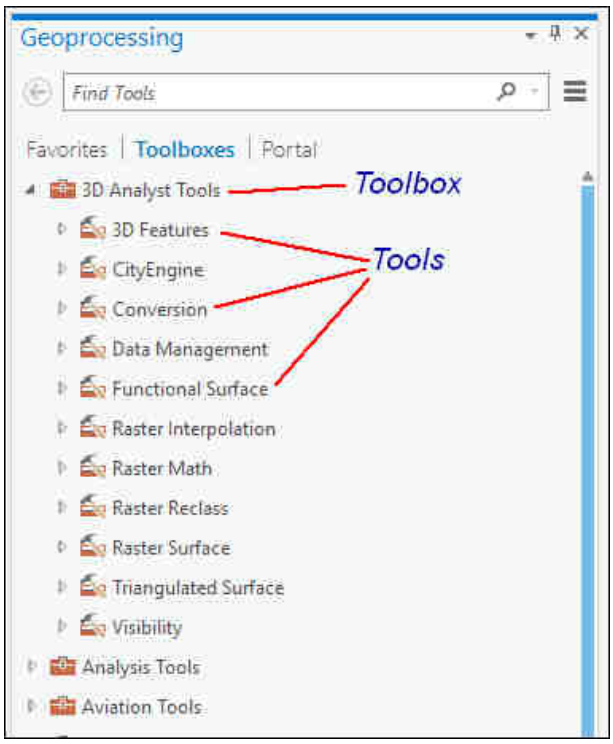


Figure 2.12: Geoprocessing toolboxes and tools

- Select British National Grid for the Coordinate System by clicking on the button to the right of the **Coordinate System** field and going to Projected Coordinate System › National Grids › Europe › British National Grid › OK
- then Run the tool

You probably won't see any difference immediately, but remove the Miniscale layer from your map, then add it back in again, and this time it should appear in the right place. Also check the projection by going to the layer properties. This time it should say British National Grid.

2.4.2 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.

Transformations work on the underlying datum so to change from a projection using the ETRS 1989 datum to British National Grid, which is the OSGB 1936 datum, you'll need to apply a transformation such as `ETRS_1989_To_OSGB_1936_OSTN15`. Preset transformations do this for you, with lots of underlying complicated maths.

When you start reprojecting data you will have a choice of **transformation** to apply to it. In many cases the default will be fine, but be aware that sometimes you will have to choose one for yourself.

There is more information about projections and transformations on the web pages at `http://epsg.io/`

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 2.4: Choosing a transformation

2.4.3 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 as each other and the map.

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 in section 2.4.1.
- You need to know whether your data is vector or raster[7]
- You need to know which coordinate system and datum you want your data to be in.

Video Clip available in Minerva - Reprojecting a feature class with the geoprocessing toolbox

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

- Geoprocessing » Data Management Tools » Projections and Transformations » Project
- Fill in the dialog box as in figure 2.13
  - selecting an appropriate location and name (maybe just add "BNG" to the end of the existing name) for your projected layer
  - and setting the **Output Coordinate System** as British National Grid
  - the **Geographic Transformation** should be set automatically, accept that for now[8]
- then Run the tool.

Follow the same steps for the other vector layer - the European River Catchments. This time the Geographic Transformation maybe different - probably something like **OSGB_1936_To_ETRS_1989_1**, but don't worry if it isn't!

[7] If you are still unsure about the differences between vector and raster formats remember that you looked them up in a dictionary in section 1.9.1 on page 15. Remember also that this will come with experience! You can also check the items on the reading list for more information, e.g. Heywood or Longley, or the Ordnance Survey video at `https://youtu.be/hbOGp51nYGI`

[8] There is more information about geographic transformations in the ArcGIS Help at `http://bit.ly/2zxiBvA`, or look in items on the reading list, such as Heywood or Longley.

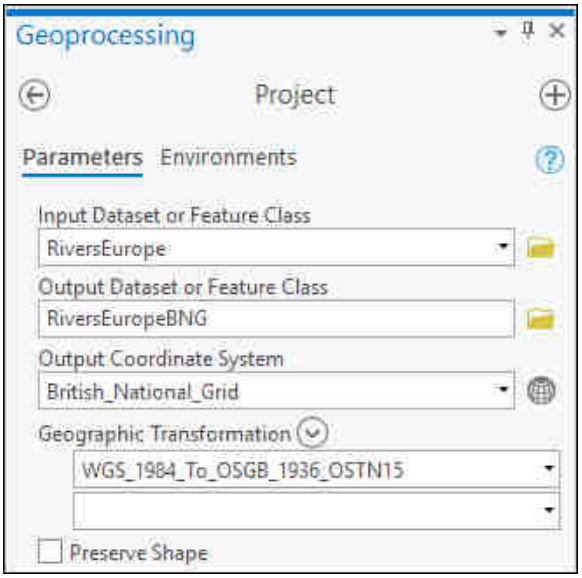


Figure 2.13: Project tool for vector feature layers

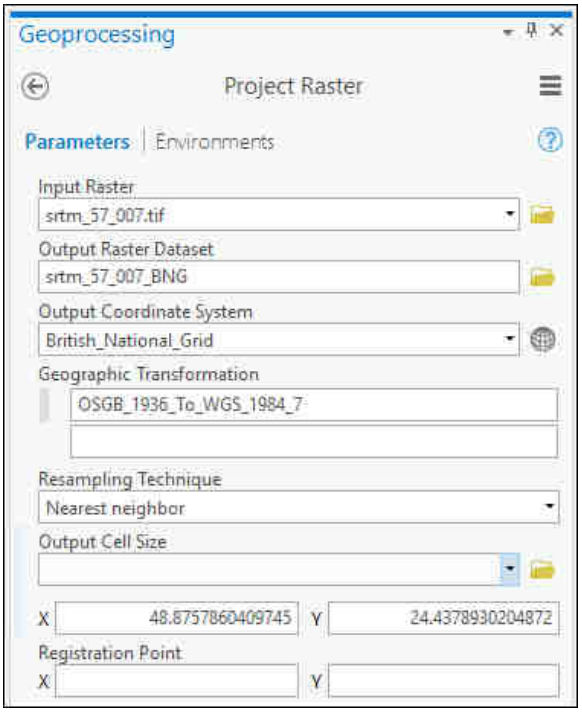


Figure 2.14: Project Raster tool for raster layers

2.4.4 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

To change an SRTM raster tile to British National Grid you'll also need to **project** it, but using a different tool to the vector layers.

- Tools > 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 the SRTM tile - see figure 2.14.

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.
- Run the process (this may take some time...)

It isn't necessary to repeat this for the Miniscale layer as that is already in British National Grid.

2.4.5 Creating a new map in British National Grid

Hopefully now if you look at the properties for each of the projected layers they will all be in British National Grid.

Now it's time to create a new map and add all of the projected layers to that.

- To create a new map within your current project go to the **Insert** tab of the ribbon and click on **New Map**
- Go to the map properties - right-click on the map title, which in this case is probably something like **Map1**
- Go to the **General** tab and under **Name** give the new map an informative name, e.g. **Rivers - British National Grid**.
- while you're here it's worth changing the **Display units** to **Meters**, which makes more sense than Decimal Degrees for a map in a projected coordinate system
- OK to close the properties. Note that it's now easy to see which map is which on the tabs at the top of the map.
- Add all four of your reprojected layers, that is the ones in British National Grid, to the map by dragging and dropping them from the Catalog pane. It shouldn't matter what order you add them in.

Check that the whole process has worked by going to the map properties again and looking at the **Coordinate Systems** tab. If you look under **XY Coordinate Systems Available** and drop down the **Layers** subheading, you should be able to find all four of your layers under **British National Grid** - as in figure 2.15.

If your properties look like figure 2.15 then it has all worked OK. If any of your layers (except the basemap layer added by Arc by default) are not under the British National Grid heading then you need to look back at the previous instructions and check that you followed them correctly.

2.5 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 2.16 on page 48 which you could use as a reminder each time you have data to load into GIS.

Video Clip available in Minerva - Summary of defining projections and projecting data in GIS.

You will be provided with another exercise to practice projecting and transforming your data as this will be an important area to understand before you move onto further analysis.

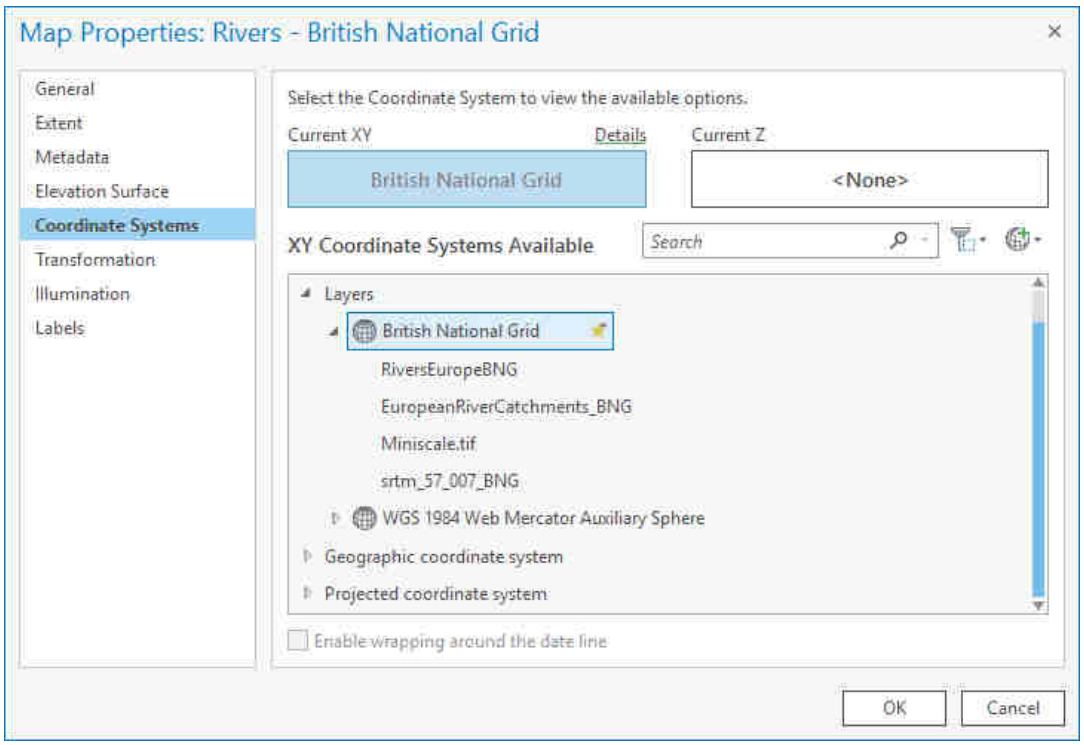


Figure 2.15: Checking that all of your layers have been successfully projected to British National Grid. Your layer names may be different.

2.5.1 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.

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)[9] and follow her instructions to work it out for yourself.

2.5.2 Define Projection

If the coordinate system is **Undefined** you first need to define it (see section 2.4.1 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.

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

2.5.3 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 2.4.4 on page 44) or vector (see section 2.4.3 on page 43).

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.

2.5.4 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.

2.6 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[10].

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.

2.6.1 Links to more information online

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

The article at `http://bit.ly/2Q2ooC6` on **Projection on the fly and geographic transformations** is a useful guide to how and why you need to use transformations.[11]

2.6.2 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`

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

[11] Last visited: 9th March 2020.

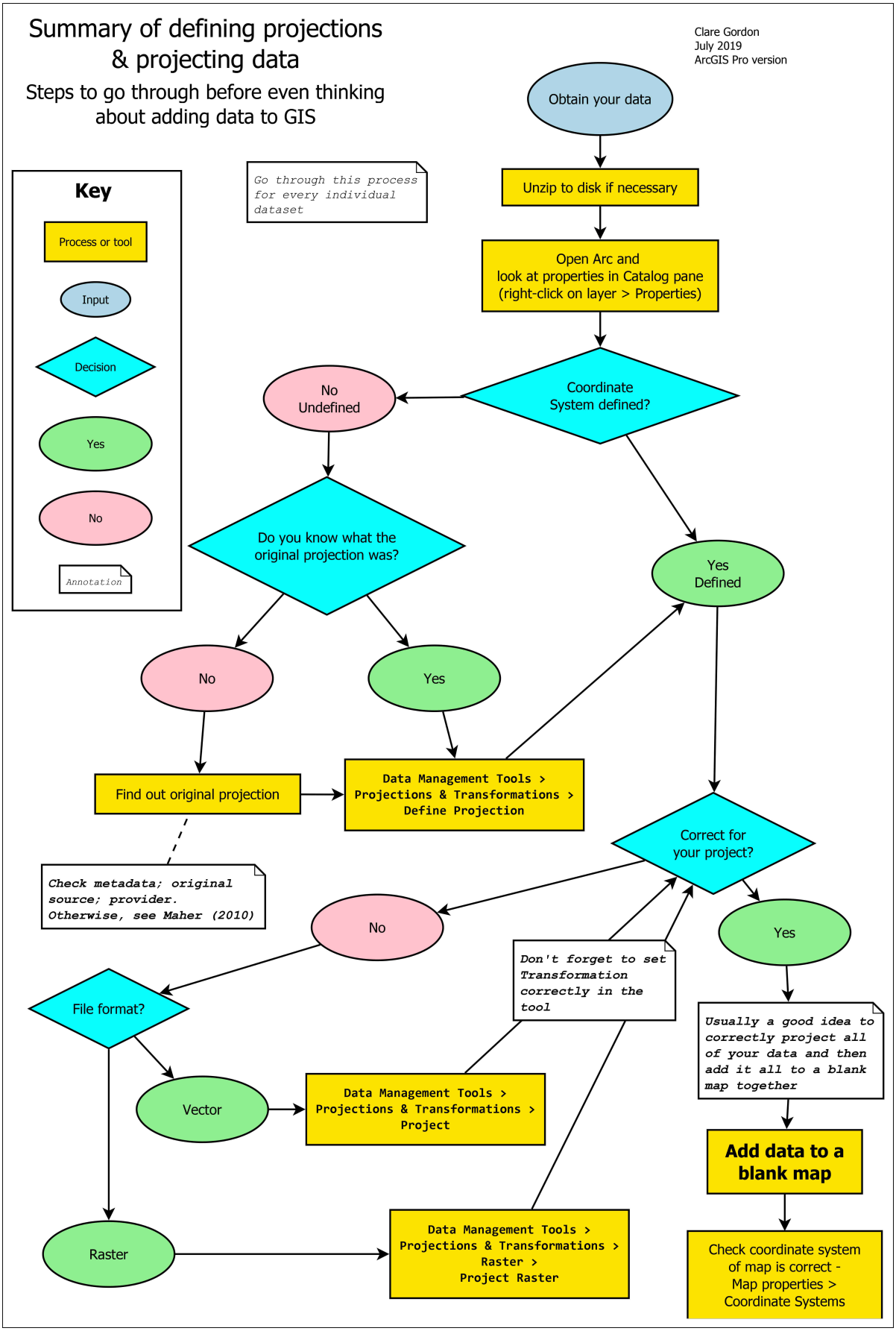


Figure 2.16: Summary showing the decision process and actions necessary to prepare data for GIS

Chapter 3

Digimap

The background to using Digimap and an explanation of what you need to do will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

3.1 Learning outcomes

When you have finished this chapter of the 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

3.2 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.

3.3 Logging in to Digimap

3.3.1 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.)**

3.3.2 Logging in

To log in go to the Digimap Collections page (figure 3.1) at

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

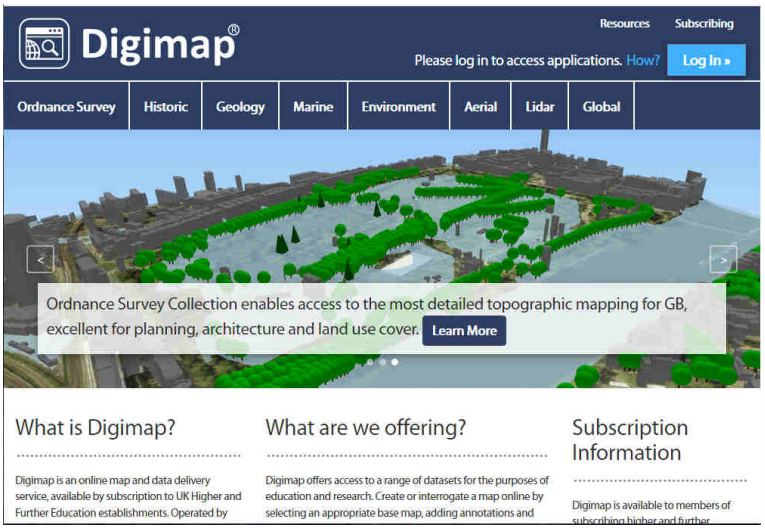


Figure 3.1: Digimap initial page

- 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 3.2), but this time with your name at the top right.

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!

[1] as of September 2018

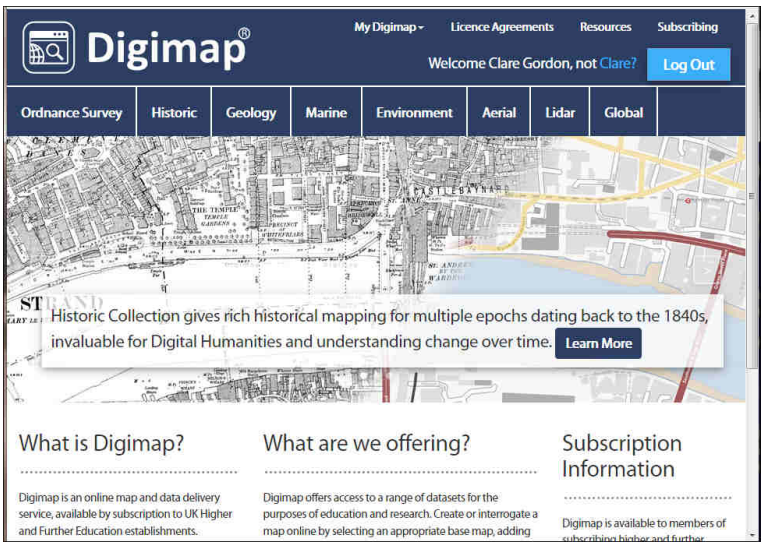


Figure 3.2: Choosing a data collection

3.4 Ordnance Survey Collection

We are going to start by looking at the **Digimap - Ordnance Survey Collection**. (Figure 3.3.) 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 3.3: 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.

3.4.1 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.

Overview

Digimap Roam enables you to view and print maps using Ordnance Survey data at various predefined scales. PDF prints can be created in A4 or A3 size and landscape or portrait orientation. See figure 3.4 for an annotated overview of the Roam window.

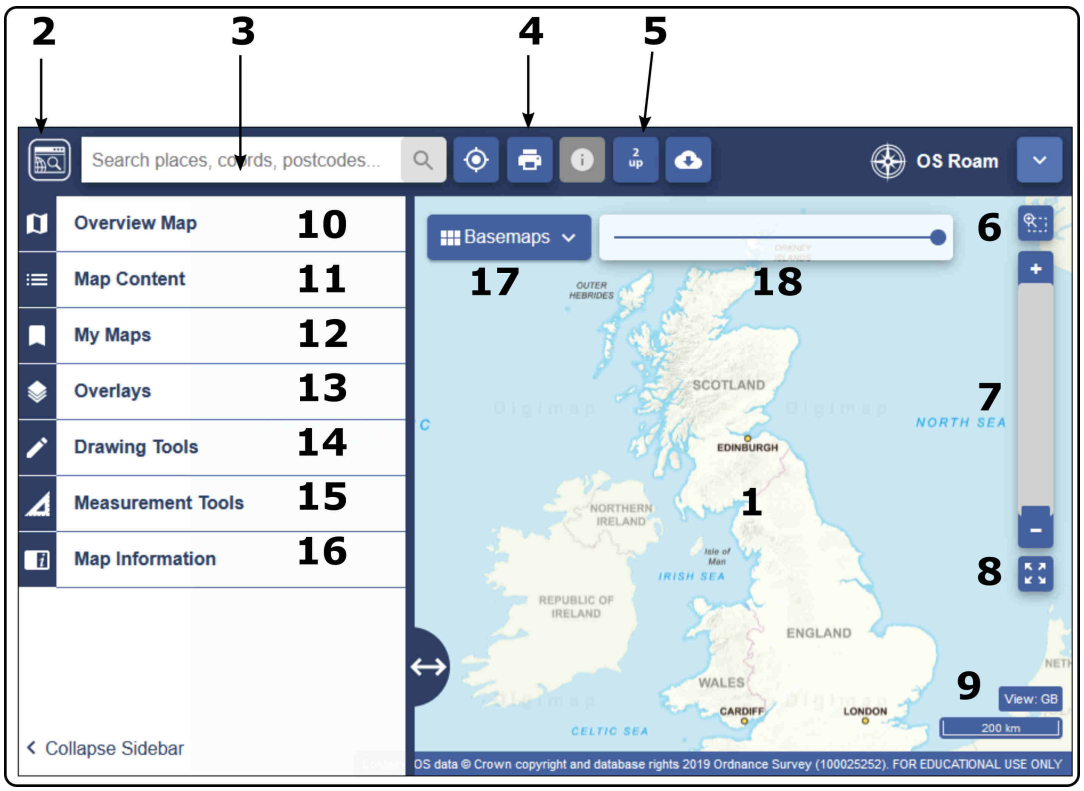


Figure 3.4: The Digimap Roam window

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 3.5. Click the place name that you are interested in to view it in the map window - in this case click on **Leeds (Leeds)**.

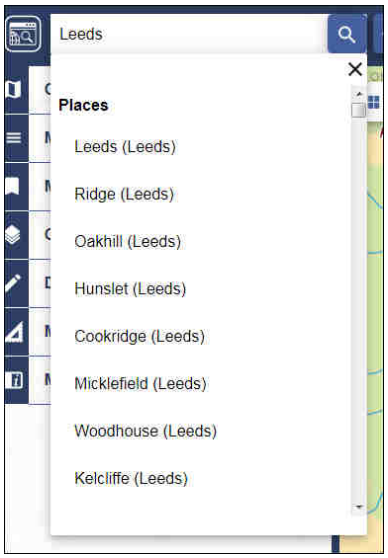


Figure 3.5: Search box and results of a search for "Leeds"

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 3.6
- 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 un-checking 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!

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.

Question 3.1. Name some other view and basemap combinations besides Neighbourhood >> VML Streetview that allow you to select content?

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

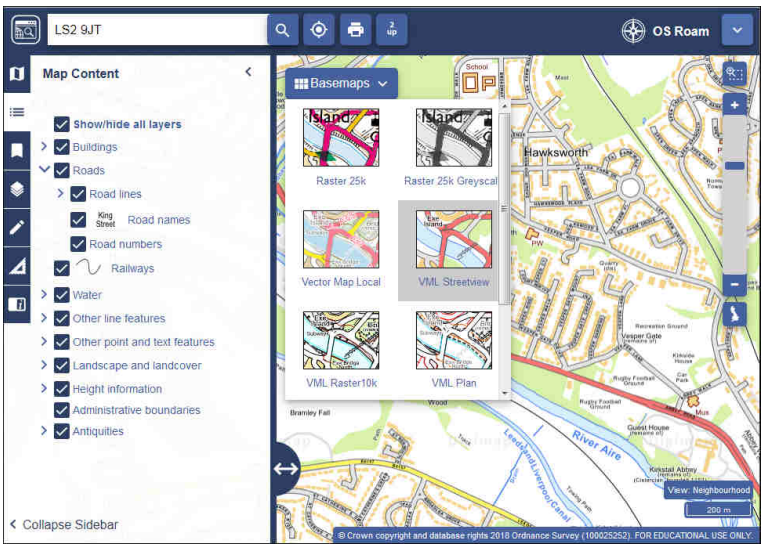


Figure 3.6: Choosing a basemap in Neighbourhood view in Roam. Note the tickboxes next to the features for the VML Streetview basemap.

Using the measuring tools

Roam provides tools for measuring distance and area.

- Click on Measurement Tools on the sidebar to open them (figure 3.7).
- 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.

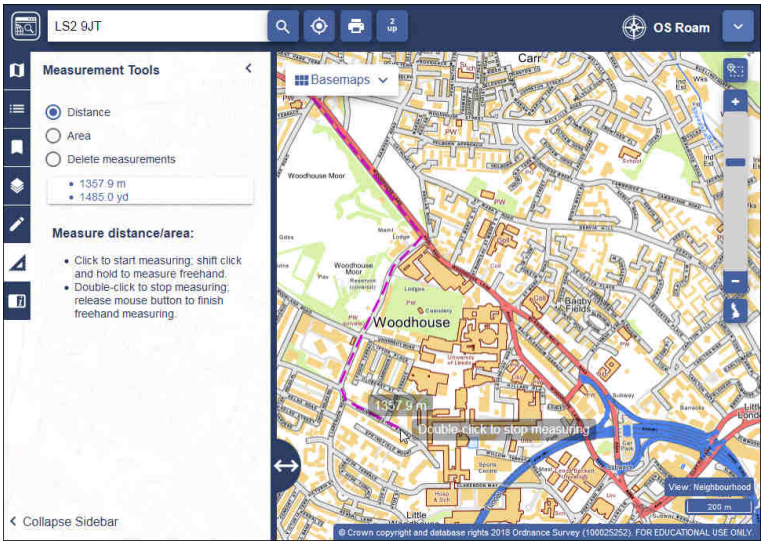


Figure 3.7: Measurement tools - click on the map to start measuring, double-click to stop

Question 3.2. 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 3.3. 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.

- Click the **Print icon** at the top right to open the print options in a new browser window (figure 3.8).
- 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 3.6 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 3.9.

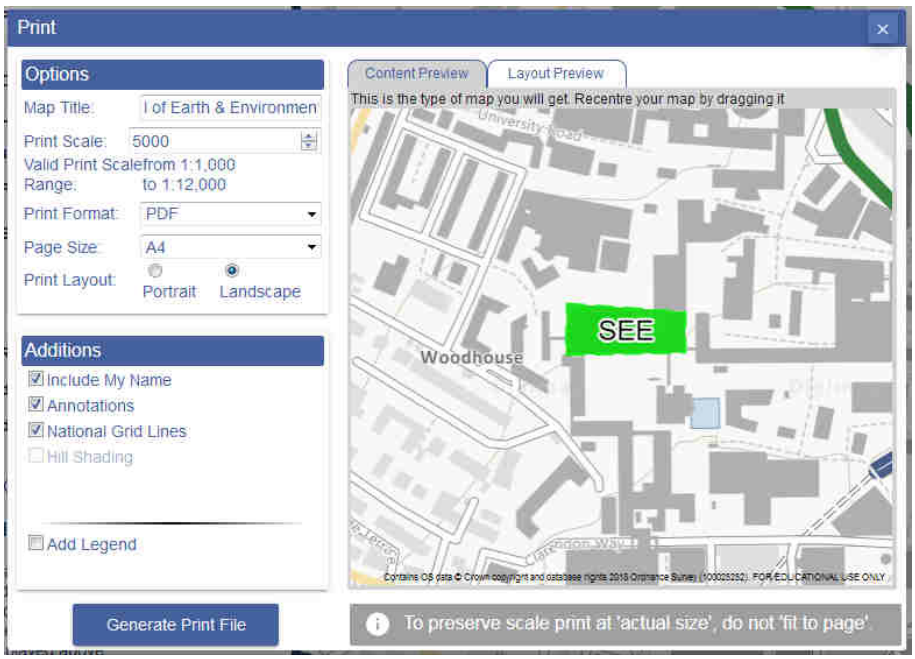


Figure 3.8: Printing to pdf or image file from Roam

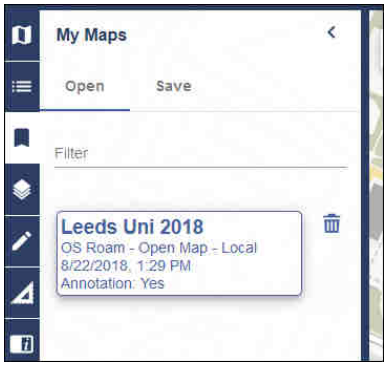


Figure 3.9: My Maps

3.4.2 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 3.10.)

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

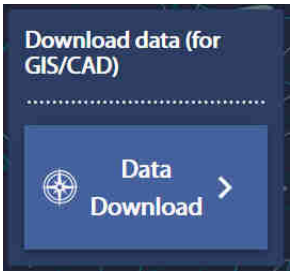


Figure 3.10: Data Download

Figure 3.11: Search for & select an area

Selecting an area

On the left there is a menu panel with options for selecting an area with a search box above it (figure 3.11).

- 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 3.12)

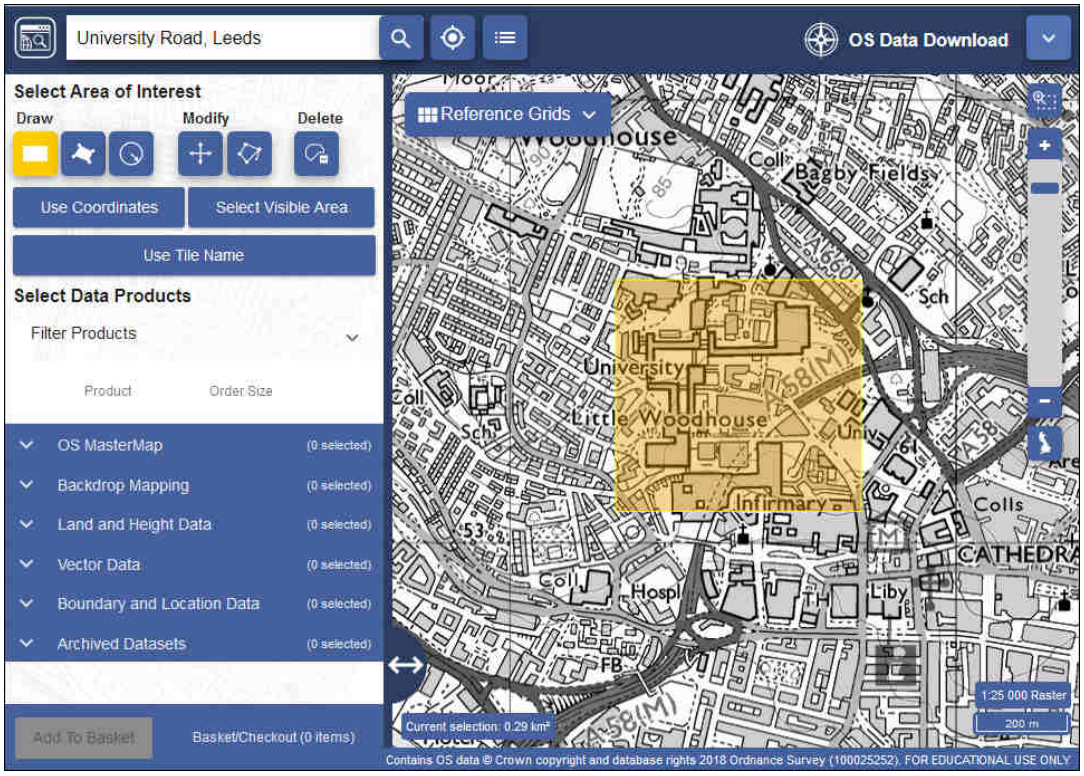


Figure 3.12: Selecting an area in Digimap Download

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.

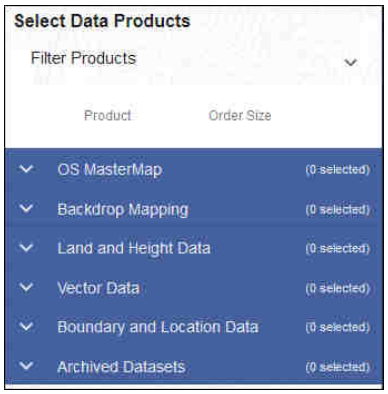


Figure 3.13: Select products from the list

- Back in the panel on the left, under **Select Data Products**, drop down each of the headings in turn. (Figure 3.13.)
- 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.

> ***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 3.14.)

- 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!

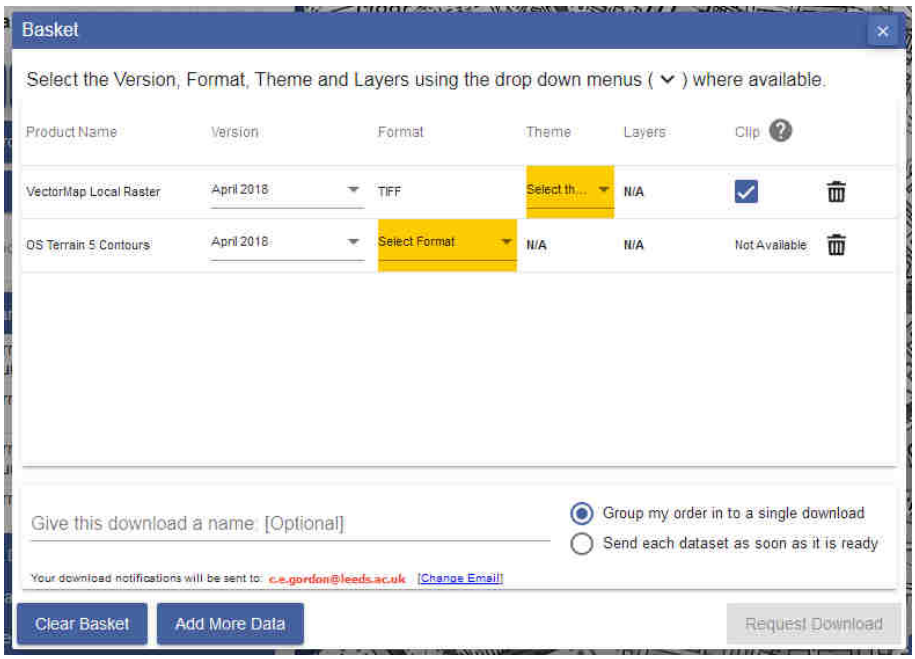


Figure 3.14: Details of your order in the Basket

- 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 3.15).

Figure 3.15: The download link in the email - click on this not on any of the other links in your email!

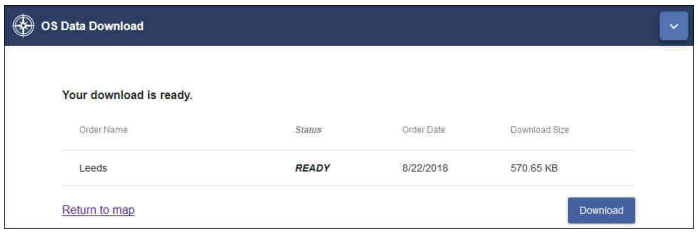


Figure 3.16: Order ready to download

Once you have clicked on the link a window should open telling you that your order is ready to download (figure 3.16).

- 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.

3.5 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.

3.5.1 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 3.17

Note that the imagery isn't available to browse at all zoom levels. Look at the bar on the right of the window (figure 3.17) 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.

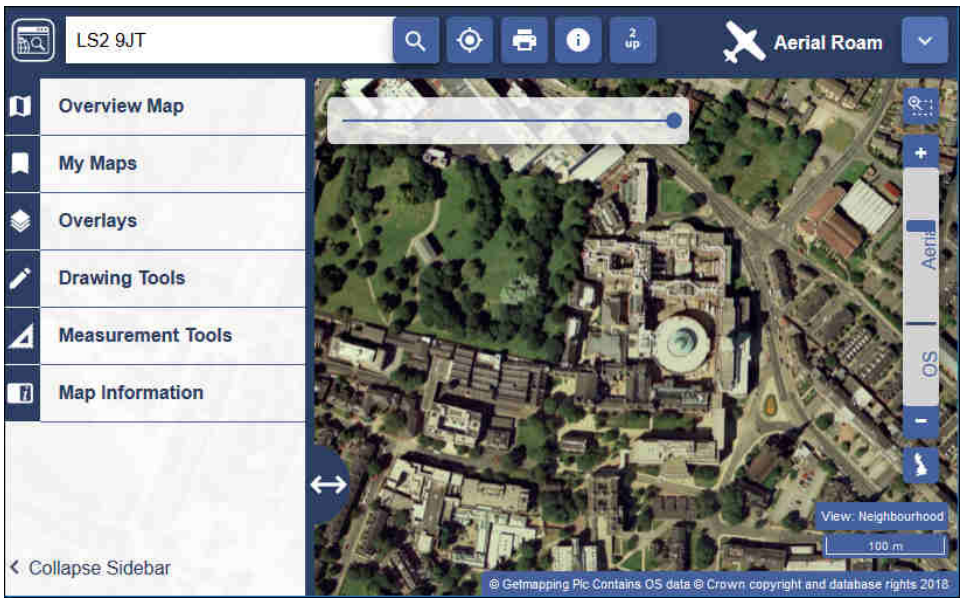


Figure 3.17: The Aerial Roam window

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 3.18

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.

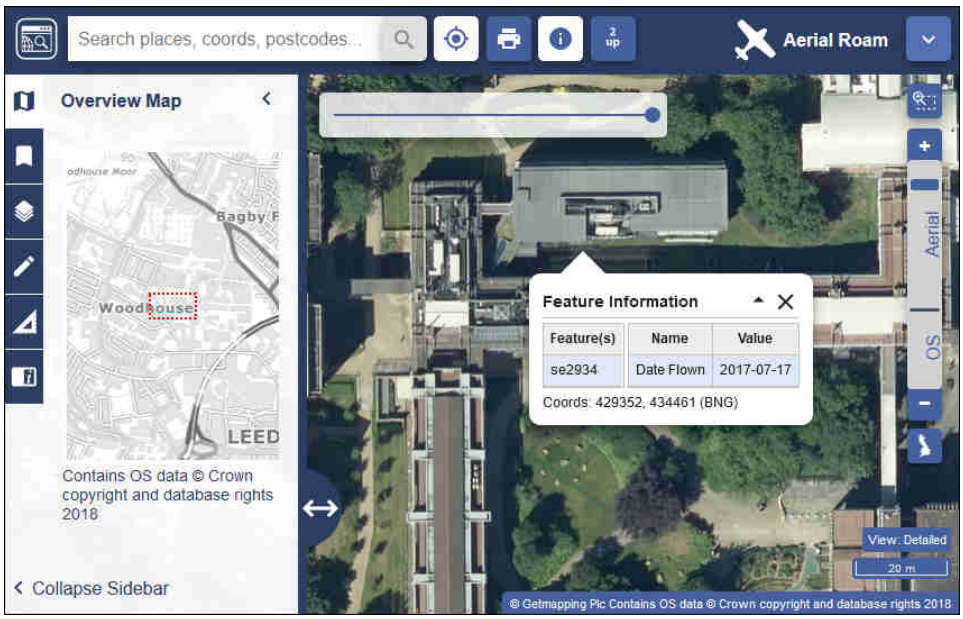


Figure 3.18: Information about the tile of aerial imagery, including the date that it was flown

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

- ***289576, 812418***

Question 3.4. 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?

3.5.2 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.

3.6 Printing and editing PDF files

3.6.1 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]

3.6.2 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.

[4] Last accessed: 17th September 2019.

3.7 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.

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 3.1: 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] Last viewed: 18th September 2018

3.8 Further help with Digimap

3.8.1 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.

3.8.2 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.

3.8.3 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 4

Coordinate systems: practice in projecting data

4.1 Introduction

This is an optional exercise. It is designed to give you more practice in working with coordinate systems and projections, a skill you will need for both of the assessments as well as the exercises in the workbook. It will not be covered in the practical sessions and you do not have to do it, but if you want to work through it and need help with the exercises you can work on it in any of the drop-in classes, or come to my office during the week.

Often the most challenging part of a GIS project is finding and adding data to the map so that it all fits together. In the first assessment you will need to put together several different data sets and then do further analysis. If the data sets don't all have the correct coordinate system before you do the further analysis then you will struggle to carry it out successfully.

4.2 What do you need to do?

This exercise is designed to give you practice in projecting data by adding the included datasets to a map.

You should aim to project/reproject all layers to **British National Grid** so that they all appear in the same position on the map. Once you have processed all of the layers provided you should open a new map and add your layers to that. The final map should have the spatial reference system set to **British National Grid**.

Refer to the instructions in the Coordinate Systems, Projections and Transformations chapter of the workbook (chapter 2 starting on page 30). Remember there is a summary and chart in section 2.5 starting on page 45, and there is a video clip available in Minerva.

Be aware that even if the layers appear to be on top of each other you still need to check their projection - don't just rely on "on-the-fly" projection. That causes problems if you're carrying out further analysis on your data.

4.3 Data provided

Files within each folder give more details of where the data was obtained from.

- **Copernicus** grassland layer for the area surrounding the Bristol Channel
- **Corine** land cover layer for the area surrounding the Bristol Channel
- **getmapping_rgb_25cm** - two tiles of aerial data for the north of Weston-super-Mare
- **OS_OpenMap_Local_Raster** - two tiles of raster mapping for the north of Weston-Super-Mare
- **OS_OpenMap_Local_Vector** - vector layers for the tidal boundary, tidal water and foreshore of the Bristol Channel
- **Sentinel** - real-colour data from the European Sentinel satellite
- **SPOT** - data from the SPOT Earth Observation Satellite

4.4 Target projection

You should end up with a map and layers ALL projected to

```
British_National_Grid
```

4.4.1 Useful information

The web page at `http://epsg.io/` can be a useful source of information about projections and transformations.

Don't forget about Arc Help. The page at `http://bit.ly/2HIn42X` gives a lot of useful information about coordinate systems and projections.

Check the module reading list and the links in the workbook for more help.

4.5 Checking the final result

Add all of your British National Grid layers to a new map within your project.

All of the layers should now lie on top of each other. In addition check the properties of the map to check that it looks something like figure 4.1 with all of your layers listed under **British National Grid**, apart from any ESRI Basemap that you have loaded which will be WGS 1984 Web Mercator Auxiliary Sphere.

4.6 Conclusion

If you've worked through all of the layers and everything appears to have worked, then congratulations, if you were working on a project or assessment you would be ready to move on to the analysis. For this particular exercise you have completed it and should return to the next chapter in the workbook.

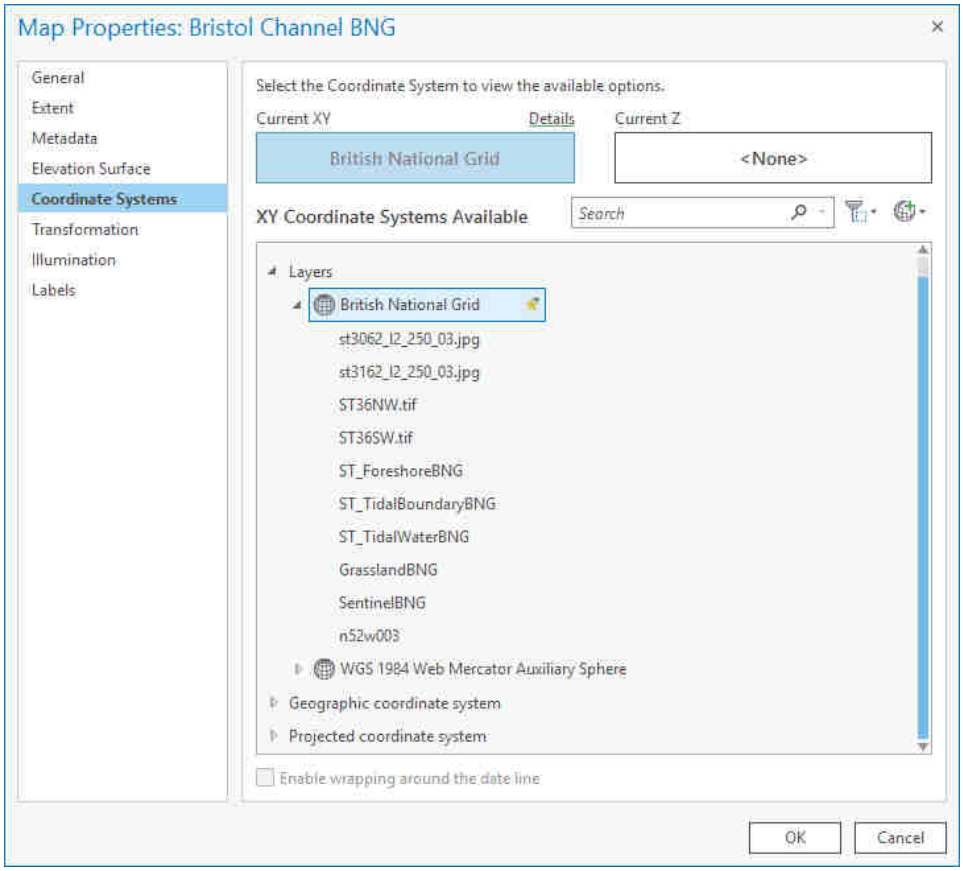


Figure 4.1: The map properties showing that all of the layers are now projected to British National Grid

Chapter 5

Creating data for GIS: Digitising

5.1 Learning outcomes

The background to digitising and storing data will be covered in the lecture segment of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

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

- Explain what a geodatabase consists of and why it is used to store GIS data
- Set up storage for GIS data
- Use the tools in GIS to draw (digitise) your own data

5.2 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 Arc 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 Pro Help.

5.3 Obtaining the background data

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

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` As you deal with more GIS data you'll start to find it easier to spot which formats are raster and which are vector, but you need to be thinking about it already.

You should have a folder containing data and an ArcGIS project file. Open the `.aprx` file in ArcGIS Pro by double-clicking on it and when it finishes opening check that the links in the contents pane 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.

5.3.1 Set up a feature dataset within a geodatabase

The first thing you need to do is to create the containers for your data. When the project was set up Arc automatically included a **geodatabase** within it. The geodatabase is the overall container for your data and will store **feature datasets** and **feature classes**. You've already worked with feature classes in previous chapters. These are vector layers which can hold points, lines or polygons. A feature dataset can contain a range of related feature classes.

See figure 5.1 for an example of what your Catalog will look like when it is fully set up.

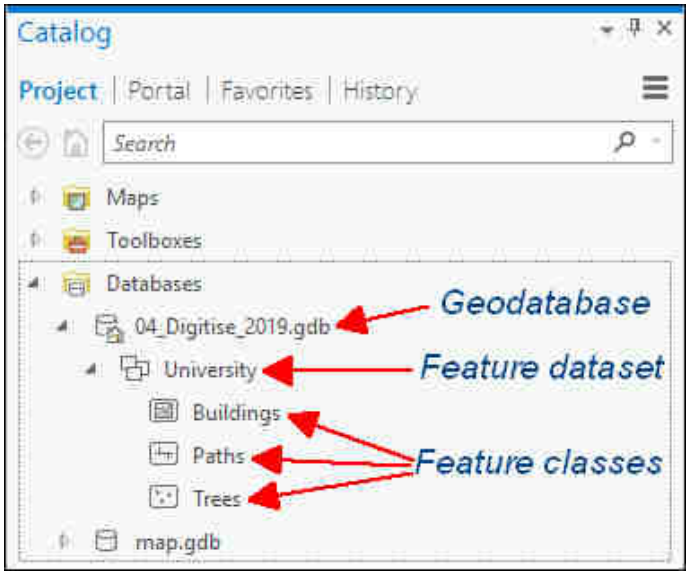


Figure 5.1: The fully set up geodatabase in the Catalog pane

- In the Catalog pane go to the **Databases** subheading and open it out. There will be a geodatabase with the same name as the project / folder
- Right-click on your geodatabase
- New > Feature Dataset

[1] If you get the red exclamation marks showing that the data links are broken follow the instructions in table 2.1 on page 31 to repair them.

[2] This is aerial data from Digimap.

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

5.3.2 Set up a feature class

Still in the catalog pane

- Right-click on the feature dataset that you've just set up (in this example the one called **University**
- New > Feature Class
- Fill in the geoprocessing dialog that opens as shown in figure 5.2
  - Give your feature class a name that explains what it shows - with no spaces or punctuation, e.g. in this case **Buildings**
  - The **Feature Class Alias** is the name that will appear in the contents pane - this can include spaces
  - Choose the correct **Geometry Type** - it's important to get this right as it isn't possible to change this once you've created the feature class. For the buildings layer select **Polygon**
  - If you are storing the feature class in a dataset which already has a spatial reference set you shouldn't need to fill that in again.
- If you click on Next you'll get an opportunity to add fields and other information, but don't worry about this for now.
- Click Finish to create the new feature class

The feature class should be added to your feature dataset, and also added to the contents pane of the map that is open. If it isn't automatically added to the contents pane just drag and drop it across.

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

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

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.

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

5.4 Digitising in ArcGIS Pro

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

- To start editing simply click on the **Edit** tab of the ribbon.

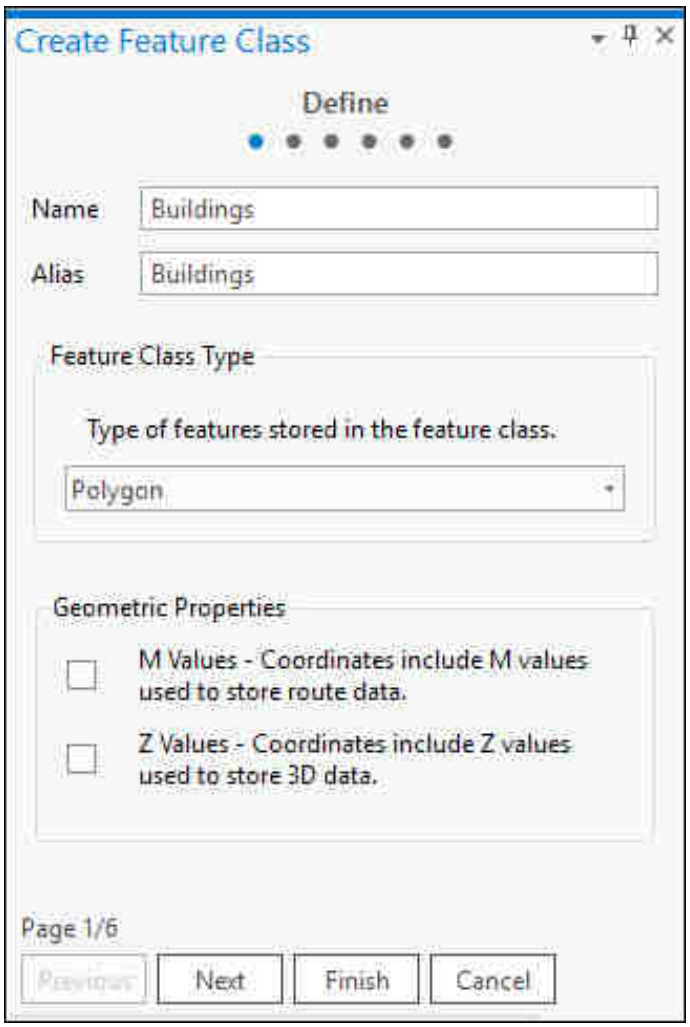


Figure 5.2: The geoprocessing form to create a feature class. Double check that the **Geometry Type** is filled in correctly each time as you can't change it later!

Video Clip available in Minerva - Digitising in Arc Part 1: Starting and finishing, and creating polygon features.

- Click on the **Create** button in the **Features** group
- A **Create Features** pane should open on the right-hand side of the window showing the editable layers in your map - see figure 5.3
- Click on the **Buildings** layer and select the **Polygons** tool - the one on the left. As usual if you hover over icons you'll get a tooltip.

Now you're already to start adding a feature. We'll start by digitising the School of Earth and Environment (SEE) by drawing an polygon around it on the aerial view. So start by zooming in to the building.

- To create a polygon left-click along the edges of the building. Each click creates a **vertex**, or corner.

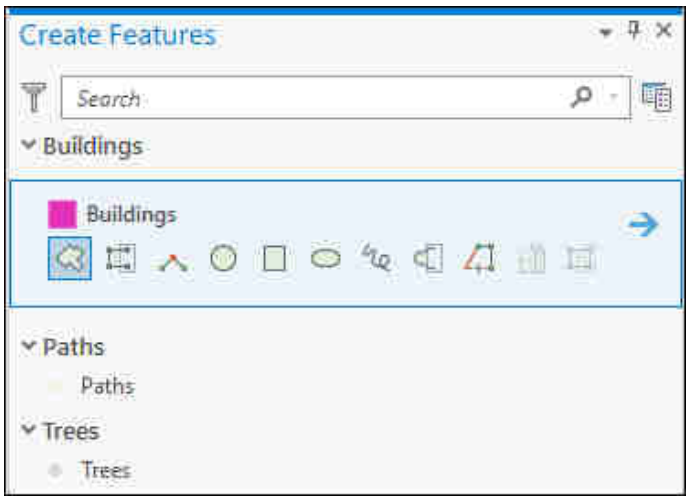


Figure 5.3: The Create Features pane showing editable layers

- To finish a polygon double-click on the last point or press the F2 key on the keyboard. The polygon should be outlined by the selection colour, e.g. turquoise, once you've done this.
- You can continue straight on to digitise another building if you wish to but remember to save your edits regularly - see next point
- To save your edits click Save on the Edit tab of the ribbon. If you don't want to save your edits click Discard instead.

It is important to save your edits on the Edit toolbar - they are not being stored in the map, but are being written to the external feature class that you have set up. If you closed Arc without saving the edits, even if you save the map, they wouldn't be there next time you opened it.

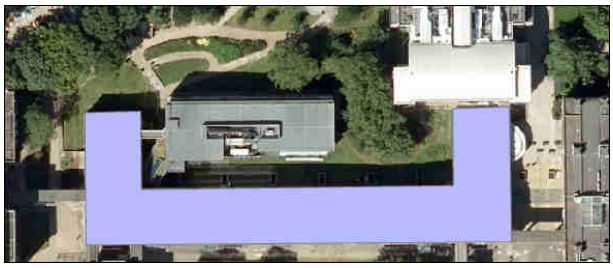


Figure 5.4: The digitised School of Earth and Environment (yours probably won't be the same colour as mine)

Continue to digitise buildings so that you have polygons for all of the buildings around Chancellors Court (the open space south of Earth and Environment). Remember to save your new polygons.

Once you've finished adding items it isn't obvious how to stop!

- Click on the **Map** tab of the ribbon
- Click on the **Explore** button from the Navigate group.

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?***

5.5 Modifying features

Once you've created a feature you may need to edit it, either to move it or to reshape it.

Video Clip available in Minerva - Digitising in Arc Part 4: Editing features after creation. (watch Digitising in Arc Part 1 for general information about digitising.)

- On the ribbon go to the **Edit** tab and click on the **Modify**
- This should open the **Modify Features** pane on the right of the window - figure 5.7
- Use the **Select** tool from the Edit tab of the ribbon to click on the feature that you want to modify so that the feature is outlined in turquoise to show that it is selected. If you have problem selecting a particular feature try the technique in table 5.1 on page 76
- On the **Modify Features** pane click on **Vertices**. The outline of the feature on the map should change - see figure 5.8
- Modifying the feature is now a case of using the mouse to move the edges or corners of the feature - try this on the building outline that you've just created
- To remove a vertex (corner) just right-click on it and select **Delete Vertex** from the menu
- To add a vertex (corner) right-click on one of the edges and select **Add Vertex** from the menu
- Once you're happy with the shape finish editing by pressing the F2 key, then Save using the button on the **Edit** ribbon.

Try some of the other tools on the Modify Features pane. In particular try Move, Rotate and Scale from the Alignment section.

Once you've finished trying out the tools delete any polygons which don't match the buildings around Chancellors Court and redraw them in the correct place.

Controlling selections
If you have overlapping layers it can be difficult to select just the feature that you want, either to find the details for it, or to edit it. When you click on your map to select a feature it is possible to select the correct one from the little dialog which pops up (figure 5.5), but this isn't always convenient. To control which layers can be selected from, and which can't, try the following: • From the top of the Contents pane click on the **List By Selection** button - remember the tool tips appear if you hover over the buttons • In the view of your layers which appears ensure that – the layer or layers that you want to be able to select from are ticked – the layer or layers that you **don't** want to be able to select from are **not** ticked. • It's a good idea to go straight back to the **List by Drawing Order** view of your layers or it's easy to get confused later

Table 5.1: Controlling selections

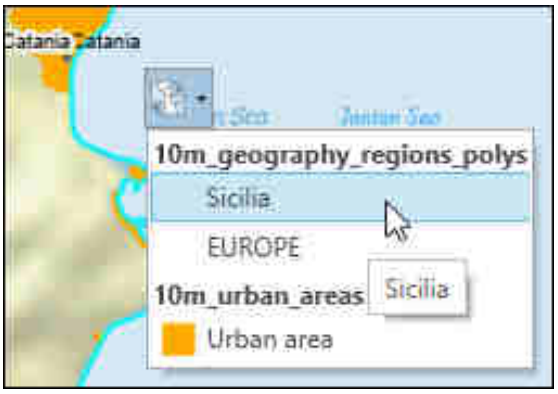


Figure 5.5: Choosing a single feature from the overlapping selections pop up

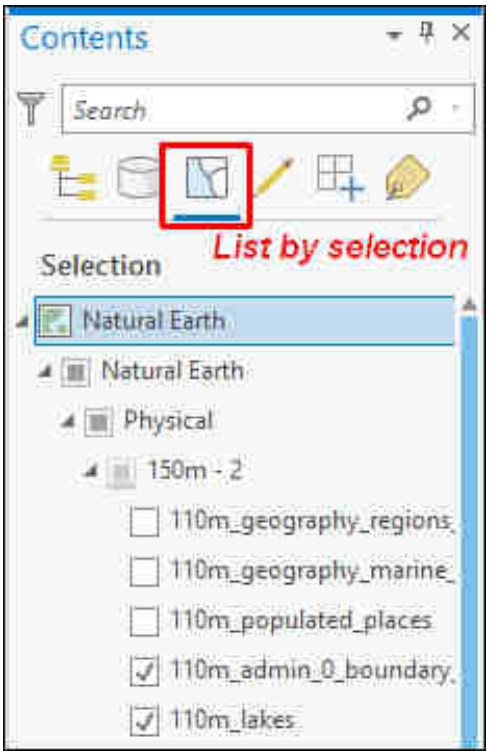


Figure 5.6: The Contents pane showing List by Selection view. Layers with no ticks can't be selected, layers with ticks are still selectable.

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.

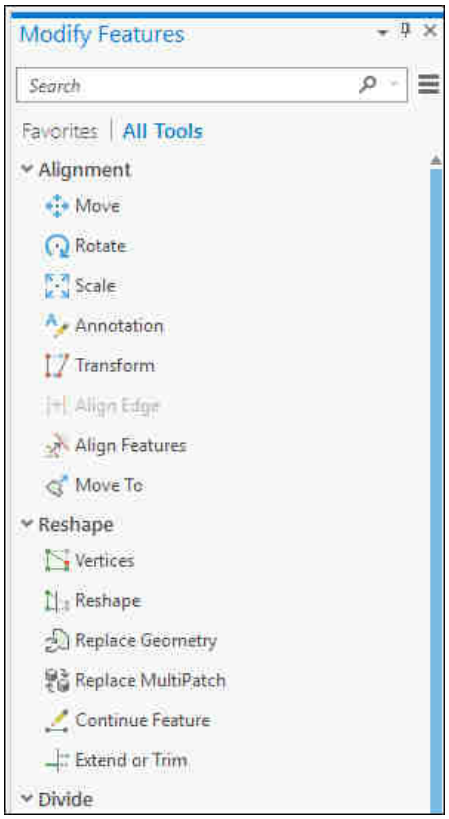


Figure 5.7: The Modify Features panel

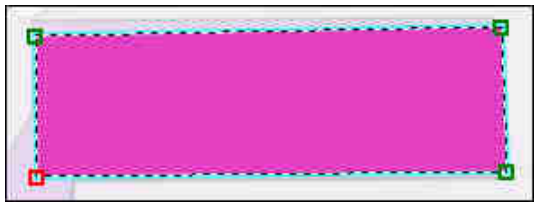


Figure 5.8: The selected feature once Edit Vertices has been selected in the Modify Features pane

5.6 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 1.7.6 on page 10.

5.7 Adding more information to a feature class

Next you'll add some extra information to your new features. It would be useful to be able to label the buildings with their names, so we'll have to add another field to the feature class so that we can add **Feature attributes**.

5.7.1 Adding new fields to a feature class

- Right-click on the **Buildings** layer in the Contents pane and open the **Attribute table**

- To add a new field click on the **Add** button on the attribute table toolbar - see figure 5.9
- The attribute table will change to **Field** view - showing more information about the data types and formats - figure 5.10
- Fill in the details to create a new field called **Name**
  - The **Field Name** should be short and contain no spaces or strange characters
  - **Alias** is how the name will be displayed and can include spaces - it's still a good idea to keep it short
  - Set the **Data Type** to **Text**
  - Set the **Length** to **120** - that's the number of characters you'll be able to use in a name.
- Once you've filled in that click on Save on the ribbon.

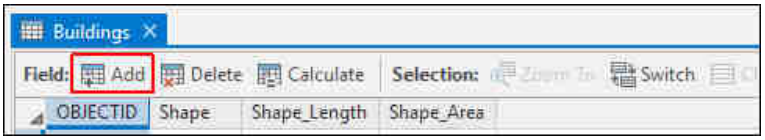


Figure 5.9: Adding a new field to an attribute table

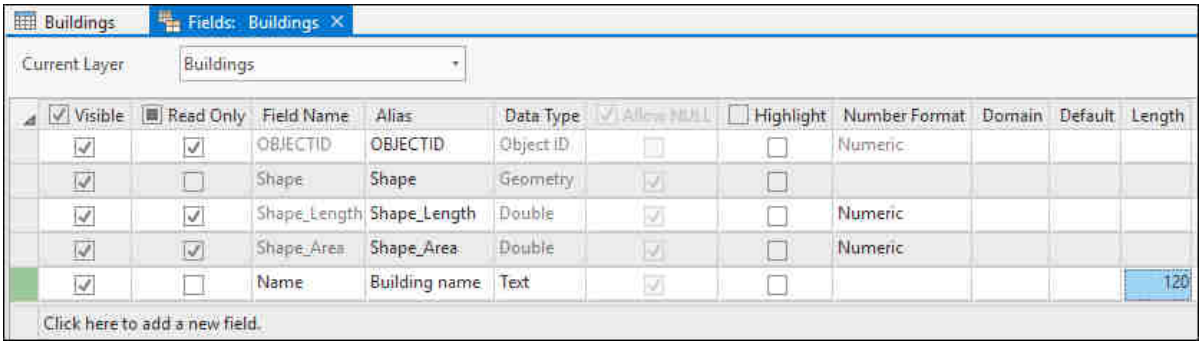


Figure 5.10: The Fields view - note the information about the data type of each field, the number format and the length. There will already be several fields set up by default, e.g. OBJECTID, Shape_Length

You can add more fields in this view if you want to, but for now close the **Fields** tab and return to the Buildings attribute table.

5.7.2 Adding attributes to a field

The first thing you need to do is work out which row in the attribute table belongs to which feature on the map. The easiest way is to select a row in the attribute table and see which feature shows as selected on the map. If you need a reminder of how to do this look at section 1.8.1 on page 14.

Once you know which feature you are entering the name for, double-click in the space under **Building Name** and type in the name. See figure 5.11 for the names of the buildings around Chancellors Court and enter them in your attribute table.

- Once again, don't forget to Save your edits frequently by clicking on the button on the **Edit** tab of the ribbon
- When you've finished adding names to each building just close the attribute table.

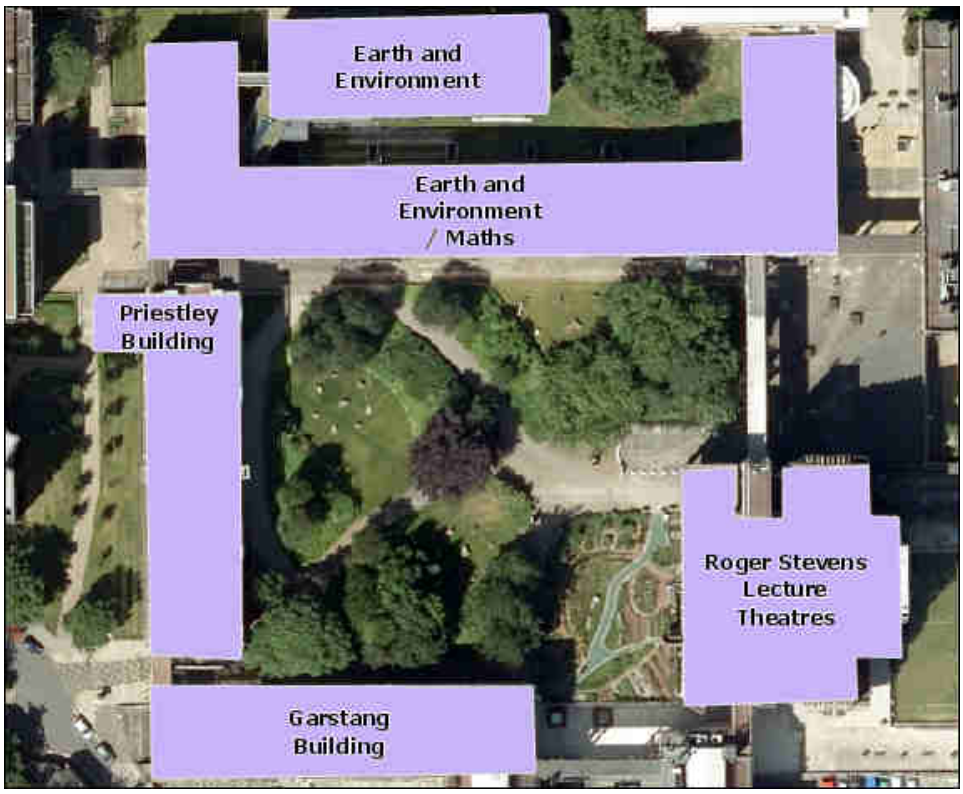


Figure 5.11: Buildings around Chancellors Court labelled with their names

5.8 Labelling features on the map

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

Video Clip available in Minerva - How to add labels to layers in Arc.

Figure 5.12: The labeling ribbon set up to label buildings with their names

- In the contents pane select the layer that you want to label - in this case the buildings layer
- On the Ribbon click the **Labeling** tab, then click on the Label button on the left-hand side.
- Check that **Label Features in this Class** is ticked, then use the dropdown next to **Field** to select the field in which you entered your building names - figure 5.12

The labels should appear on top of the features to which they apply and should look something like figure 5.11. You can try out some of the options in the **Text Symbol** and **Label Placement** groups on the ribbon to see what they look like.

Try changing the font of your labels, and maybe making them larger.

What effect do the options under Label Placement have? Do any of them look better to you than the default?

5.8.1 Digitising line features

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

Video Clip available in Minerva – Digitising in Arc Part 2: Creating line features. (watch Digitising in Arc Part 1 for general information about digitising.)

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

Follow the instructions given in section 5.4 on page 72 for digitising the buildings, but this time trace the paths across Chancellors Court into the Paths feature class.

Don't forget to save your edits when you've finished.

You don't need to add any labels for the lines layer in this case but if you did it all works in exactly the same way.

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.

5.8.2 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.

Video Clip available in Minerva - Digitising in Arc Part 3: Creating point features. (watch Digitising in Arc Part 1 for general information about digitising.)

Follow the instructions given in section 5.4 on page 72 for digitising the buildings, but this time place a single point for each tree you can see in Chancellors Court into the Trees feature class.

Don't forget to save your edits when you've finished.

You don't need to add any labels for the lines layer in this case but if you did it all works in exactly the same way.

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.

5.9 Symbolising your data

Or in other words, making it look better.

Changing the colour of any of the features on your map is simple -

- Select a layer in the contents pane, e.g. the Buildings.
- Click on the **Appearance** tab of the ribbon, and then on **Symbology**
- This should open the symbology pane on the right of the window
- Click on the symbol to change its colour, either via the **Gallery** for presets, or via **Properties** to set your own

Try this with the paths and trees too.

If you want your trees to look like trees you'll need to import a **style** to your project. Once imported styles will show up in your Gallery.

Full instructions are at `https://pro.arcgis.com/en/pro-app/help/projects/connect-to-a-style.htm`

Styles to download are available from `https://esri-styles.maps.arcgis.com/home/index.html`

5.10 Finally...

Check that you've finished 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.

Once you've turned off the background imagery layer, and the ESRI base map layer, your data could look something like figure 5.13. We won't worry about setting up a full layout at this stage as that is covered in another chapter.

Figure 5.13: Possible final layout for digitised map of Chancellors Court

5.11 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.

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

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 **digitizing**. For example, have a look at the video at `https://youtu.be/4VVXD8EKnz8`

Chapter 6

Layout and presentation

The background to laying out and presenting your data and maps will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

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

6.2 Introduction

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.

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 about what you need to include based on the principles that will be covered in class.

6.3 Viewing a map layout

In Arc a **layout** 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 any map that you have created in the previously in Arc
- Add a layout by going to the **Insert** tab of the ribbon and clicking on **New Layout**
- You'll be given a choice of paper sizes - for this map select **A4 portrait**
- A new layout will open as a new tab over the map with a blank layout, and the ribbon will change to give you options relevant to layout - 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.

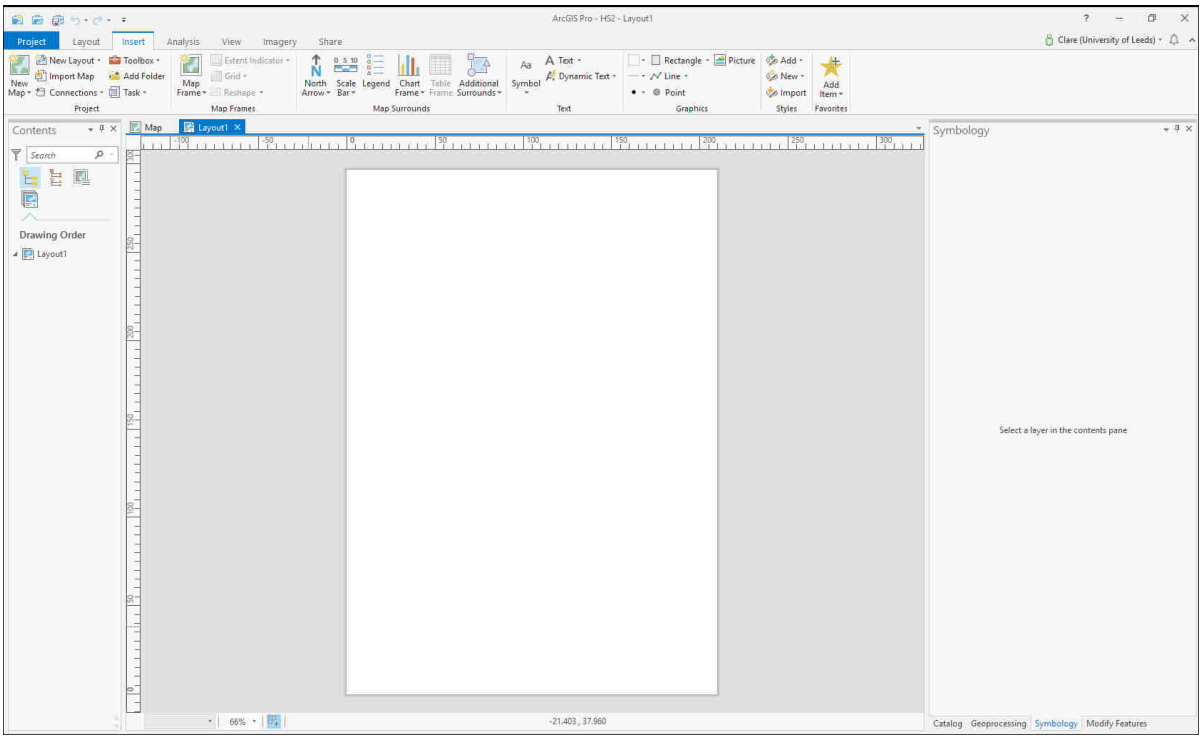


Figure 6.1: Layout view showing the initial blank layout

6.4 Adding a map frame to a blank layout

To add a map to a blank layout:

- Click on **Map Frame** on the **Insert** tab of the ribbon
- If you just click on the button you'll be given a World map.
- If you click on the arrow underneath **Map Frame** you'll be given some options which in include any spatial bookmarks that you have set up[1] and the map views in your project.

Click on any of the options to add a map frame to your layout. If you have a map showing the World you can zoom in to the area of your data.

[1] See section 1.5 on page 4 if you need a reminder about spatial bookmarks

6.5 The contents pane for a layout

As when you're working on your map, layout view makes use of the Contents pane on the left of the window. Click on the little arrows next to the headings to see the contents - figure 6.2.

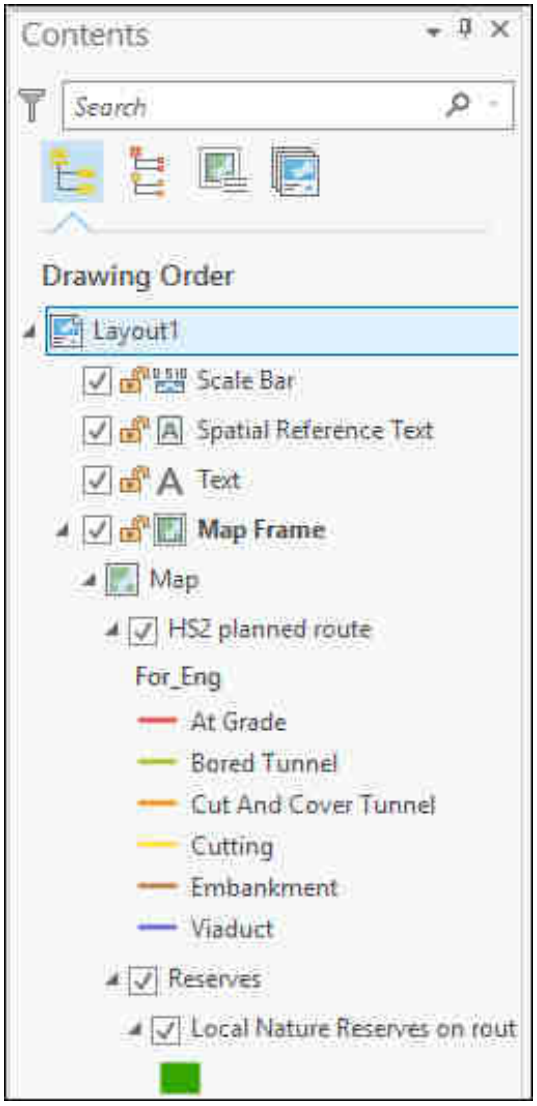


Figure 6.2: The contents pane in a layout with the elements and layers opened out

The top layer is the layout itself. Within that you'll find all of the elements on your page. This includes any map frames (there can be more than one), but also scale bars, legends, text etc.

As with the contents pane on a map, elements are drawn in the order they appear here. So if you want something to appear above something else, make sure that it is above it in the table of contents.

You can select any element within the contents list and move it on the layout or edit its properties in the pane on the right.

An element can be "locked" in place by clicking on the padlock symbol next to its name

6.6 Size and scale of a layout

6.6.1 Page size and scale

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

- Click on the **Layout** tab of the ribbon

Video Clip available in Minerva - Setting the size and scale of a map layout.

- the **Orientation** button allows you to change between portrait and landscape orientation
- the small button to the right of that one is for **Size** - hover over it to see the tool tip. This allows you to choose from a wide range of standard sizes, or use **Custom page size...** if you need something different.

Change your page orientation and size to A3 landscape. This will give you more space to experiment with adding other elements to your page.

6.6.2 Resizing the map frame in a layout

When you first set up a layout the size of the map frame that you see will not necessarily be the the size you want. Changing the size of the map 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 map frame in a layout.

- Make sure that the map frame is selected in the layout by clicking on it
- When the map frame is selected you should be able to see that it small boxes at the corners and on each side - see figure 6.3.
- Use the boxes as "handles" to resize the map 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 map frame again
- If you need to move the map itself you need to **Activate** the map by right-clicking on it and selecting Activate.
  - Move the map as appropriate
  - then go to the top of the layout window, where there is an arrow pointing to the right (see figure 6.4), and click on **Layout** to get back to the previous view
- Keep repeating this until the size/extent and scale of your map are correct

Warning: this process can take patience to get the map frame the correct size for the scale and area. There don't appear to be any short cuts so just stick with it and keep repeating the process!

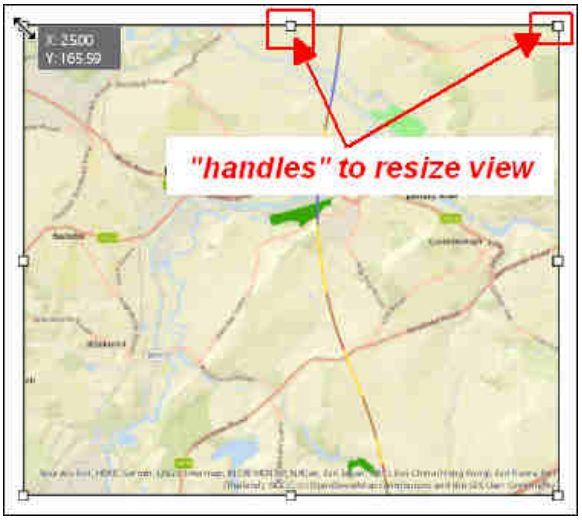


Figure 6.3: Using the “handles” on each corner and side of a map to resize a map frame in a layout

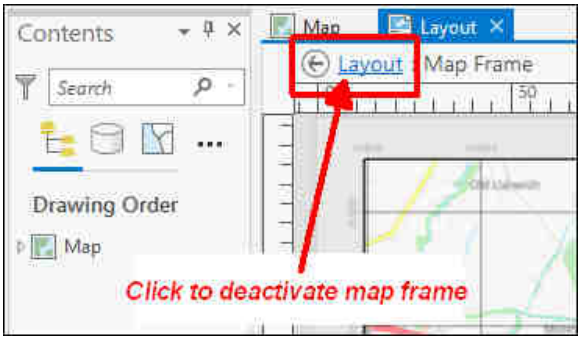


Figure 6.4: Top right of the layout window, showing where to click to deactivate a map frame

6.6.3 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 map frame in a layout 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!**

- In a layout click on the **Map Frame** in the Contents
- In the **Format Map Frame** panel on the right of the window go to the second button across - if you hover over it, it will say **Display Options**
- Use the dropdown box under **Constraint** to select your choice, e.g. **Fixed Extent** and set the **Location Settings as appropriate**
- To get back to the default of being able to pan etc, just set the **Constraint** back to **None**

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.

6.7 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. Some of the references in the cartography section of the reading list should help you with this. See section 6.10 on page 101 for suggestions.

Remember that **Arc 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 tab of the ribbon. 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 added to the page you can move the elements around. If you need to change properties then click on an element in the contents pane.

Video Clip available in Minerva - Adding a scalebar, title and text to a layout.

6.7.1 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. If you add scale text you must also ensure that you print the map at the correct scale.

To add a scale bar:

- Click on **Scale Bar** on the **Insert** tab of the ribbon
- Select an appropriate scale bar from the list - if you are working in a projected coordinate system such as British National Grid and the map units are metres, then use a metric scale bar.
- You can make changes to the format of the scalebar in the properties pane on the right
- To change things such as the number of divisions and the units make sure that the scale bar is selected then go to the **Design** tab on the ribbon

To add scale text:

- Click the little arrow next to **Dynamic Text** on the **Insert** tab of the ribbon
- Select **Scale** from the choices provided

Arc will add text to your map which will automatically update if you change the scale of your map.

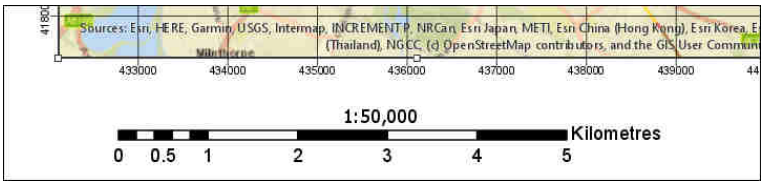


Figure 6.5: Scale bar and scale text on a layout. Note that the divisions and length of the scale bar relate to the measured grid on the map.

It's worth having a look at what other text elements can be added via Dynamic Text too, e.g. information about the spatial reference.

6.7.2 Title and text

Maps need an informative title so that people looking at them know what they are supposed to show. You should use the insert text command to add a title, or 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.

To add text:

- From the **Insert** tab of the ribbon click on the little arrow next to the **Text** button and select a form of text. **Rectangle** works best, particularly if you're likely to want to add a background.
- Click on the layout, or click and drag for rectangle, and type your text
- You can use the **Format text** pane on the right to change the text
- The **Text symbol** dialog will allow you to change the font, and font size - it's worth exploring all of the options

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.

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 6.1: 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[2] 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`

6.7.3 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.

- Click on **Legend** on the **Insert** tab of the ribbon
- then click close to where you want the legend on your map

Arc will automatically add all of your layers to the legend, including those you don't want to include.

- Use the Contents pane to view the layers which are included in your legend by clicking on the arrow next to its heading
- To remove a layer from the legend just untick it in the Contents - figure 6.7

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.[3]

It is very likely that you will want to change the legend in some way to make it clearer. Do as much as you can while it is still being generated automatically.

- Make sure that all the symbology is correct
- Rename layers in the map contents pane so that they are in plain English, e.g. no unexplained abbreviations, or strange characters, such as underscores.
- On the example in figure 6.6 the heading `For_Eng` either needs to be removed or written in full as something like `Type of engineering required`.
- To change the format of an item right-click on it in the Layout contents pane and select **Properties** then try changing the options there.

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.

[2] Last viewed: 18th September 2018
[3] Last viewed: 18th September 2018.

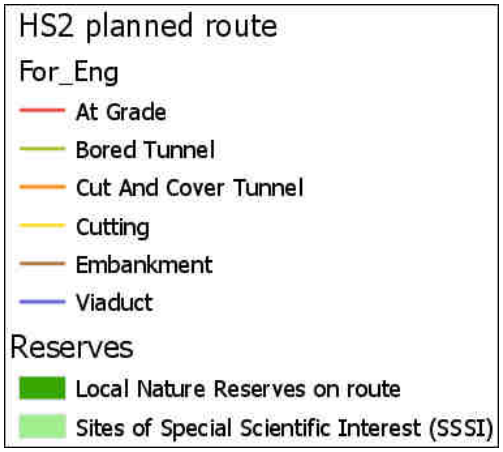


Figure 6.6: An example of a basic legend or key. It needs some work on it now!

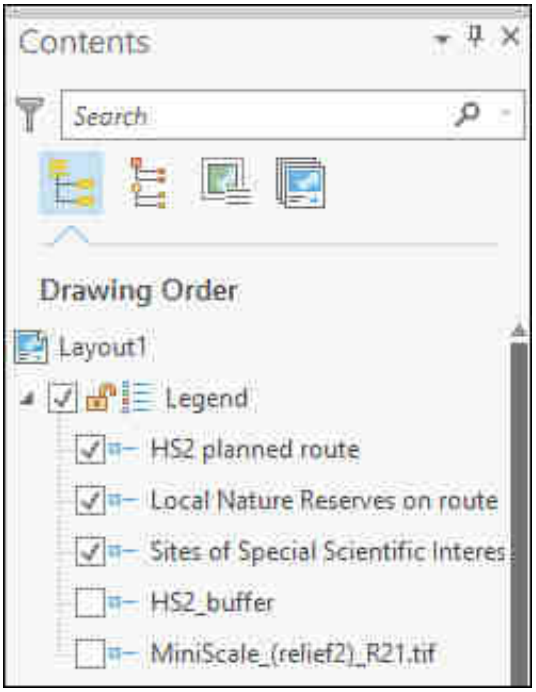


Figure 6.7: Selecting the layers which should appear in the legend

Converting a legend into a graphic

- Right-click on the legend Convert to Graphics.
- Right-click on the legend again Ungroup.
- Repeat the last step again as necessary on each part of the legend

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.***
>
> ***Add any extra text that you want to add by using the Text button on the ribbon, or remove text that you don't need.***
>
> ***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 waste time sitting there wondering where that symbol is on your map?)

6.7.4 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.

Video Clip available in Minerva - Adding a measured grid to a map.

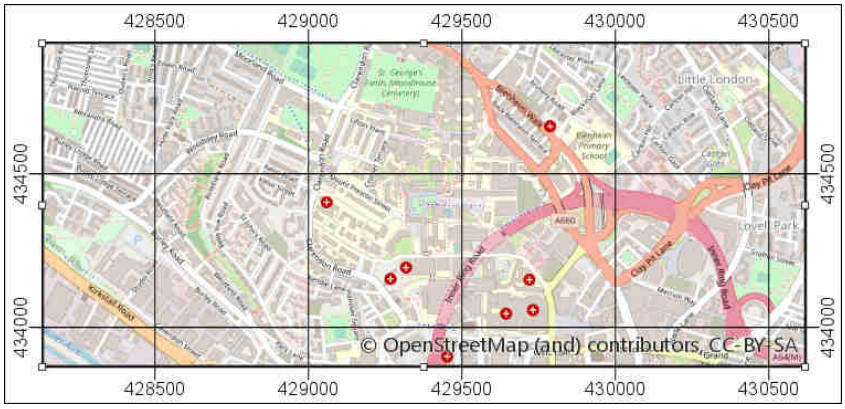


Figure 6.8: A map with a measured grid that shows British National Grid coordinates on a 500 m grid

- With the map frame selected, from the **Insert** tab of the ribbon click on **Grid**
- You should be presented with a selection of choices. For a map in a projected coordinate system such as British National Grid you will want to choose one of the **Measured Grids**, and probably **Black Vertical Label Grid**
- You can make changes to the grid in the **Format Map Grid** pane to the right of the window when the Grid is selected in the Contents pane
- check that the intervals are suitable to the scale of the map, you don't want the lines to be too dense, but you do want to have enough to make it possible to see measurements between them. To change the intervals
  - In the **Options** tab untick **Automatically adjust** under **Interval**
  - Go to the **Components** tab and change the intervals for Labels, Ticks and Gridlines.

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 A on page 237.

6.7.5 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, particularly if you, or anyone else, are going to be using the map in the field.

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 6.9 shows the different types of north and the declination.

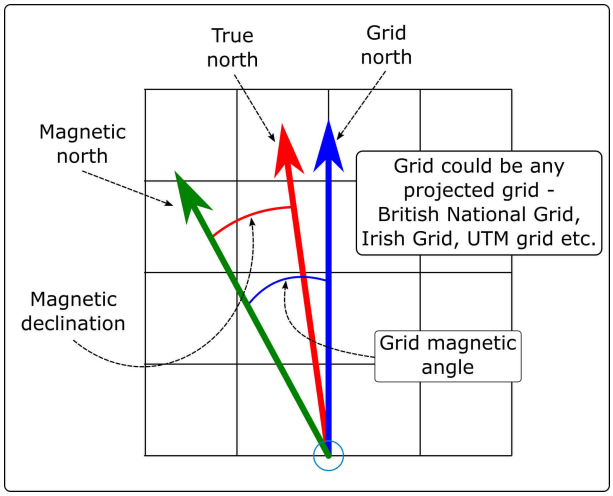


Figure 6.9: The different types of North that you'll find on a map set to a projected coordinate system, such as British National Grid

If you add any 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.

North arrow: Grid north / Map north

If a map is in a projected coordinate system Arc 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:

- From the **Insert** tab of the ribbon click on the down arrow under the **North Arrow** button
- select an arrow style (it's usually much better not to go for something too fancy!)
- Double-click on the arrow to open the **Format North Arrow** pane that opens to the right and check that **Type** is set to **Map North**

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.

The ArcGIS Pro Help describes True North as "The north arrow angle points to geodetic north (to the north pole) as calculated by the coordinate system of the associated map frame, at the center of the map."[4]

In layout view:

- From the **Insert** tab of the ribbon click on the down arrow under the **North Arrow** button
- select an arrow style (it's usually much better not to go for something too fancy!)
- Double-click on the arrow to open the **Format North Arrow** pane to the right and check that **Type** is set to **True North**

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 calculated by grid magnetic angle

Magnetic north is the direction from the area of your map to the magnetic North Pole. This is the number that is given on the corner of Ordnance Survey maps and the one geologists need for setting their compass-clinos in the field, so it is worth making a note of this on your map too.

Since version 2.4 of ArcGIS Pro setting a north arrow to magnetic north has become simple, but if you do need to work out the declination for yourself the website below will give you the calibration angle for anywhere in the world.

BGS Geomagnetism Group at `http://bit.ly/2uGMfdp`. 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 two decimal places. The key to the table you are given is underneath the map.

To set magnetic north automatically - in layout view:

- From the **Insert** tab of the ribbon click on the down arrow under the **North Arrow** button
- select an arrow style (it's usually much better not to go for something too fancy!)
- Double-click on the arrow to open the **Format North Arrow** pane to the right and check that **Type** is set to **Magnetic North**
- The properties will give the **Calculated Angle**. It's a good idea to add this and the current date to your magnetic north arrow as magnetic north changes with time.

If you check this north arrow against your measured grid lines you will probably find that the north arrow is slightly tilted. Note that at the moment the line where magnetic north and grid north are the same is passing across the UK so you may find that there is no, or very little difference[5].

If you need to set the angle manually with the declination from the site above, enter the value into the **Calibration Angle** box. Note that due to the way Arc calibrates the angle, if your figure is negative you need to add it as positive, if positive, put a minus sign in front of it! The arrow on the preview should change to reflect the magnetic angle.

[4] `https://pro.arcgis.com/en/pro-app/help/layouts/north-arrows.htm` Last visited: 10th October 2019.

[5] See blog post from the Ordnance Survey - `https://www.ordnancesurvey.co.uk/blog/2019/03/magnetic-north-continues-its-march-to-the-east/` Last viewed: 10th August 2019.

6.7.6 Adding extra map 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 map frames.

Video Clip available in Minerva - Adding extra map frames to a layout.

Showing a different area of the same map

If you just want to add another frame showing a different area of the same map, and using the same data layers then the process is simple and is basically repeating what you did to add the first map frame.

- Click on **Map Frame** on the **Insert** tab of the ribbon
- If you just click on the button you'll be given a World map.
- If you click on the arrow underneath **Map Frame** you'll be given some options which in include any spatial bookmarks that you have set up[6] and the map views in your project.

Click on any of the options to add a map frame to your layout. If you have a map showing the World you can zoom in to the area of your data.

You can move each map frame separately, but if you turn data layers on or off on one of them, they will be turned on or off on both.

Create a new map frame using different data

Adding another map frame which uses different data layers is a bit more involved.

- Start by setting up another map - from the **Insert** tab of the ribbon click on **New Map**
  - It's a good idea to rename the maps so that you can remember what each one shows. Do this by bringing up the **Map Properties** and changing the **Name** field.
  - Set this map up with the data you need and symbolise as required then return to your layout.
- Click on **Map Frame** on the **Insert** tab of the ribbon
- If you just click on the button you'll be given a World map.
- If you click on the arrow underneath **Map Frame** you'll be given some options which in include any spatial bookmarks that you have set up[7] and the map views in your project.

Click on any of the options to add a map frame to your layout. If you have a map showing the World you can zoom in to the area of your data. See figure 6.10 to get an idea of how the map frames and the contents pane will look (your data and areas will of course be different).

Once you have two map views on your layout you can copy and paste layers between the two if necessary and symbology will be preserved.

[6] See section 1.5 on page 4 if you need a reminder about spatial bookmarks
[7] See section 1.5 on page 4 if you need a reminder about spatial bookmarks

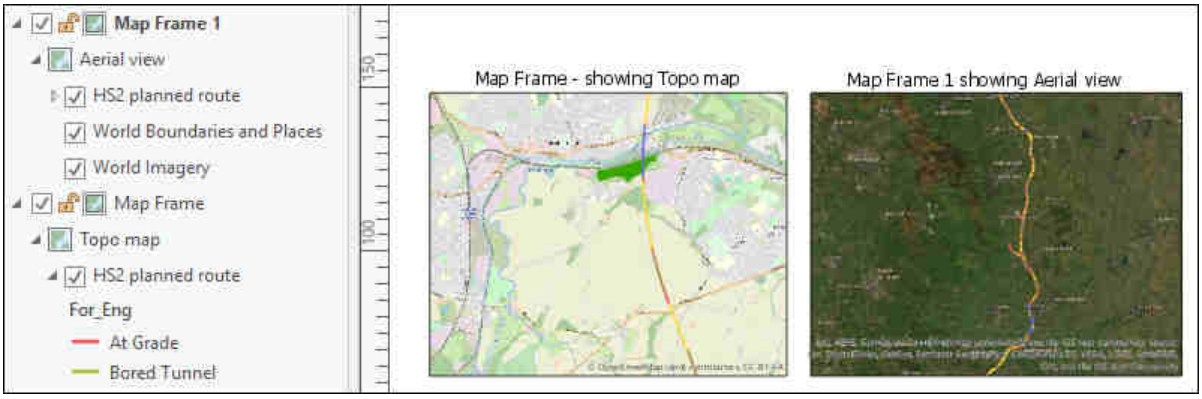


Figure 6.10: A layout showing two map frames containing different data

6.7.7 Adding an extent indicator

For some maps, particularly large scale (detailed) 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 6.11). To do this you need to obtain small scale data and then add it to a second map frame in Arc. You really only need a general map, even just an outline of a whole country, so it can be best to use data from Natural Earth[8].

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. Not least it is suprisingly easy to end up with the marker in the wrong place.

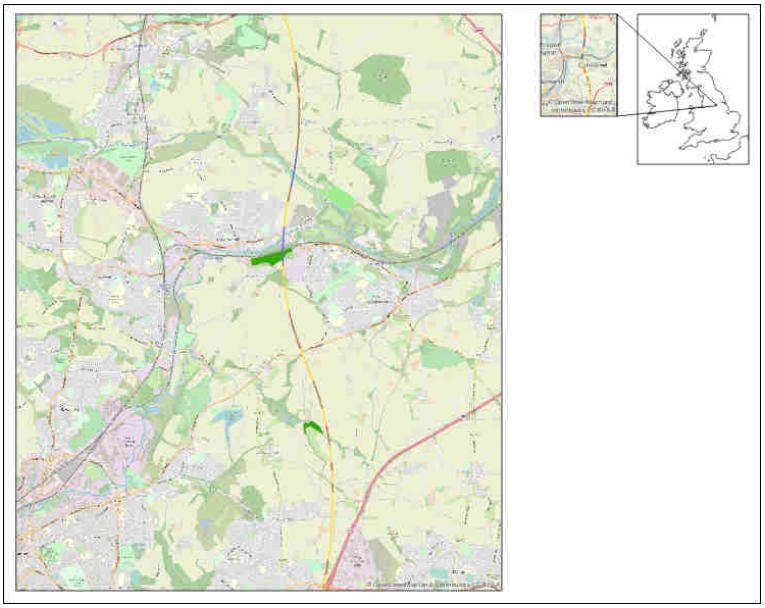


Figure 6.11: An extent indicator on a layout: using a smaller map to show the general area of the main map. In this example the main map has been duplicated and shrunk down, but set to cover the same extent as the main map. The extent is then shown on an outline map of the UK. You can also make the extent straight from the larger map. Note that the indicator does not need to be large, but should be a small map which doesn't take up too much space on the layout.

Start by adding a new map frame to your map as shown in section 6.7.6 on page 96 and add

[8]Download from `https://www.naturalearthdata.com/` Last visited: 13th August 2019. Look for Downloads › Large scale data › Cultural › Download Countries. Don't forget you'll need to reference this data.

your choice of map layers, e.g. the Natural Earth Data countries, to the new map and symbolise appropriately.

Set up the extent indicator

- Resize and relocate the map frame and set it to an appropriate scale (e.g. start with 1:1 000 000) and the area of the country of your main map.
- Select the outline map (the one that is going to be the extent indicator)
- Click on **Extent Indicator** on the **Insert** tab of the ribbon
- From the dropdown select the map frame of the more detailed map that you want the extent indicator to show the area for
- Arc should add a dot to the map at the correct location. You can now use the **Format Extent Indicator** pane on the right to set the properties, e.g. try changing the symbol, or use the dropdown under **Leader** and try out the options there

You should now have a map with a marker showing the area covered by your main map and with a line or lines leading to it as in figure 6.11 on page 97.

If you use a smaller map, as in the example, select that map, and in the **Format Map Frame** pane choose **Linked map frame extent** under **Constraint** so that it continues to show the same area as the main map.

Try moving and rescaling both maps (remember you have to Activate the frame you want to pan and zoom in) - the marker on the extent indicator should resize and relocate to reflect your changes.

You can change the style of the box and the leader line by selecting the correct extent indicator under **Extent Indicators** in the contents pane, then editing the properties in the **Format Extent Indicator** pane on the right.

6.7.8 Inserting photographs and images

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 a layout select **Picture** from the graphics group of the **Insert** tab on the ribbon
- Click on your layout and then browse for the image you want.
- 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 of your layout before you worry about it (see section 6.8.1 on page 99). What you see on screen isn't always how the final result will look.

6.8 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

6.8.1 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 6.9.2 on page 100.
- 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

6.9 Printing and exporting maps from Arc

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.

6.9.1 Printing a map from Arc

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

- Start by checking that the page size and scale are correct (section 6.6 on page 86)
- Whilst in a layout go to the **Share** tab of the ribbon and click on the **Print** icon
- Set up the printer as you usually would (this is system specific so I can't include exact instructions here)
- then click to print

6.9.2 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.

- Whilst in a layout go to the **Share** tab of the ribbon and click on the **Export** icon
- 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 **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[9]).
- Export - 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 in the pdf reader you use 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.

[9] 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.

6.9.3 Exporting a map to import to other programs

You can also export the Arc 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 Arc layout as required
  - check that the page size, and the scale/size of the map 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.
- Export the map using the instructions in section 6.9.2 on page 100 but this time choose the appropriate output format (see below) and set the resolution - to **600 dpi** if you have the disk space
- Choose a location then Export

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.

6.10 Recommended reading: layout and presentation

The module reading list[10] 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.

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

Data preparation for chapter 7: 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 6.12 for the approximate area. (See section 3.4.2 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

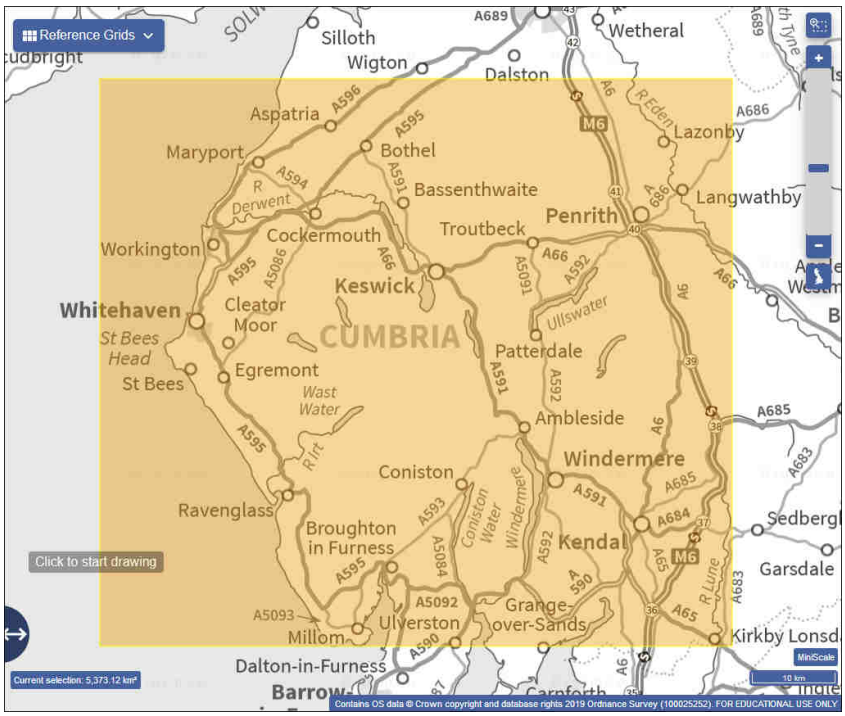


Figure 6.12: Area for which to download data for the Lake District

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

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 7

Elevation models: the shape of the land

7.1 Learning outcomes

The background to elevation models and terrain analysis will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

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

7.2 Raster elevation models: DEM/DTM

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 7.11 on page 129.

You should already have downloaded data for this exercise as detailed in the section on **Data preparation for raster elevation models** on page 102. If you haven't, follow the instructions there now.

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`

7.2.1 Preparing the DTM data

Note that you do only need to mosaic the DTM files by following the instructions below. The other raster files that you downloaded for this exercise (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.

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 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 7.1 is the NY03 tile from the OS Terrain50 DTM dataset. The files in the folder which don't end in .asc are there to provide more information about the ascii files.

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.

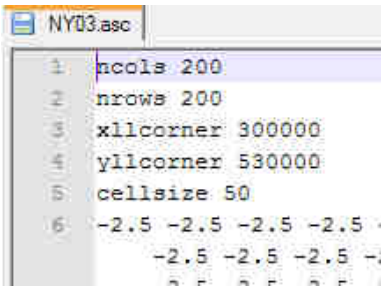


Figure 7.1: Ascii format DTM file in a text editor (Notepad++). The numbers in your file will more than likely be different to the ones shown here.

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 catalog pane before you start processing it too[1]. See section 2.2.1 on page 31 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**. Make a note of each of these properties in the space below.

Note that if your data has a **Pixel Type** of **Short**, you will need to enter it in the tool as **signed**. Unsigned and floating point match the terminology in the tool. Table 7.1 on page 107 summarises the type of data that each of these pixel types holds.

[1] Remember that you will need to look under the **Folders** subheading, and if you haven't put the data in the project folder you'll need to **Add a Folder Connection** - see section 1.3 on page 10 for a reminder of how to do this.

7.2.2 Producing “seamless” datasets from more than one tile of dtm data

Often data is provided as tiles, each covering a small part of the total area. If you have more than one tile of dtm data for the area that you need 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.

Note that this only applies when each tile contains data for a small part of the area. If the raster data tiles that you have all cover the same area then mosaicking them will not work.

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

If you only have a single tile of dtm data you don’t need to create a seamless mosaic. Just continue with the next section.

Video Clip available in Minerva - Creating a seamless mosaic from multiple DEM tiles.

- If you don’t already have a map, create or open one now
- In Map view go to the **Analysis** tab of the ribbon
- set the extent for carrying out geoprocessing operations - Environments › Processing Extent set to Union of Inputs and click OK.
- click on the **Tools** button on the ribbon
- Then use the geoprocessing toolbox to open the correct tool - Data Management Tools › Raster › Raster Dataset › Mosaic to New Raster.

Fill in the dialog that opens as shown in figure 7.2. You’ll need to add all of the .asc files that you downloaded, and save the result to the geodatabase in the project. Your file names will be different to the ones used here.

- 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. For this example click on your file geodatabase to select it, but don’t double-click to enter it
- 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 7.2.3 on page 107.

- **Pixel Type** should be set to the same as the original files - have a look at the properties in the Catalog pane if you haven't made a note of this already.
  - If you understand what the pixel type indicates it can help you to check your data. Check the properties of the layer, but also use the **Explore** tool to click on the layer when it is displayed on your map and check what values the file contains. Table 7.1 gives a summary of the type of data that each pixel type will store.
  - 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.
- 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.
- Run

Pixel type	Decimal places?	Negative numbers?
Unsigned	no	no
Signed or short	no	yes
Floating point	yes	yes

Table 7.1: A digression on pixel type

Arc 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 7.3 - yours will look different to this one).

7.2.3 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. If you are working with terrain data from Digimap you won't need to do this step **unless** you are creating a map that isn't in British National Grid.

- From the geoprocessing toolbox select 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_Petroleum**

7.2.4 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 symbology by clicking on the **Appearance** tab on the ribbon, the layer is symbolised by a **Stretched color ramp** which shows a continuous surface from low to high. The layer should look something like figure 7.4.

To increase the contrast go to the symbology properties and change the stretch type from Standard Deviation or Percent Clip to Minimum Maximum.

If you wish try a different color ramp. Click on the color scheme and at the bottom of the dropdown that appears make sure that Show names is ticked. Then select Elevation 1. Try some of the others too and see how they look.

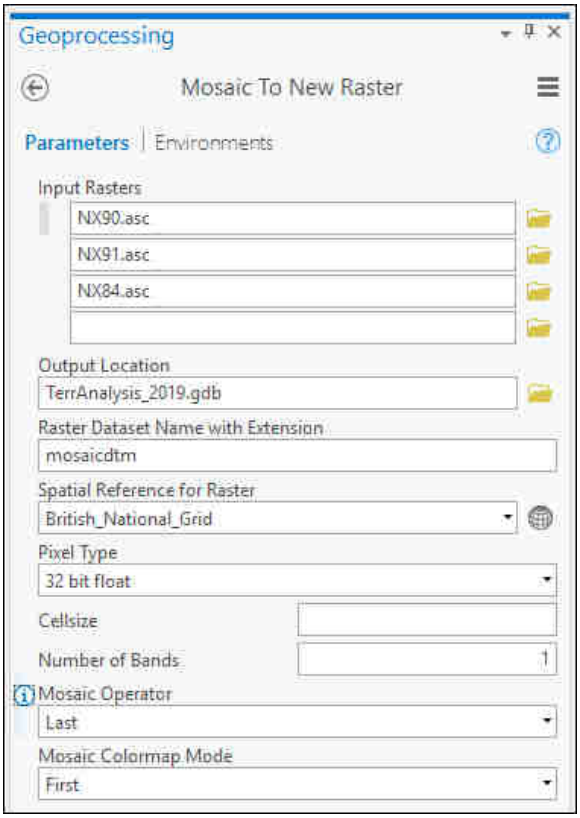


Figure 7.2: The Mosaic to New Raster tool. Note that the details for your data may be different to those shown here, in particular check the Pixel Type - this is crucial to running the tool successfully. Remember to include **all** of your input rasters - only a small number are shown here for convenience.

Figure 7.3: Grid file mosaic made by combining smaller tiles. Note that yours probably won't look identical to this one as it will cover a different area.

7.3 3D Analyst Tools

The 3D Analyst Tools provide tools for working with data with a height component, such as the DTM files that you have just opened in Arc. This section of the workbook will look at some of the spatial analysis that you can do with height data.

7.4 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.

7.4.1 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.

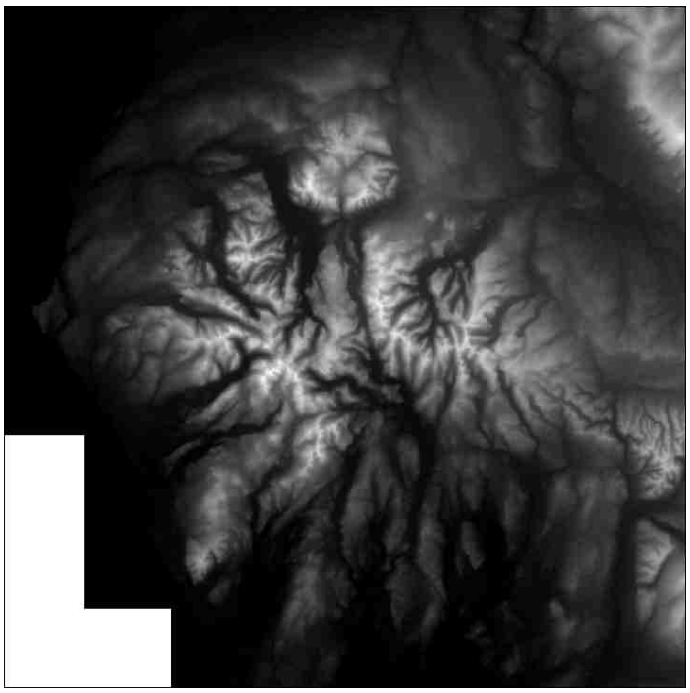


Figure 7.4: The mosaicked DTM for the Lake District with the stretched colour ramp

Video Clip available in Minerva - 3D Analyst: hillshade, slope and aspect.

- Tools > 3D Analyst Tools > Raster Surface > Hillshade
- Fill in the dialog with your mosaiced dtm layer as the input. Select where you want to save the output (this can be the geodatabase again) 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 7.5. Then click Run

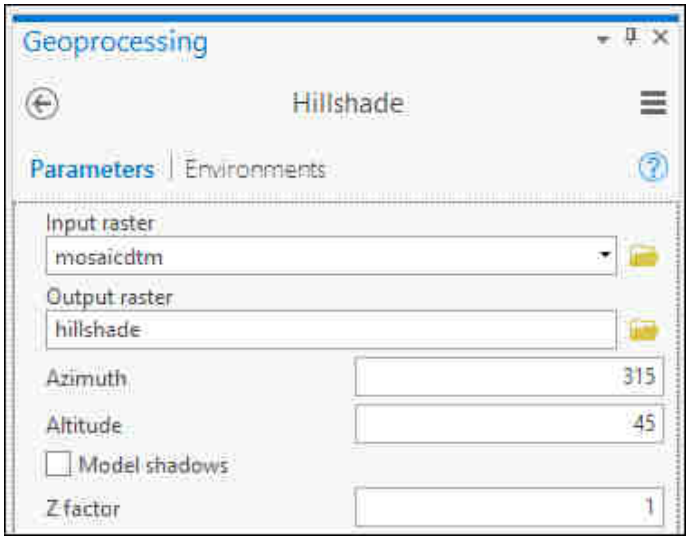


Figure 7.5: Filling in the Hillshade dialog

The tool should run and add a new hillshade layer to your map. If you find you are unable to run the tool and it has a padlock icon next to it in the list, try the instructions in table 7.2

Zoom in and have a closer look at the hillshade you have generated. Try making it transparent so that the DTM shows through[2].

Enabling extensions for geoprocessing
Geoprocessing tools within some toolboxes, e.g. 3D Analyst and Spatial Analyst, are controlled by separate licences. These should be enabled by default, but if you find that there are padlock icons next to some tools and you are unable to run them, then try the following instructions. • Open ArcGIS Pro without opening a project, i.e. just from the start menu • click Settings > Licensing > Configure your licensing options • Give the licensing options window time to load then you should be able to tick the extensions that you need - for this course just tick **3D Analyst** and **Spatial Analyst** • OK You should now be able to open a project and run the tools from those toolboxes.

Table 7.2: Enabling extensions for geoprocessing

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 projection - if you check the source it is listed as Unknown. 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.

7.4.2 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.

- Tools > 3D Analyst Tools > Raster Surface > Slope
- Fill in the dialog with your mosaiced 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 Run.

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 **Explore** tool to click around the map and compare the results with the table of contents (make sure you select to identify the slope layer).

[2]See section 1.7.6 on page 10 if you need a reminder of how to make a layer transparent

7.4.3 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.

Video Clip available in Minerva – Reclassifying rasters: by changing symbology.

- Go to the **Symbology** pane for the slope layer
- Check that Symbology is set to Classify – if it isn't select that from the dropdown
- You'll get a dialog similar to figure 7.6. Change **Method** to **Natural Breaks (Jenks)** and the number of **Classes** to **2**. Then change the first **Upper Value** in the table to the number of degrees required – **15** – by clicking on it and typing **15**. (The method will change to **Manual Interval**, this is fine)
- To set the measurements **over** 15 degrees so they're not visible click on the colour patch next to the higher figure and set to **No Color**. You can change the colour of under 15 degrees in the same way.

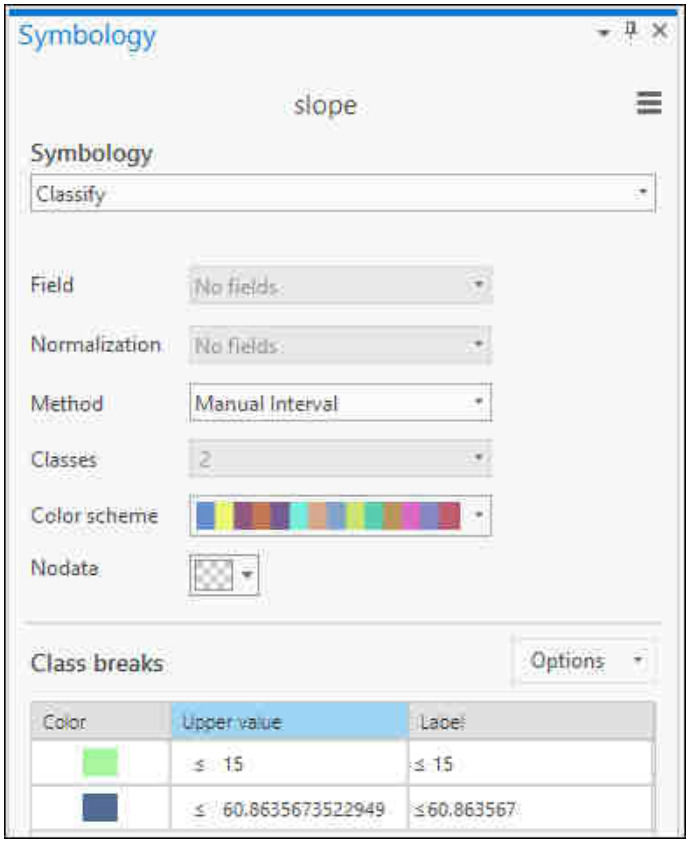


Figure 7.6: Changing the classification of a stretched layer

Now you should have a raster that shows you just one colour.

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.

7.4.4 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.

- Tools > 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 generally South are symbolised - you don't need to be too exact.***

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.

7.5 Adding raster background data

As well as the height data you should have downloaded a 1:50 000 raster tiff layer from Digimap. This is background data. You can open it in an image viewer and would be able to see a map that looks identical to the paper maps that you can buy. We'll use this as a background layer for the other maps - it's more detailed than the ESRI basemap layers and will allow you to see hill names etc.

- In the catalog pane find the 1:50 000 raster data that you unzipped and just drag and drop it into the contents pane
- You may want to group the layers as there are rather a lot of them. You can then "fold" the group and it won't get in the way!
- Make sure that this group is above the basemap and the mosaicked dtm in the contents pane.

7.6 Adding xy data to a map

For the next couple of exercises it will be useful to have a layer showing the hill summits in the Lake District. In the data preparation section 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 Arc.

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

Note that the data you need is in the **Hills** data sheet.

7.6.1 Converting .xls or csv to a feature class

This works for either Excel files or 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[3], then import it to Arc using the instructions below. It often works much better than the Excel file.

In the Catalog pane in Arc:

- For an Excel spreadsheet
  - click on the down arrow next to the Excel file to show the contents (figure 7.7)
  - You should be able to see at least one layer with a name which ends with with a **$** sign.
- For a csv file
  - work with the file directly, there won't be layers underneath it

If you add the file to Arc as it is you won't be able to view it on a map - though you can see the grid references these currently don't mean anything to Arc. To be able to view the data on a map you need to convert the table to a feature class. As part of this process you'll be telling Arc where to find the grid reference of each point is so that it can place it on the map.

- In the Catalog pane right-click on the data sheet to be imported and go to Export > Table to point feature class...
- This will open the geoprocessing tool, fill it in as shown in figure 7.8
  - Select either the excel spread sheet or the csv file by clicking on the folder icon next to **Input table**
  - Choose a location and name for the **Output Feature Class** - the best place is probably inside the project geodatabase
  - Fill in the X and Y Fields using the spreadsheet columns which show the coordinates in British National Grid. You don't need to worry about the Z field.
  - Click on the icon next to Coordinate System and select **British National Grid**
- Run the tool

The output feature class should be added to your map automatically. If it isn't, in the Catalog browse to the location that you chose to save it and drag and drop it on to your map.

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

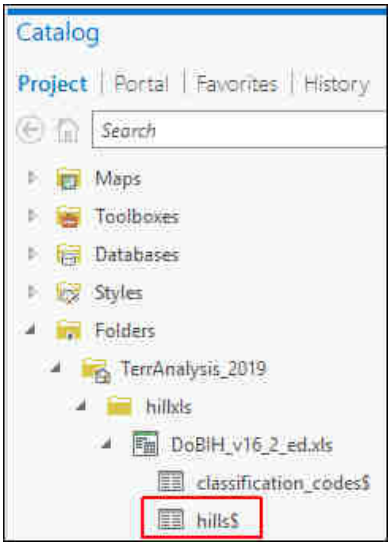


Figure 7.7: Excel file in Catalog opened out to show contents

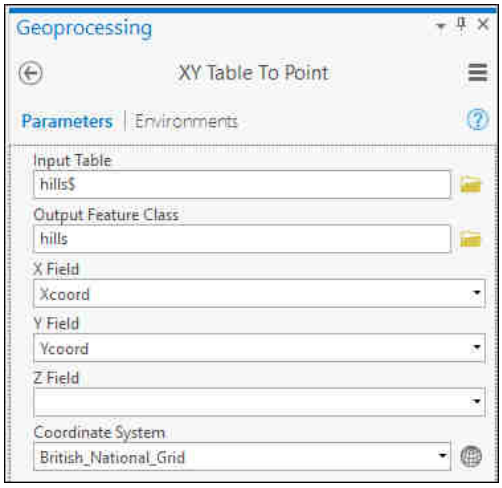


Figure 7.8: Creating a feature class from an XY Table (your field and file names probably won't be the same as this)

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

Check your location by doing zoom to layer. You should find that you have a map of dots covering the whole of the UK - with maybe a few outliers somewhere near the north pole! The Irish points will also be rather out of place as they actually use a different coordinate system, but that won't affect this exercise.

If when you zoom to layer you are taken to a location away from the UK, then you may have got the 100 km grid numbers wrong. Go back to the previous section and check that you have eastings and northings or x and y the right way round.

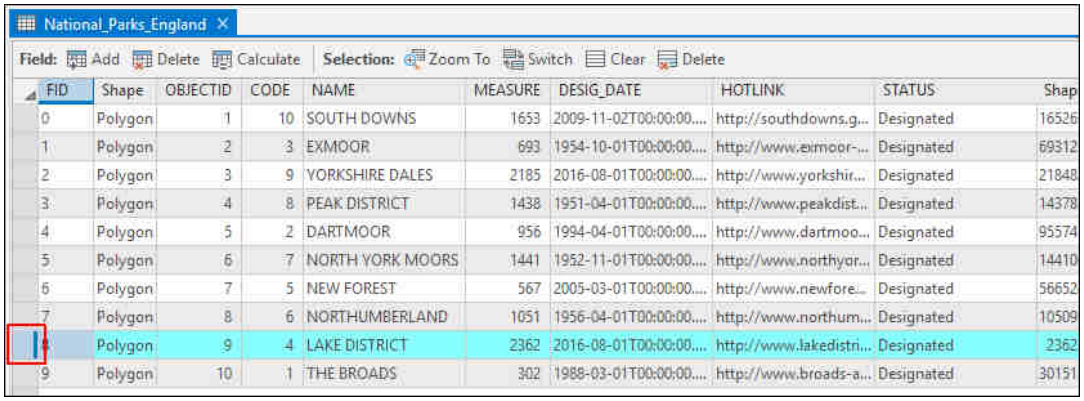
7.6.2 Selecting data in the attribute table

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 contents pane and open the 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 7.9) but also on the map.

7.6.3 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.



FID	Shape	OBJECTID	CODE	NAME	MEASURE	DESIG_DATE	HOTLINK	STATUS	Shap
0	Polygon	1	10	SOUTH DOWNS	1653	2009-11-02T00:00:00....	http://southdowns.g...	Designated	16526
1	Polygon	2	3	EXMOOR	693	1954-10-01T00:00:00....	http://www.exmoor-...	Designated	69312
2	Polygon	3	9	YORKSHIRE DALES	2185	2016-08-01T00:00:00....	http://www.yorkshir...	Designated	21848
3	Polygon	4	8	PEAK DISTRICT	1438	1951-04-01T00:00:00....	http://www.peakdist...	Designated	14378
4	Polygon	5	2	DARTMOOR	956	1994-04-01T00:00:00....	http://www.dartmoo...	Designated	95574
5	Polygon	6	7	NORTH YORK MOORS	1441	1952-11-01T00:00:00....	http://www.northyor...	Designated	14410
6	Polygon	7	5	NEW FOREST	567	2005-03-01T00:00:00....	http://www.newfore...	Designated	56652
7	Polygon	8	6	NORTHUMBERLAND	1051	1956-04-01T00:00:00....	http://www.northum...	Designated	10509
8	Polygon	9	4	LAKE DISTRICT	2362	2016-08-01T00:00:00....	http://www.lakedistri...	Designated	2362
9	Polygon	10	1	THE BROADS	302	1988-03-01T00:00:00....	http://www.broads-a...	Designated	30151

Figure 7.9: Selecting a feature in the attribute table by clicking in the grey box on the left

- Right-click on the layer that contains the selected features - the national parks layer in this case
- Data > Export Features
  - Choose where to save the new file to, probably the project geodatabase, and the name that you want to call it
  - Click Run

The new layer should automatically be added to your map. If it isn't, drag and drop it from the Catalog pane. If you **Zoom to Layer** on it, you should only see the area of the Lake District National Park.

Once you have the new layer **remove**[4] the original layer from the contents to keep things tidy.

7.6.4 Select by location

Now it would be useful to restrict the summit points to only those within the Lake District National Park, rather than the whole UK. 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 1.12 on page 18.

- Make sure that you don't have any features from any other layers selected by clicking on the **Clear** button on the ribbon. If there isn't anything selected anyway this will be greyed out.
- On the **Map** tab of the ribbon click on the **Select by location** button then fill in the dialog as shown in figure 7.10.
  - The **Input Feature Layer** should be the layer you want to select features **from**. In this case the hills layer.[5]
  - In this case the **Relationship** will be **Intersect** so select that from the dropdown
  - The **Selecting Features** are those with the area you want to select by
  - **Selection type** is **New Selection** - you're not creating any output at this stage, just selecting features.

[4] Right click on it in the contents pane and **Remove**.

[5] If you get confused when filling in a tool try hovering over the information icon that appears when you click on a field.

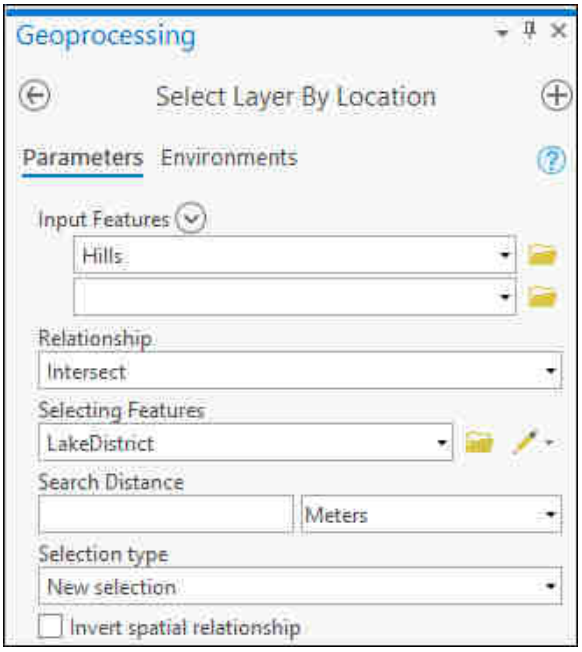


Figure 7.10: Select features by location within the Lake District National Park

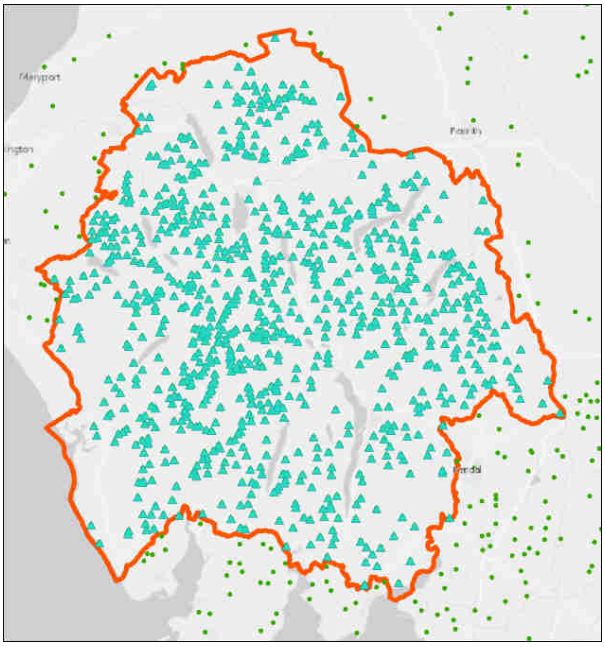


Figure 7.11: Points selected after running "Select by Location" - marked as triangles. The selected points should all be within the Lake District National Park boundary.

Once you click on Run you should have all of the points within the Lake District National Park selected - they should appear as turquoise blobs as in figure 7.11 and the points outwith the National Park should be whatever colour they have been symbolised as.

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 7.6.3 on page 114. Make sure that you add the new layer to your map and remove the old one.

7.7 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:

- start by clicking on the **Analysis** tab on the ribbon and click on the **Environments** button
- Under **Processing Extent** click on the **Extent** drop down to see the options that are available to you.

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. Now that you have a layer which defines the outline of the Lake District National Park you can select that to restrict processing.

- At the bottom of the list should be a list of your layers under a subheading saying **Same as layer:** - select your layer containing just the Lake District national park outline
- The display will show **As Specified Below** and the coordinates of the bounds of the national park - as in figure 7.12
- Click OK

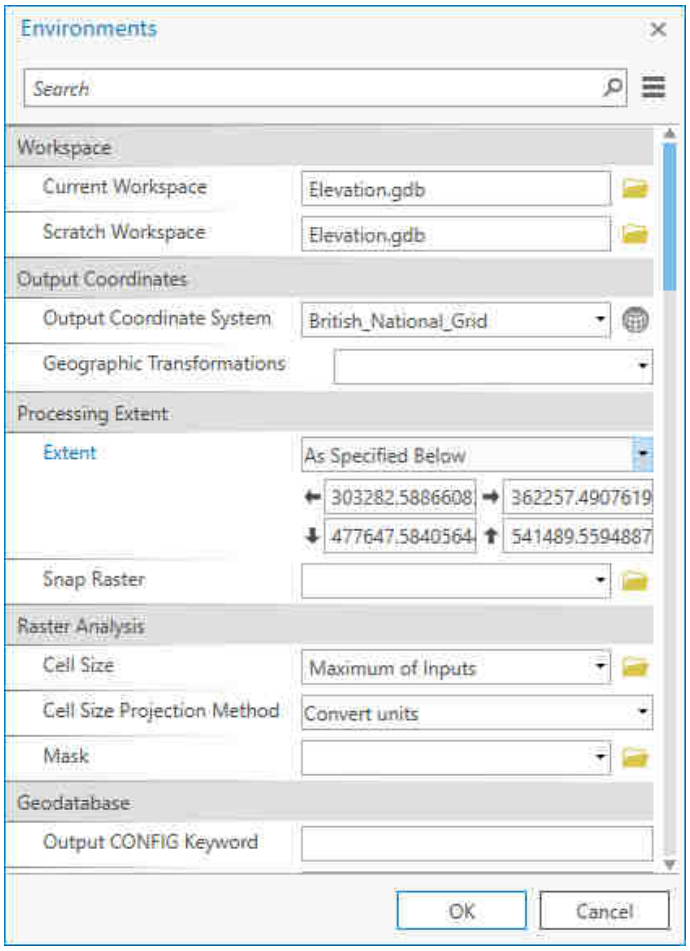


Figure 7.12: Choosing a layer to set extent in the Geoprocessing Environment Settings dialog

Try running the hillshade tool now and you should find that the output is only a bit smaller than the original terrain layer but should only cover the Lake District national park, in some cases this can make a really big difference to processing time and disk storage.

7.8 Viewshed analysis

Julia Bradbury[6] is 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.

[6] See `https://theoutdoorguide.co.uk/walks/julia-bradbury-walks/` if you're not sure who Julia Bradbury is.

Video Clip available in Minerva - Viewshed analysis in Arc.

7.8.1 Selecting the observer point and running the viewshed tool

The first 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, which can take an awfully long time.

Use **Locate** from the ribbon[7] to find **Blencathra**.

Right-click on **Blencathra, Cumbria, England, GBR** in the list of results (see figure 7.13) and **Zoom to** that point, which should have an **A** symbol next to it.

If you look at the 1:50 000 background layer you should be able to find **Hallsfell Top** - that's the location we'll use for this exercise.

- Select the point for **Hallsfell Top** from the Lake District Hills feature class using the **Select** tool from the **Map** tab of the ribbon.

Figure 7.13: The result that you choose for Blencathra should look something like this one - it's a mountain, not one of the street names that come up.

Once Hallsfell Top is selected you can fill in the Viewshed tool

- To open the tool click on the **Tools** button on the **Analysis** tab of the ribbon
- Open the tool by going to Toolboxes > 3D Analyst Tools > Visibility > Viewshed
- Fill in the dialog in a similar way to figure 7.14. The input raster will be your mosaiced dtm and the input point file will be the feature class with the Lake District summits.
- Run

Once the tool has run you should find a raster layer in your map with just one random colour indicating the areas which are visible from your viewpoint. This is is a good start, but you could go one step further by taking account of the height of the observer - that could make a difference to the number of summits visible.

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

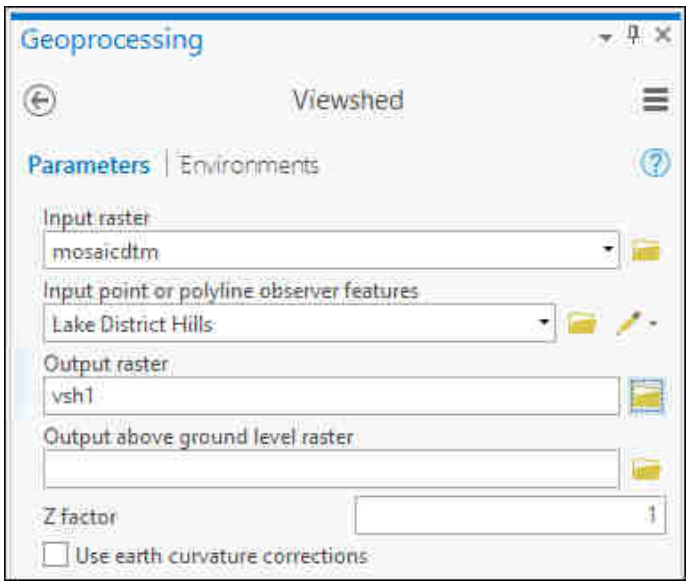


Figure 7.14: Filling in the viewshed tool

7.8.2 Adding an offset - the height of the observer

It is possible to **offset** the height of the observer above the base heights provided by the dtm. 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 metre - 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** of the *source* of the observation, not to the dtm/height data. So to add an offset of 1.75 m to the height of each hill do the following:

- Clear selections by clicking on the clear button on the ribbon 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 12.6.3 on page 206 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 **Calculate Field**
- Type the required offset in the box where it says **OFFSETA =** as shown in figure 7.15 and click Run

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**.

Try running a viewshed for Hallsfell Top again using the instructions in section 7.8.1 on page 118 but giving the output a slightly different name.

Compare both results on the map - the Swipe tool can be useful for this. Go to the Appearance tab of the ribbon and click on Swipe in the Effects group. You can then use the cursor on the map to swipe the layer that is selected in the table of contents either left/right or up/down.

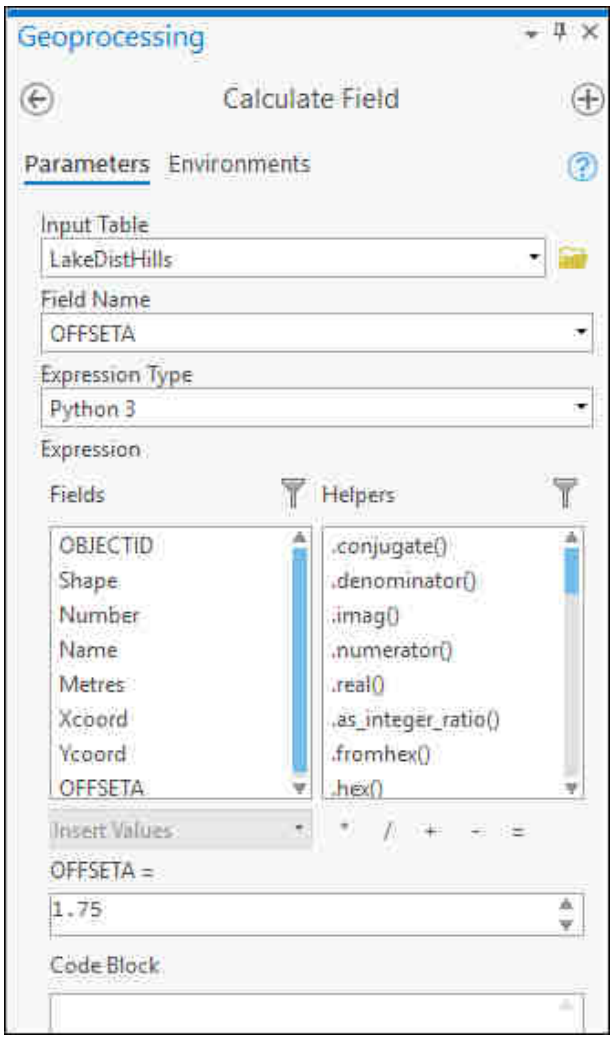


Figure 7.15: Using the Calculate Field geoprocessing tool

7.8.3 How many summits?

If you go back to the start of this section on page 117 you can see that the original question asked how many summits it is possible to see from the summit of Blencathra.

This is one of those times when you have to start breaking down exactly what you are trying to do so that you can see what steps you need to carry out. At this stage you have points in a vector file, and a raster file with two different symbols showing which areas are and are not visible. You now need to put the two together and work out which points are in the area which is visible.

Have a close look at the raster viewshed layer. Use the Explore tool[a] to click on pixels in both the visible and not visible areas.

Question 7.1. What information can you use to differentiate the two areas?

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

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 how I would do it.

Convert raster file to vector polygons

Start by converting the raster file to vector polygons.

- Geoprocessing toolbox > Conversion Tools > From Raster > Raster to Polygon
- Fill in the dialog as in figure 7.16 with the **input raster** being the viewshed layer, and the **Field** being **VALUE**
- choose where to save your output and give it a name then Run

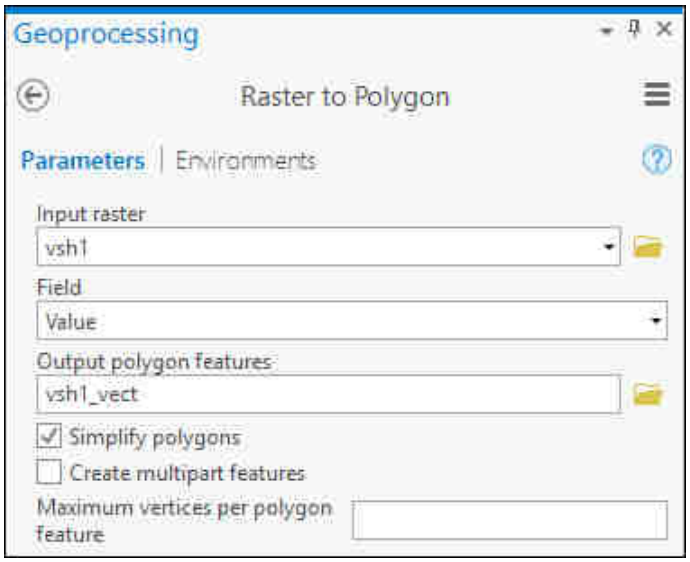


Figure 7.16: Converting Raster to Polygon

The new polygon feature class will be symbolised with all features 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 7.2. 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? Hint: look for a column which contains similar values to those you found in question 7.1

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.

- Start by clearing all selections. If there are selections in more than one layer you won't be able to delete anything.
- Click on **Select by Attributes** on the **Map** tab of the ribbon
- Fill in the geoprocessing dialog as shown in figure 7.17.
  - The **Layer Name** should be the name of the vector layer you have just created
  - **Selection Type** should be **New Selection**
  - for the **Expression** click on the New expression button and fill in with the field you selected above as having the content that shows whether it is visible or invisible, then select **is Equal to** and use the next dropdown to select the value that shows that a record is **invisible** - which should be `0`
  - then click Add to actually save the clause you've just added
- click Run to create the selection

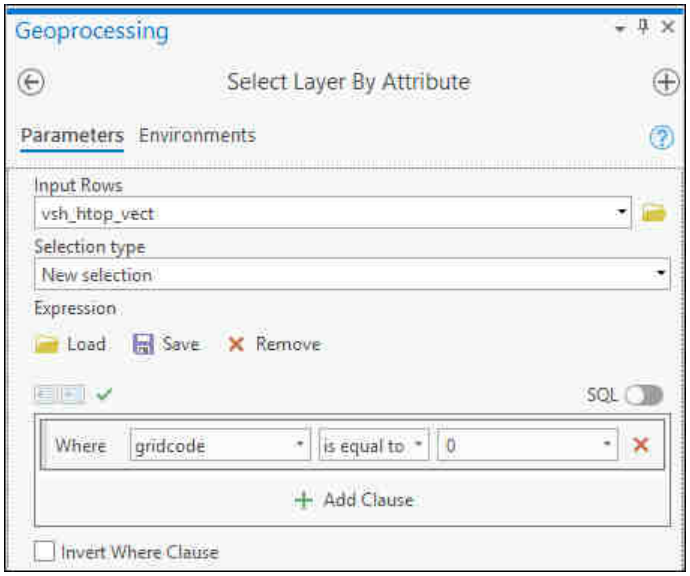


Figure 7.17: Filling in the clause for Select by Attributes - select where gridcode is equal to 0

Once you have the features selected that are **not visible** you need to open the attribute table then just click on Delete at the top of the attribute table (remember that hovering over buttons gives you a tool tip).

Then go on to the **Edit** tab on the ribbon and **Save** your edits.

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
- Geoprocessing toolbox > Analysis Tools > Overlay > Intersect
- Fill in the dialog as in figure 7.18 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

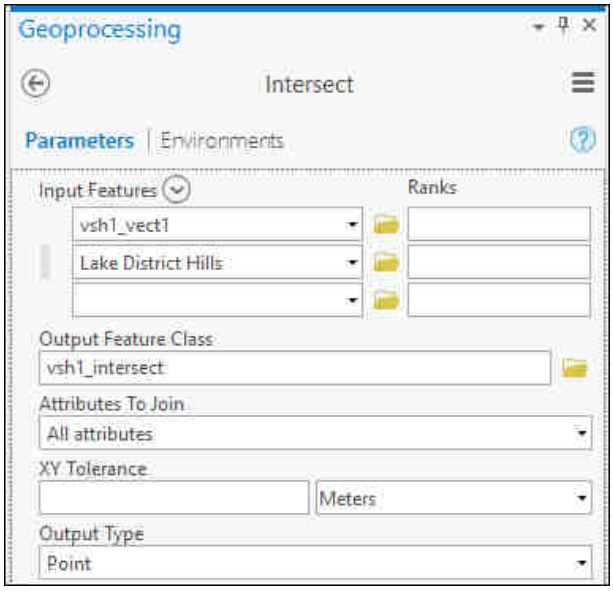


Figure 7.18: Filling in the Intersect tool

Finally you should have a feature class that just contains the summits that are visible from the top of Hallsfell Top on Blencathra. Zoom in and check that the summits in the new layer are indeed within the viewshed / visible areas.

Open the attribute table to see how many summit records the feature class contains.

Question 7.3. How many Lake District summits are visible from Hallsfell Top?

Repeat the process, this time starting with the point for the summit of Helvellyn.
Question 7.4. How many summits are visible from Helvellyn?

7.8.4 Save your map and data

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. To save yourself time when you start work on that chapter, make sure that you save the data that you have used for this one as you'll be using the same area.

7.8.5 Suggested layout

The final step of any analysis is to display your results. To practice the techniques from chapter 6 (page 84) 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 9 on page 23 if you need a reminder of the details) and for the Database of British and Irish Hills (check their website for their requirements).

7.9 Viewing your map in 3D

Within Arc it is possible to view your maps in 3D by creating a **Scene**. We'll look at this now with the data you have already, but it's something you can do with any data that you create in future chapters too.

Video Clip available in Minerva - Viewing your map in 3D in ArcGIS Pro

7.9.1 Creating a Scene

To set up an empty scene

- Go to the **Insert** tab of the ribbon
- Click on the down arrow under the **New Map** button
- Click on **New Local Scene**

Arc will create a new scene which currently looks very much like a new map - something like figure 7.20. Note that the new scene appears under the **Maps** subheading in the Catalog. In the Contents pane the Drawing Order view now shows layers divided into **3D Layers** and **2D Layers**.

7.9.2 Adding data to a Scene

We'll use one of the viewshed layers that you generated in previous exercise to show how the 3D view works.

- In the Catalog navigate to the geodatabase or folder in which you saved the output of the geoprocessing

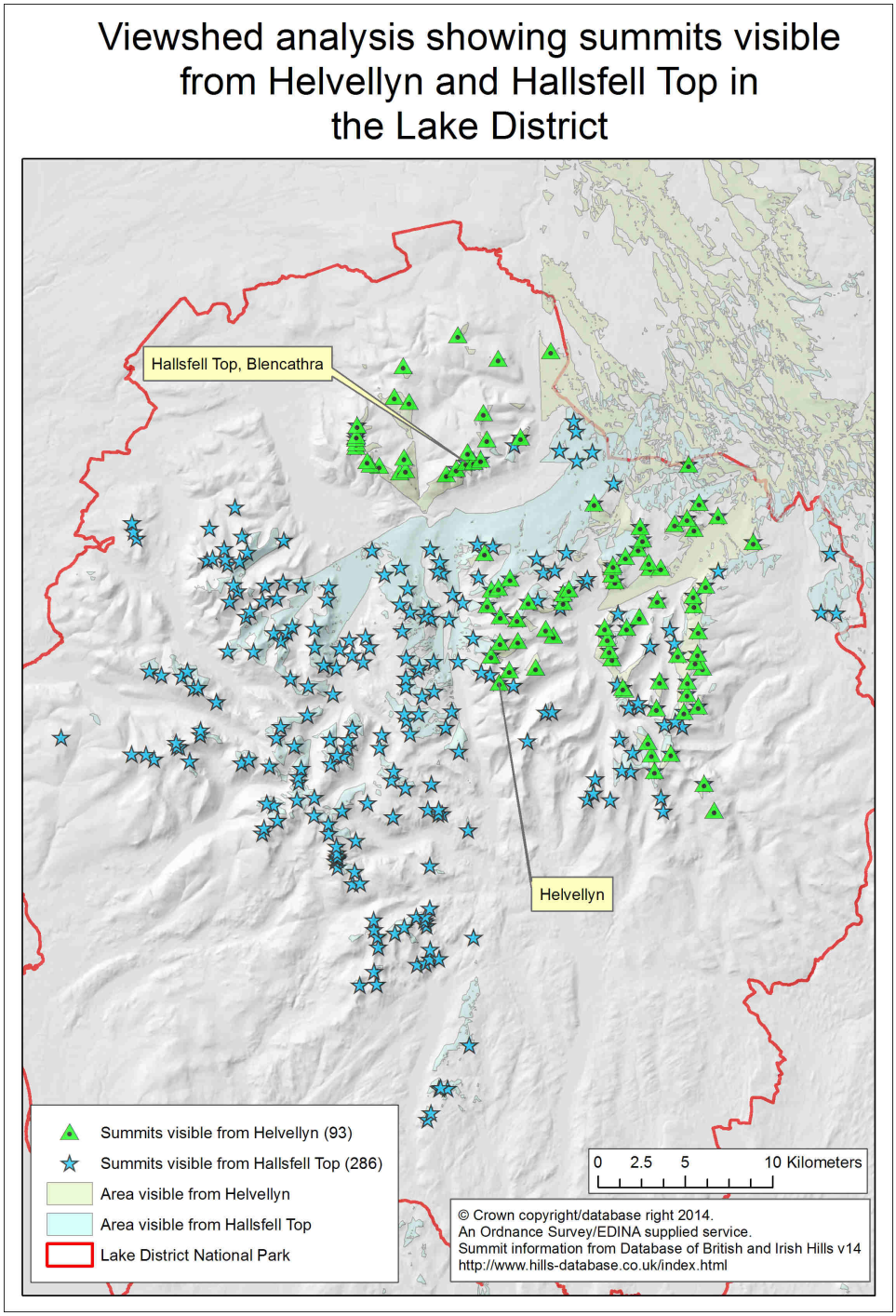


Figure 7.19: Possible final layout for a map of visible summits from Hallsfell Top and Helvellyn

- Find one of your vector polygon feature classes showing the viewshed for one of the hills and drag and drop it onto the globe

It may take a while for Scene to load your layer, but just be patient! It should appear in the **2D Layers** part of the Contents pane, and Arc should zoom to the area of your layer in the main window.

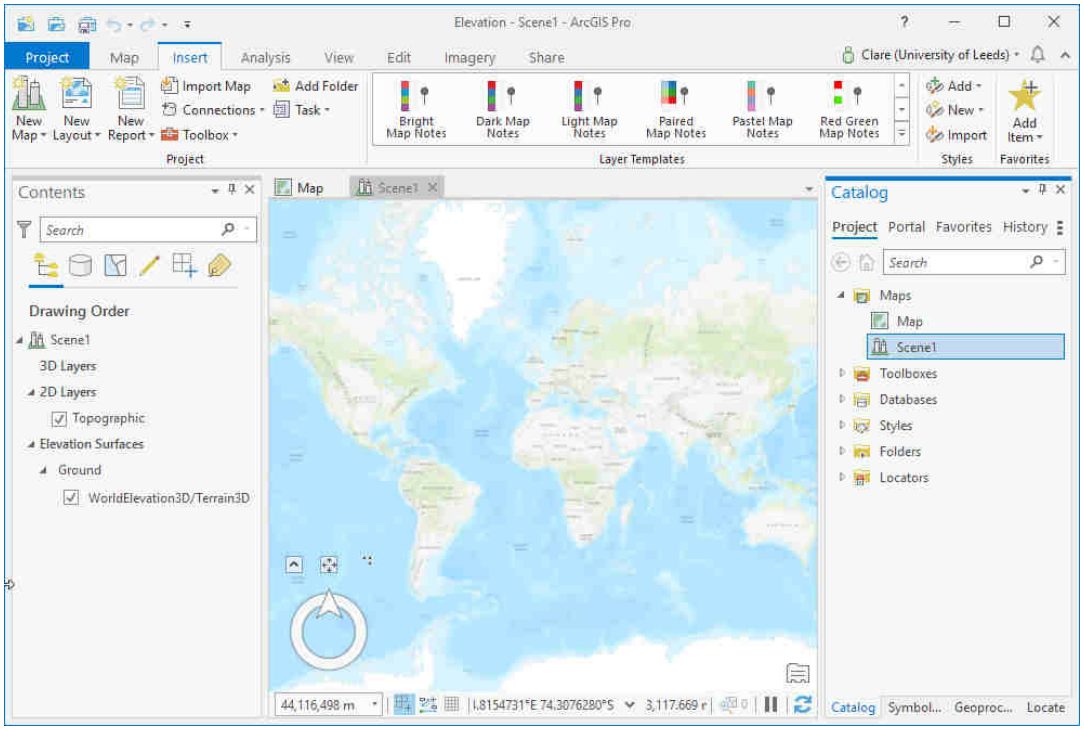


Figure 7.20: The initial view when you create a new local scene

In addition add the following two layers:

- ***Lake District National Park outline***
- ***Lake District Hills layer***

Symbolise the layers in exactly the same way as you would symbolise them in a map so make the National Park outline into an outline with no fill so that you can see the other contents of the map.

ArcGIS Pro Help has information on how to navigate in 3D at `http://bit.ly/32pZWOB`. The main difference from navigating in a map is that you can use the mouse wheel to "tip up" the map and rotate it, or use the navigation tool at the bottom left of the map to move around. Try this now.

You can also change the **Basemap** in exactly the same way as you can change it in a map. Check the instructions in section 1.7.9 on page 12 if you can't remember how to do this.

Change the basemap to Imagery now.

7.9.3 Interactive line of sight

Interactive line of sight allows you to see whether an observer at a particular point would be able to see something at another point. Whereas viewshed shows areas, line of sight is from point to point, and shows the obstacle that prevents the target from being seen.

Video Clip available in Minerva - Interactive line of sight in ArcGIS Pro

- Using the Lake District Hills layer navigate to the summit of one of the hills - it doesn't matter which one.
- Go to the **Analysis** tab of the ribbon
- Find the **Interactive Analysis** button and click on the down arrow below it
- You'll be given a choice of analysis methods - select **Line of Sight** - figure 7.21

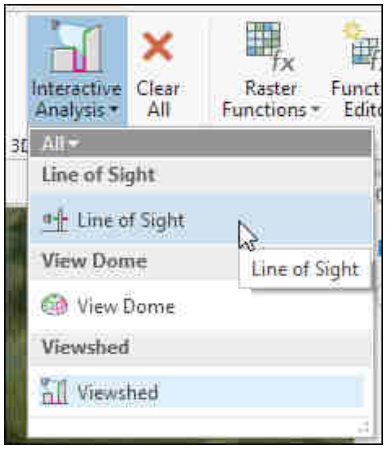


Figure 7.21: Choosing Line of Sight from the Interactive Analysis tools

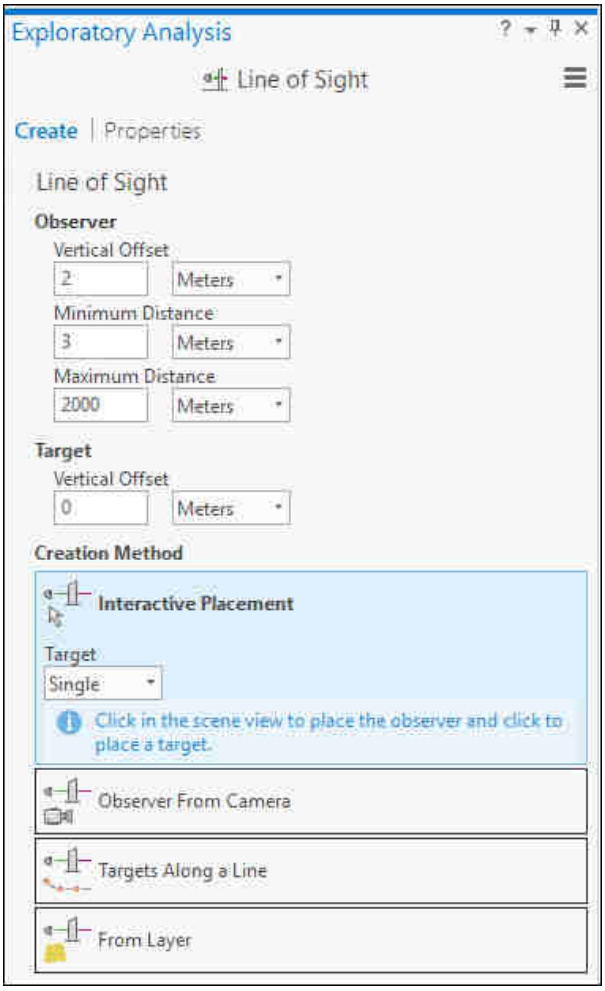


Figure 7.22: The creation options for Interactive Line of Sight

---

A new panel will open on the right of the scene giving you the creation options - figure 7.22.

- For now accept all of the defaults except for **Maximum Distance** - this restricts the distance the target can be from the observer. Change it to something like **5000 meters**
- If you need to navigate in the scene whilst using the Interactive Line of Sight tool hold down the C key to do so

- To create the line of sight
  - Click on the point for the observer - in this case one of the hill summits
  - Then click again, this time for the target - in this case click somewhere in the valley below the summit

Arc should create a line which will be coloured red or green, or a mixture of the two. Green showing the part of the line which is visible from that point, red showing the part which isn't visible. See the examples in figures 7.23 and 7.24.

Figure 7.23: The line of sight is green throughout, showing that the target is visible from the observer.

Figure 7.24: The line of sight is red, showing that the target is not visible from the observer.

As the name of the tool tells you, this is interactive. So try dragging the observer point and the target and see how the line of sight changes.

If you want to change any of the properties of the line try right-clicking on the observer point. You can also change the properties in the Create panel.

If you want to **Clear** the line of sight and start again, use the **Clear All** button on the Analysis tab of the ribbon.

7.9.4 Including a scene in a layout

It is possible to include your scene in a layout in exactly the same way that you can include a map.

From within a layout (see chapter 6 on page 84 for more information)

- click on the arrow underneath **Map Frame** button on the **Insert** tab of the ribbon
- In the list that appears choose a **Scene**
- then wait a while for it to appear on your layout!

You can move the scene around and resize it on the layout in exactly the same way that you can move and resize a map frame.

7.9.5 Exporting a 3D view

Once you have a useful view in Scene you can export it as an image to import into other programs, such as Word or Powerpoint.

- Go to the **Share** tab of the ribbon
- Click on the **Map** button in the **Export** group
- choose where you want to save the output, and what format you want (png or jpg will import into Word or Powerpoint)
- Check the Resolution - higher gives higher quality, but a bigger file - experiment but don't go higher than 600 without being very careful. 300 is usually enough.
- Export

7.10 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[8].

Kennedy, K.H. (2010), Chapter 6.

Chang (2016), Chapter 13 covers raster and vector terrain analysis.

7.11 Vector elevation models: TINs

Triangulated Irregular Networks, or TINs, are vector elevation models which show surfaces as sets of contiguous, non-overlapping triangles - see figure 7.25 for an example. The surface of each triangle is a plane, and the points where they join are called **mass points**.

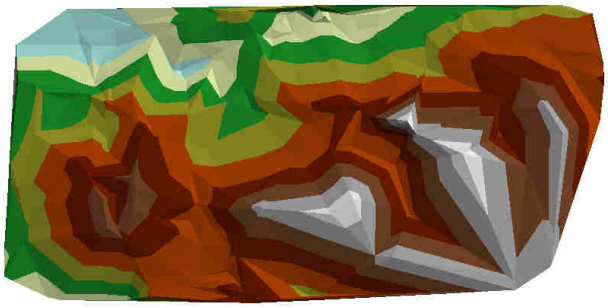


Figure 7.25: An example of a Triangulated Irregular Network (TIN) showing the triangles and mass points.

TINs are an efficient way of storing data, and have the ability to describe different levels of resolution in the same file. They do often require visual inspection, though, and manual control of the network.

We won't be working with vector elevation models in this module. But if you are interested in finding out more have a look at the following references from the module reading list:

Chang (2016), Chapter 13 covers raster and vector terrain analysis.

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

Chapter 8

Model builder: making repetition easy

In chapter 7 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 viewshed 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.

8.1 Learning outcomes

The background to model building will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

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

8.2 Data for this exercise

If you still have your Lake District map from chapter 7 you can use this to work through the exercises in this chapter. If you no longer have it or you would prefer a "clean" copy of the map you can download a zipped map from Minerva - `LakeDistrictHills.7z`

8.3 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.

Start by thinking about what question you are trying to answer (this is a good start for any GIS project) - in this case the question is:

How many summits from within the Lake District National Park can be seen from the top a list of 10 Lake District hills?

Chapter 7 has already shown you the process that you want to automate in this model to answer that question, 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.

Question 8.1. What data do you need to start with?

Question 8.2. What processes or tools do you need to run on that data?

Remember possible answers to the questions above are given in appendix B starting on page 239.

8.4 Building a model

To open the Model Builder click on the **ModelBuilder** button on the Analysis tab of the ribbon (figure 8.1).

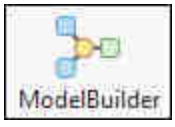


Figure 8.1: Button to open Model Builder window

You'll have opened a blank window in the space previously occupied by your map (figure 8.2) and will build the model graphically in this window. Have a look at the tools that are available to you on the **ModelBuilder** tab of the ribbon. These allow you to add existing geoprocessing tools, data from your map or from disk, and allow you to zoom in and out on the model.

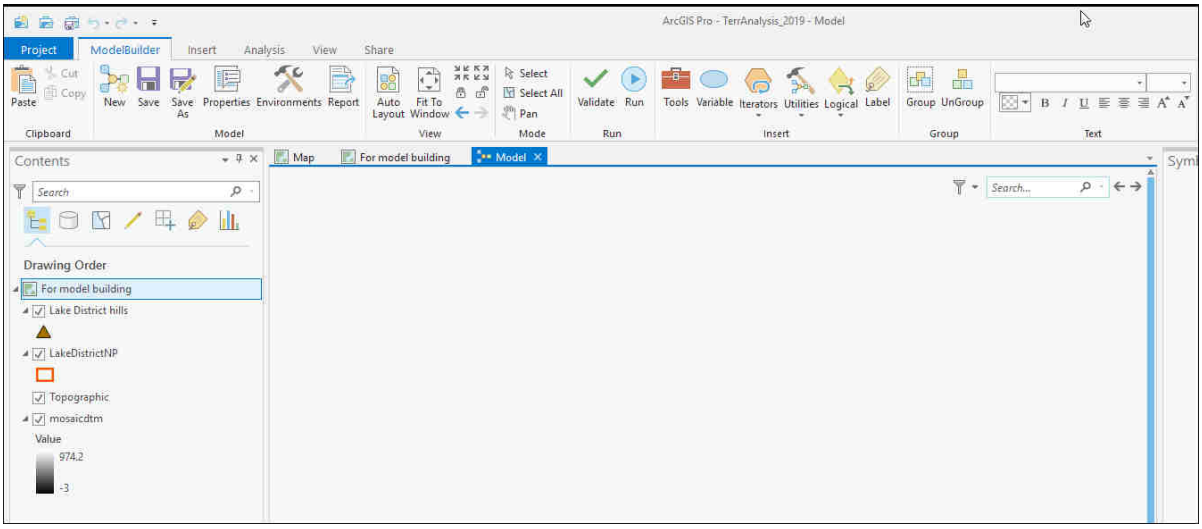


Figure 8.2: The blank Model Builder window with the ModelBuilder tab of the ribbon showing at the top

Video Clip available in Minerva - Arc Model Builder: Making repetition easy. Direct link: `http://bit.ly/2su07pX`

8.4.1 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 Arc. You'll need the **dtm mosaic** as height data, and the feature class 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 8.3 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.

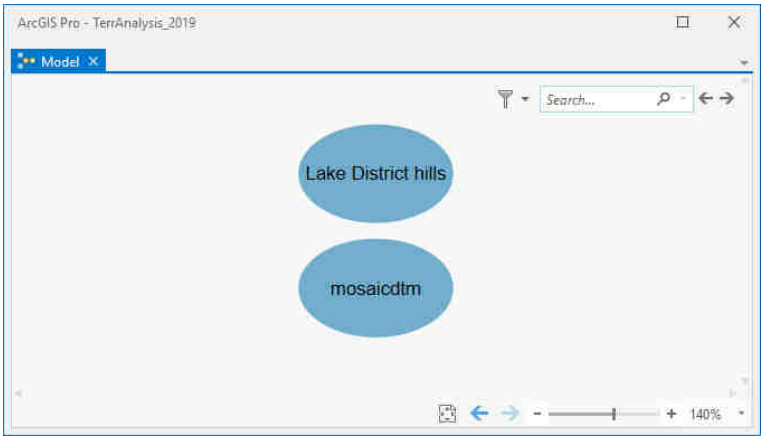


Figure 8.3: The model builder window with the height data and point shapefile.

8.4.2 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 As on the Model Builder tab of the ribbon
- Your model will be saved to the default project toolbox - you can find it via the Catalog pane.
- Give your model a name which will help you to remember what it does. In this case call it **ViewshedHill**.

Once you have saved your model to a toolbox for the first time, you'll just have to click Save next time.

Then, when you close it, you should be able to find your model again using the **Toolboxes** subheading in the **Catalog pane**. To edit it again right-click on the model in the Catalog pane and select Edit.

8.4.3 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 the geoprocessing toolbox 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 8.4.

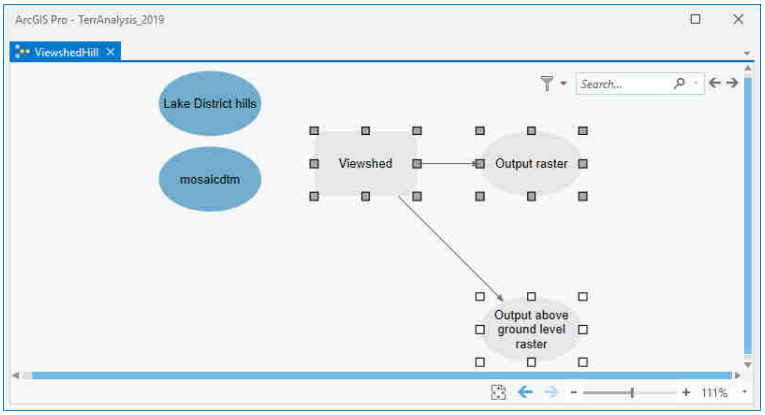


Figure 8.4: The model builder window with the Viewshed tool added.

Linking data to tools in a model

Now you need to link the data with the tools. It's simply a case of clicking and holding on the input and dragging a line to the appropriate tool

- Use the mouse to click and hold on the shape for the mosaic dtm input, then drag to 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 8.5, 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 raster** item.

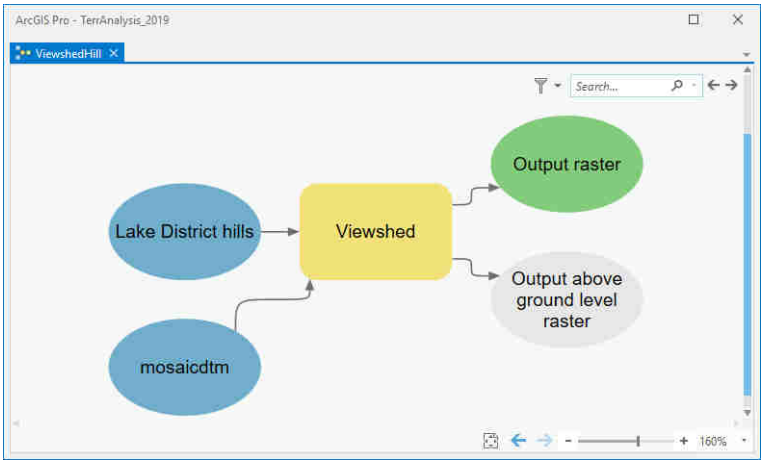


Figure 8.5: Linking the data to the Viewshed tool

8.4.4 Renaming output

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,

- double-click on the Viewshed tool
- click on the folder symbol after the **Output raster** box and change the path and file name so that the output is saved to the project geodatabase

I would suggest creating a new file geodatabase[1] called something like **Output** for the resulting output of the model and saving all of the output into that.

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 8.6 rather than 8.7. 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.

8.4.5 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.

[1] In the Catalog right-click on the **Databases** subheading and select New File Geodatabase

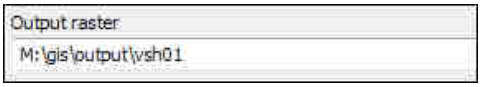


Figure 8.6: The correct way to link output file paths

Figure 8.7: The wrong way to link output file paths

- 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 the **Run** button on the **ModelBuilder** tab on the ribbon. If you can't find it make sure that you do have the model open.
- If you don't have the model open find it in Catalog, right-click and Edit... then Run.

It can take a while for the model to run! You should be able to see progress in a new window which opens - figure 8.8

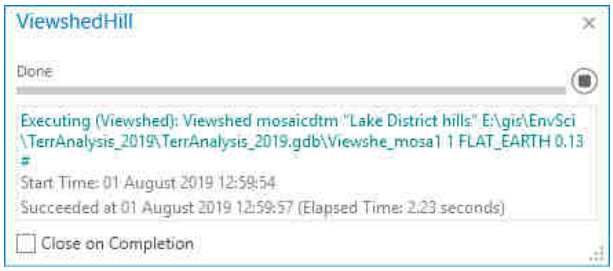


Figure 8.8: The window which opens when you run the model. This one shows that it has run successfully and has finished running.

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 the model 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 by adding it to your map 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.

8.4.6 Adding more tools

Raster to Polygon tool

To add the Raster to Polygon tool do the following.

- Geoprocessing 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 8.9. Don't forget to check the name and path for the output and change those again.

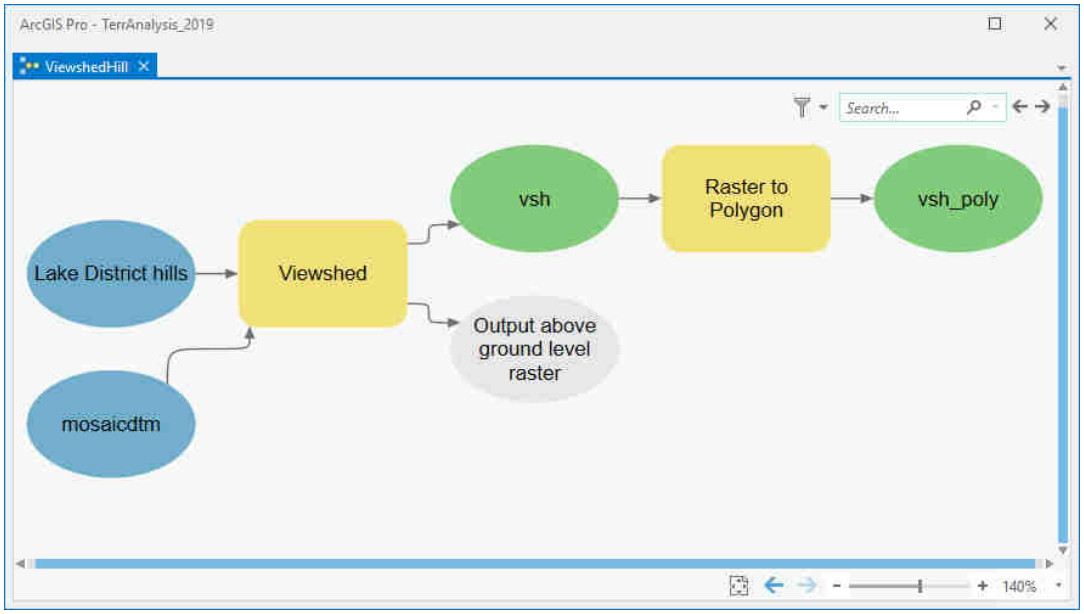


Figure 8.9: Linking the output from the Viewshed tool to the Raster To Polygon tool

Again, run the model, not forgetting to select a single summit, (section 8.4.5 on page 134) and check that it works so far.

Select tool

Add the **Select** tool as follows:

- Geoprocessing 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.

Again link the output from the **Raster to Polygon** tool to the **Select** tool.

- 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 use the Add Clause button to enter the expression **GRIDCODE is equal to 1**.
- Don't forget to click on Add
- OK

The result should be something like figure 8.10

Once again, run the model (section 8.4.5 on page 134) and check that it works so far.

[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.

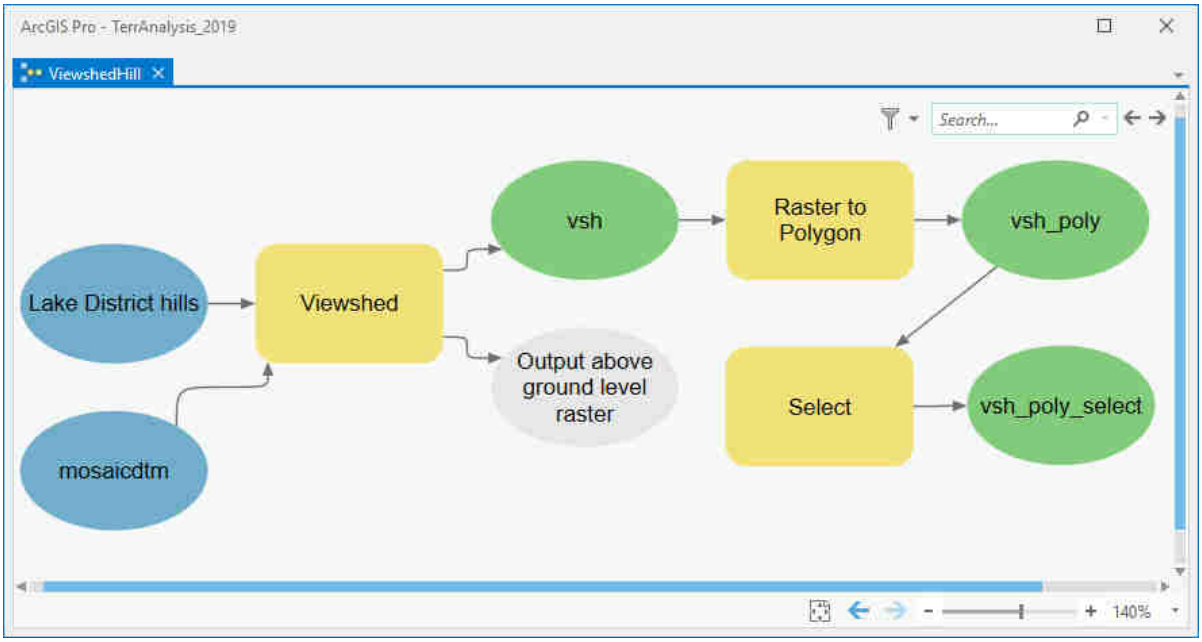


Figure 8.10: Linking the output from the Raster to Polygon tool to the Select tool

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:

- Geoprocessing 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 the current selection** as in figure 8.11 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 8.12 - 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 8.11: Model building: Select Layer By Attribute

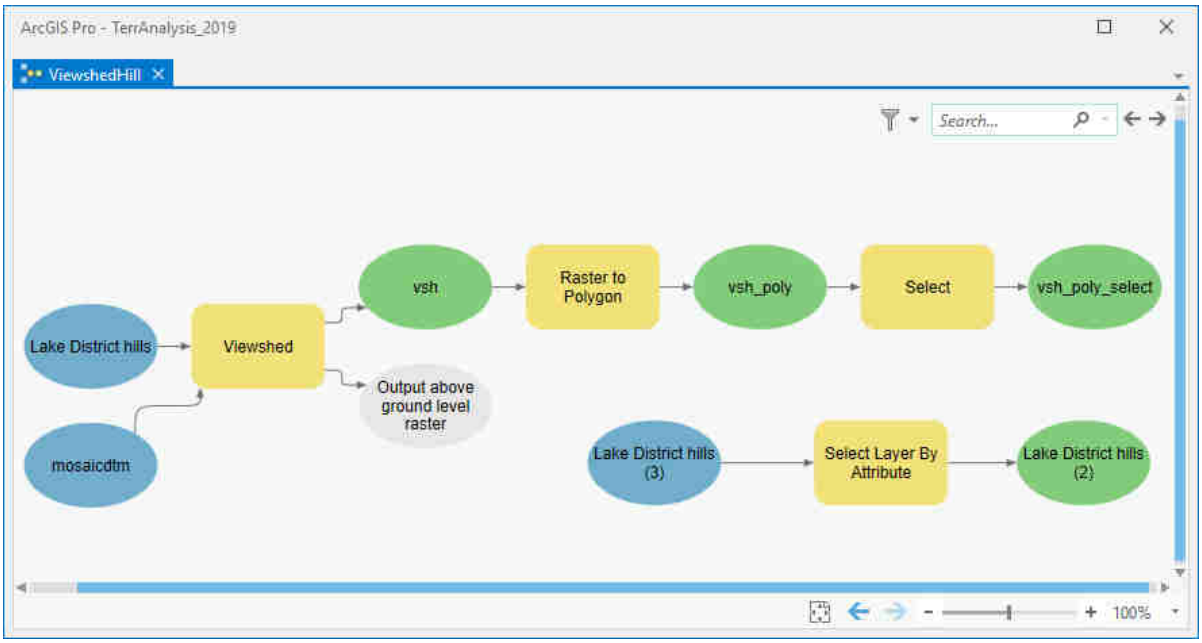


Figure 8.12: Clearing selections on the Lake District Hills layer

Intersect tool

For the final step add the **Intersect tool** as follows:

- Geoprocessing 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 8.14.

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 8.13

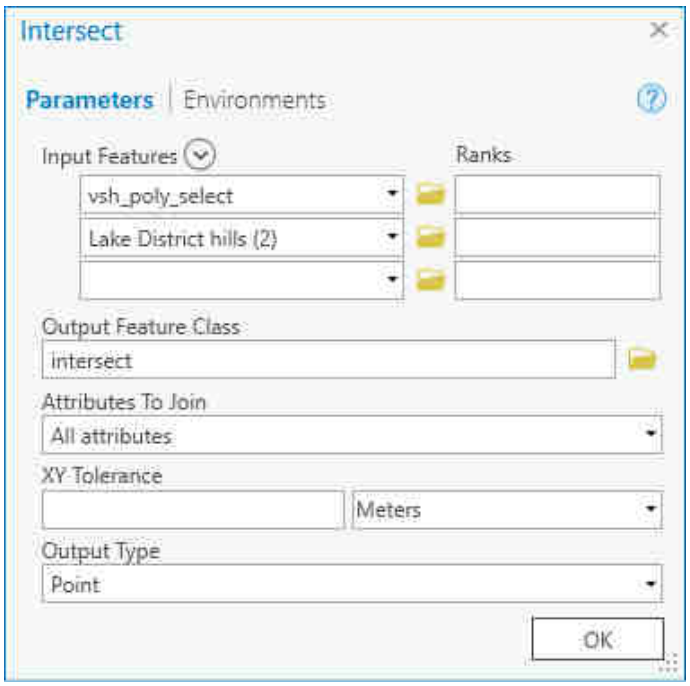


Figure 8.13: Settings for the Intersect tool

8.4.7 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.

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 8.14 (but not necessarily arranged in the same way).

Don't forget to **Save** your model which should look similar to figure 8.14 by now. The full instructions are in section 8.4.2 on page 133 if you need reminding, but you should just need to press Model > Save this time.

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.

8.4.8 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.

- 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.

[3] See section 1.4 on page 2 for a reminder

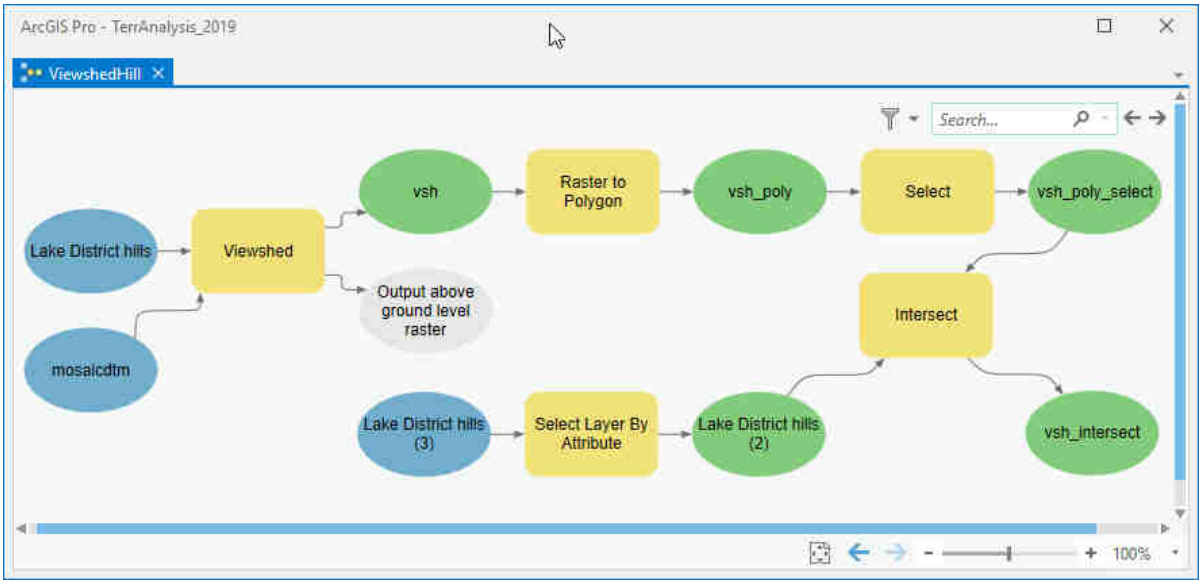


Figure 8.14: Your completed model

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 final output a point file and is it automatically added to your map? Are any other layers are created, and maybe 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.

8.5 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 Run

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.

- Once again select a single summit on your map
- Open up your model for editing again - right-click on it in the Catalog pane and select Edit
- Right-click on the output from Viewshed and select 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 8.15.
- 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.
- Save the model and close it. Then run it again by double-clicking on the model in the Catalog.

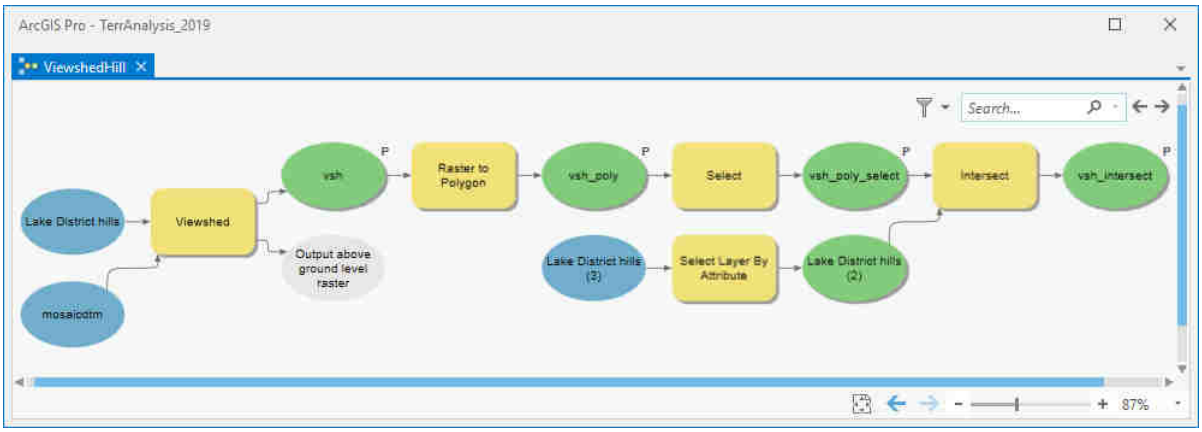


Figure 8.15: Your completed model with parameters set - note the "P" next to the outputs

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 8.16.

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 Run 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

Figure 8.16: Entering new file names into the Model Builder

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 8.1.

8.6 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.

Table 8.1: Lake District Hills - visible summits

Run no.	View point	No. of visible hills
1	Scafell Pike	
2	Helvellyn	
3		
4		
5		
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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 8.8 on page 144 gives specific suggestions). As usual YouTube videos can be really useful - try the suggestions in section 8.8.1 on page 144.

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 (more than a complex model that doesn't work would), but this will be an opportunity to show how much further you can go to earn extra. 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! In the next chapter, which you can work on in your own time or at the drop-in class, you'll get a chance to experiment with some different models and model building techniques as preparation for the assessment exercise.

8.7 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 8.17. It is unlikely to look identical as you should make your own decisions about where to place elements and how to display your map.

8.8 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.

8.8.1 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`

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

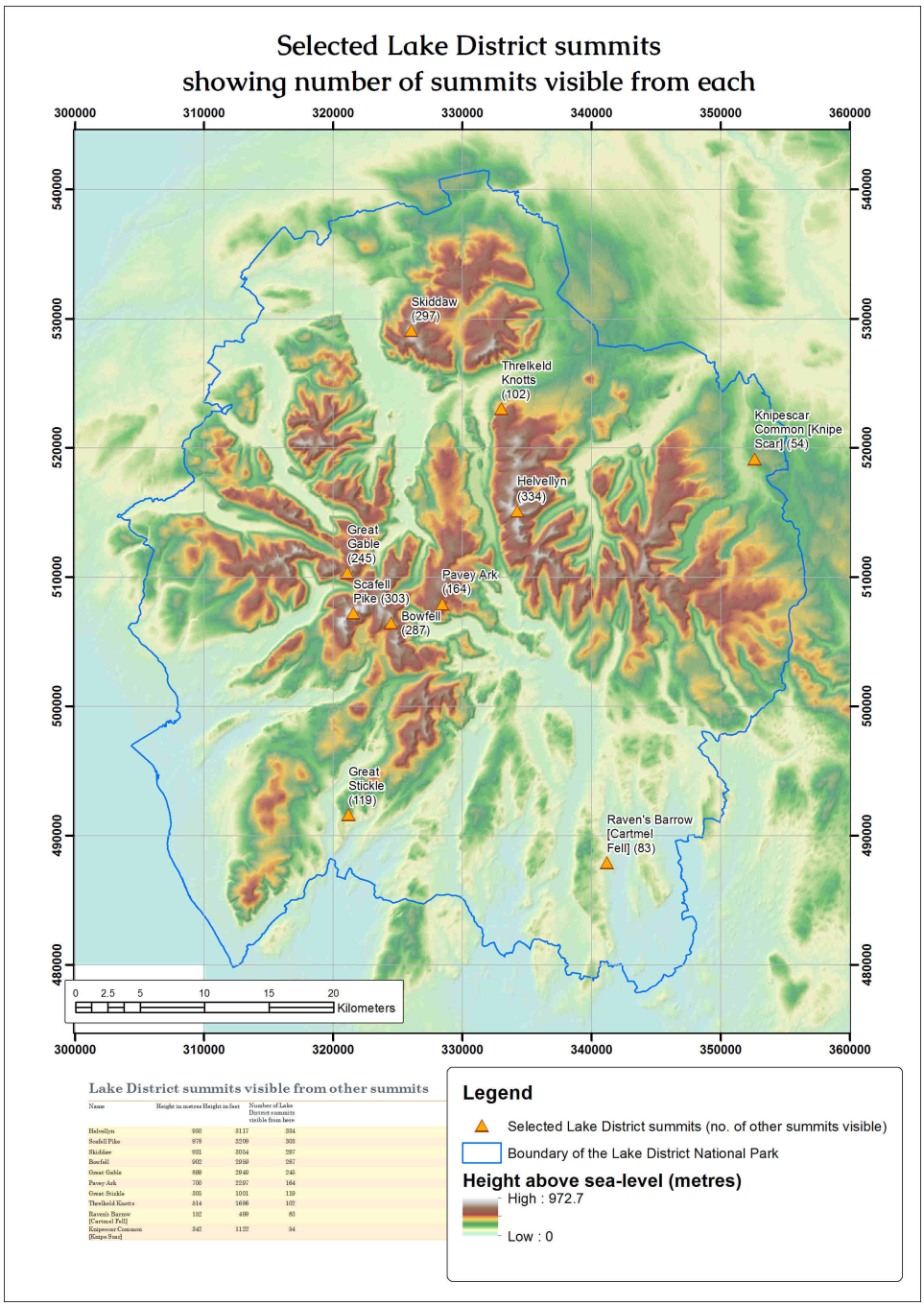


Figure 8.17: Possible layout for the map of summits in the Lake District

Chapter 9

Model builder: practice and further techniques

9.1 Introduction

This is an optional chapter. It will not be covered in the practical sessions, and you do not have to do it, but if you want to work through it and need help with the exercises you can work on it in any of the drop-in classes, or come to my office during the week.

You have covered the basics of model building in the exercises in chapter 8. For the second assessment for the module you will be expected to put together a model, and the exercises in this chapter are designed to give you more experience before you do that. There are suggestions for tools and techniques to use. Possible solutions are given, but try to work out for yourself how to get the models to work before you look at the solutions.

Before starting on these exercises do make sure that you have successfully run the final model from chapter 8 of the workbook. If you can't get that to work please make sure that you speak to Clare or a demonstrator.

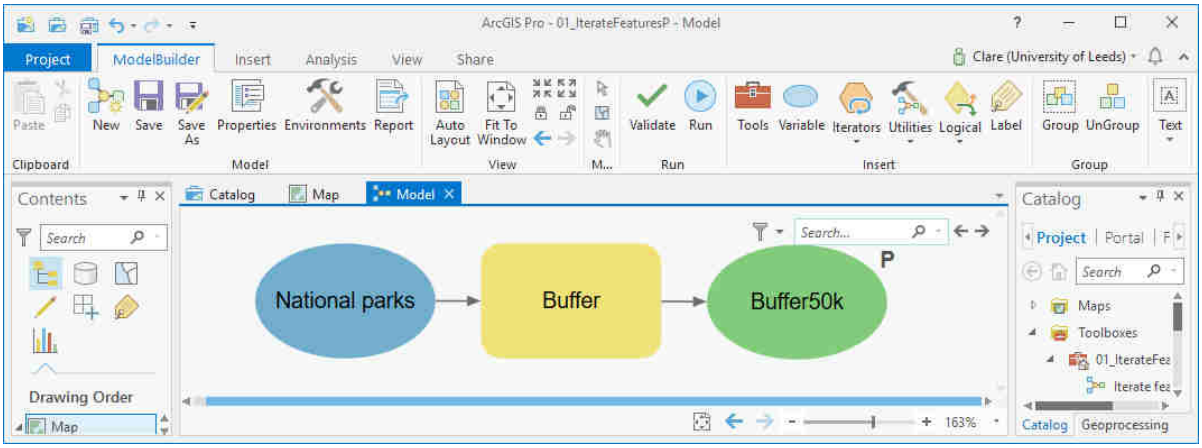


Figure 9.1: A simple ArcMap graphical model and the tools on the ribbon

For the assessment a simple model which produces the desired output and shows an understanding of what you are doing will earn you decent marks. If you feel you can take it further then that is great, but remember that you have other work to do, so don't get too focussed on producing a complex model.

The exercises are basically presented in order of complexity, but feel free to work on them in any order that you choose. In addition, you do not have to complete all of them but are free to

do as many as you wish. All can be extended to become more complex, and some additional suggestions are given, but don't be limited by those.

Also feel free to work in small groups of two or three people. As long as each of you has a good understanding of how you have been able to get each model to work, being able to combine knowledge and share solutions to problems should help you all to learn.

9.2 General Instructions

9.2.1 Obtaining the data

The data for these exercises can be downloaded from Minerva. Each folder within the `Model-Building_Extras.7z` file is an ArcGIS Pro project and contains a single exercise. You are provided with the necessary data and a model which carries out a basic task. You should use the model as a basis for a more advanced one using the information given in each section.

9.2.2 Running the basic model

For each basic model your first action should be to check that you can run it as it is. You will probably find that you need to edit the model to alter the location of the input, and the locations where you want to save the output. Indeed, you may need to repair the data links in the map first - remember to see the workbook for instructions if you need them.

Remember that when running models, **file and folder naming is a major cause of errors**. If you are having trouble with this, refresh your memory by looking at the File Management presentation in Minerva and its associated video clip.

9.2.3 Extending the models

Use the information in chapter 8 on model building, and the extra links for model specific tools in section 8.6 on page 142, as well as the Recommended reading in section 8.8 on page 144, to give you more information on how to extend these models. There are plenty of videos on YouTube about the Arc model builder and a Google search can usually come up with an answer. The challenge can be to formulate your search so that you get an answer that works.

You are welcome to go beyond the suggestions and add more processes to a model if you think any would be useful. Explore the options in the **Insert** menu of the model builder for some extra ideas.

9.3 Finding tools

Rather than having to find tools within the appropriate toolbox it can be easier to search for something.

- Enter your search term in the box at the top of the Geoprocessing panel, and select the appropriate entry
- You can drag tools from the results panel straight into the model builder.
- Don't forget that some tools are **Model only** tools and can be found in the ribbon when you're in the model builder.

9.4 1: Model to buffer fields from a feature class

This exercise takes as an input layer a shapefile of the National Parks of England and uses a model to generate buffers around them. You could use this in combination with other data as a basis for answering a question such as "what percentage of the population of England live within 50 km of each National Park?"

9.4.1 Instructions

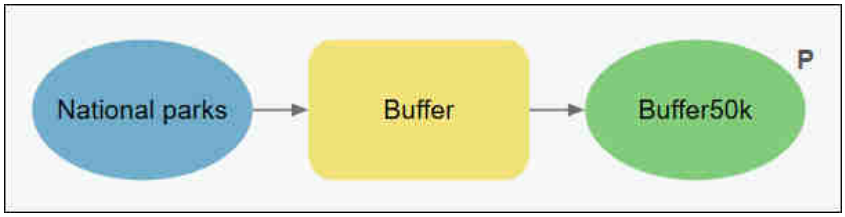


Figure 9.2: The model as supplied.

The model as supplied puts buffers for all features in the National Parks feature class into a single new feature class - in figure 9.3 you can see that all of the buffers have been symbolised as the same colour.

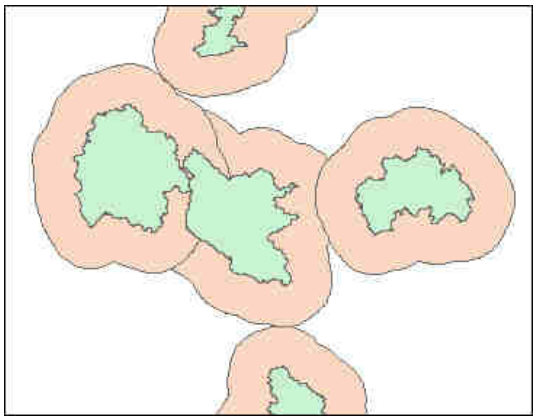


Figure 9.3: Output of the original model showing all of the buffers within the same feature class.

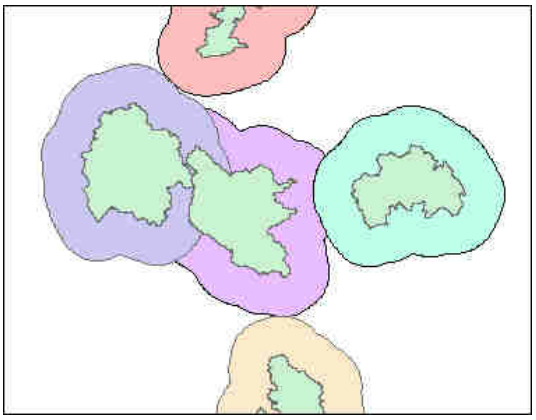


Figure 9.4: Output of the iterating model showing that each buffer is in a different feature class and is symbolised a different colour.

Edit the model (saving a copy first in case your changes don't work) so that it **iterates** through each feature separately and outputs **each** buffer to a new feature class. You should end up with ten separate feature classes. The output should look something like figure 9.4 (though probably with different colours).

- You will need to use one of the options from the Iterators menu on the ribbon - if none of them are obvious to you, try adding them to your model and see whether they fit, or do what you want them to.
- You will also need to use **Inline substitution variables** to rename each output file - Arc Help should help you with these.

9.4.2 Additional suggestions

You could also extend this model to allow buffer size/width to be input as a parameter when the model is run.

- Try right-clicking on the **Buffer** tool and see what you can do.
- If you have set the parameter can you then see how to use it as part of the name of the output?

9.4.3 Suggested solution

Remember that this probably isn't the only solution. If you have a model which is different but runs and produces the required output, then that's fine.

To iterate through the features in the feature class use Iterators > Feature Selection. The input will be the **National Parks** layer.

Iterate Feature Selection automatically outputs the **Value** variable which you can use for **Inline substitution variables**. If you hover over the **Value** item you should be able to see what the model thinks the value is at the moment.

To use the variable to name output files differently on each iteration enter `%Value%` as part of the file name. In this way you should end up with ten output files, each with a name which includes the National Park it buffers.

An alternative way to add a parameter manually in the model builder is to go to the Variable button on the ribbon and select the type of parameter. This way does mean that you have to know what the different types of variables are. It is usually more straightforward to right-click on the process that you want to create the variable for, because then it selects the type for you. The **Distance** variable was set like this, by right-clicking and adding the **Distance [Value or field]** from the parameters and then renaming it to **Distance**

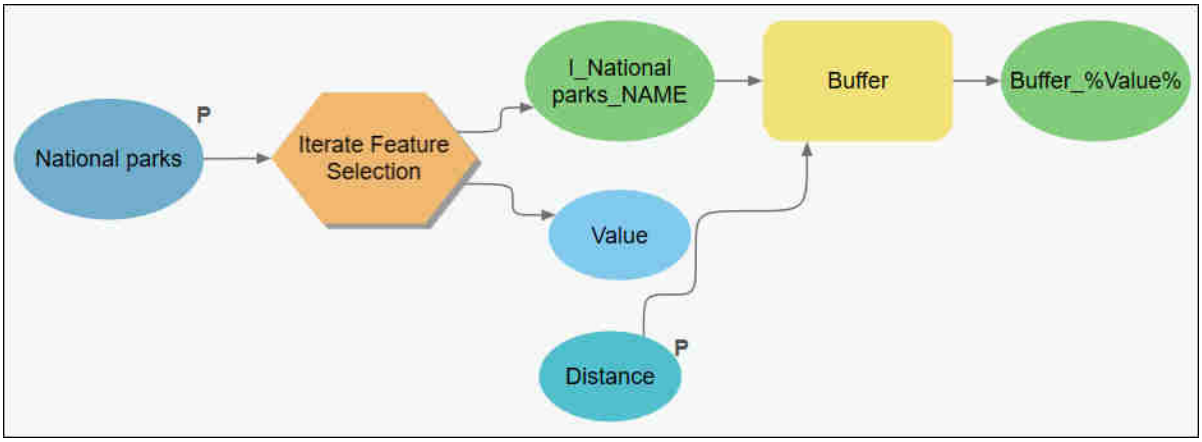


Figure 9.5: A possible solution using Iterate Feature Selection to step through the features in the feature class. Note that the National Parks input to the Buffer tool has been set as a parameter and the value from it can now be used as a variable in the output file.

9.5 2: Model to buffer fields - step through distances with an iterator

This model is similar to the previous one. Again it takes a shapefile of the National Parks of England, this time the output remains as a single shapefile, but you are asked to extend the model so that buffers are output as a series of feature classes at a range of distances.

9.5.1 Instructions

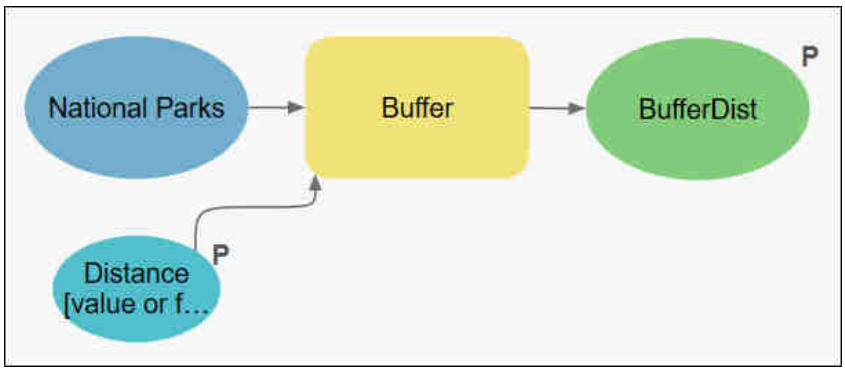


Figure 9.6: The model as provided

The model as it stands will generate a single buffer for all of the features in the National Parks feature class - as in figure 9.3 for the previous model. Edit the model so that it creates buffers at a range of distances and outputs the result to a series of new feature classes - one for each distance, **not** one for each national park.

You will need to use an **iterator** which takes as input the numbers to run **From** and **To** and the steps to move **By**. Try out the potential iterators from Iterators in the model builder menu and see which one will work this way.

You will also need to use **Inline substitution variables** to rename each output file.

Hint: don't try to generate too many buffers, e.g. just go from 10000 to 40000 by intervals of 10000 for example. You just need to do enough to prove that it works, and don't want to be sitting waiting for it for ages, or filling up your disk space with unnecessary data.

This is a tip which should help anytime you need to run a process lots of times to get it right before running it for the final time.

If this runs successfully you should end up with a series of buffer files which make regular rings around each national park, something like figure 9.7.

9.5.2 Additional suggestions

You could also extend this to allow **From, To and By** values to be input as Model Parameters to the **For** iterator when the model is run.

9.5.3 Suggested solution

Remember that this probably isn't the only solution. If you have a model which is different but runs and produces the required output, then that's fine.

Find the **For** iterator by going to Iterators > For.

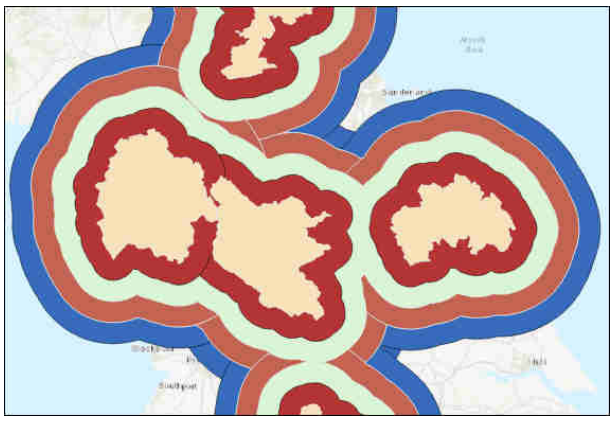


Figure 9.7: An example of output from a model generating multiple buffers around each national park

This is a common computer programming construct when you want to iterate through a section of code a certain number of times. The limits are set by `From` and `To`, and the `By` variable shows the size of the steps that you want to take. These variables should be added automatically when you add the **For** iterator to your model. You can enter a default value, but if you set each as a model parameter you can also add them at run time, as suggested.

There are more details about **Inline substitution variables** in the first exercise. The For loop outputs a **Value** which is fed into the Buffer tool, but which can also be used as part of the output name, e.g. `BufferDist%Value%`

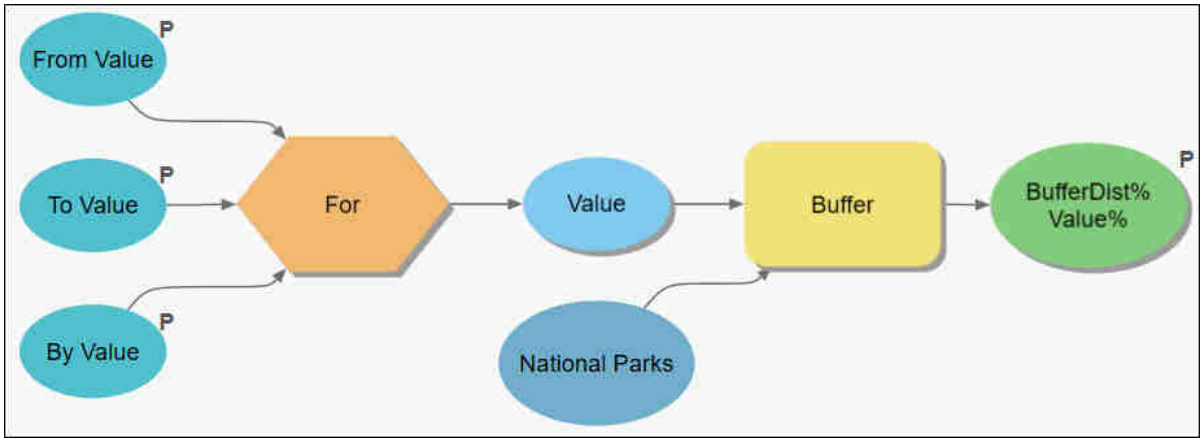


Figure 9.8: Possible model including iteration with a For loop, and inline variable substitution. The input values and final output are set as parameters.

9.6 3: Model to reproject a series of dtms and create slope rasters from them

In this model you're moving on to handling raster format files firstly to reproject them, and then to run a slope analysis. There are several tools which work in a similar way to the slope tool and you could use any of them in the same model, e.g. aspect or hillshade. You could use a model like this to generate maps for a series of non-continuous areas without having to download and process the data to fill the areas which aren't relevant.

9.6.1 Instructions

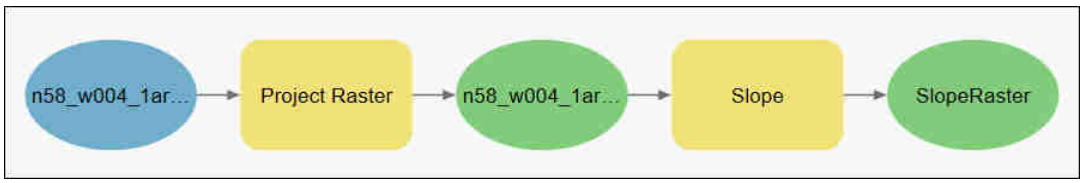


Figure 9.9: The model as provided

The model as supplied reprojects a single srtm[1] dtm into British National Grid then generates a slope raster for the projected dtm.

Your aim here is to change the model so that it will project each of the rasters in the srtm folder in turn, then generate an individual slope raster for each of the projected dtms. Note that these rasters don't cover a continuous area but are spread out over the whole UK - see figure 9.10. You will also need to use **Inline substitution variables** to rename each output file. The slope output should look something like figure 9.11 when you zoom in to it.

Figure 9.10: The SRTM input rasters - showing their locations on a map of the UK

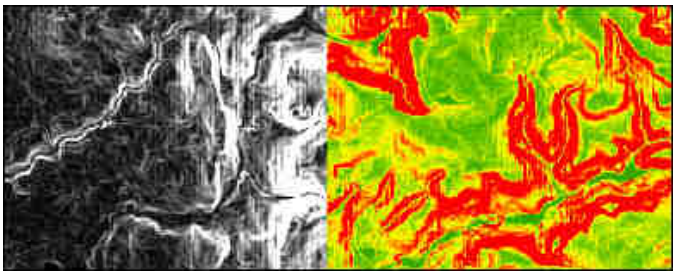


Figure 9.11: The output slope rasters - zoomed in. If the model has added the rasters to your map automatically they'll probably be symbolised in colour, as on the right. If you have to add them yourself from the Catalog they'll be greyscale, as on the left. You can symbolise them in colour by selecting the **Slope** colour ramp.

Note: If you were looking at a continuous area you'd probably usually want to mosaic the rasters before reprojecting the raster height maps. You'll notice that there are gaps between some of

[1] Downloaded from: `https://earthexplorer.usgs.gov/`

the output files where they neighbour each other, but this does serve to show how a model will handle the multiple rasters.

9.6.2 Additional suggestions

- Add another tool to generate hillshade layers from the height data
- Extend the model so that you **reclassify** the resulting slope rasters to show only the slopes steeper than 5 degrees. Do this by using a tool to create a new output raster with the values of 5 and above reclassified to `1`.
- Try using a folder variable to hold the name of the output folder. This would mean that you can change the name of the output folder without having to change it in every output file.

9.6.3 Suggested solution

Remember that this probably isn't the only solution. If you have a model which is different but runs and produces the required output, then that's fine.

As in the previous exercise you can use **Iterate Rasters** to step through each raster file from a folder in turn - Iterators » Rasters. See figure 9.12.

The **Name** variable that the iterator outputs can also be used for **Inline variable substitution** to rename the output files at each stage.

You may find that you need to create a new output folder within your project folder and save raster output to that - saving rasters to your geodatabase may cause your model to crash. If you keep all of your output in a single folder you can delete it easily between running your model so that your disk space doesn't fill up too quickly.

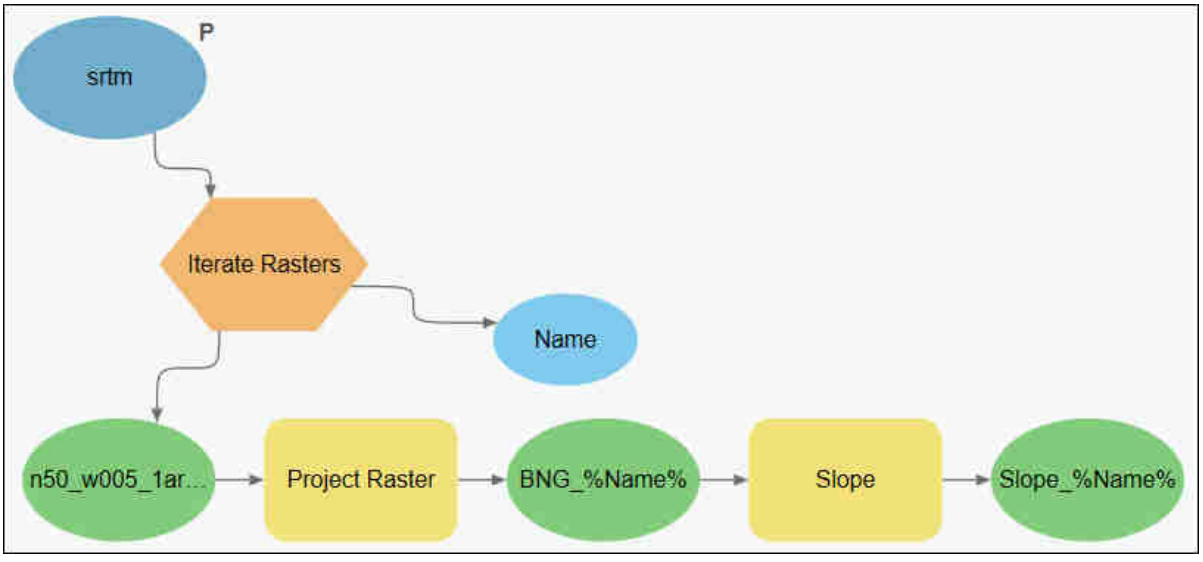


Figure 9.12: Using Iterate Rasters to step through a folder of raster files

Reclassify the slope raster

To reclassify the slope rasters once they have been generated you can use the **Reclassify** tool, though there are a variety of other ways to do this.

- Add the tool to the model - Geoprocessing > Spatial Analyst Tools > Reclass > Reclassify - and set the output of the **Slope** tool as the input to the **Reclassify** tool.

You need to think about what you're trying to do, but basically set values that you don't need as **NoData**, and values that you do as **1**. This will mean that only areas classified as 1 will show on your map. Try something like figure 9.13.

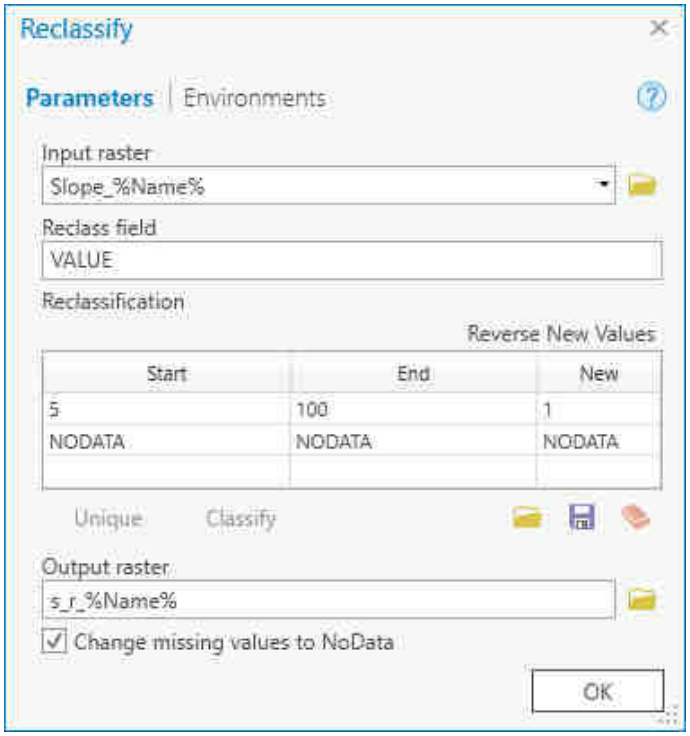


Figure 9.13: The Reclassify tool filled in to output rasters where only values above 5 degrees show on your map. All other values are set to NoData

The final output should look something like figure 9.14, which just shows the steepest slopes.

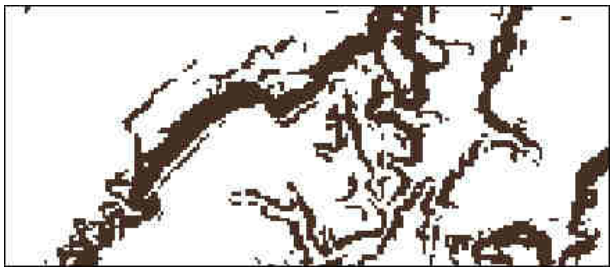


Figure 9.14: Part of the slope raster reclassified to show only slopes of 5 degrees or steeper.

Add the **Hillshade** tool from Toolbox > Spatial Analyst Tools > Surface > Hillshade. The trick is to remember that is is another branch of the model after the output of the **Project Raster** tool - see the extended model in figure 9.15.

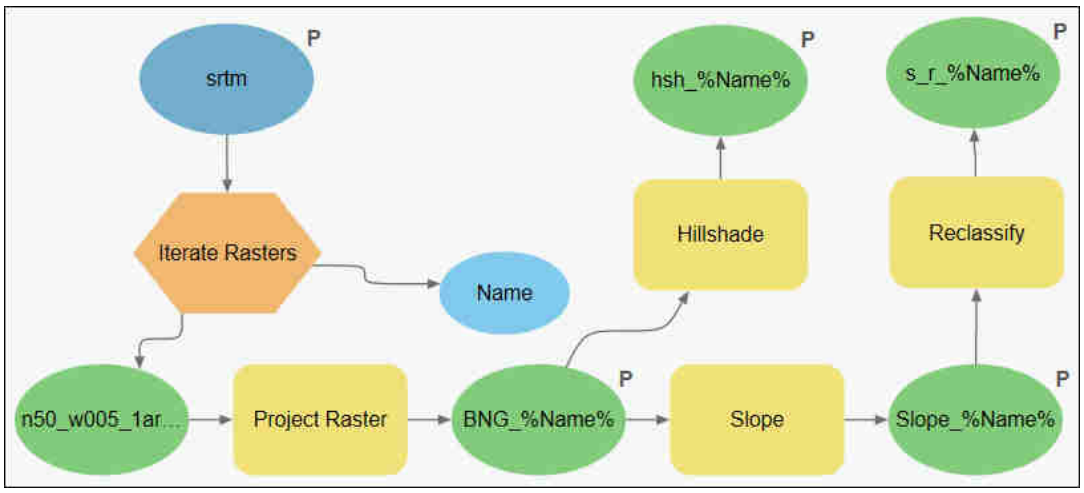


Figure 9.15: Using Iterate Rasters to step through a folder of raster files. This version of the model also adds the **Reclassify** tool and the **Hillshade** tool.

9.7 4: Model to make selections from a series of feature classes and save them to another layer

This exercise returns to vector feature classes, but this time instead of looping through a single feature class it loops through a series of feature classes. Being able to generate statistics for a series of input files can be extremely useful. This model starts relatively simply, but also shows more advanced ways of extending a model to increase the amount of automation. Remember, when developing a model make sure that the simple version works first, then start adding more functionality.

9.7.1 Instructions

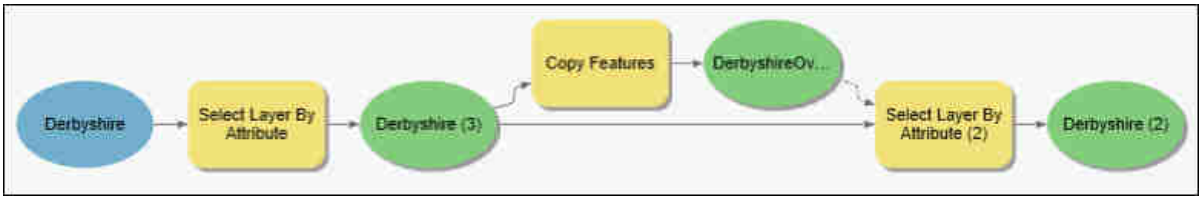


Figure 9.16: The model as given

The feature classes in the geodatabase, which are already shown on the map, contain points for each hill summit in that county taken from the Database of British and Irish Hills[2].

The model currently selects hills over 499m from the Derbyshire feature class and saves them to a new layer.

Extend the model so it does the same for each of the county feature classes in the geodatabase and saves them to a separate layer for each county. You will also need to use **Inline substitution variables** to rename each output file.

There is a sting in the tail of this one. If you use the correct iterator the output isn't the correct format to go straight into the **Select Layer By Attribute** tool. Have a go with the **Make Feature Layer** tool[3] and see how that helps.

9.7.2 Additional suggestions

There's quite a bit you can do to extend this model.

In a similar way to previous models

- Make it possible to output hills at different heights by inputting a variable for minimum height and making it a model parameter.

More advanced possibilities include

- Using a tool from the toolbox to generate **statistics** for the output from **Copy Features**. for the total hills. Remember that you are searching for a tool that will generate statistics for a feature class, not a raster.

[2] `http://www.hills-database.co.uk/` Last visted: 30th August 2019.
[3] Don't forget you can search for tools within the toolbox

- The tool will also output a table which can be viewed by adding it to your list of layers in the Catalog then right-clicking on it selecting Open.
- Have a look at the other output statistics that can be generated by the tool that you chose and output those too. All the figures can be added to the same table.
- Try merging the output from the statistics tool into an Excel spreadsheet. This involves **nesting models** (Arc Desktop Help has information on this) and using **Collect Values** from the model-only tools, and the **merge** tool, and **table to excel** from the toolbox.[4]

9.7.3 Suggested solution

Remember that this probably isn't the only solution. If you have a model which is different but runs and produces the required output, then that's fine.

This time you need to iterate through multiple feature classes, rather than raster files. The iterator works in a similar way but you need to select Iterators > Feature Classes. Similarly, select a folder or a geodatabase that contains your input feature classes.

As I said in the instructions, the output from **Iterate Feature Classes** isn't in the correct format to feed into **Select Layer by Attribute** so you'll need to find the **Make Feature Layer** tool and put that between the two. This creates a temporary layer which can be used for the selection but which won't persist once the model has run. In this case that is fine as the important thing is that you can copy the selected features to a new feature class using the **Copy Features** tool.

The **Name** variable that the iterator outputs can also be used for **Inline variable substitution** to rename the output files at each stage.

Use the **Summary Statistics** tool to generate an output for the **Total** number of hills in the output from **Copy Features**. The Summary Statistics tool will output a database table (probably with a `.dbf` extension) which can be be viewed by adding it to the table of contents, and then right-clicking and going to **Open**. See figure 9.17 for the inital solution.

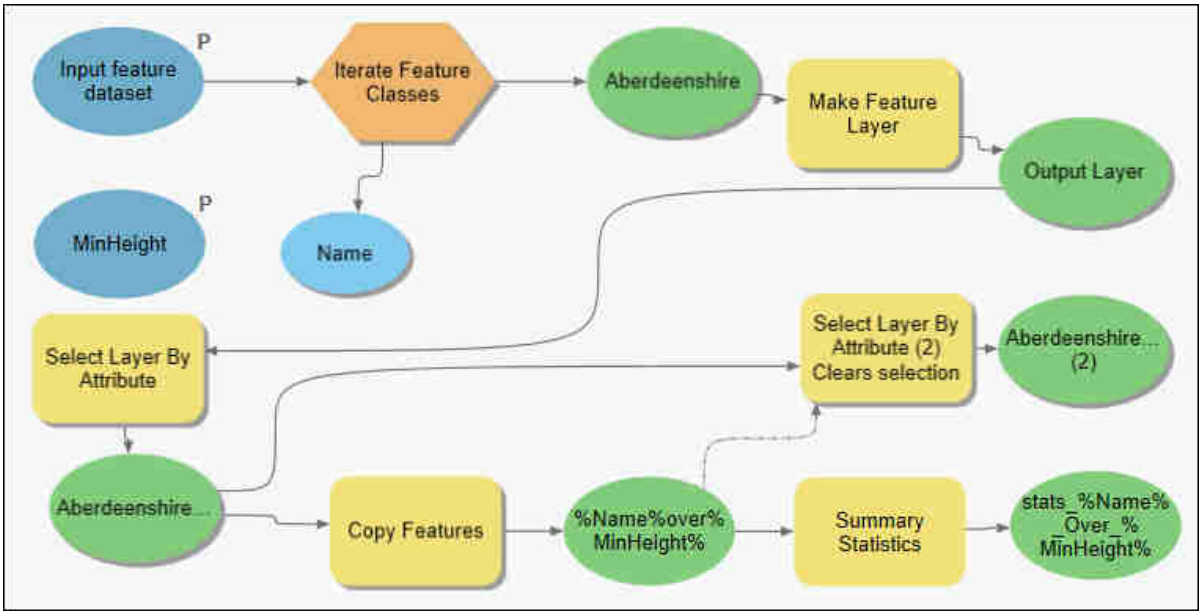


Figure 9.17: Possible solution for Iterate Feature Classes

[4]So far I haven't found a way of putting the original file name, e.g. the county name, into the Excel spreadsheet. Arc only adds object IDs. If you can come up with a way of doing this then you're really doing well!

Nested models

To extend the model to collate all of the values into one Excel file you need to set up nested models.

Start with the current model with iterator then

- add Utilities > Collect Values from the ModelBuilder ribbon to the current model as in figure 9.18
- Set the **Output Values** as a **Model Parameter**

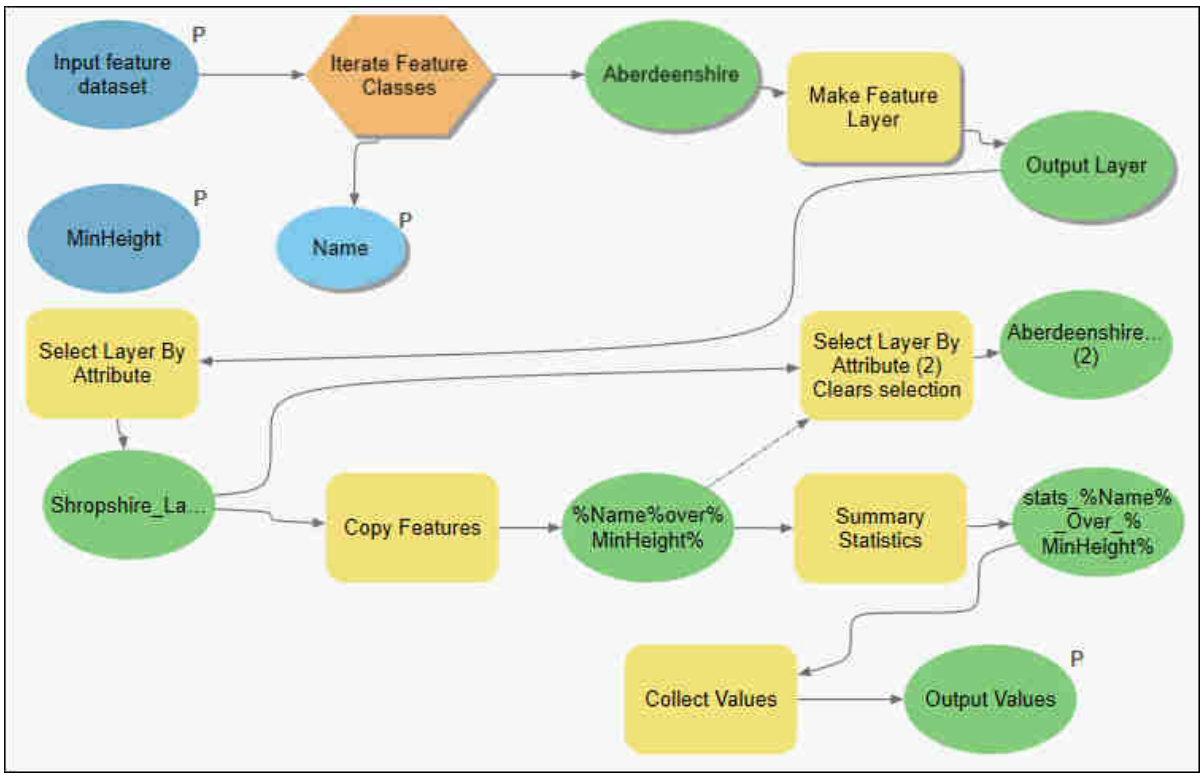


Figure 9.18: Possible solution for exercise 5 using Collect Values

Now set up a new model

- Add the iterating model to the new model by dragging and dropping it from the catalog into the Model Builder window. The input is the **Output Values** from the original model
- Set the output folder and the name as model parameters
- Add the **Merge** tool and set the output details. This will export a table which can be viewed in ArcMap
- To convert the table to Excel use the **Table To Excel** tool[5].

See figure 9.19 for the final model, and figure 9.20 for an example of the resulting Excel table. You may need to look in the Windows file manager to find the Excel file, rather than in Catalog.

[5]So far I haven't found a way of putting the original file name, e.g. the county name, into the Excel spreadsheet. Arc only adds object IDs. If you can come up with a way of doing this then you're really doing well!

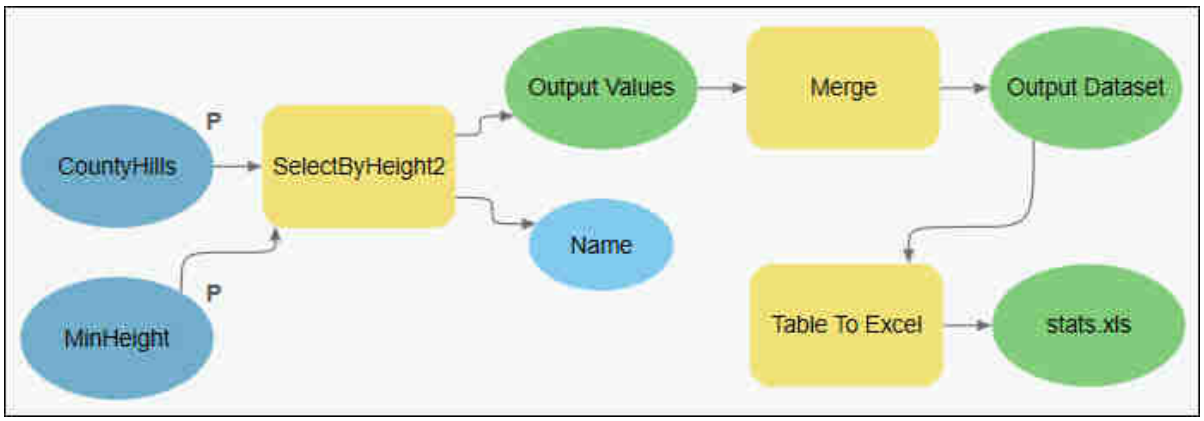
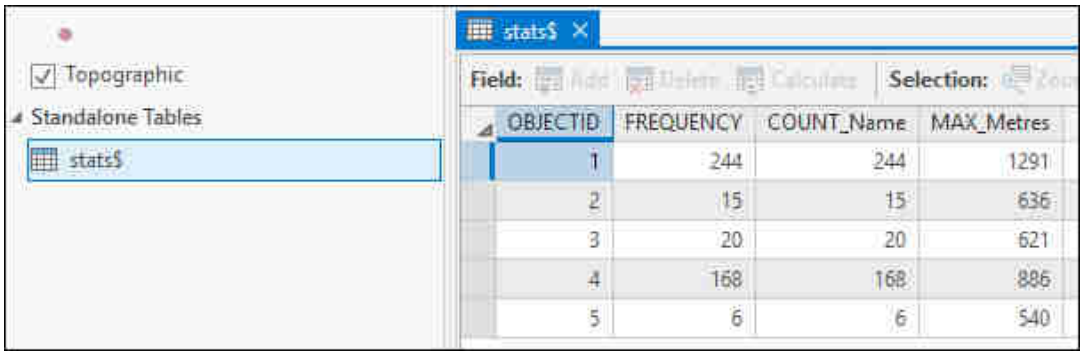


Figure 9.19: The final model with the iteration model shown in figure 9.18 nested inside it. The final output should look something like figure 9.20



OBJECTID	FREQUENCY	COUNT_Name	MAX_Metres
1	244	244	1291
2	15	15	636
3	20	20	621
4	168	168	886
5	6	6	540

Figure 9.20: The resulting Excel table. Note that the names of the feature classes haven't been used as identifiers instead there is just an 'OBJECTID'. This table also has the maximum of the metres field included for each record.

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 minimum area around **Hebden Bridge** which is shown as selected in figure 9.21)[6]
  - Background mapping - Vector Map District Raster
  - Height data - OS Terrain 5 DTM - ASC (ascii text) format
- From Minerva
  - Rainfall data for 2016 [7] This is in the `RainfallData.7z` zip file.

Preparing the data

Add the Background mapping (Vector Map District Raster) to a new map. Check that the project coordinate system is British National Grid.

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 or you won't have the full area that you need**) so that you are running processes on a single tile of data (instructions are in section 7.2.2 on page 106). Make sure that you save the resulting mosaic as a Grid file - i.e. don't add a file extension to the output file[8]. Don't delete the original .asc files this time - you will also need these during the practical.

[6] for a reminder of how to download O.S. data from Digimap see section 3.4.2 on page 57

[7] Extracted from data downloaded from `https://www.metoffice.gov.uk/research/climate/maps-and-data/data/index`. Met Office (2018): HadUK-Grid Gridded Climate Observations on a 1km grid over the UK for 1862-2017. Centre for Environmental Data Analysis, 2018. `http://catalogue.ceda.ac.uk/uuid/2a62652a4fe6412693123dd6328f6dc8`. Registration is required. Once you have permission to download data there are a wide variety of datasets covering UK historical climate and weather.

[8] You will find out more about raster data formats and properties in the practical

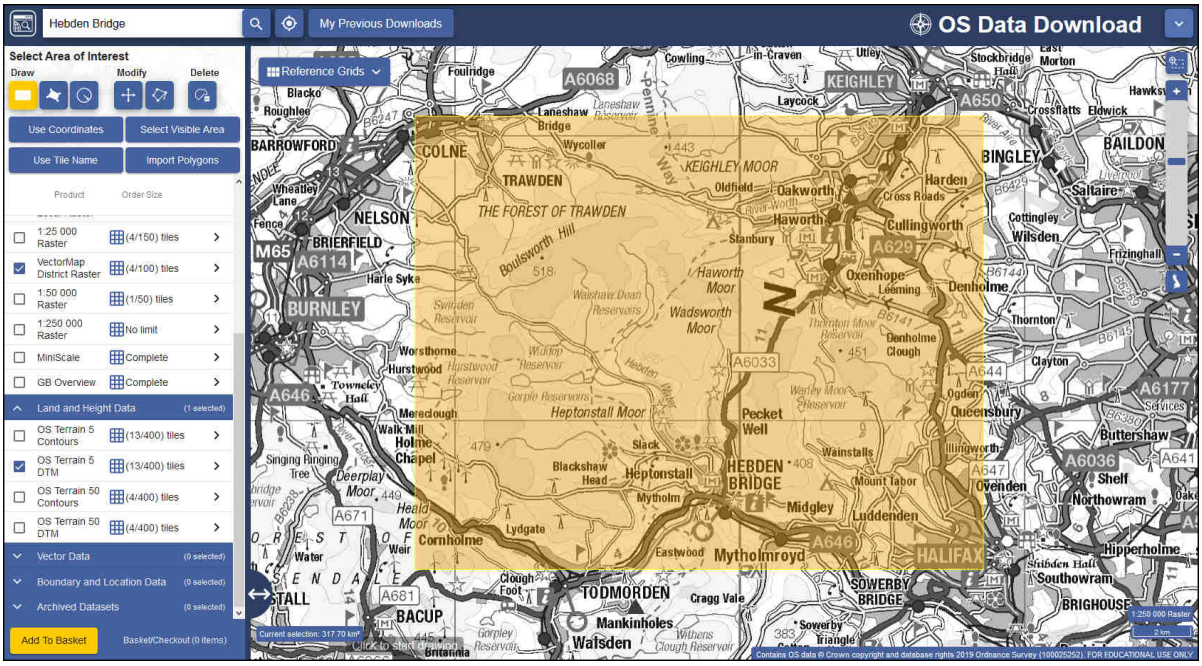


Figure 9.21: Minimum area for which to download data from Digimap for the Hebden Bridge exercise

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 7.4.1 on page 108) 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:

- 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

The background to raster analysis will be covered in the lecture segment at the beginning of the class and the presentation and any other supporting materials will be available in Minerva. The lecture segment should help you to understand **why** you are doing these exercises. If you still aren't sure, please ask Clare.

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. Cloudbursts 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 160. If you haven't, follow the instructions there now.

[1] See the news story at `http://www.bbc.co.uk/news/uk-england-leeds-18768291`

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.

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.

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.

To find file properties in the Catalog pane:

- Find the file in the catalog pane and right-click on it
- Choose Properties
- Use the subheadings to find whatever you are looking for - try opening them all out to see what information is available to you

To find file properties in the Contents pane:

- Find the layer in the Contents pane
- Right-click on the layer and select Properties
- Use the headings on the left to find whatever you are looking for - click on each in turn to see what information is available to you

Question 10.1. Using the Catalog pane have a look at the properties for the following files following the instructions above 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***

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		

There is a lot of useful information here, but what does it all mean? Make sure that your DTM mosaic is open in Arc and that you have at least one tile of the original DTM ascii files added to your map.

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**.

Question 10.2. Given the cell size and columns and rows 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.

- Find the **Explore** tool on the **Map** and click on the arrow underneath it
- Make sure that **Visible Layers** is selected
- Make sure that a tile of the original ascii DTM and the hillshade layer are both visible in your map
- Use the **Explore** tool to click somewhere in the area where the ascii tile and the hillshade overlap
- You should get something like figure 10.3 showing information for the topmost layer - the name of the layer should be shown at the top.
- To see the information for the layer below click on the little arrow to the right at the bottom of the Explore window.
- To see a summary of the values for each visible layer click the little downwards arrow

Can you see the difference between the pixel values in the two files? They will be different numbers anyway, but the floating point layer (the dtm) should have decimal points, the integer layer (the hillshade) won't.

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 10.5 shows the attribute table or value table for the hillshade layer.

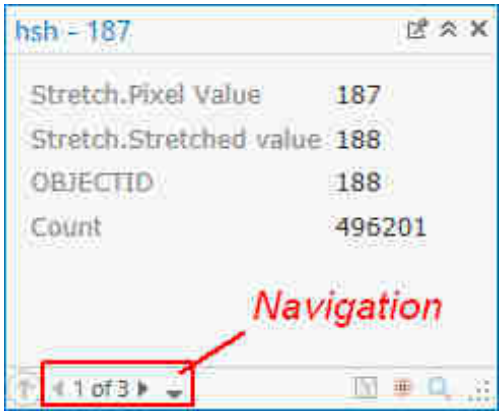


Figure 10.3: The information for the uppermost layer - in this case the hillshade raster. Note the navigation tools at the bottom left of the Explore window.

Figure 10.4: The information for the next layer down - in this case the ascii dtm 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)(Zero counts as a value so will be calculated).

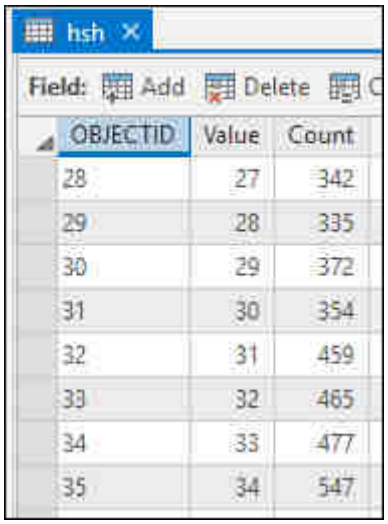


Figure 10.5: The attribute table, or value table, for an integer raster

So in the attribute table in figure 10.5 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 Help.

Try selecting one of the values in the attribute table (preferably one with a high count - preferably 6 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.

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 Geoprocessing 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 mosaicked 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 under the **Statistics** subheading. If you weren't able to calculate the statistics have a look anyway - it probably means that they are already available.

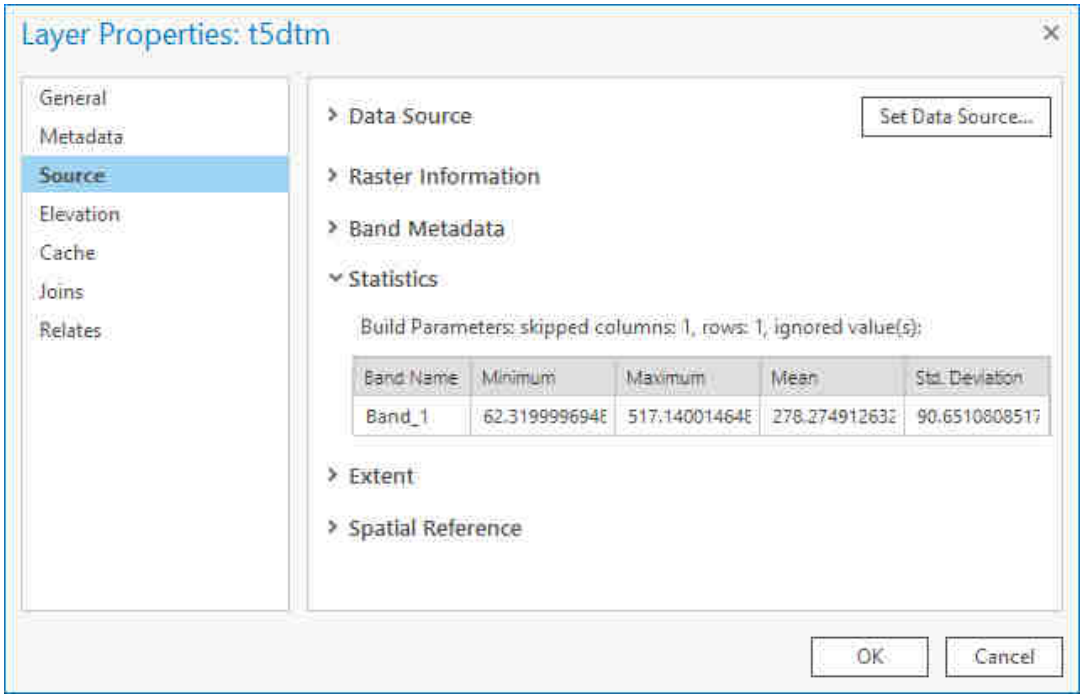


Figure 10.6: Raster statistics

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 **Environments** which apply to all processes.

Video Clip available in Minerva - Setting global geoprocessing environments.

- To set geoprocessing environments globally go to the **Analysis** tab of the ribbon and click on Environments

Have a look at the options available and set the following environments:

- Set **Current** and **Scratch workspaces** should automatically be set to the geodatabase for this project - check that that is the case and if it isn't, use the folder icon to select the correct location.
- Set the **Output Coordinate System** to **British National Grid**. You can also set the default **Geographic Transformations**
- Set **Processing Extent** to the same as your mosaic DTM using the dropdown list next to **Extent**. 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 (comma-separated values) 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 so need to do a bit of further preparation.

- 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 7.6 on page 112, remembering that this time you're using csv rather than Excel format.)

[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.

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.[3]

- **Zoom to layer** on the Rainfall layer - you should find that you have data for the whole UK - see figure 10.7.
- 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 Features command to export data 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

Because you set the **Extent** in section 10.6 your new feature class should only contain points covering the area of your mosaicked dtm as shown in figure 10.8.

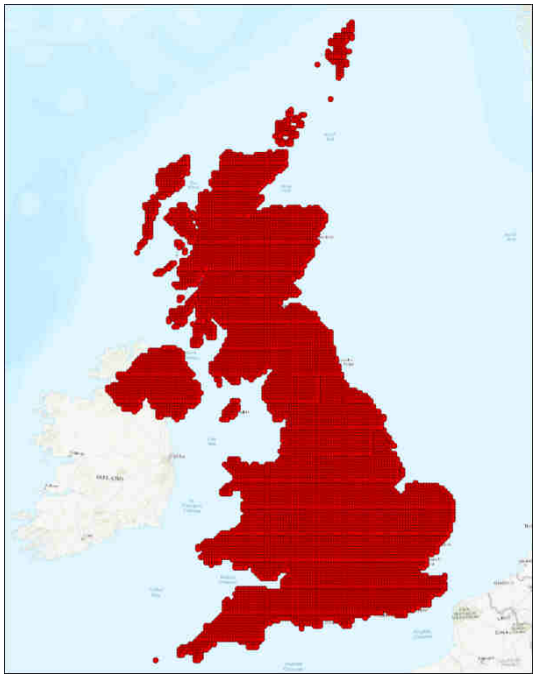


Figure 10.7: 5 km gridded rainfall data for 2016 covering the UK.

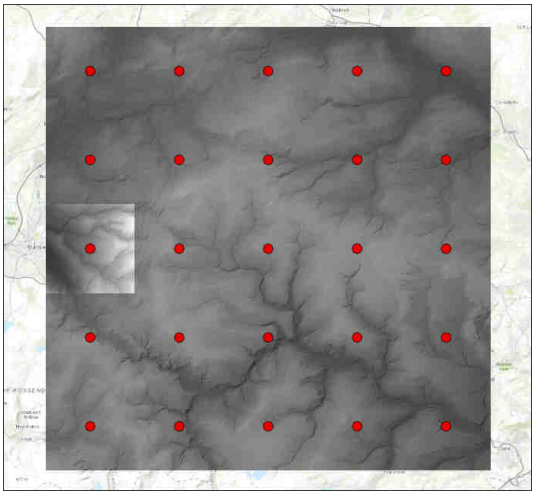


Figure 10.8: 5 km gridded rainfall data for 2016 covering only the area selected in the geoprocessing options - the area of your mosaicked DTM

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, or **totals**, 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.

[3] If you don't add a total field to the csv file at this stage 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.

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.

There is more information in ArcGIS Help - search for **Raster Interpolation**. Also see ArcUser for a useful article freely available online[4] -

`http://www.esri.com/news/arcuser/0704/files/interpolating.pdf`

- From the geoprocessing toolbox select 3D Analyst Tools » Raster Interpolation » Spline
- Fill in the dialog box
  - use the rainfall points as the input
  - enter a name for your output
  - select the field that shows the total rainfall for 2016 as your Z value field (figure 10.9)
  - leave the rest of the fields as the defaults for now - you can always experiment later
- and Run the tool.

Arc 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 10.10

10.7.3 Change the symbology of the surface

The surface is divided into discrete units or colour bands at the moment.

Use the Explore tool to click on various points within one colour band.
Question 10.5. What do you notice about the readings for the interpolated layer?

[4] Last visited: 18th September 2018

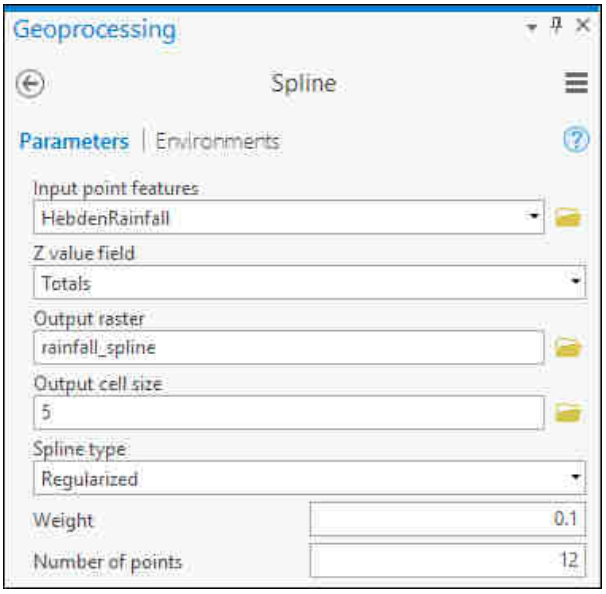


Figure 10.9: The Spline interpolation dialog

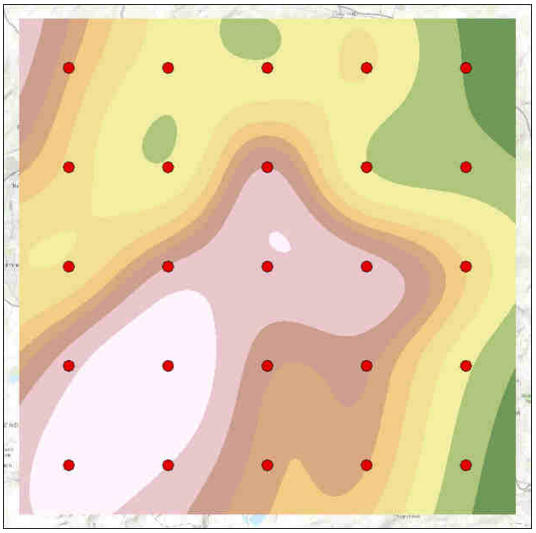


Figure 10.10: Spline interpolation of total rainfall

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**.

- With the spline layer selected click on the **appearance** tab on the ribbon.
- Under **Symbology** on the ribbon click the down arrow and select Stretch - figure 10.11
- In the **Symbology** panel which should open on the right click on the down arrow next to the **Color scheme** and tick the box next to **Show names** so that you have a list of names as well as colour ramps. From the list select a suitable colour ramp, e.g. **Blues (Continuous)** to denote rainfall, or **Spectrum - Full bright** for high and low.
- You may need to reverse the colour ramp so that it makes sense with your data, in this case think about whether you'd expect one colour to be high rainfall and another low. If you do need to reverse the colour ramp, do the following
  - Click on arrow next to the **Color scheme**
  - Format color scheme...
  - From the **Color scheme editor** hover over the buttons to find Reverse color scheme and click on that.
  - The bar at the top should reverse colours, to accept the change click OK
- The result should look something like the example shown on the suggested layout in figure 10.23 on page 180.
- Use **Transparency** (section 1.7.6 on page 10) 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:

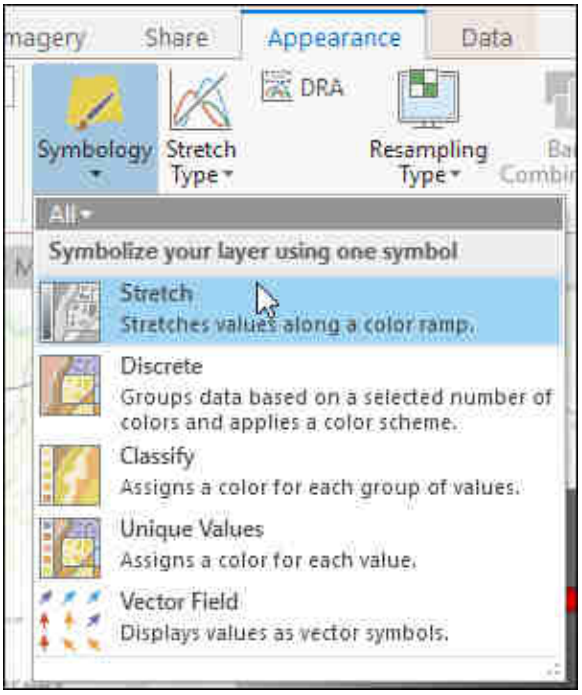


Figure 10.11: Selecting to stretch the symbology according to a colour ramp

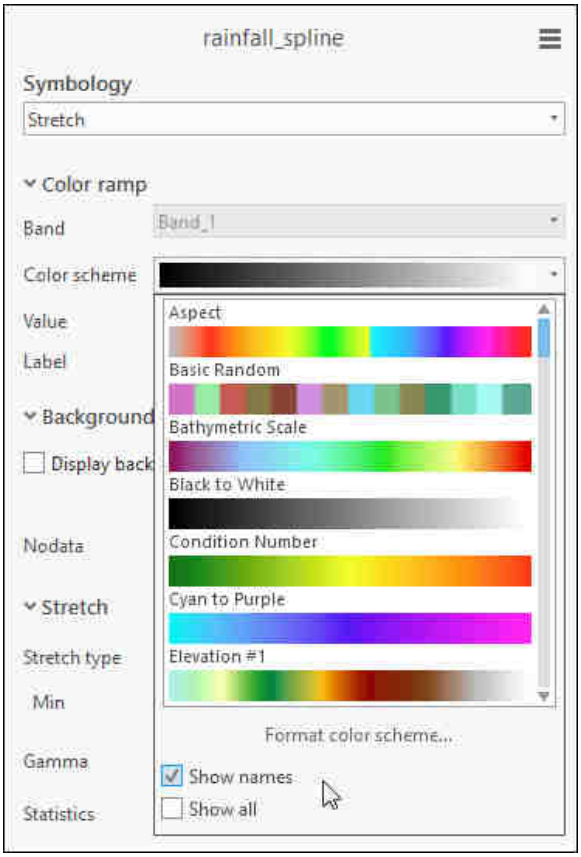


Figure 10.12: Selecting a colour ramp and showing the names of the colour ramps

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 **Appearance** tab of the ribbon 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

This section will give you more experience of running geoprocessing tools and also of keeping track of new layers. Try to understand what each layer that you produce shows so that you can give it a name which makes sense, and so that you can keep track of what you are doing. It isn't always easy so do ask if you find you are getting confused!

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 mosaicked dtm.

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.

- Geoprocessing » 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
- give the **Output flow direction raster** a name which makes sense to you.
- check that **Flow direction type** is set to **D8**

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 10.13. 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 10.14).

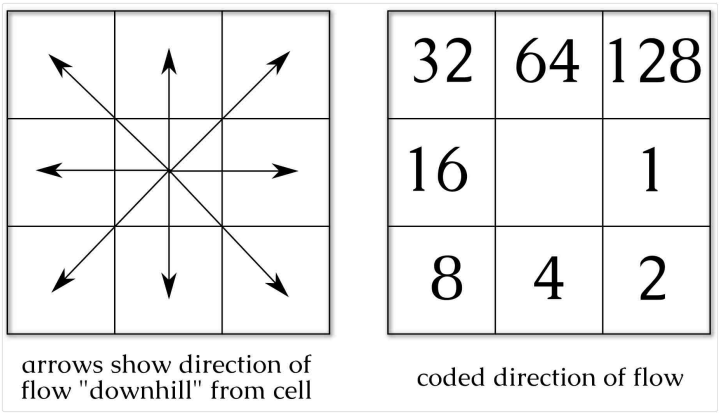


Figure 10.13: Coded flow direction - these numbers should match those showing for this layer in your contents pane

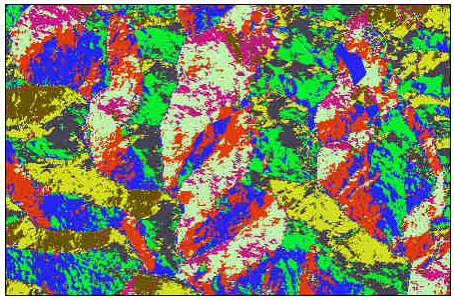


Figure 10.14: Part of the symbolised output from the Flow Direction tool

Video Clip available in Minerva - Watersheds: classifying a flow accumulation raster to show water courses.

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 10.15). To make the cells with high flow visible you need to alter the legend for the raster.

- Click the arrow under the **Symbology** button on the **Appearance** tab of the ribbon and change the symbology method to **Classify**
- Set the number of classes to two.
- Under the Classes tab below alter the **Upper value** for the first class to **5000**
- Change the symbology for the two classes so that values of less than or equal to 5000 are no colour and over 5000 are blue - see figure 10.17. You can change a colour by clicking on the colour patch and selecting a new one.

Your flow accumulation layer should now look something like figure 10.16.

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?

Figure 10.15: The output of the Flow Accumulation tool **before** reclassification. If you look very carefully you can just about see a thin white line.

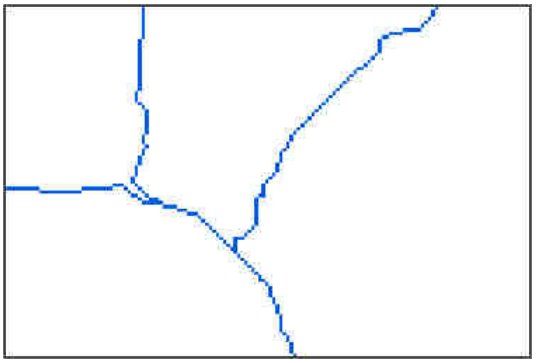


Figure 10.16: The output of the Flow Accumulation tool **after** reclassification. Now you should be able to see "streams"

- 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 as they will only be one pixel wide.

Zoom in close and use the **Explore** 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.

- Create a new point feature class in your project geodatabase and call it `pour_points` - see section 5.3.2 on page 72 for a reminder of how to do create a new feature class. If you're not creating it in a feature dataset you'll next to go Next > Next to enter the spatial reference as British National Grid

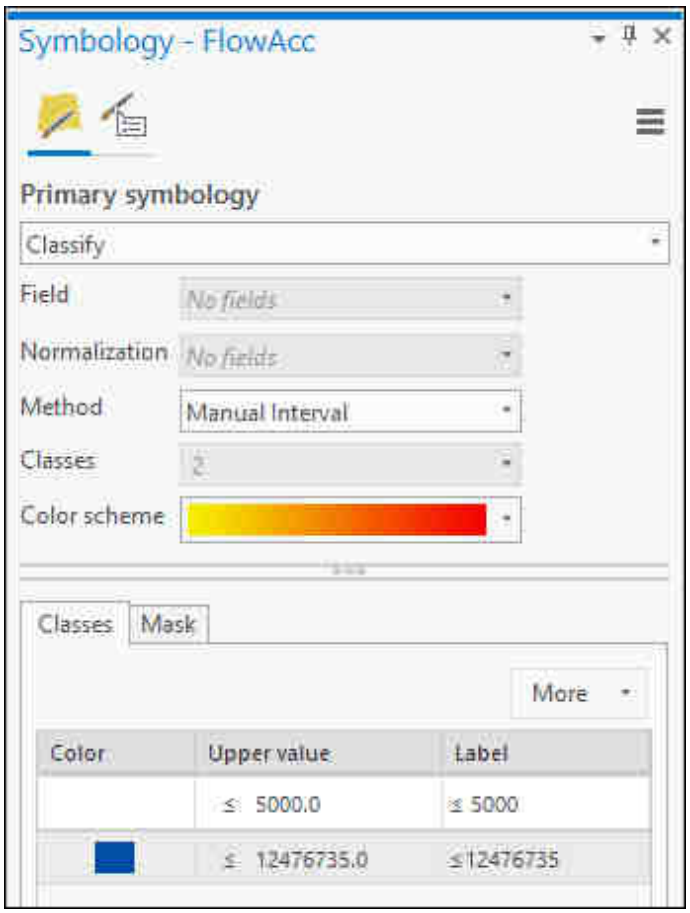


Figure 10.17: Setting the symbology for the flow accumulation layer so that the "streams" are visible. Clicking on the patches next to the class breaks allows you to change the colours.

- 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 from the Map ribbon to find a specific grid reference, when you click on the button you'll get a dialog - change the units to metres rather than decimal degrees. Just type in the grid reference I've given you then right-click and zoom to the point if you need to.
- Edit the pour points layer[5] and place a dot within the blue line (the flow accumulation) of the Hebden Water just before it joins the main river (figure 10.18). 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 on the flow accumulation layer.
- Don't forget to save your edit.

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 167 for a reminder of how to set these.

[5] see section 5 on page 70 for a reminder on how to edit

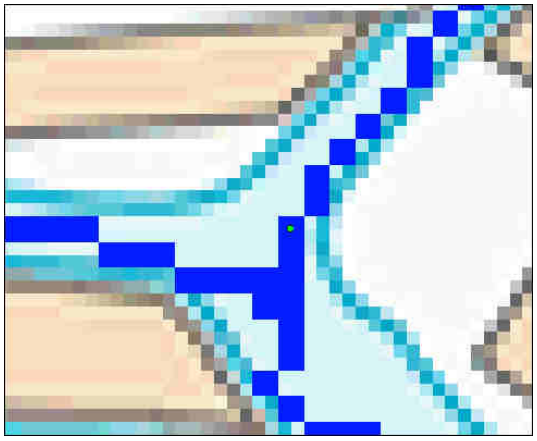


Figure 10.18: Placing a pour point - at high zoom level

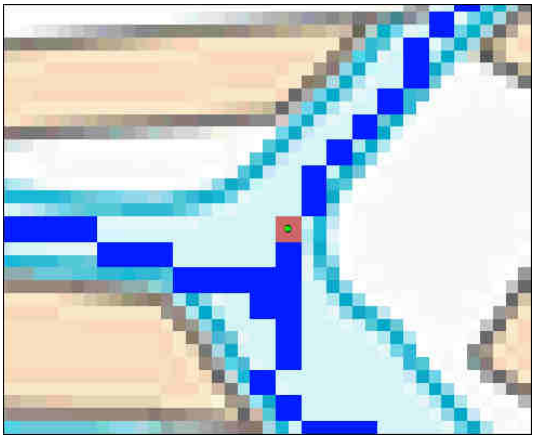


Figure 10.19: Raster pour point overlying high flow pathway

10.8.5 Convert the vector points to a grid (optional)

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 in the next step try converting the vector pour point feature class 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 10.19. This is important - if it doesn't the watershed tool won't work.

10.8.6 The watershed tool

Finally it is time to run the watershed tool!

Video Clip available in Minerva - Watersheds: Creating the final watershed

- Spatial Analyst Tools » Hydrology » Watershed
- Fill in the dialog box - figure 10.20, 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.
- if your input pour point is a vector then the **Pour point field** will be **OBJECTID**; if your input pour point is a raster then the **Pour point field** will be **Value**
- Click OK to run the tool.

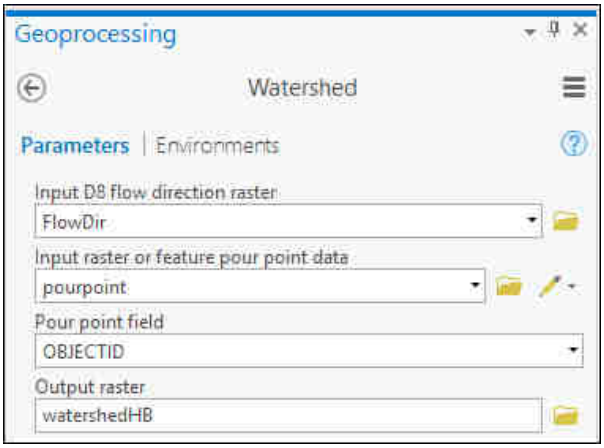


Figure 10.20: The watershed tool - the pour-point can be either a vector or raster file. If it is a vector the pour point field will be **OBJECTID**, if it is a raster the field will be **Value**

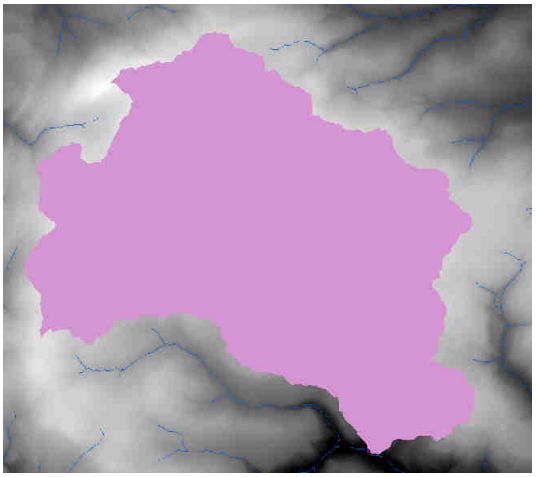


Figure 10.21: Hebden Water watershed

You should end up with something similar to the shape in figure 10.21. 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 **Explore** 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 raster grid. To convert it use the Raster to Polygon tool - figure 10.22.

- Conversion Tools > From Raster > Raster to Polygon
- Symbolise the vector watershed so that it is only an outline - see figure 10.23

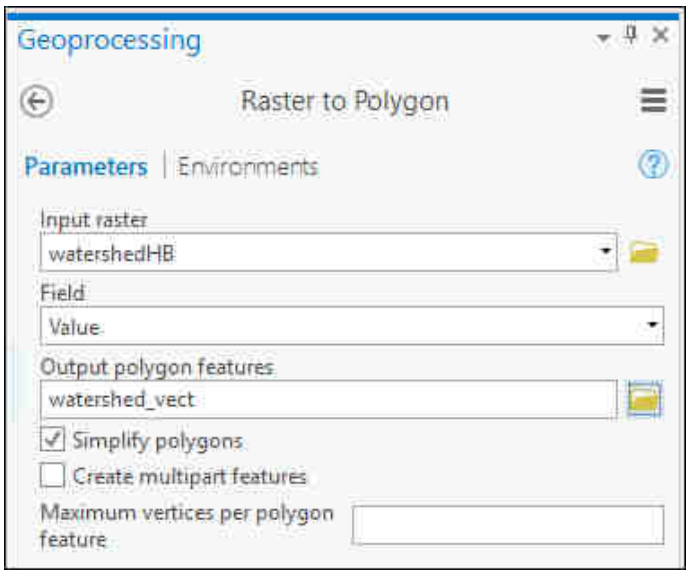


Figure 10.22: Converting the raster watershed layer to a vector polygon layer

10.9 Suggested layout

Use the layers that you have created to layout a map similar to the one in figure 10.23. Include your chosen interpolated rainfall 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 - refer back to chapter 6 for ideas and instructions.

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[6].

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.

10.11.1 Online videos

Hans van der Kwast from IHE Delft has created a series of videos with in-depth information about various GIS subjects. His video on Raster processing would be helpful for the background

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

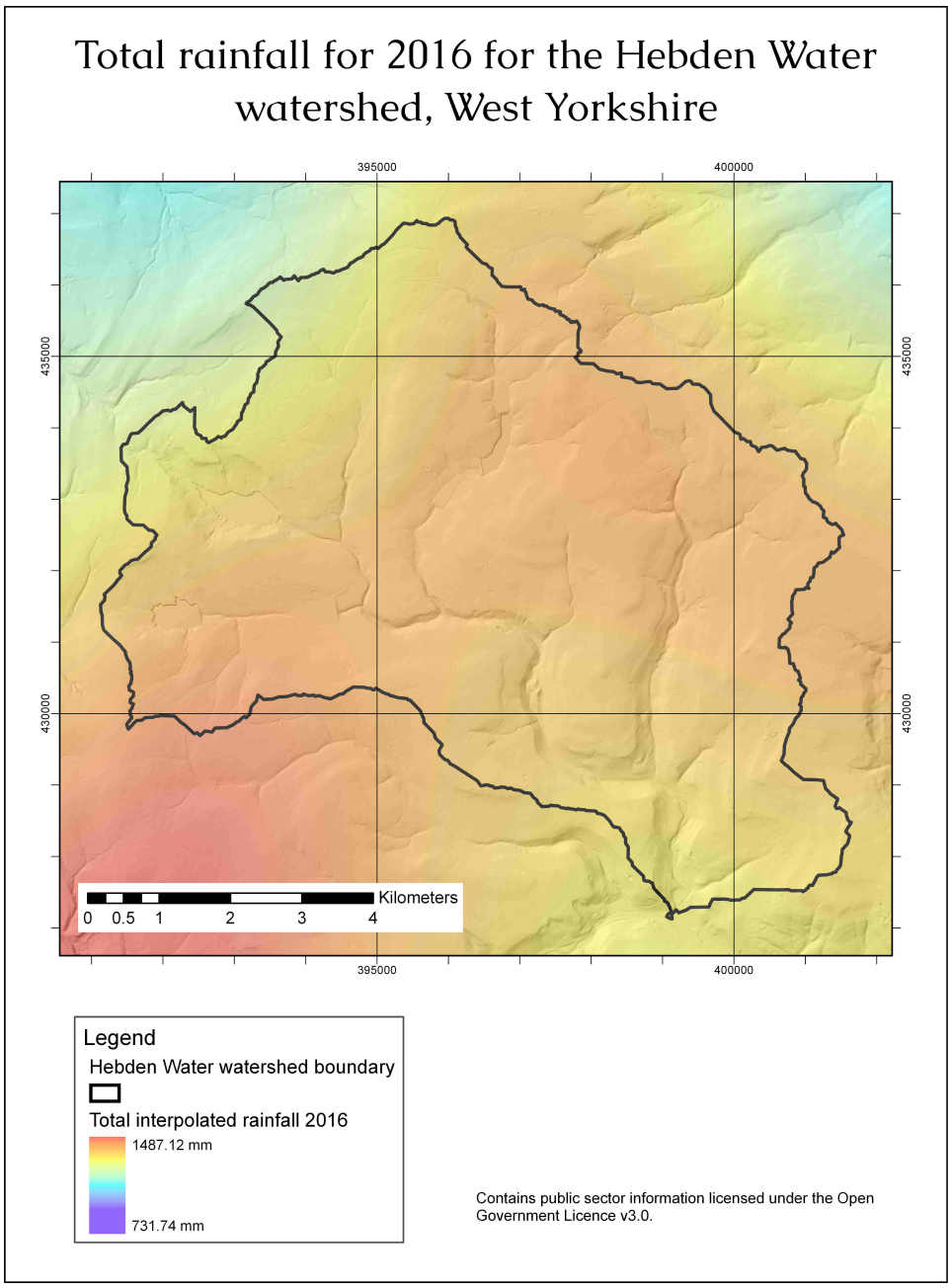


Figure 10.23: Example map of the Hebden Water watershed with total annual rainfall for 2016

to this chapter of the workbook and it would also be worth looking at his other theory videos for help with other chapters. His practical video clips are also very good, but use QGIS rather than ArcGIS.

`https://youtu.be/kZRcP7NrobU`

Chapter 11

Raster analysis II

11.1 Introduction

In the previous chapter, 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.

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?

Video Clip available in Minerva - Setting a raster mask.

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.

Use the Explore 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, which could be of **0**, or **1**, or some other positive number. So this layer is exactly the one you need. If your raster has more than one value within the watershed then you may need to go back and try running the watershed again. [1]

- Open the Environments dialog by clicking **Environments** on the **Analysis** tab of the ribbon
- In the **Mask** dropdown under **Raster Analysis** 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 - it should be just the Hebden Water watershed.

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 box at the top of the geoprocessing pane.

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 the 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.

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 Help.

- To open the raster calculator go to Spatial Analyst Tools › Map Algebra › Raster Calculator - figure 11.1

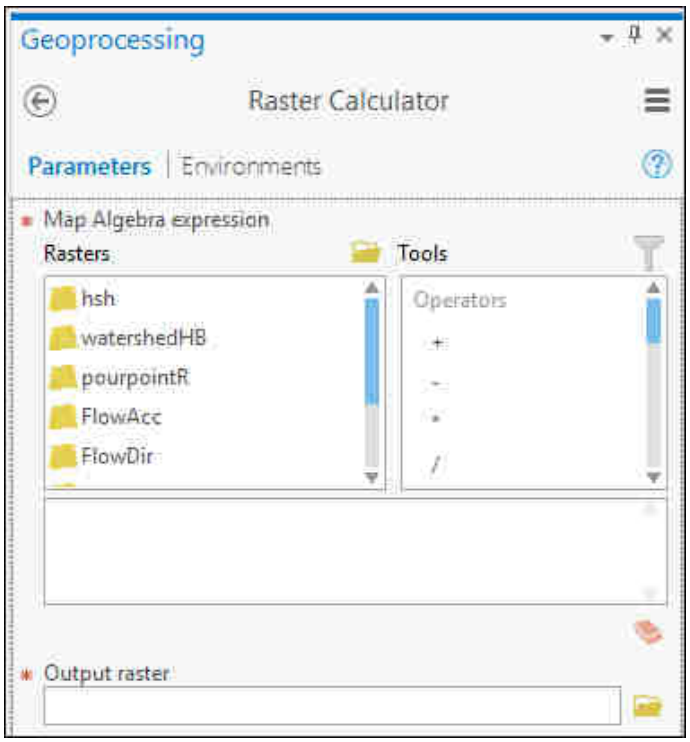


Figure 11.1: The raster calculator opens in the geoprocessing pane

Video Clip available in Minerva - Reclassifying rasters: with the raster calculator.

11.4.2 Reclassifying rasters: setting cells to null

The flow accumulation raster shows the stream network, and you have symbolised it using a classified symbology to show just the streams (in section 39 on page 174). 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 as shown at the beginning of this section (page 182)
- Use the tools provided to enter the following statement exactly as it appears below (though with the name of your flow accumulation layer replacing **FlowAcc**) in the window as for figure 11.2:

```
SetNull("FlowAcc" <= 5000,1)
```

- Select a location to store the output and enter a **short** output file name then click OK

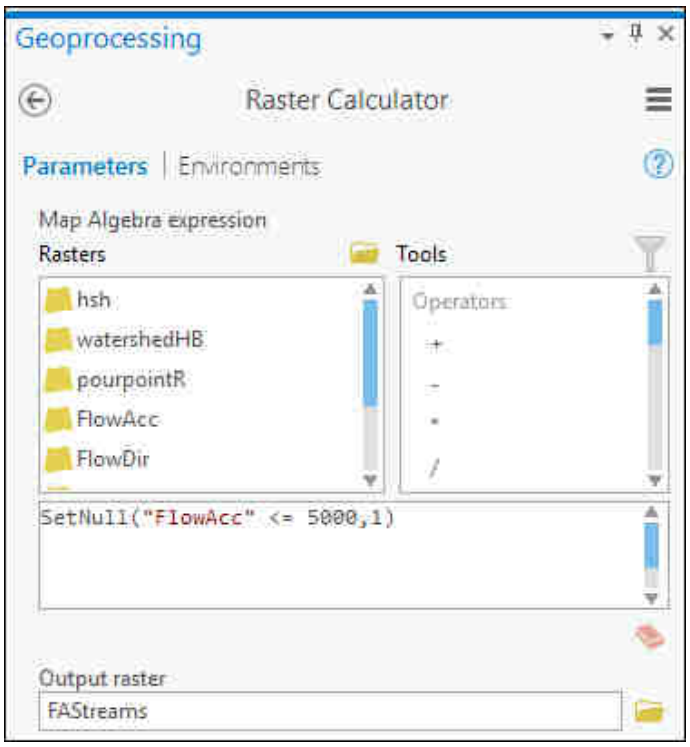


Figure 11.2: Using SetNull any parts of the Flow Accumulation raster with a value of less than or equal to 5000 as Null or NoData in the raster calculator

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 by looking at the attribute table and using the **Explore** 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 though, the raster calculator provides more flexibility, but it can be useful to have an interface where you can enter your input and statements.

[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.

11.4.3 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
- Enter your new stream raster as the input and fill in the output details as usual for the **Output distance raster**.
- Set the Maximum Distance to **500** - this is map units.
- Change **Output cell size** to **5** if necessary
- Click Run

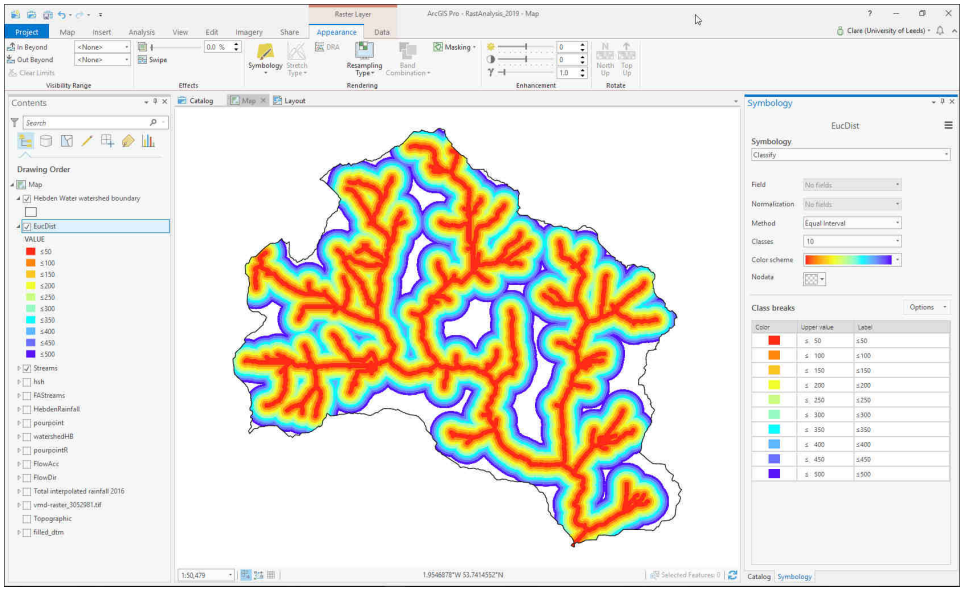


Figure 11.3: The result of the Euclidean Distance tool - your colours will probably be different

The output should look something like figure 11.3, though your colour scheme may vary. As usual explore the output further using the **Explore** 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 2016 in the catchment area of Hebden Water?

[2] Section 1.12 on page 18

- Open the raster calculator and enter and run the following statement, using your file names for the raster watershed and rainfall layers, e.g. your rainfall may be called something like *spline*.
- the statement below assumes your watershed raster has the value **1** to show the area the watershed covers - check your answer to question 11.2 on page 182 to check the value **you** need to enter, or check the value of **Value** in the attribute table of your raster watershed layer

```
SetNull("Watershed"!=1,"Rainfall")
```

The statement above means "make a new grid where the cells in the watershed raster that are not equal (`!=`) to one are left/made **null**; the remaining cells, i.e. the ones that are equal to one, 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 **Explore** tool. Compare it to the original rainfall raster surface. Do the values match?

Raster calculator data types

Something to explain statement along the lines of using float etc with Value

```
SetNull("%mosaic%" >= (float(%Value%)/100,1)
```

Table 11.1: Raster calculator data types

Put something more in this text box about float, int etc and use in raster calculator statements - find a link to more information

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.
- 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.

[3] For more detailed information on local, neighbourhood and zonal operations see Chang (2016) pp. 249 - 257

- 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**
  - the rainfall raster that you produced in the previous step and which only covers the watershed 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 Run

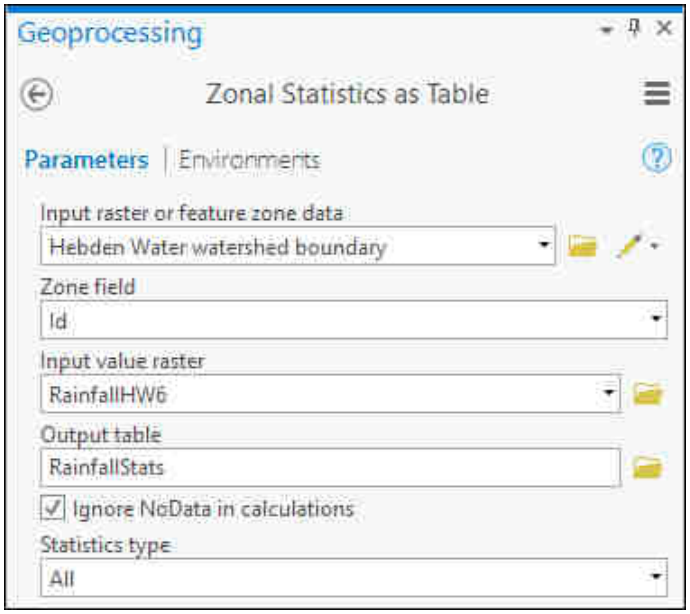
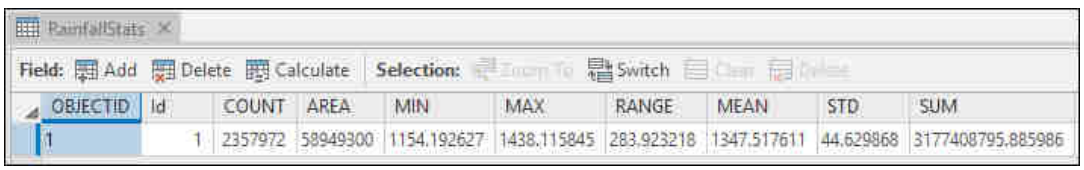


Figure 11.4: Zonal Statistics as Table tool

The table will be generated and added to Arc. You'll be able to find it at the bottom of the Contents pane listed under **Standalone Tables**.

- Right-click on the new table and select 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.



OBJECTID	Id	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	2357972	58949300	1154.192627	1438.115845	283.923218	1347.517611	44.629868	3177408795.885986

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 in particular what units of measurement each field uses. Make notes below.

Unit of measurement:

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 re-classifying.

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, and if the flooding comes from the sea then you probably wouldn't need the watershed to restrain it).

Make a note of the height of the pour point that you have already drawn at grid reference 399077 427147. Use the Explore tool to find the Pixel Value of that point from the dtm.

Using the raster calculator

Have a go at using the raster calculator to reclassify the dtm / height 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 183 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 244.

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) to show that the value is **1**. The raster cells outside of the coloured area should have a "value" of **NoData**.

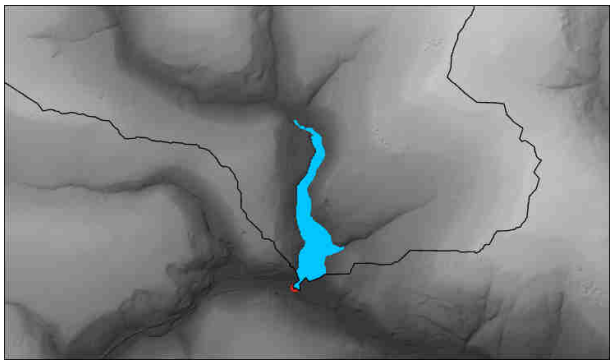


Figure 11.6: "Flooded" raster showing areas which have been reclassified as being below the height of flooding within your watershed. Areas outside of the flooded area are set to NoData.

Using the Reclassify tool

Now try the same process in the **Reclassify** tool as follows:

Video Clip available in Minerva - Reclassifying rasters: with the Reclassify tool.

- 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 to one class. This should be familiar from the Symbology dialog.
- Change the **End** value to the height of your pour point plus 30 - you'll have to do the maths yourself this time
- Tick to **Change missing values to NoData**
- Click Run to run the tool.

Compare the result to the flooded area you created with the raster calculator. Use the **Swipe** tool from the **Appearance** tab of the ribbon if it helps.

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.

[4] see section 11.3 on page 181

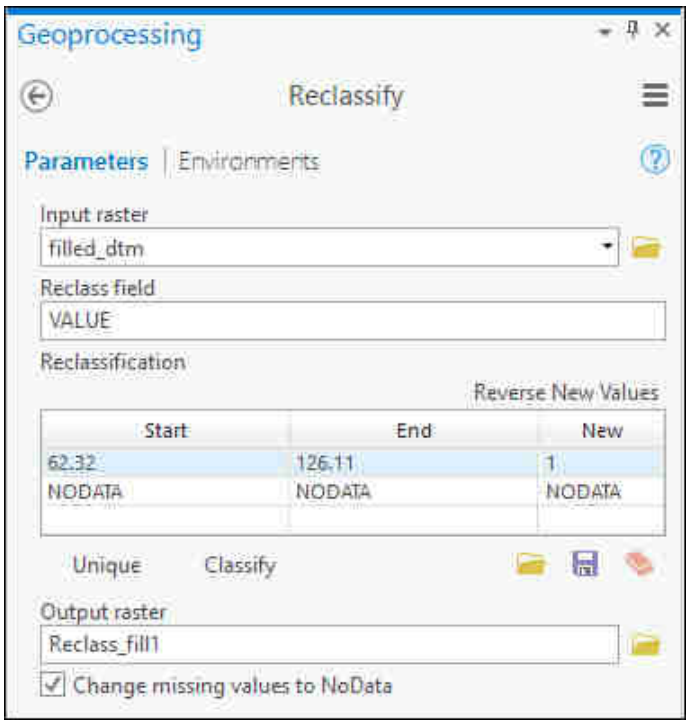


Figure 11.7: Using the Reclassify tool

11.5 Census data for England and Wales

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. To find out more about the population you can download the census data for this area and use that to work out how many people would be affected if the area was flooded.

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.[5]

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.

The DataShine Census web map - `https://datashine.org.uk/` allows you to play around with different data and view the results on a map. Try looking at the percentage of houses with five or more bedrooms in Headingley compared to most other parts of Leeds, or where are people with professional qualifications most likely to live in Leeds?[6]

[5] 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`

[6] Last accessed: 7th August 2019.

11.6 Downloading UK Census Data

As a member of UK Higher Education you have access to data via the UK Data Service and UK-Borders.

InFuse on the UK Data Service includes 2011 data 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/`

11.6.1 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.

11.6.2 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 11.8). The topics in the list on the left allow you to filter the choices in the boxes in the main area.

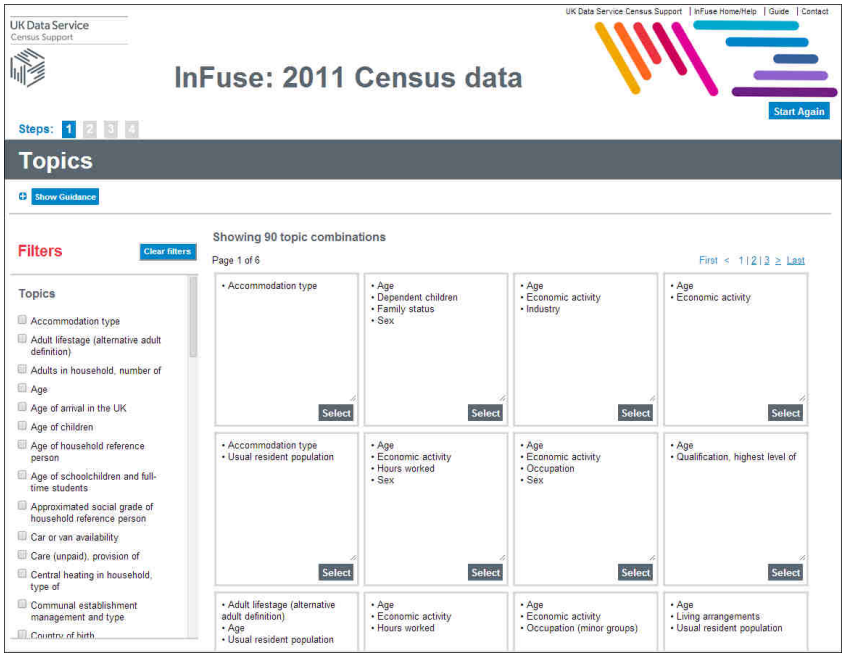


Figure 11.8: The InFuse selection screen

- For now click to select **Age** in the left-hand list.
- 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 11.9).
- 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 11.9: 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 11.10 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 11.10: 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 Arc 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.

11.6.3 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/`
- 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 - see figure 11.11. Select the set that you need.

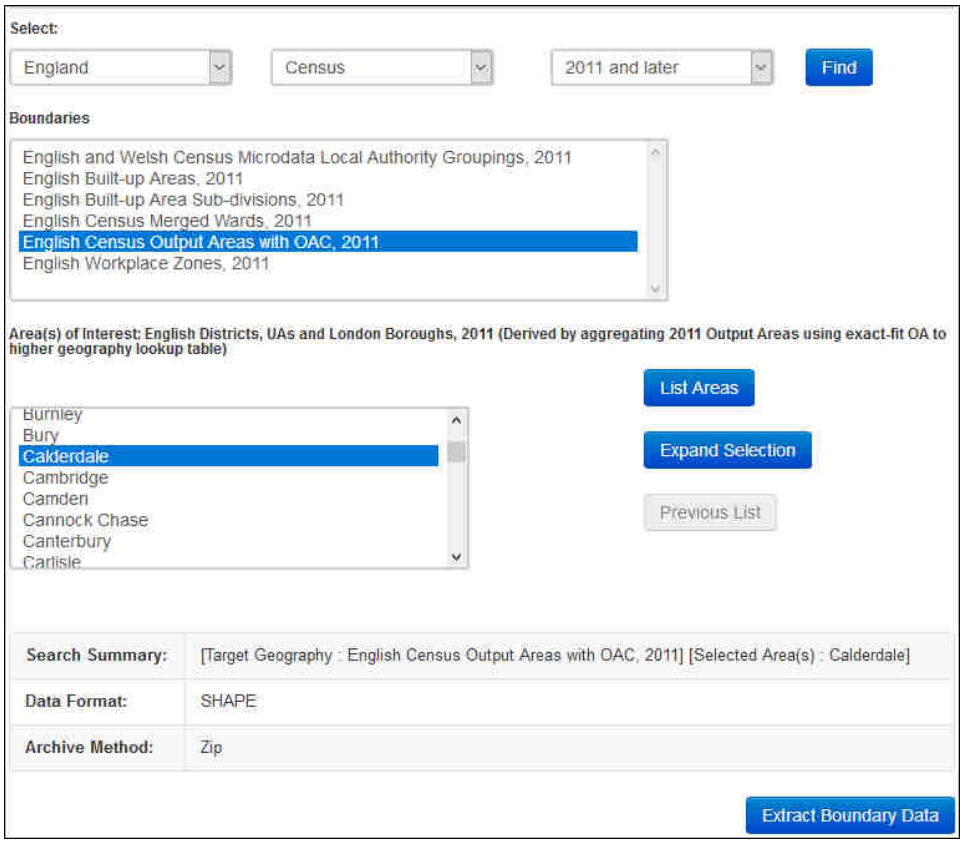


Figure 11.11: The completed form for the Boundary Data Selector

- 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.

[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.

11.7 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.

11.8 Adding census data to a map

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.

Start by cleaning up the csv file so that it will work in Arc.

- 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.

Then you are ready to open Arc 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 but will appear under **Standalone Tables** at the bottom of the Catalog pane.

11.8.1 Joining data

To join the data you need to have fields in each source file that match. So have a look at both the boundary layer and the data file 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 contents pane and select Joins and Relates > Add Join
- Fill in the dialog as in figure 11.12 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

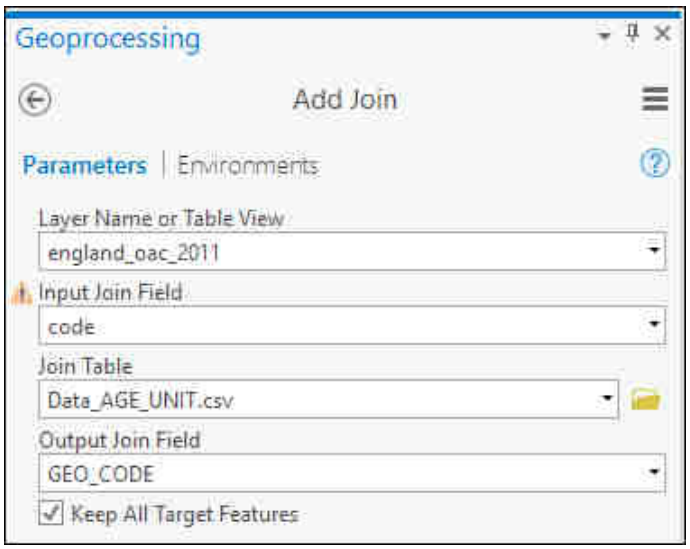


Figure 11.12: Joining census attribute data to boundary data

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 feature class in your geodatabase using **Export features**[8]. Add the resulting feature class to your map and remove the shapefile and table.

11.9 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 in section 2.3.4 on page 38

11.10 What is the population of the flooded area?

- To be able to select the population for the output areas that intersect that area the raster showing the flooded area needs to be converted to a vector file so use the Conversion Tools > From Raster > Raster to Polygon to convert it.
- Then use Select by Location to select all output areas in the census data that **intersect** with the new output feature class[9].
- 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 **Summary Statistics** and fill in the geoprocessing form to obtain the **Sum** of the number of people in the output areas exported - see figure 11.13
  - A new table will be added to the contents pane under **Standalone tables**. Open the table and make a note of the total population in **your** statistics below.

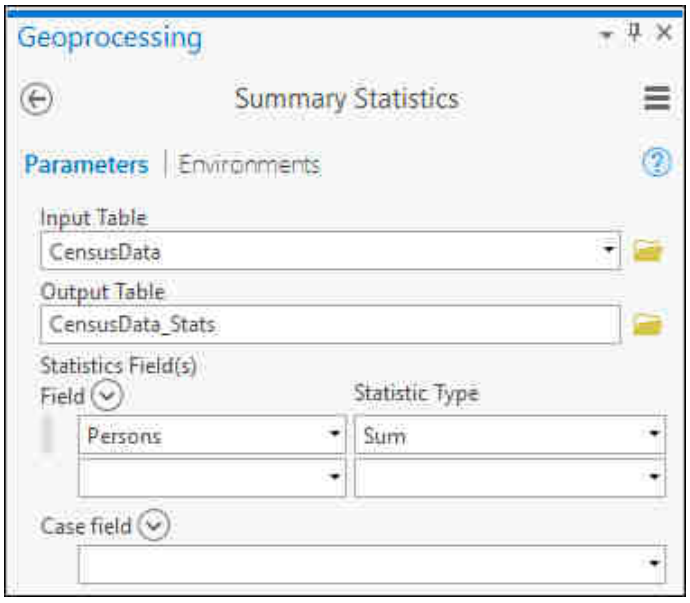


Figure 11.13: Filling in the Summary statistics form. Make sure there is nothing in the Case field

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?

[9] See section 1.12 on page 18 if you need a reminder about Select by Location

11.11 Suggested layout

Use the layers that you have created to layout a map similar to the one in figure 11.14. Include the flooded area, the output areas affected by the flooding, and the location of the 30 m dam. You should also include a brief explanation of what you are showing, and the number of persons in the selected output areas. Don't forget to include the usual map elements, such as title, key, scalebar etc.

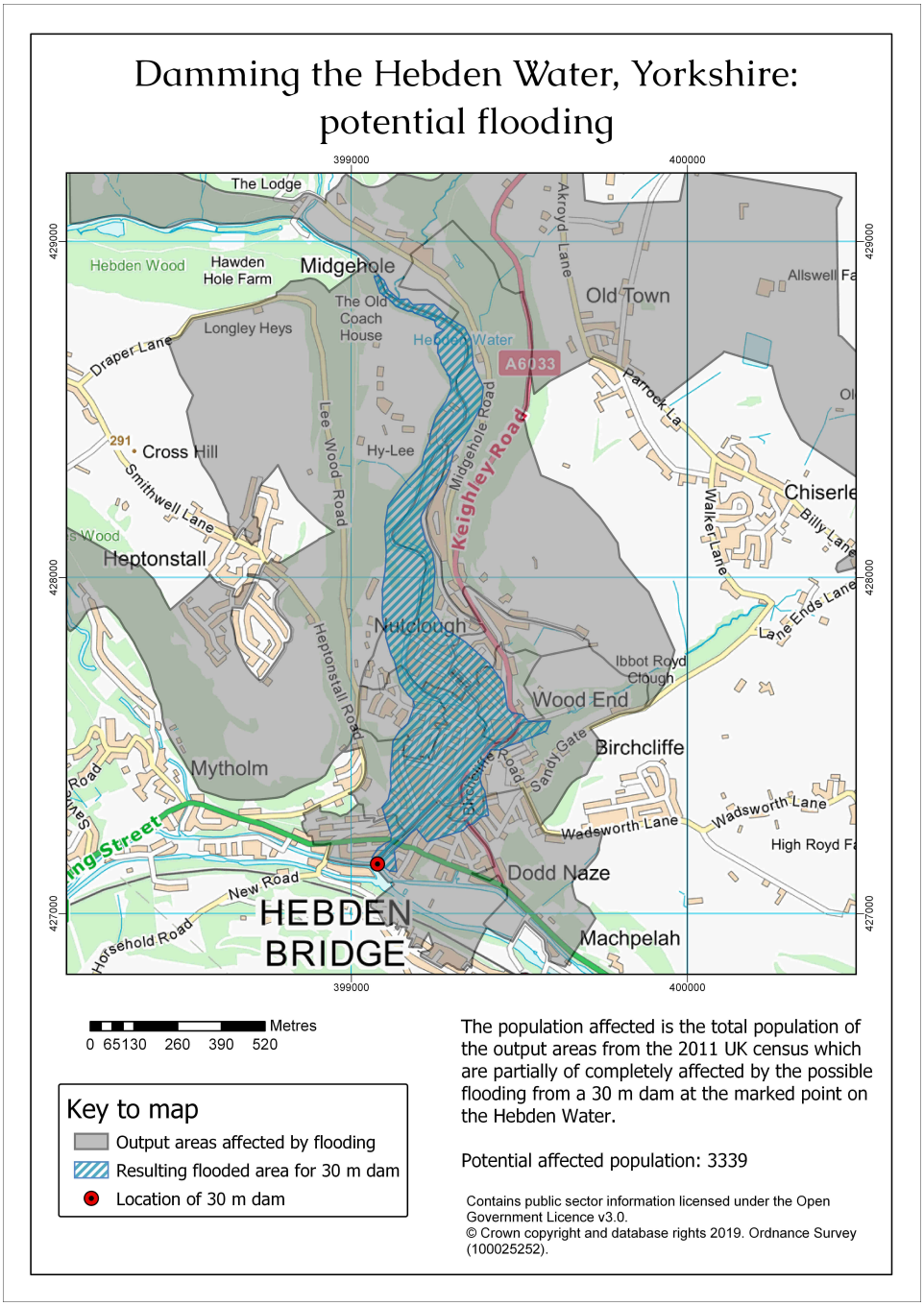


Figure 11.14: Example map of the result of damming the Hebden Water in Hebden Bridge

11.12 Recommended Reading: Raster analysis II

Full references are in the module reading list[10].

Chang (2016), Chapter 12: Raster Data Analysis, p.248-267.

[10] 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 Arc.

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 is a beginners guide at:

Garmin:

`http://www8.garmin.com/aboutGPS/index.html`[1]

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 2019

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 12.11). The official Quick Start manual for the Garmin eTrex 10 is available online[2] at

`https://support.garmin.com/en-US/?productID=87768&tab=manuals`

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.[3]
- 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.

[2] Last visited: 18th September 2019

[3] 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!

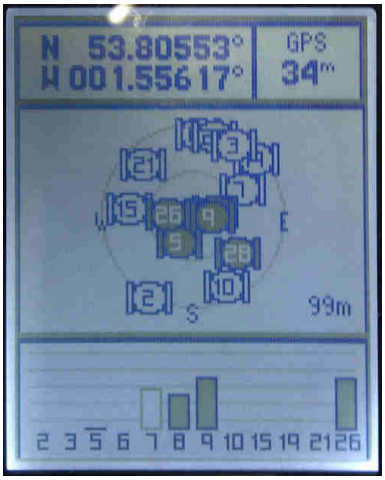


Figure 12.1: Garmin eTrex 10 satellite information screen

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." [4]

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.

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

[4] `http://bit.ly/1cPJkCw` [Last accessed: 18th September 2018]

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.[5]

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

Open a new map in ArcGIS Pro - you should get a world map don't worry about that for now!

Start by investigating the contents of the gpx file that you have created, by opening it 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

Video Clip available in Minerva - Converting gps files to display in Arc.

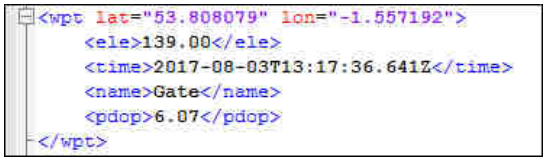


Figure 12.2: This is how a waypoint looks in Notepad++ - note the line beginning **<wpt lat=** . Also note that the coordinates will be in lat and long even if you had the GPS unit set to British National Grid.

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.

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**.

You'll use one of the tools in the geoprocessing toolbox to convert the gpx file. The geoprocessing toolbox gives you the opportunity to do a lot of very advanced processing tasks without needing to use a command-line interface.

- Click on **Tools** on the **Analysis** tab of the ribbon to open the geoprocessing toolbox. Be patient, it can be slow to open - it should look something like figure 12.4 once it does.
- You can either browse for the correct tool by going to **Toolboxes** then Conversion Tools › From GPS or search for **GPX to Features**. Either way 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** to save your output to the project geodatabase and give your output feature class a name, e.g. `Waypoints`
- Click Run

The tool should run and add a point feature class to your map.

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 above then the coordinate system will be **WGS1984** by default. 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 map frame (double-click on the map 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`)

[5] 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.

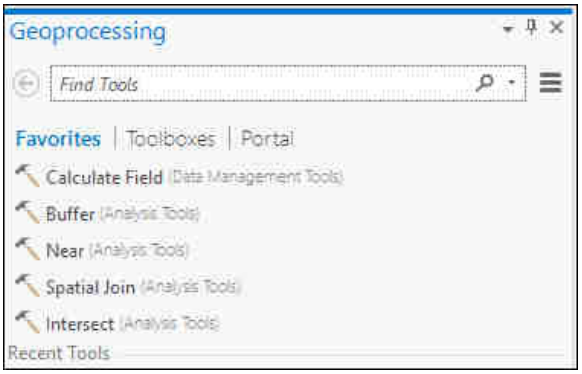


Figure 12.4: Geoprocessing toolbox - showing GPS to Features selected

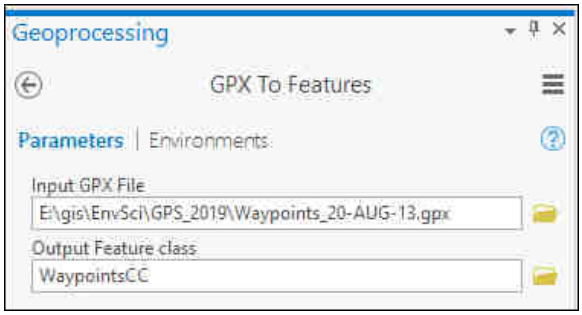


Figure 12.5: The filled in GPS To Features tool

- 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`)

12.6.1 Changing to a different basemap

By default ArcGIS Pro maps are usually set up with a topographic basemap. It would be useful to change this to a satellite imagery layer instead.

- On the **Map** tab of the ribbon click on **Basemap**
- Click to load the **Imagery with Labels** layer.

The imagery should replace **Topographic** as the basemap for your map. The other layers in this menu can be very useful too - it's worth investigating what is available.

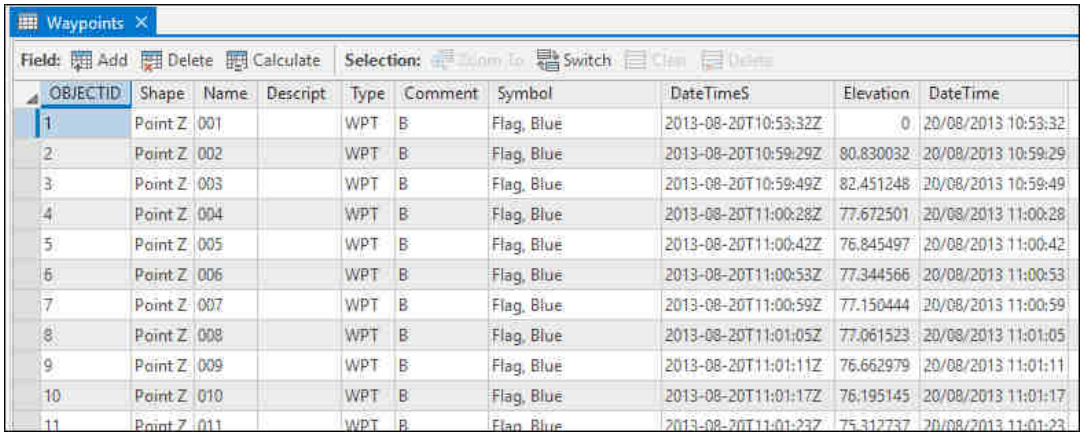
12.6.2 Checking your data

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?

12.6.3 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 Attribute Table. It should look something like figure 12.6



OBJECTID	Shape	Name	Descript	Type	Comment	Symbol	DateTimeS	Elevation	DateTime
1	Point Z	001		WPT	B	Flag, Blue	2013-08-20T10:53:32Z	0	20/08/2013 10:53:32
2	Point Z	002		WPT	B	Flag, Blue	2013-08-20T10:59:29Z	80.830032	20/08/2013 10:59:29
3	Point Z	003		WPT	B	Flag, Blue	2013-08-20T10:59:49Z	82.451248	20/08/2013 10:59:49
4	Point Z	004		WPT	B	Flag, Blue	2013-08-20T11:00:28Z	77.672501	20/08/2013 11:00:28
5	Point Z	005		WPT	B	Flag, Blue	2013-08-20T11:00:42Z	76.845497	20/08/2013 11:00:42
6	Point Z	006		WPT	B	Flag, Blue	2013-08-20T11:00:53Z	77.344566	20/08/2013 11:00:53
7	Point Z	007		WPT	B	Flag, Blue	2013-08-20T11:00:59Z	77.150444	20/08/2013 11:00:59
8	Point Z	008		WPT	B	Flag, Blue	2013-08-20T11:01:05Z	77.061523	20/08/2013 11:01:05
9	Point Z	009		WPT	B	Flag, Blue	2013-08-20T11:01:11Z	76.662979	20/08/2013 11:01:11
10	Point Z	010		WPT	B	Flag, Blue	2013-08-20T11:01:17Z	76.195145	20/08/2013 11:01:17
11	Point Z	011		WPT	B	Flag, Blue	2013-08-20T11:01:23Z	75.312737	20/08/2013 11:01:23

Figure 12.6: 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, in this case the number of each point. 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 feature class, 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. You could use the existing **Descript** field, but for experience here you can 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.

- Right-click on the **Buildings** layer in the Contents pane and open the **Attribute table** if it isn't already open
- To add a new field click on the **Add** button on the attribute table toolbar - see figure 5.9
- The attribute table will change to **Field** view - showing more information about the data types and formats - figure 5.10
- Fill in the details to create a new field called **FType**[6]
  - The **Field Name** should be short and contain no spaces or strange characters

[6]To denote **Feature type** - field names need to be short with no spaces

  - **Alias** is how the name will be displayed and can include spaces - it's still a good idea to keep it short
  - Set the **Data Type** to **Text**
  - Set the **Length** to **100** - that's the number of characters you'll be able to use in a name.

- Once you've filled in that click on Save on the ribbon.

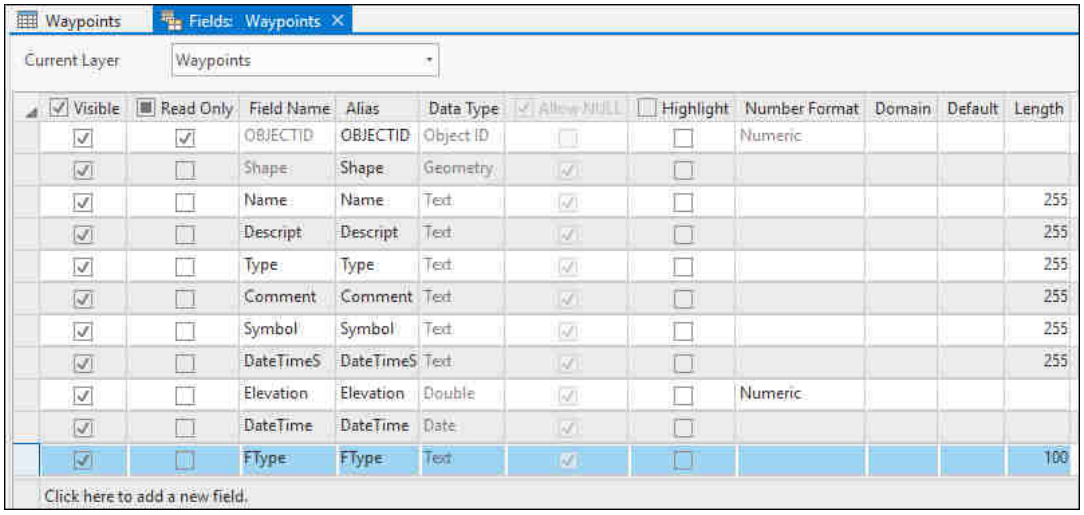


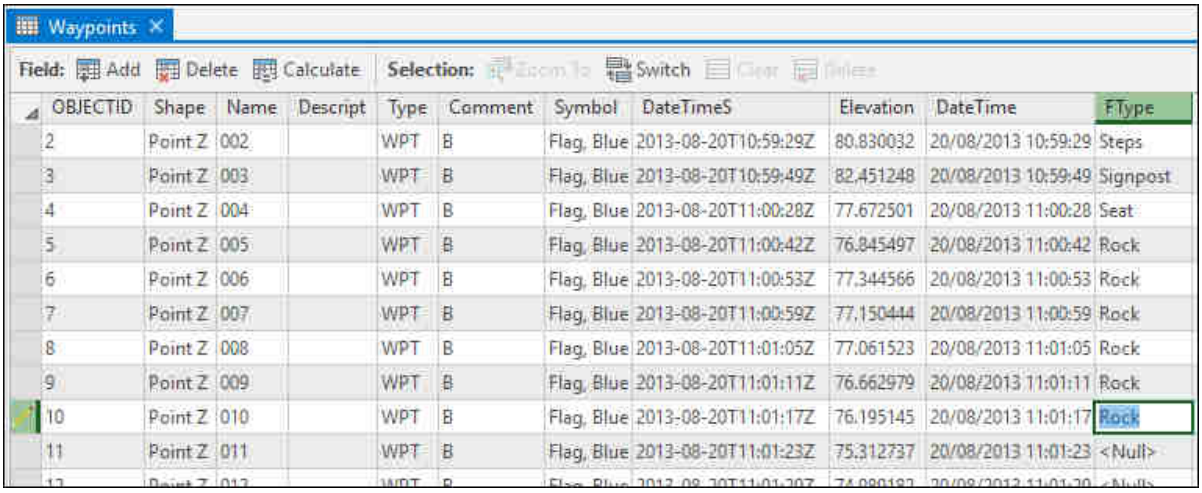
Figure 12.7: Adding a field to a feature class attribute table

12.6.4 Adding feature attributes to a feature class

Now you're ready to add information, or **attributes**, to your new field.

- Start by opening the attribute table for the waypoints layer, if it isn't already open, by right-clicking on the layer in the contents pane and click on **Attribute Table**
- If you have any features that you don't need, e.g. if you haven't written down any information for one, you can delete it by right-clicking in the little grey box on the left of the attribute table next to that record and **Delete Row**
- Click in the first box of the `FType` field - 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.
- go through the list and add all the feature types, see figure 12.8.
- then save your edits by clicking the **Save** button on the **Edit** tab of the ribbon - it's easy to forget this but you don't want to lose your work!

Video Clip available in Minerva - Adding attributes to the attribute table in ArcGIS Pro



OBJECTID	Shape	Name	Descript	Type	Comment	Symbol	DateTimeS	Elevation	DateTime	FType
2	Point Z	002		WPT	B	Flag, Blue	2013-08-20T10:59:29Z	80.830032	20/08/2013 10:59:29	Steps
3	Point Z	003		WPT	B	Flag, Blue	2013-08-20T10:59:49Z	82.451248	20/08/2013 10:59:49	Signpost
4	Point Z	004		WPT	B	Flag, Blue	2013-08-20T11:00:28Z	77.672501	20/08/2013 11:00:28	Seat
5	Point Z	005		WPT	B	Flag, Blue	2013-08-20T11:00:42Z	76.845497	20/08/2013 11:00:42	Rock
6	Point Z	006		WPT	B	Flag, Blue	2013-08-20T11:00:53Z	77.344566	20/08/2013 11:00:53	Rock
7	Point Z	007		WPT	B	Flag, Blue	2013-08-20T11:00:59Z	77.150444	20/08/2013 11:00:59	Rock
8	Point Z	008		WPT	B	Flag, Blue	2013-08-20T11:01:05Z	77.061523	20/08/2013 11:01:05	Rock
9	Point Z	009		WPT	B	Flag, Blue	2013-08-20T11:01:11Z	76.662979	20/08/2013 11:01:11	Rock
10	Point Z	010		WPT	B	Flag, Blue	2013-08-20T11:01:17Z	76.195145	20/08/2013 11:01:17	Rock
11	Point Z	011		WPT	B	Flag, Blue	2013-08-20T11:01:23Z	75.312737	20/08/2013 11:01:23	<Null>

Figure 12.8: The attribute table for the converted gps data with the feature type added manually in the FType field

12.7 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.
- Select your waypoint layer in the contents pane
- Go to the **Appearance** tab of the ribbon and click on **Symbology** to open the Symbology pane on the right of the window

Video Clip available in Minerva - Symbolising a layer by unique values in Arc.

At the moment the layer is symbolised as a single symbol - a single random colour which is used for all features (figure 12.9).

- In the symbology pane select **Unique Values** in the dropdown at the top
- in the **Value Field** box that appears select **FType** - or whatever you called the field that you added attributes to.

You should find that you get a list of the values of FType to which Arc will have assigned random coloured symbols - figure 12.10.

- 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. You may need to follow the instructions in table 12.1 on page 210 to add extra symbols to find what you need
- You may find it easier to see what you are doing if you turn off the base map layers.

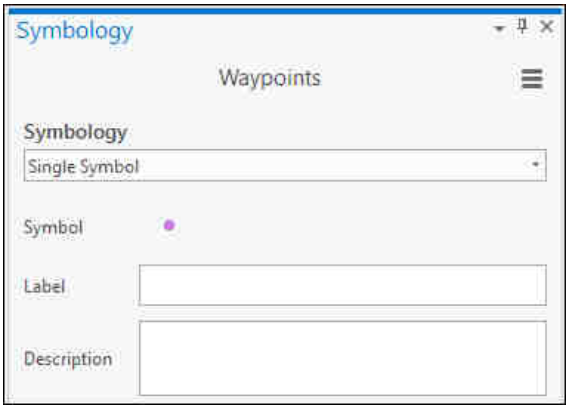


Figure 12.9: The waypoints layer symbolised as a single symbol

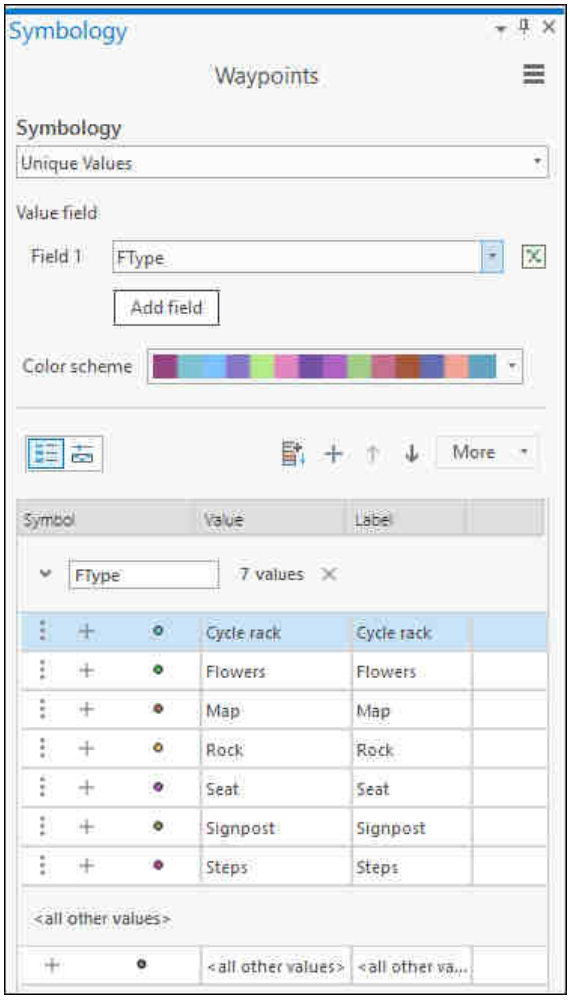


Figure 12.10: Setting symbols for a layer with unique values based on the FType field

12.8 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 **map 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** at the bottom of the map window. In this case set the scale to **1:1 000** (you can just type **1000** into the box).

Finding and using additional ArcGIS Pro Styles

There are only a relatively limited range of symbols available in ArcGIS Pro and sometimes you'll need more.
ESRI provide further styles via a gallery at
`https://esri-styles.maps.arcgis.com/home/gallery.html`
Unfortunately it doesn't seem to be possible to preview the symbols, but there are symbol sets such as **Ordnance Survey** and **Geology 24K** which should be helpful.
To install a style in your project:

- Download a style from the Gallery by clicking on it. You should end up with a `.stylx` file.
- copy or move the stylx file into your map project folder
- Go to the **Insert** tab of the ribbon and click on **Add** in the **Styles** group and select to **Add Style**
- Navigate to where you saved the `.stylx` file and select it. You may get a message about the style not being the correct version, if you do click to allow it to update.

The style should be added to your project and next time you symbolise a vector layer you'll see the extra symbols and be able to select from them.
Unfortunately you do seem to need to do this for each project so it is probably worth keeping the `.stylx` files that you download for future use.

Table 12.1: Finding and using additional ArcGIS Pro Styles

- Right-click on the **map frame title** in the contents pane.
- 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.

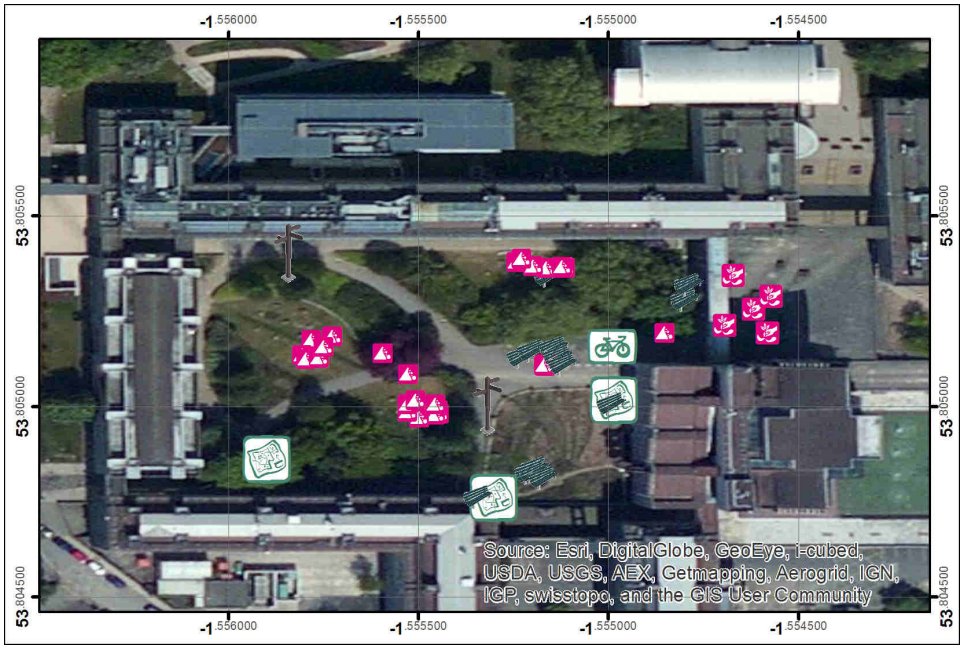


Figure 12.11: An example of symbolised waypoints for Chancellors Court (WGS84 coordinate system)

12.9 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.[7]

- Open a new map in Arc by going to the **Insert** tab of the ribbon and clicking on **New Map**
- add the **LocationBNG** shapefile that you can download from Minerva as **GPS_data.7z**. Remember that the first layer that you add to a map frame automatically sets the coordinate system.
- Change the basemap to **Imagery with labels**
- Now try adding your **Waypoints** layer.

Arc should show your waypoints layer in the correct location above the polygon for the area you have surveyed - either Chancellors Court to the south, or St Georges Fields to the north.

Have a look at the coordinate system of your map -

- Right click on the name of the map in the contents pane
- Properties > Coordinate Systems
- Make a note of the **Current XY** coordinate system below

[7] 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.

Now check the coordinate system of the waypoints layer that you've just added:

- Right-click on the Waypoints layer
- Properties » Source » Spatial Reference
- Make a note below of the coordinate system which is given, and whether it is geographic or projected

Are the two the same? You should find that the waypoints layer is in a geographic coordinate system called **GCS WGS 1984**, while the map is in **British National Grid**.

If you were going to do any analysis or measurements on your data you would need to make sure that the two match. In this case, you want to end up with a map in **British National Grid**, which is a projected coordinate system, so you need to **reproject** the waypoints layer to match the map.

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 Geoprocessing » Data Management Tools » Projections and Transformations. There are separate tools for feature classes and raster layers, in this case you would select Feature » Project

Video Clip available in Minerva - Reprojecting a feature class with the geoprocessing toolbox.

If you haven't already try changing the basemap to Imagery with Labels again (instructions in section 12.6.1 on page 205) and switch off the LocationBNG layer.

Look at both of your maps from this chapter 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.

12.10 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?

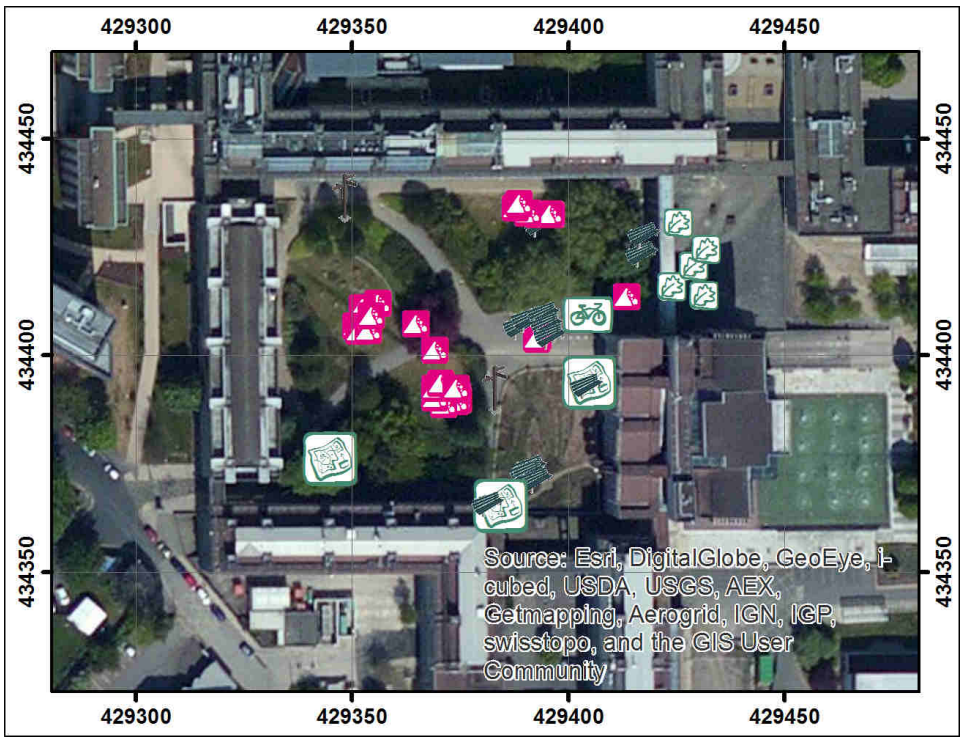


Figure 12.12: An example of symbolised waypoints for Chancellors Court in British National Grid coordinate system. Compare with figure 12.11 on page 211, which is in WGS 1984.

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 201) 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!

12.11 Recommended reading: collecting data with GPS

For more detailed information have a look at the following references from the module reading list[8].

Chang (2016), Section 5.4. on creating new data includes information on GPS.

Garmin (a major gps unit supplier) has some information about GPS on their website[9] - `https://www8.garmin.com/aboutGPS/`

Heywood, I. (2011), Chapter 10 covers data quality issues, including accuracy.

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

[9] Last visited: 18th September 2019

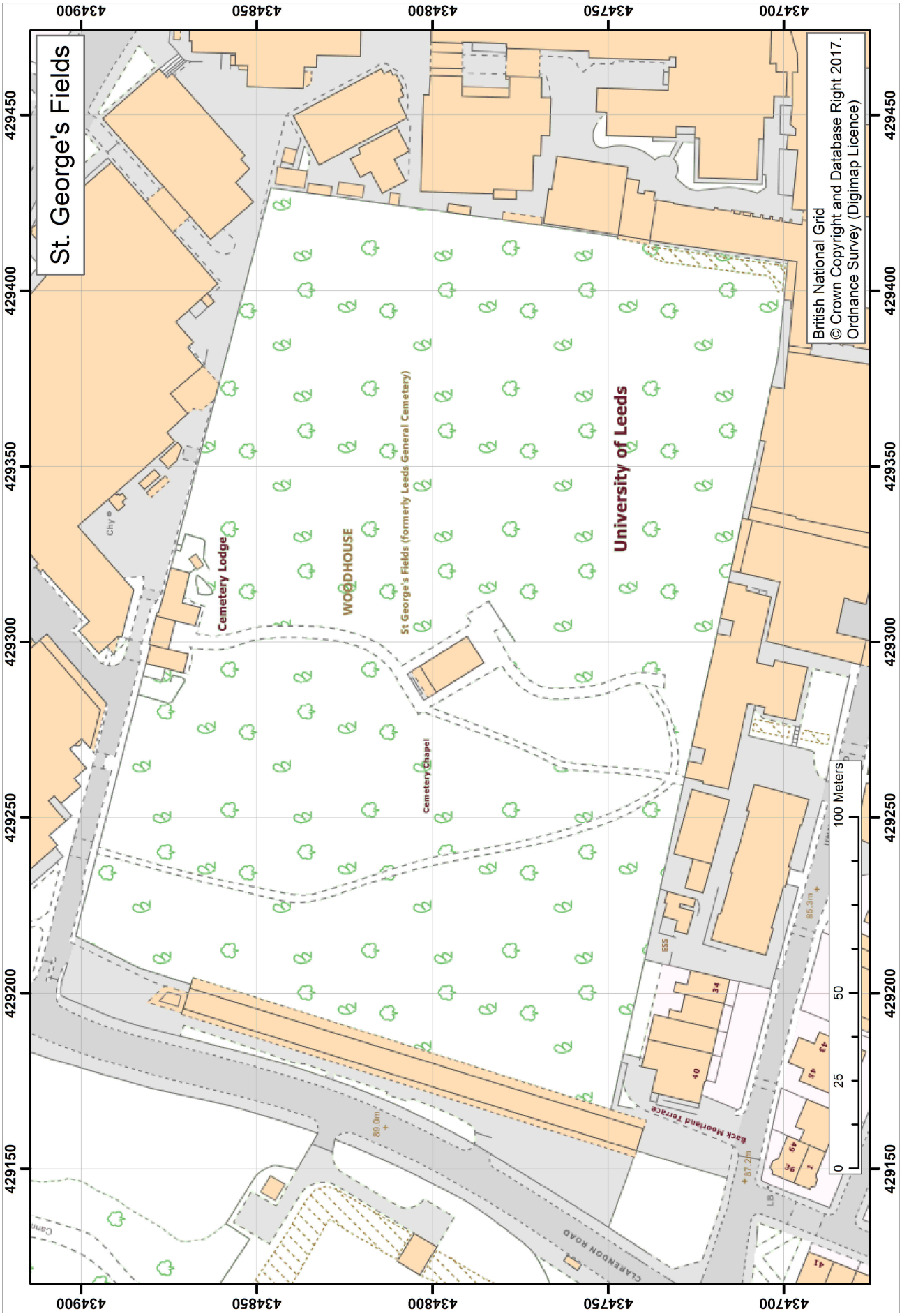


Figure 12.13: Field slip for St George's Fields

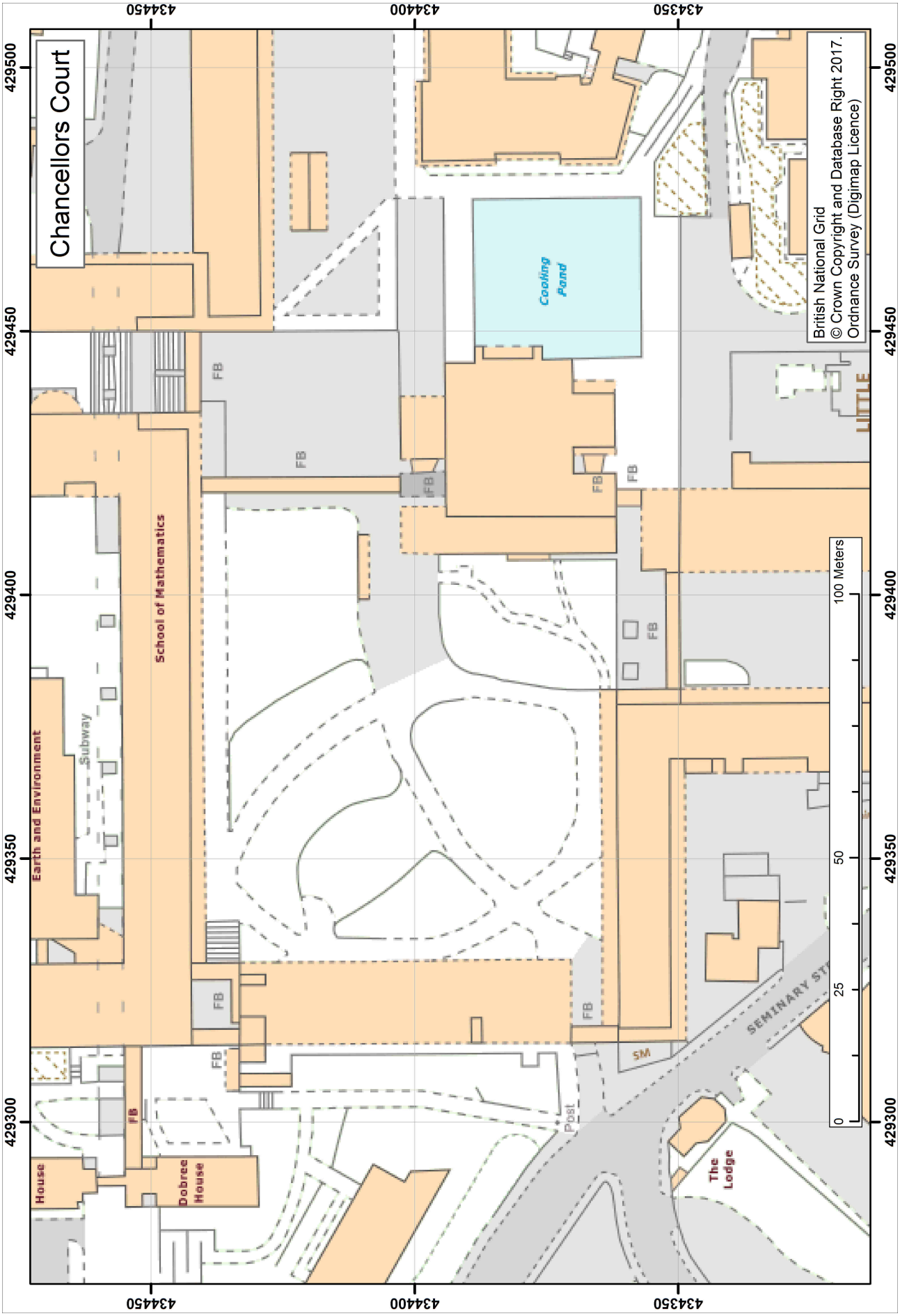


Figure 12.14: Field slip for Chancellors Court

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 12.15.

- Ordnance Survey Terrain 50 DTM - from Land and Height Data
- OS Open Roads in SHAPE format - from Vector Data
- British Geological Survey 1:50 000 bedrock and superficial geology in SHAPE format from Onshore Geology in 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 7.2.2 on page 106 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** - instructions are in section 7.4.2 on page 110
- **aspect** - instructions are in section 7.4.4 on page 112

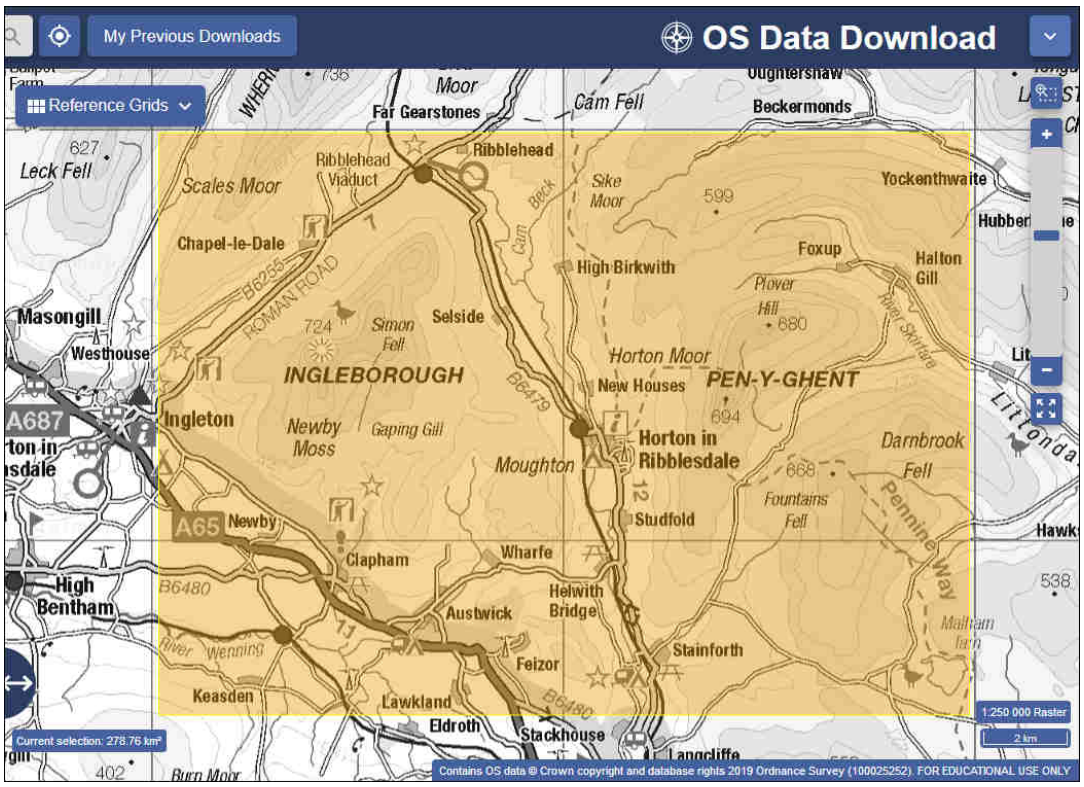


Figure 12.15: Minimum area around Horton in Ribblesdale for which to download data for environmental decision making exercises

OS Open Roads

The OS Open Roads dataset consists of three shapefiles. For this exercise the only layer that you need is the **SD_RoadLink** layer, so add that to your map now.

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 > Data Management Tools > Merge
- OR from the Analysis tab of the ribbon find **Merge** in the Tools group.
- Add both layers as input
- Save the output to the project geodatabase

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 `DecisionMaking.7z` from Minerva and unzip it to your disk. The zip file should contain two shapefiles - `LPSource` and `LPDestination`. You'll need these for the exercises in section 13.4 on page 227.

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 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 216. 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 167 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 project geodatabase.

Make sure that you have a map open in Arc 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

Also check the map properties to ensure that the coordinate system is set to **British National Grid** and map units are **meters**.

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 185) to generate a new raster showing proximity to roads and add it to your map (example in figure 13.1). Use the Road layer from OS Open Roads as the input. Don't enter a distance - then the output will cover the whole area.

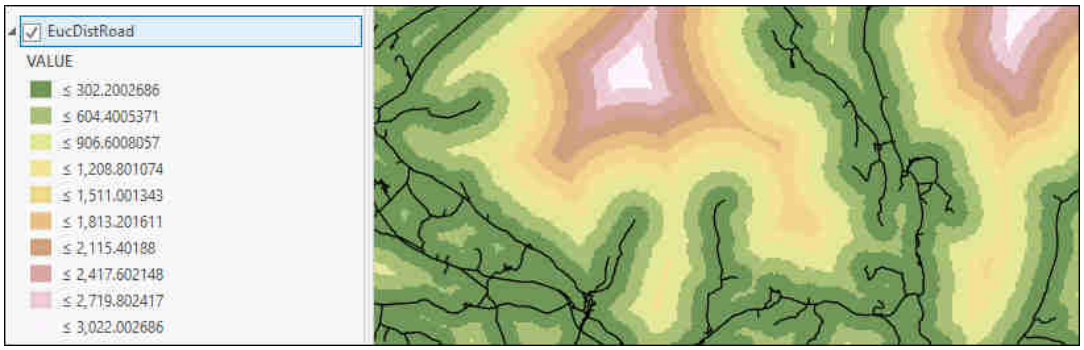


Figure 13.1: The result of running the Euclidean Distance tool on the roads layer. The key shows distance from nearest road in metres. The lines on the map are the roads.

Selecting the limestone areas

You should have a merged shapefile that shows the bedrock 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 map tab of the ribbon click on Select by Attributes
  - Use **Add Clause** to construct a query that will select all limestone features - you should be able to build the query by choosing the field name, then **is Equal to**, then enter **LIMESTONE**.[1]
  - click on Add then Run the tool
- 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**:

- Geoprocessing › Conversion Tools › To Raster › Polygon to Raster
- Fill in the dialog using the limestone layer as the input.
- Save the output to the project geodatabase
- Set the Value Field to **RCS_D** and keep the other selections to the default

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.

[1] This will select the features which are **just** limestone. If you entered **contains the text** you would select features which are a mixture of limestone and other rock types too.

[2] Right-click on the layer and go to Data › Export Features

- Open the raster calculator (see section 11.4.1 on page 182)
- 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.[3]
- 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 using the **Swipe** tool from the Appearance tab of the ribbon to check that it is correct.

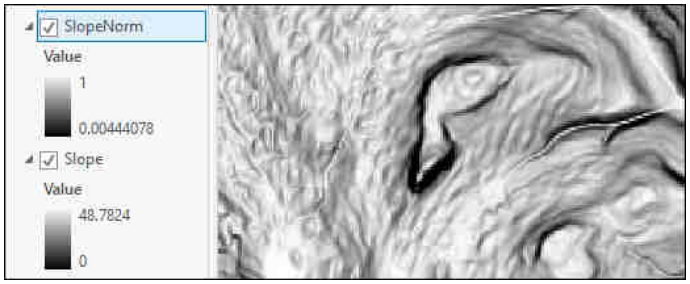


Figure 13.3: Normalised slope raster

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.

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.

[3] Check by setting your slope layer to a stretched symbology and setting **Stretch type** to **Minimum Maximum**. The Contents pane will show you the maximum.

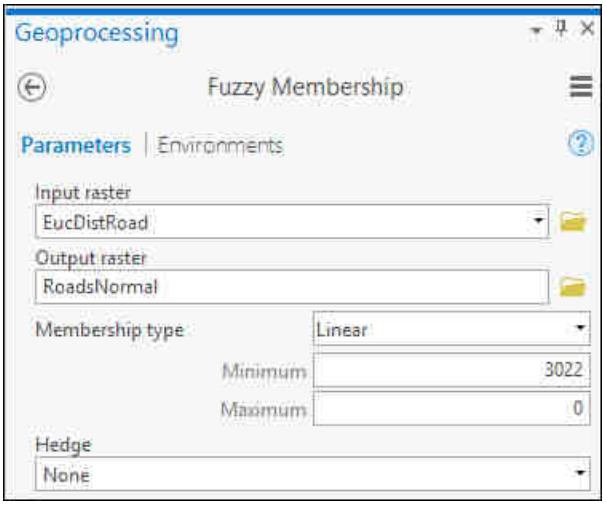


Figure 13.4: Filling in the Fuzzy Membership tool

Figure 13.5: Normalised road proximity raster. Cells closer to the road have a value closest to 1 and are paler coloured.

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 and give the output a name
- Set Membership Type to **Gaussian**; Midpoint to **180** and Spread to **0.0001**

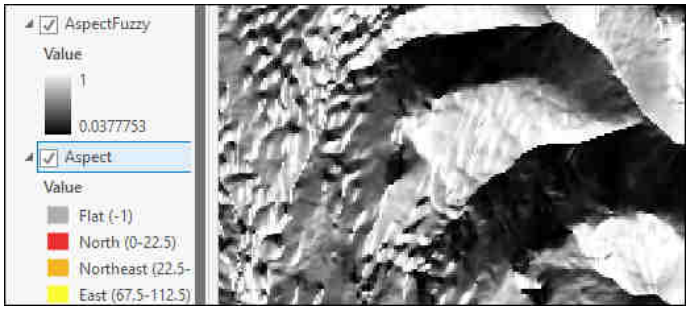


Figure 13.6: Normalised Aspect raster

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[4].

- 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 below and in figure 13.7, and also a name for the project e.g. **Site selection** then click OK
  - Slope
  - Aspect
  - Geology
  - Distance from roads
- 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

Figure 13.7: Entering criteria

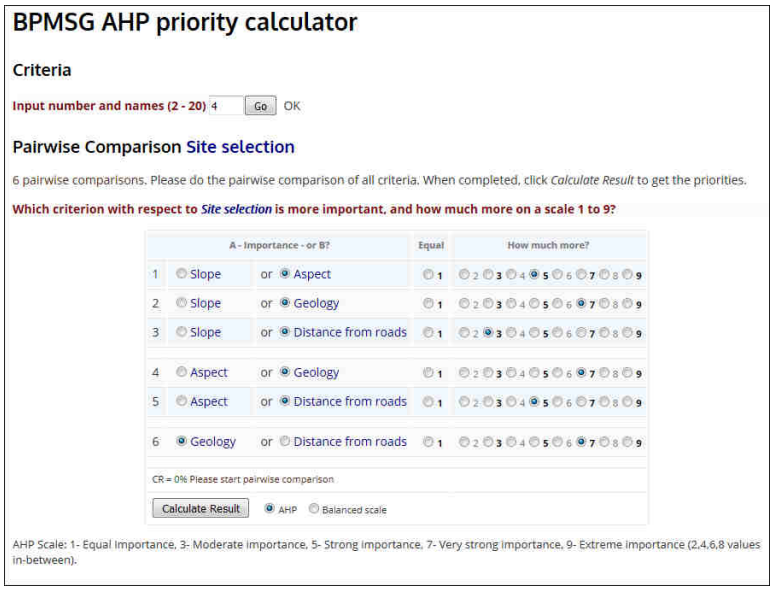


Figure 13.8: Setting the priority and importance for each pairwise comparison

---

For this example

- Geology is the most important criteria
- Aspect is more important than slope or distance from road
- Distance from road is more important than slope

[4]Web page last visited: 17th September 2018. If this disappears try searching online for **pairwise comparison calculator** to find alternatives

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.

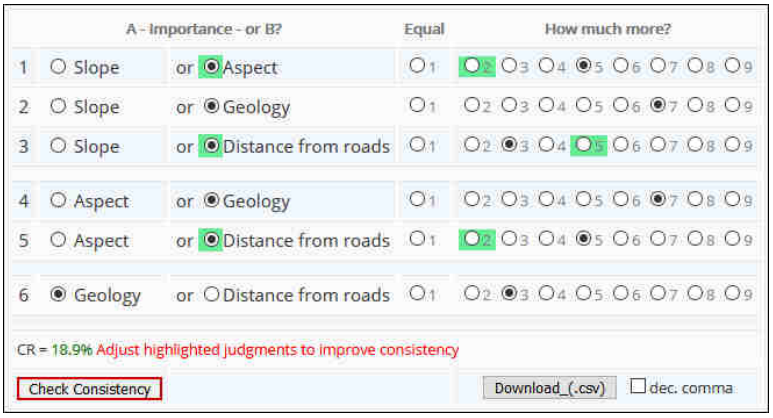


Figure 13.9: Suggestions for how to make the priorities more consistent

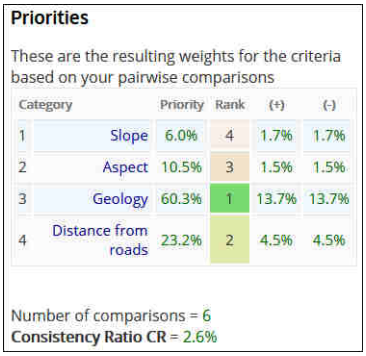


Figure 13.10: Priorities - Resulting weights: the output from your choices. Make a note of these percentages

---

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 (remember they should add up to 100!)
- Give the output a location and name and then run the 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.

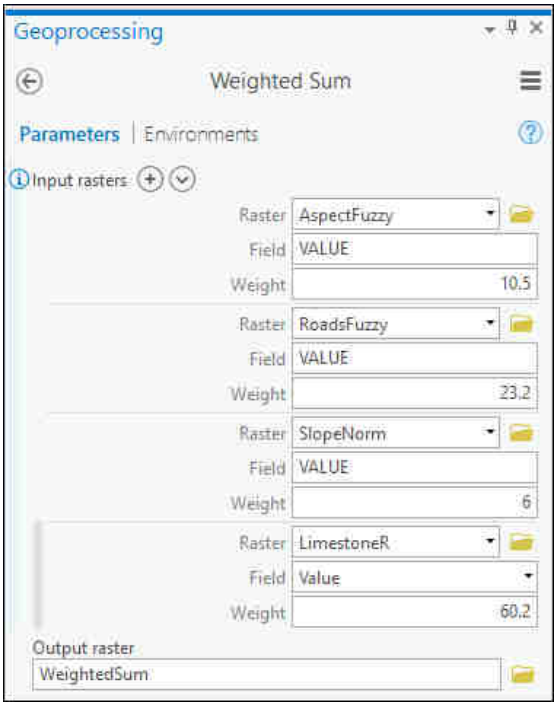


Figure 13.11: Using weights for each of the normalised rasters in the Weighted Sum tool

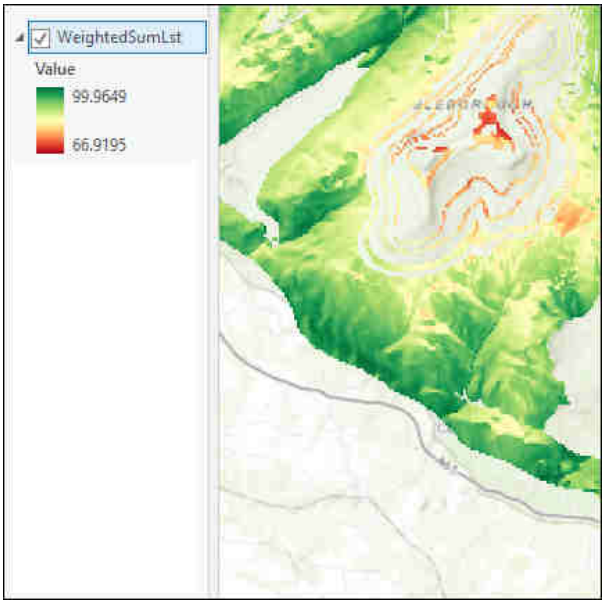


Figure 13.12: Output of the weighted sum tool

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.

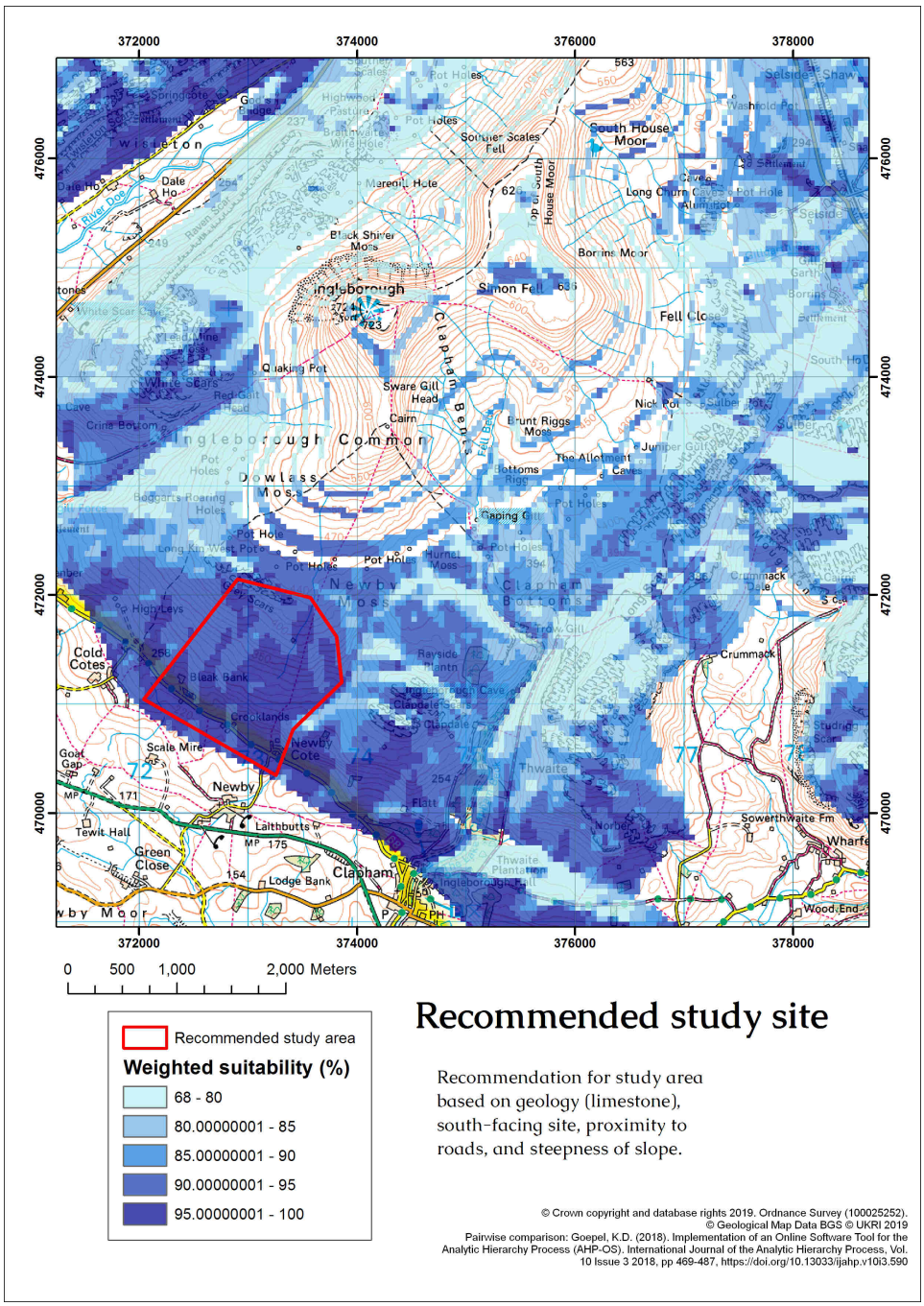


Figure 13.13: Possible layout for the map showing the recommended study site based on the criteria given

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` shapefile[5]. 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 `LPDestination` shapefile shows an existing cable running close to the road across the map[6]. We'll be using a simplified range of

[5] You should already have downloaded `DecisionMaking.7z` from Minerva and unzipped it. The zip file contains the two shapefiles required for this section.

[6] Note that this existing cable is only given for the purposes of this exercise and is not real data.

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.
- 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 229 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.

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?

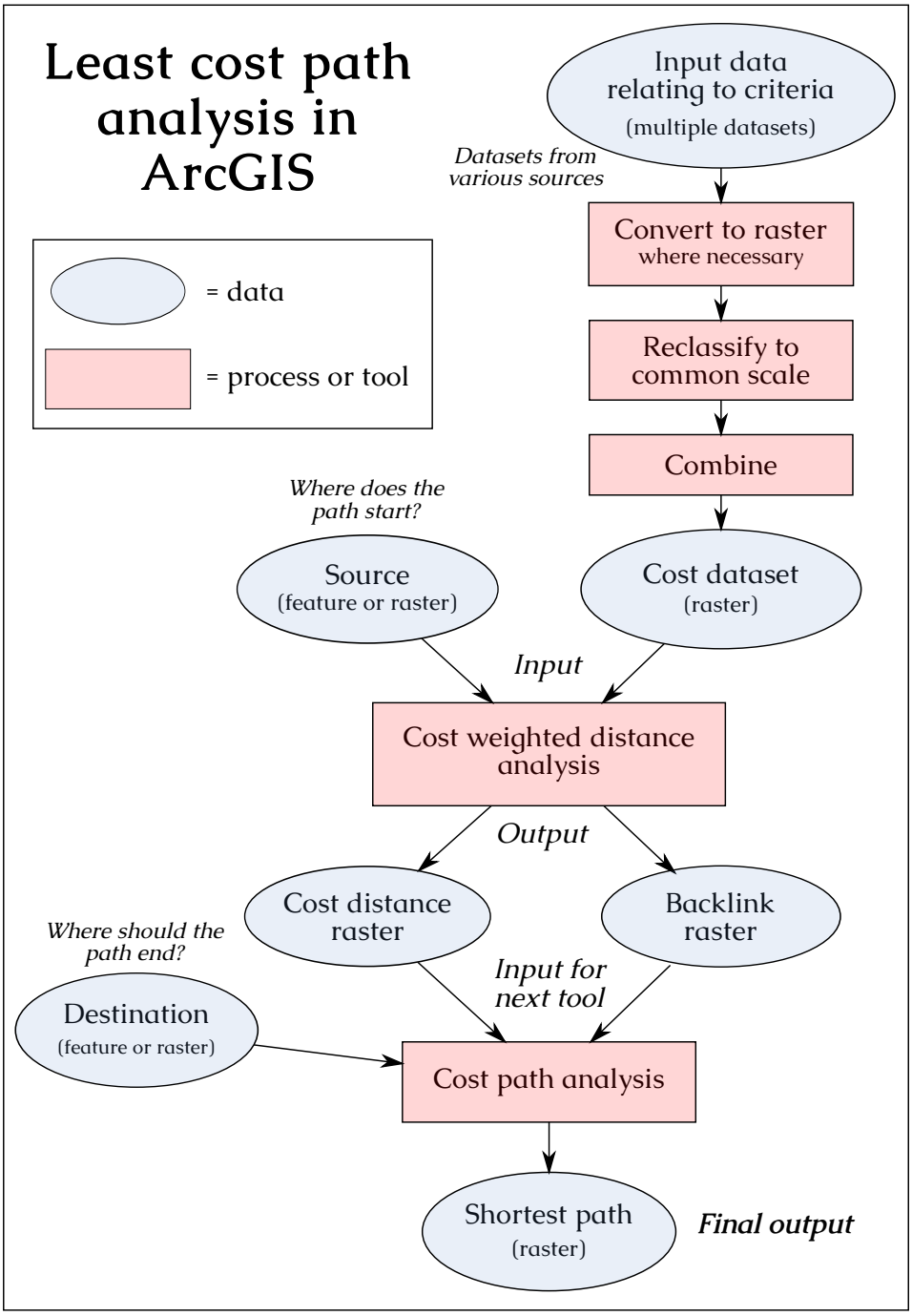


Figure 13.14: Flow diagram for least cost path analysis

Each layer must be a raster either originally, or to be saved as one, 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 216. 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 dtm layer from the previous exercise
- A feature class containing the merged superficial geology tiles.
- A polygon feature class containing the site of the new building - the *source* (the **LPSource** shapefile)
- A line feature class containing the powerline to which the cable needs to be connected - the *destination* (the **LPDestination** shapefile).

Prepare the layers as follows:

Height data - OS Terrain 50 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 **Number of classes** to **10**. The form should look something like figure 13.15 though your numbers may be different.

The resulting layer (figure 13.16) 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 13.17) 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.
- Give your output a name then run the tool

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 13.18).

The next step is to **reclassify** the superficial geology raster in order to **weight** the different types of geology.

- Spatial Analyst Tools » Reclass » Reclassify

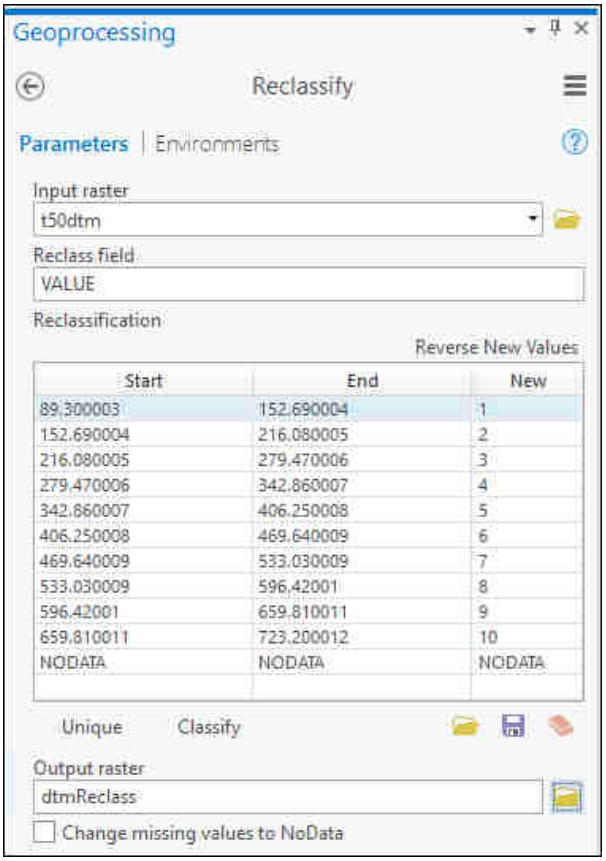


Figure 13.15: Filling in the reclassify dialog to reclassify the DTM

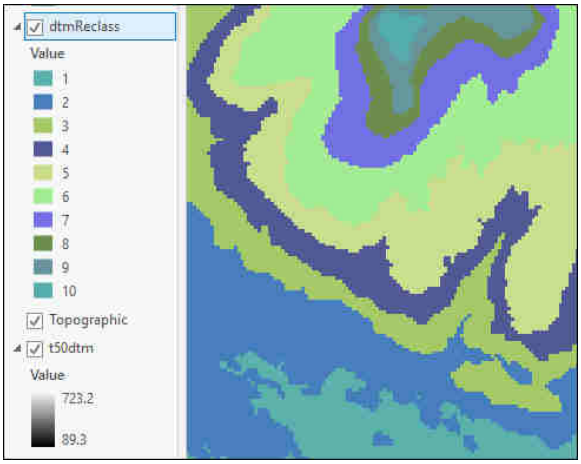


Figure 13.16: The reclassified DTM. There are now 10 classes where 1 = the lowest ground, and 10 = the highest ground.

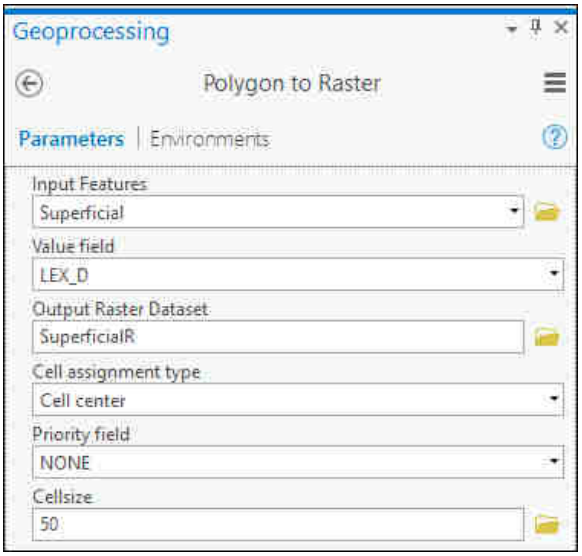


Figure 13.17: Converting the superficial geology feature class to a raster

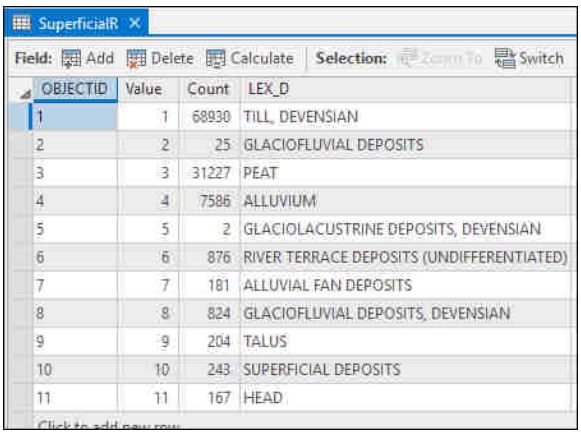


Figure 13.18: The attribute table of the rasterised superficial geology - the value field was set to LEX_D.

Old values	New values
PEAT	9
TILL	3
ALLUVIUM	3
GLACIOFLUVIAL DEPOSITS	3
Set all other values to	2
NoData	10

Table 13.1: Values to use when reclassifying the superficial geology raster

- Fill in the dialog (figure 13.19) using the raster superficial geology layer as input
- 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 232. 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 Run to run the tool.

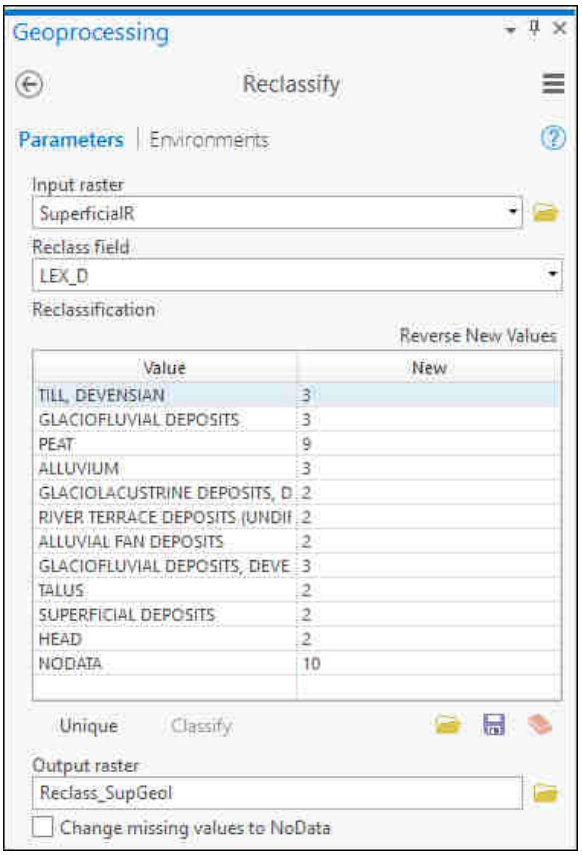


Figure 13.19: Reclassifying the superficial geology layer

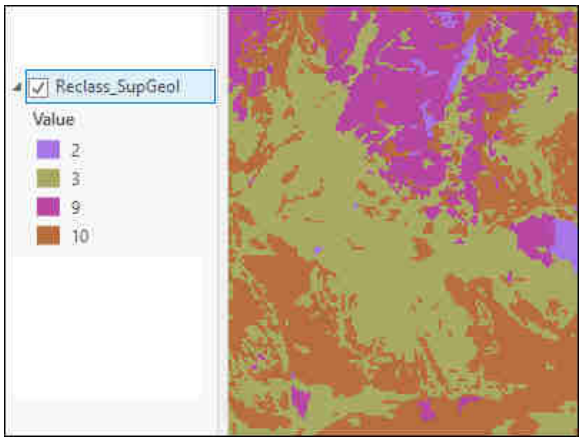


Figure 13.20: The reclassified superficial geology layer symbolised according to the numerical value. Your colours may well be different.

The output raster should include only the new values listed above and should not include any blank areas.

To check the output you may need to symbolise your new layer by the **Value** field instead of the **LEX_D** field. The layer should look something like figure 13.20 with four numbered classes.

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 **Explore** tool. If you set it to **Visible layers** and make sure that the Cost raster, reclassified superficial geology and reclassified dtm are visible, 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 13.21 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.

The output should be two files from this tool - the cost distance raster (figure 13.22) and the backlink raster (figure 13.23). 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

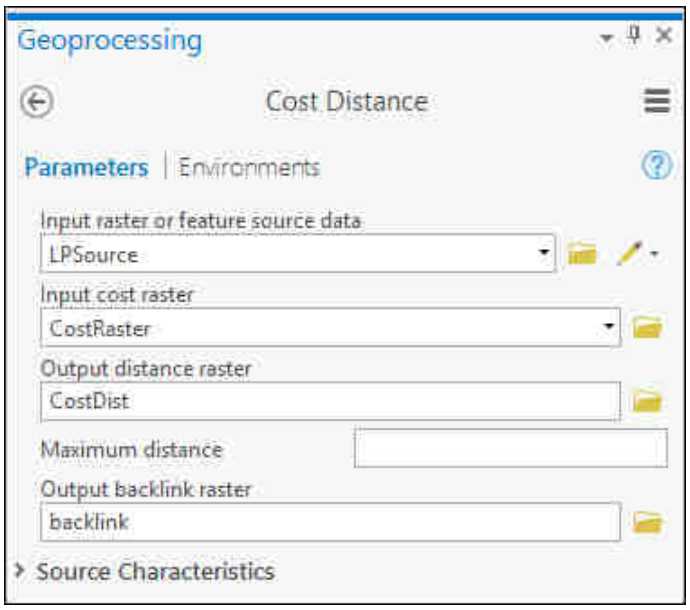


Figure 13.21: The Cost Distance tool. If you leave **Maximum Distance** blank it covers the whole of your extent.

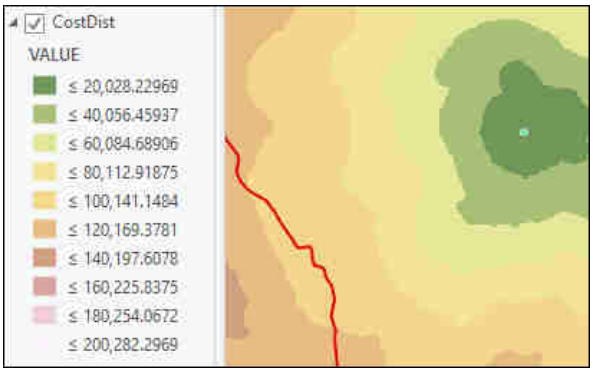


Figure 13.22: The Cost Distance raster

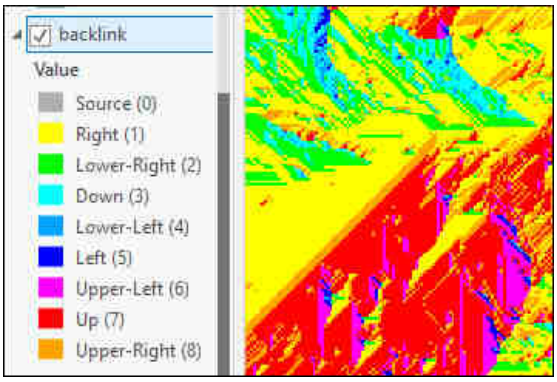


Figure 13.23: The backlink raster

- Fill in the dialog as in figure 13.24 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 important careful file naming becomes!
- Set Path type to **Best single**

This time the layer that is added to your map should show a single line of cells leading from the source to the destination - see the example layout in figure 13.25 on page 236, though your result may be different. 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?

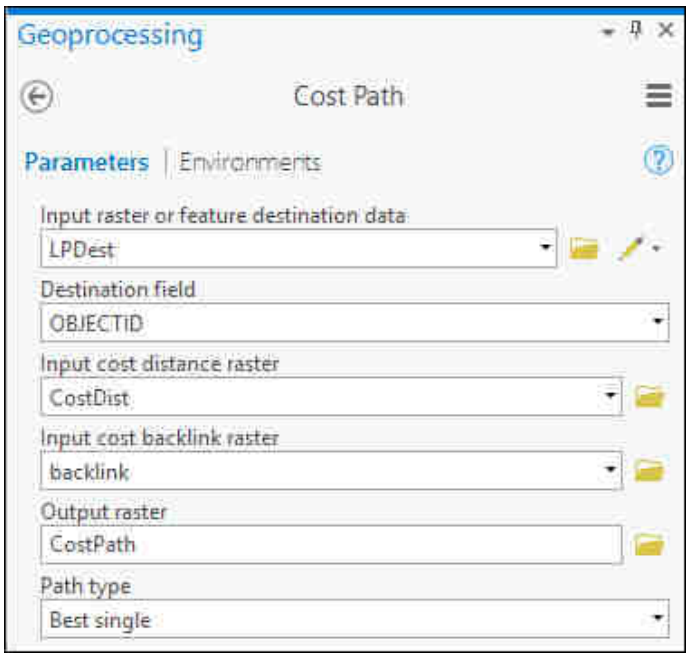


Figure 13.24: The Cost Path tool

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 13.25. 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[7].

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

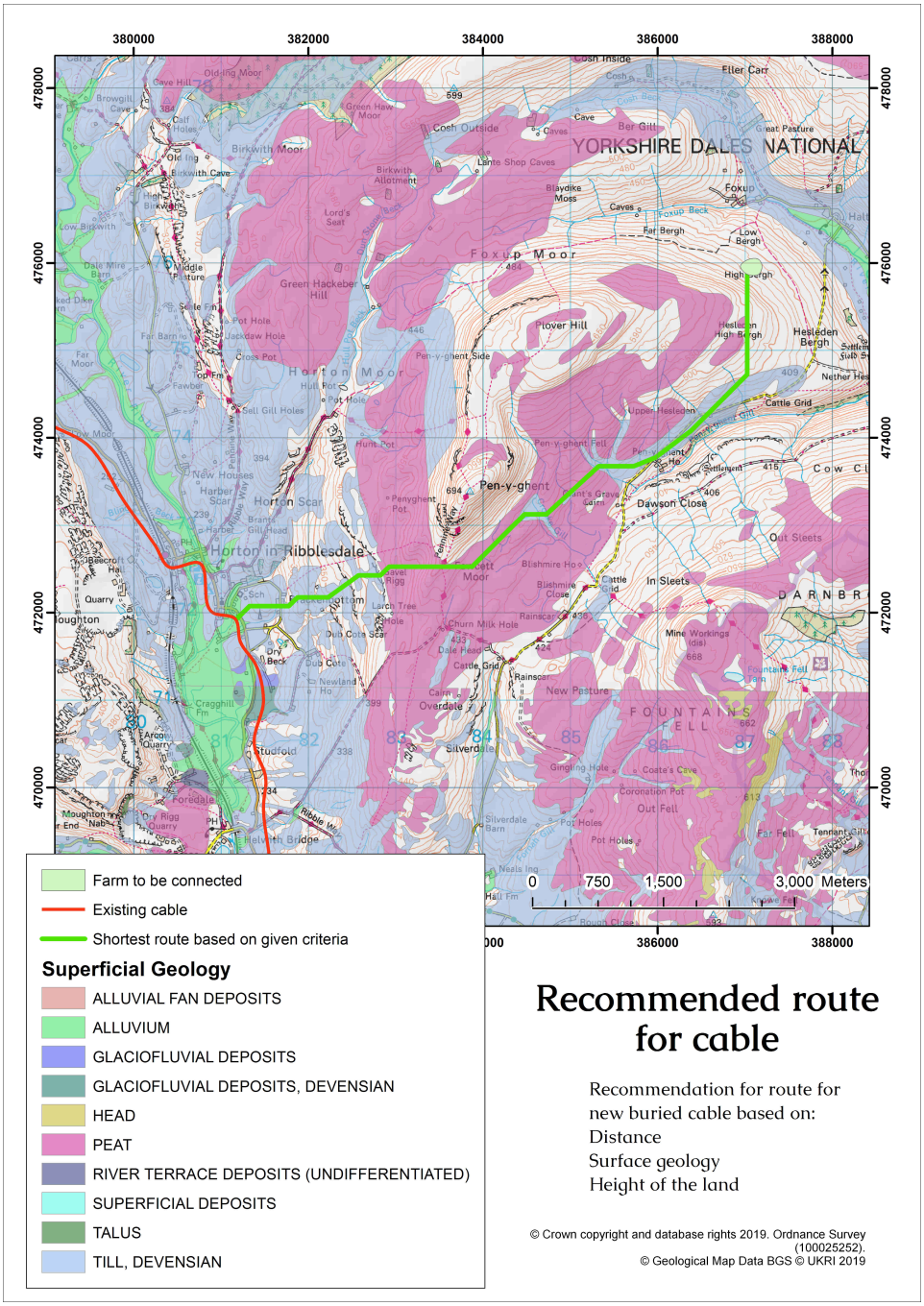


Figure 13.25: Possible layout for the map showing the recommended route for a new buried cable based on the criteria given

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

British National Grid 100 km squares

A.1 Introduction

British National Grid references are most commonly given in the form NN60052674, with grid **letters** at the start to give the 100 km grid square. These letters need to be replaced by numbers if the grid references are to be read by ArcGIS.

If you use GIS regularly you may also find that you need to replace grid numbers from GIS with grid letters in order to give grid references to other people.

If you are given a reference that does not include the grid letters but consists entirely of numbers it is worth checking whether the grid numbers make sense. Of course, it may just mean that the person who created the references forgot about the letters, in this case the reference could refer to any of the 100 km squares covering the UK - not helpful!

A.1.1 Replacing grid letters with numbers

To replace grid letters with numbers as is required when importing British National Grid references into Arc:

Using the example **NN 6005 2674** (This is not necessarily on your current map!)

- find the number of the line **to the left** of the grid square (i.e. one of the numbers from the line at the bottom) in figure A.1 - for **NN** this is "2".
- This number will apply to all of the references in the eastings column of the spreadsheet.
- then the number of the line **below** the grid square (i.e. one of the numbers to the left) - in this case "7".
- This number will apply to all of the references in the northings column of the spreadsheet.
- So in this example, grid reference **NN 6005 2674** would become **26005 72674**.
- In addition, x and y numbers all need to be six figures to appear in the correct place in Arc, so if, as in the example, there are fewer digits then add zeros to the end of each so make it correct. Finally the grid reference above will become **260050 726740** and at this point will be ready to enter into Arc.

Question A.1. Starting from a grid reference NG 344 576 what will be the grid reference with NG converted to figures?

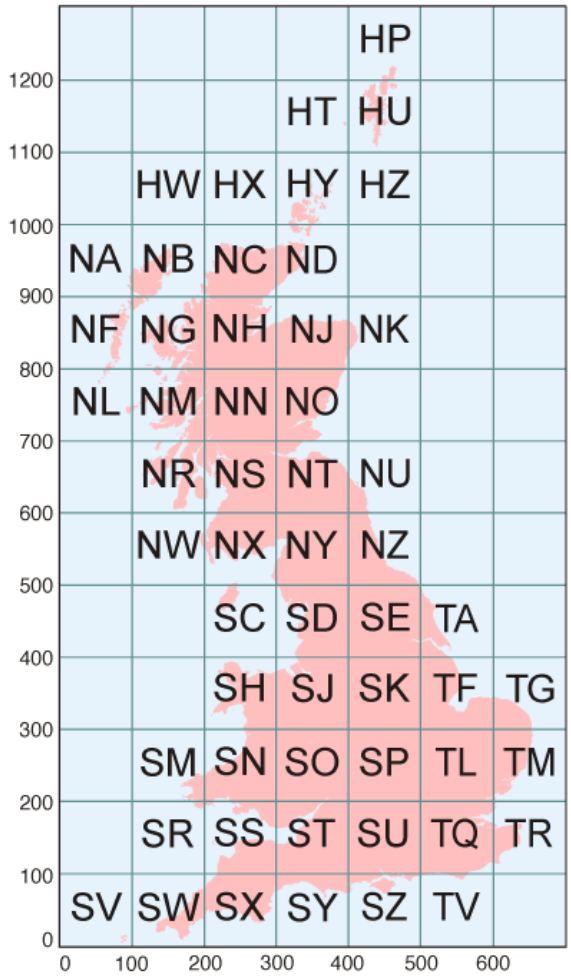


Figure A.1: British National Grid 100 km squares

If you look at the corners of a published hardcopy Ordnance Survey map such as the Landranger (pink covers) or Explorer (orange covers) series you'll be able to see these numbers as small figures on the labels of the grid lines - only at the corners, though, not right around the edges. The grid letters will appear in the corner of the published maps too.

A.1.2 Replacing grid numbers with letters

Try doing a similar exercise in reverse:

Question A.2. Starting with grid coordinates 5433 2433 what will be the grid reference with the figures converted to letters?

Appendix B

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: On the map ribbon look for each of the tools suggested in table 1.2 in turn and try them out to see what they do.

Tool	What it does
Fixed zoom in	*Moves the view closer in to the map so that you are viewing a smaller area in more detail*
Fixed 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 ribbon. Right-click on the title of a layer in the contents pane zoom to layer)	*Zooms to the extent of the data in the layer you clicked on*
click the **Select** button then click and hold on the map, drag, and let go	*Select particular features, or items from the selected layer*
click the **Clear** button in the Selection group	*This clears all of the selections that you made with the previous tool*
click on **Explore**, then click on one of the nature reserves on the map	*The explore tool should enable you to find out more about the features at a particular point on the map.*
click on **Locate**, the locate pane should open on the right of your map. Type **Sheffield** in the search box and select one of the results	*Locate should allow you to zoom straight to a place that you've searched for. If you right-click on one of the search results you'll get options to zoom or pan to that location.*

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 is the name of the other layer in the HS2 map?

*The other layer is called **Topographic**.*

Question 1.4: What are the map units of the current map?

The map units should be set to meters[1]

Question 1.5: A possible definition of raster format.

A file format consisting of cells of data with each cell defined by x and y coordinates.

Question 1.6: 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 1.7: How many features are there in the new layers showing only the reserves and SSSIs within 1000 meters of the route?

There should be about 21 local nature reserves and 26 SSSIs within 1000 m of the planned route - check the numbers by opening the attribute table for each layer and looking at the bottom left.

Question 1.8: What is the difference between zooming with the tools in the Navigate group of the Layout tab and with the tools in the Map group in layout view?

You should find that the zoom in the Navigate group changes the zoom of the layout so that you are zooming on the "sheet of paper", while the zoom in the map group changes the zoom level of the map itself without changing the size of the paper.

Chapter 2: Finding and using spatial data: Coordinate systems, projections and transformations

Question 2.1: 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, or World Geodetic System 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 2.2: What is the distance from London to Istanbul? What units are the measurement in?

2,500,721 Meters or 2,500.72 km depending on your settings (Don't worry if your answer is slightly different)

[1] The spelling of words such as metres and colour are Americanised in Arc.

Question 2.3: 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 2.4: What are the coordinate systems of the Miniscale and rivers layers?

Your answer should be similar to the entries below:

Table B.2: Projections for European region map

Layer	Projected coordinate system	Geographic coordinate system
Miniscale map of the UK	Unknown	Unknown
ArcGIS portal rivers layer	WGS 1984 Web Mercator Auxiliary Sphere	GCS WGS 1984
European river catchments	ETRS 1989 LAEA L52 M10	GCS ETRS 1989
SRTM height layer	*no projection*	GCS WGS 1984

Chapter 3: Digimap

Question 3.1: 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 3.1: 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 3.3: What is the area of Woodhouse Cemetery?
The area is approximately 36450 m^2

Question 3.4: 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 7: Elevation models: the shape of the land

Question 7.1: 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 7.2: 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 7.3: How many Lake District summits are visible from Hallsfell Top?
Your answer should be similar to 286.

Question 7.4: How many Lake District summits are visible from Helvellyn?
Your answer should be similar to 93.

Chapter 8: Model builder: making repetition easy

Question 8.1: What data do you need to start building your model?

- dtm mosaic
- Lake District hills (with one selected...)

Question 8.2: 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 B.3:*

Table B.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 96.1 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 dtm raster).*

```
SetNull("fill">(96.1+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 220 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]

Appendix A: British National Grid 100 km squares

Question A.1: Starting from a grid reference **NG 344 576** what will be the grid coordinates with NG converted to figures?

The grid coordinates will be 1344 8576

Question A.2: Starting with grid coordinates **5433 2433** what will be the grid reference with the figures converted to letters?

The grid reference will be TL 433 433

[2] `http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp` You used this site to download data for chapter 7

Index

Todo list

Put something more in this text box about float, int etc and use in raster calculator statements - find a link to more information 186