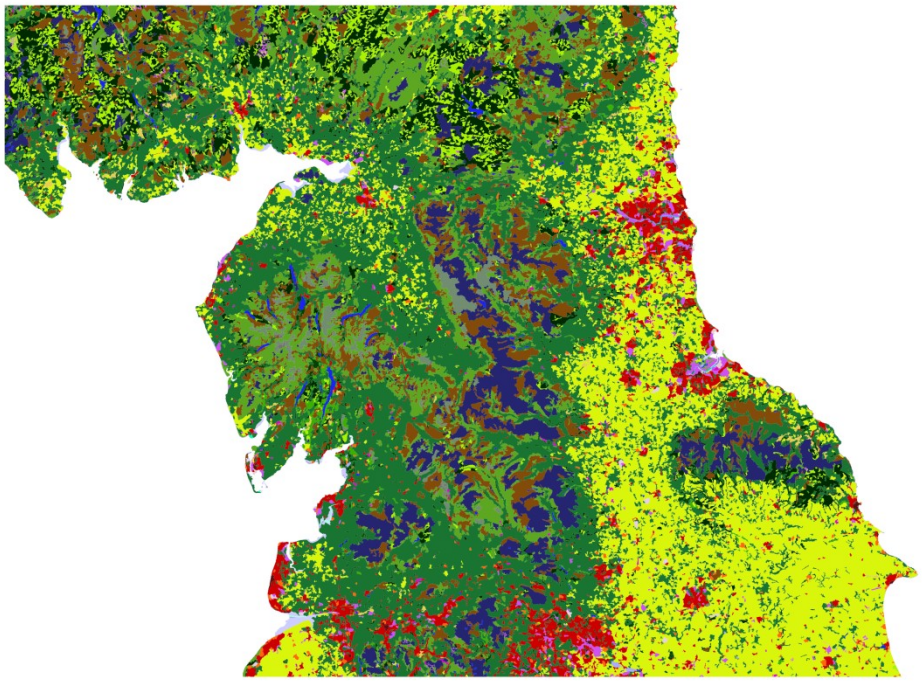
Lesson 1: A (very gentle) Introduction to Geographic Information Systems (GIS) and making a simple shapefile

The first geological map of Britain, William Smith (1815)

GIS provides a powerful tool for presenting spatial data

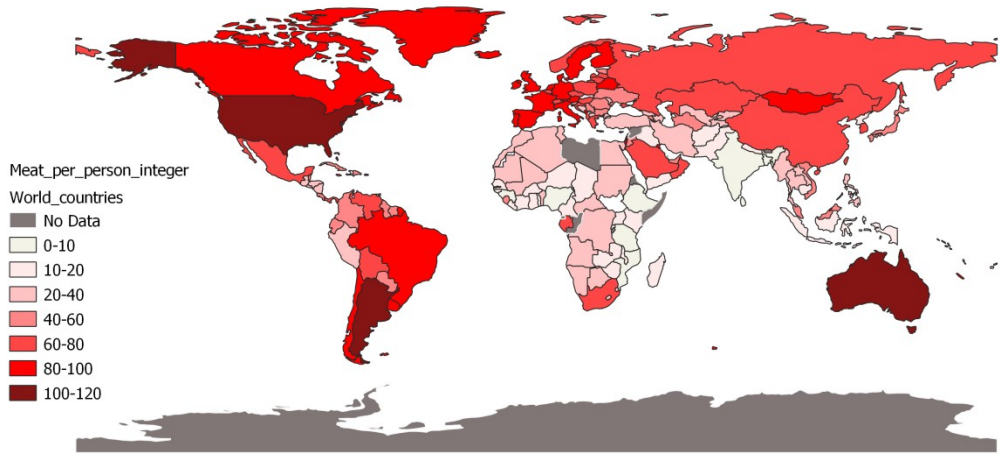
- Climate data
- Population data
- Species distribution
- Disease occurrence
- Land use
- Cultures and peoples
- Urban landscapes
- Underlying geology
- Global to garden scale mapping



Land use in the north of England and southern Scotland (Bell 2019)

Two primary types of data: Vector and raster

Meat production per person (kg) by country

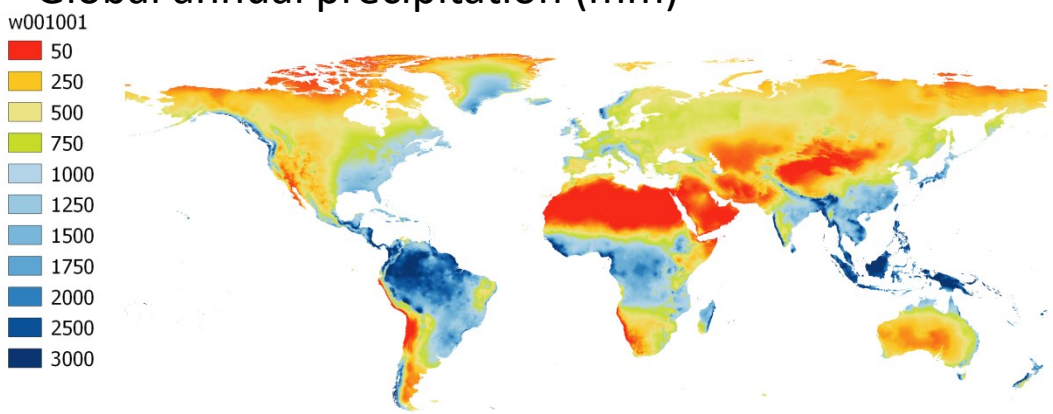


Vector

- Each country is a polygon within a shapefile
- Each polygon assigned value from data table ("Table Join")
- Value categorized by colour
- Can also be used for points or grids

(we will start with these types of maps)

Global annual precipitation (mm)

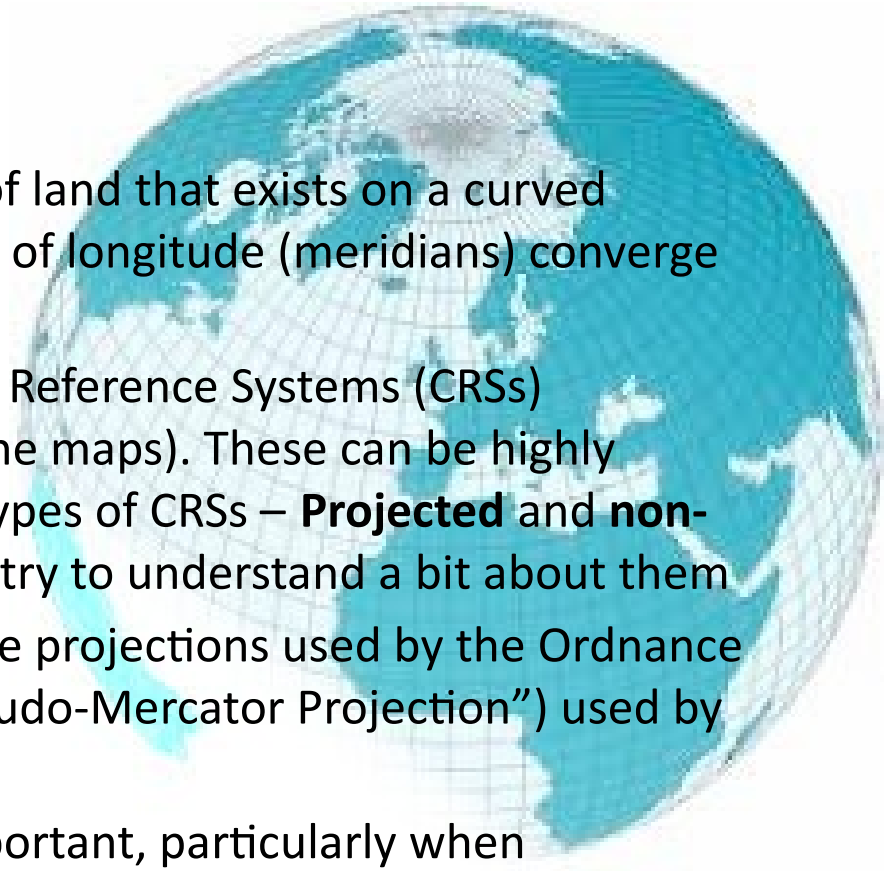


Raster

- Values assigned to pixels / unit areas (not linked to polygons)
- Less scalable
- More limited analysis
- Good for very large / granular datasets, give smooth gradations

(we will meet these later on)

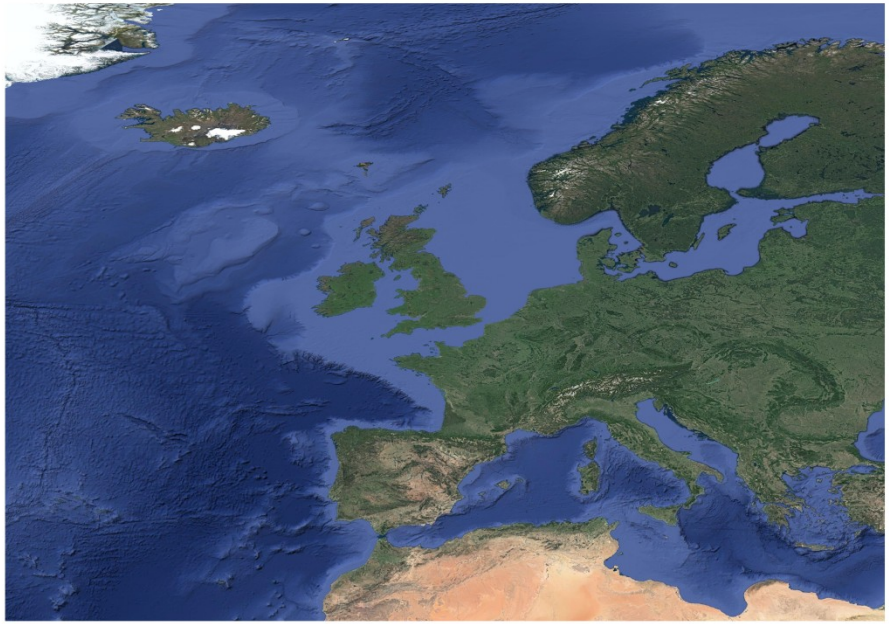
First things first: Understanding the CRS is *very* important



- Maps create a flat projection of an area of land that exists on a curved surface; maps have square grids but lines of longitude (meridians) converge (i.e. are not parallel).
- Different maps have different Coordinate Reference Systems (CRSs) (mathematical principles that underpin the maps). These can be highly regional or global. There are two major types of CRSs – **Projected** and **non-projected** – we will meet both types and try to understand a bit about them
- Examples include the **OSGB 36,** one of the projections used by the Ordnance Survey for the UK, and the **WGS 84** ("Pseudo-Mercator Projection") used by Google etc.
- Working in the right CRS is extremely important, particularly when determining areas, distances etc. and creating multiple layered maps.
- Let us look at some examples of the UK under different CRSs (projections) to see why they matter...

The CRS influences the shape of the map

Mathematical transformations can reproject maps from one CRS into another in many cases (with varying degrees of accuracy).



OSGB 1936 (EPSG:4277)

- British National Grid (version of)
- Specific to British and Irish Isles

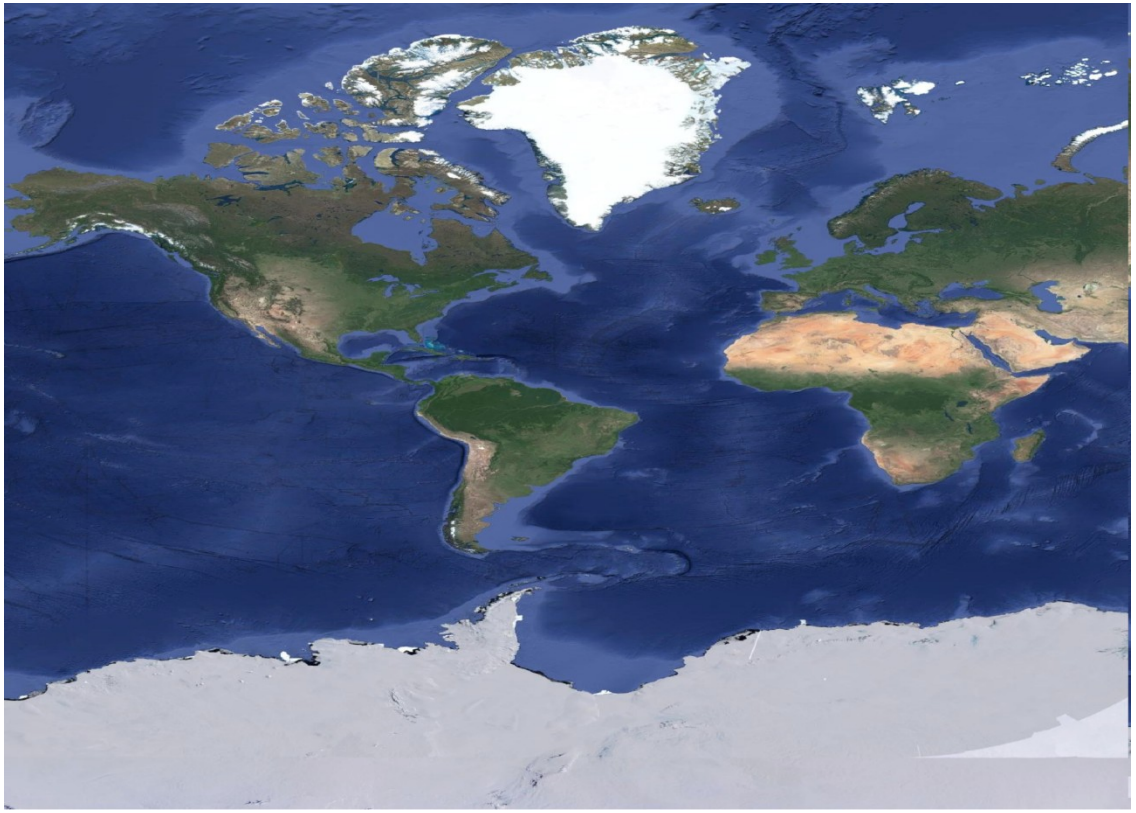
WGS 84 (EPSG:4326)

- Use by Global Positioning Systems
- Based on Earth's centre of mass
- Web based version is WGS 84 (EPSG:3857)

EPSG = European Petroleum Survey Group who oversee such matters

At the global scale the picture is more pronounced

WGS 84 / EPSG 4326
(Looks about right)

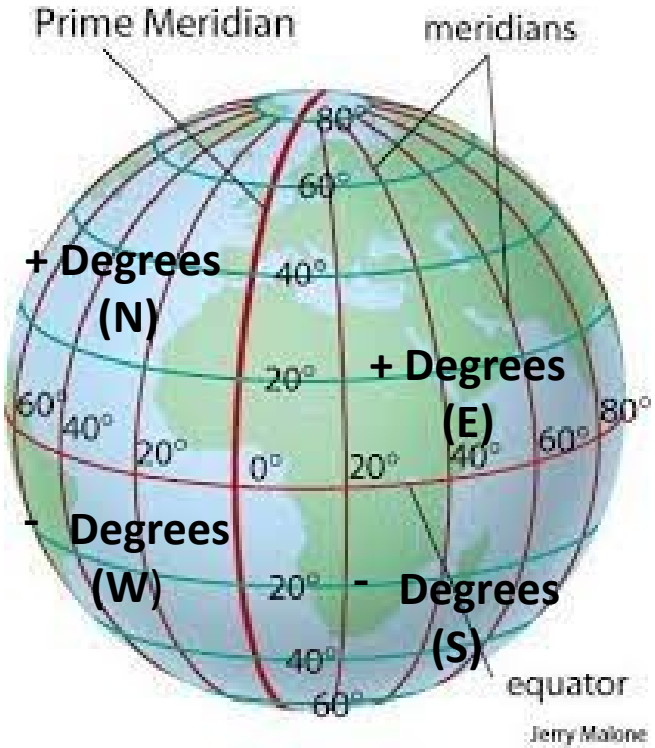


OSGB 1936 / EPSG:4277 (Not pretty, not intended for whole world projection as is very clear!)

The projection that maps are produced in can sometimes be contentious due to the apparent resizing of countries. Most CRS systems are designed for local use only.

A note on coordinates

- Google maps etc. will return coordinates as decimal degrees e.g. Carlisle -2.92 (west), 54.89 (north) or Sydney 151.26 (east). -33.892 south).
- West and south assigned negative values, North and East Positive, measured from Greenwich meridian.
- Others will show coordinated in degrees, minutes and seconds. Some show measurements in metres from set points on Earth)
- Carlisle (-2.92 W) = 2 degrees, 55 minutes, 12 seconds west - 2 degrees + (0.9x60)minutes + (0.2x60)seconds) west i.e. multiply decimals sequentially by 60.



Let’s get started with a GIS program - QGIS

- Excellent and FREE software.
  - **(https://qgis.org/en)/site/**
- Open Source, uses Python.
- Multiple platforms (Windows. Mac, Linux).
- Frequent update cycle; lots of plugins. Lots of help on the internet.
- Excellent alternative to commercial programs (e.g. ArcGis).
- A little buggy and frequent updates move things around, solving some problems then adding others (normally minor). Minor issues can be caused by PC architecture. If something does not work, do not worry as there is almost always a work-around.
- Let’s use v. 3.10 or higher (I use 3.14 “pi” mostly but I go to 3.16 and 3,18 later), go to the site, download and install and we can start.
- Other software that comes in useful is an image editor – GIMP **(https://www.gimp.org/)** is free and does everything we need. Also, a spreadsheet such as Excel or LibreOffice Calc is essential in the long run.

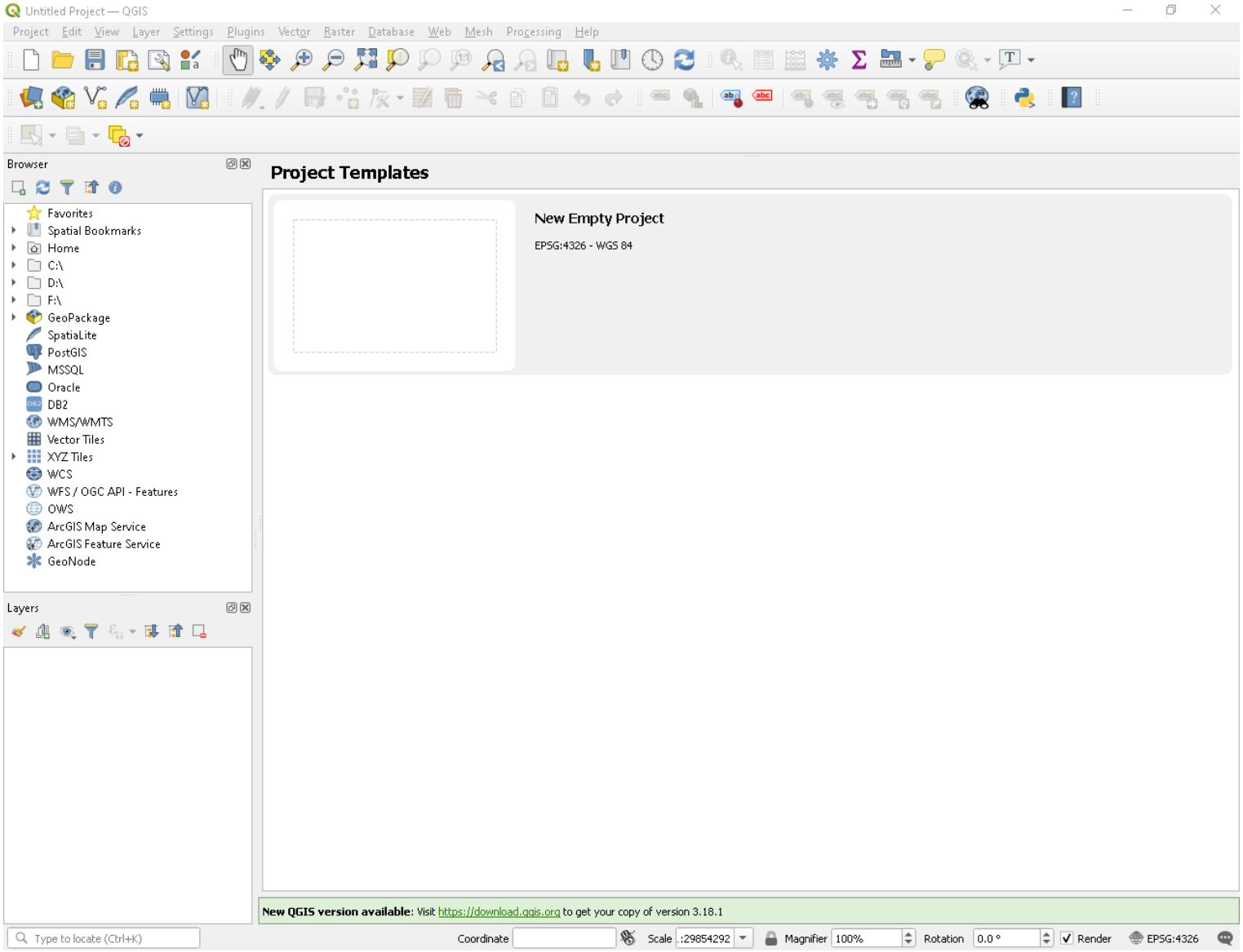
Lesson 1. Making a shapefile

We are going to make a simple shapefile of the county of Cumbria

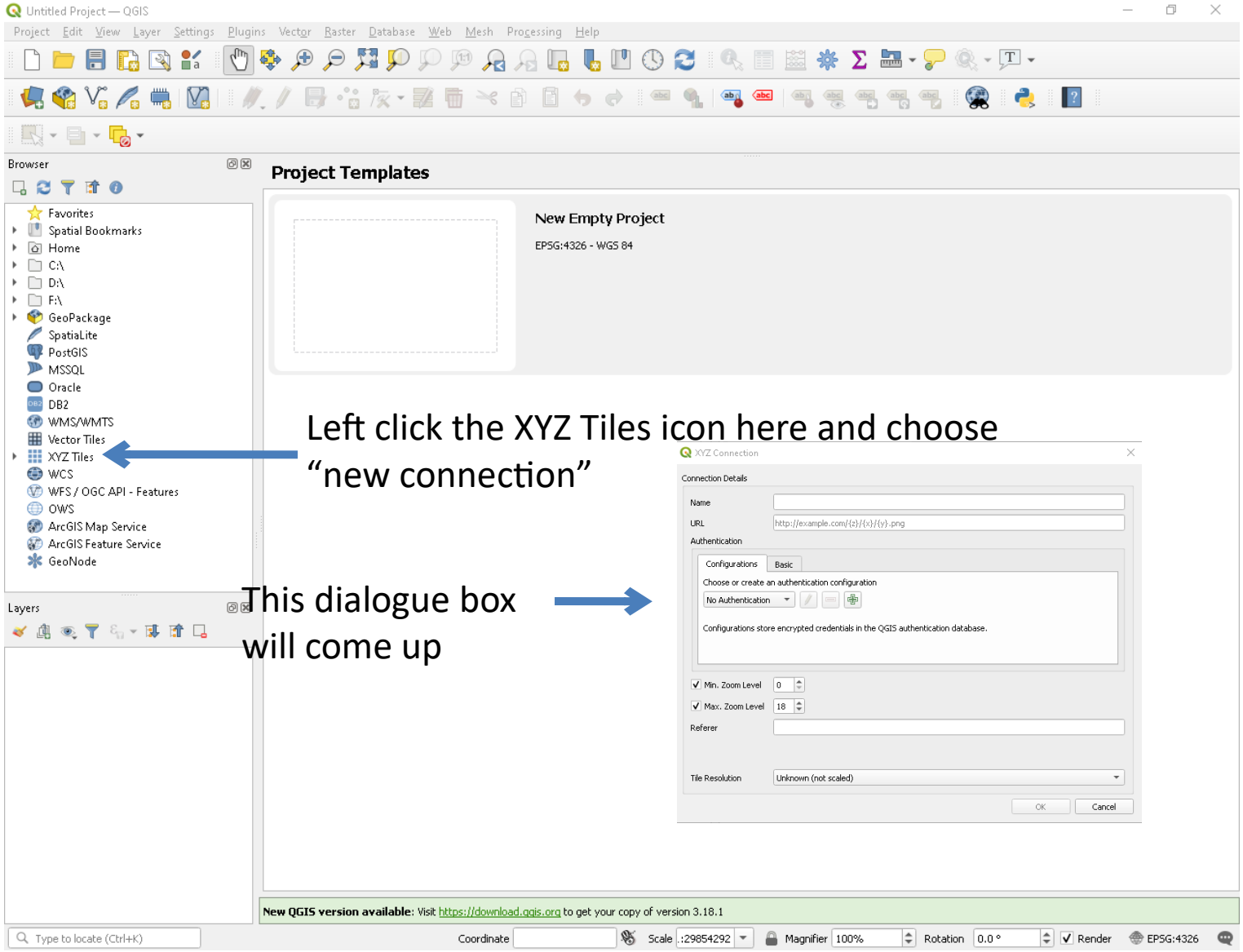
Lesson 1 video covers this so watch if you have any problems.

This is what you will see when you first start

First we need to do some house keeping



Set up some base (tiled) map services...we will need these from the outset



Set up several tiled map providers

(gives us nice backgrounds (base maps) to play with)

- Google satellite

https://mt1.google.com/vt/lyrs=s&x={x}&y={y}&z={z}

- Google road

https://mt1.google.com/vt/lyrs=m&x={x}&y={y}&z={z}

- Google hybrid

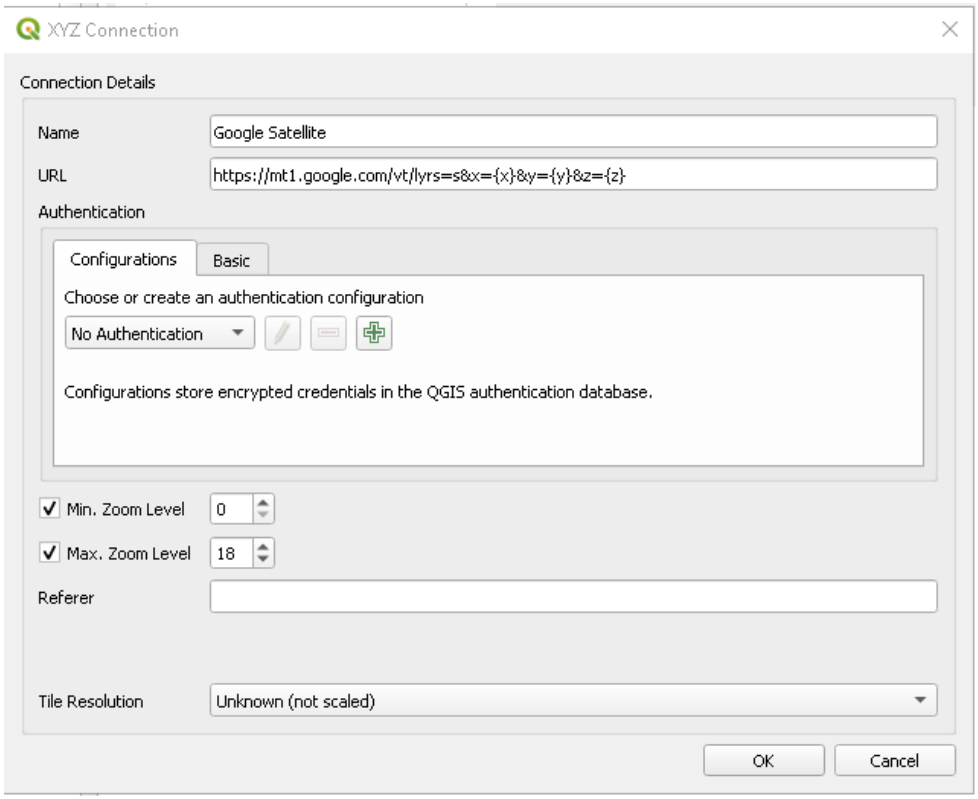
https://mt1.google.com/vt/lyrs=y&x={x}&y={y}&z={z}

- Bing satellite

http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1

- Open Streetmap

https://tile.openstreetmap.org/{z}/{x}/{y}.png



Create a new connection for each of the above, entering the details as per the example shown. Leave other settings as is.

I will probably add a few more tile servers as we go along

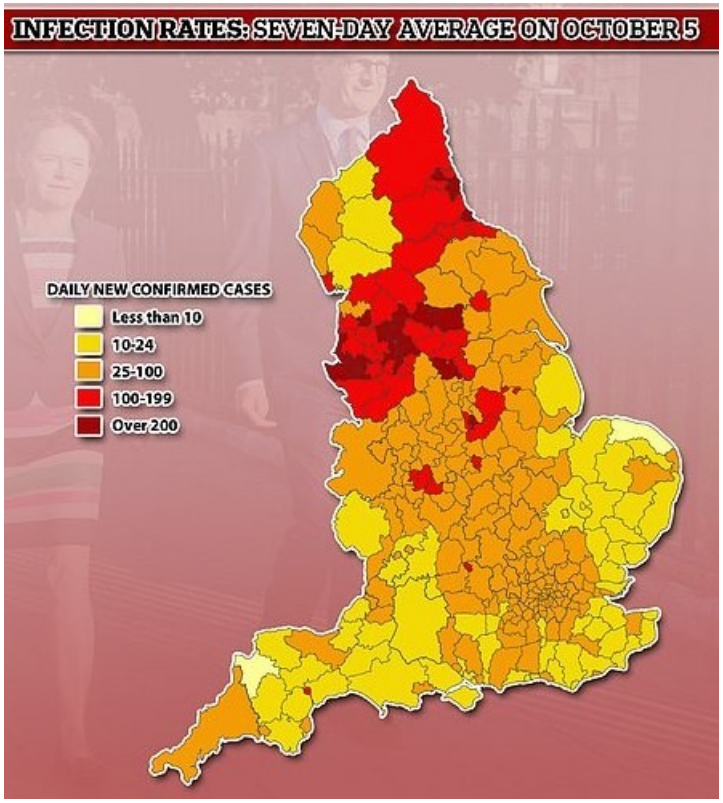
Things can get messy if we do not have a good filing system

- QGIS projects act as a container and access different files from the location they were first imported from (or saved to)...move the files and the project will not find them. Therefore a stable file structure is required. I suggest the following or similar….
- Create a folder called “MyGIS”.
- Create these subfolders with these or similar names...
  - MyShapefiles
  - OtherShapefiles
  - Projects
  - Images
  - Georeferenced maps
  - MyMaps
- This structure is just a suggestion but we will be using and creating lots of files and a good and logical way of storing them is essential.
- Having a decent amount of storage on your PC is useful as projects can readily eat up gigabytes.
- **Using the database functions of QGIS makes things tidier but we will leave that to a little later on.**

Let’s get started: Creating shapefiles

- The interface of QGIS is complex and many functions are duplicated across the interface.
- As such there are often two or more ways to achieve the same goal.
- The best way to learn is to get a project up and running and start getting to grips with what all theses buttons mean and do.
- We will use the basic install of QGIS and not the versions with extended functionality that are also present with your install (e.g. QGIS with GRASS etc) – you will see these alternatives appear in the start menu. We will probably use the extended version later on.
- Shapefiles form the core of many maps and provide the framework to which data is attached so we will start by creating one of our own.

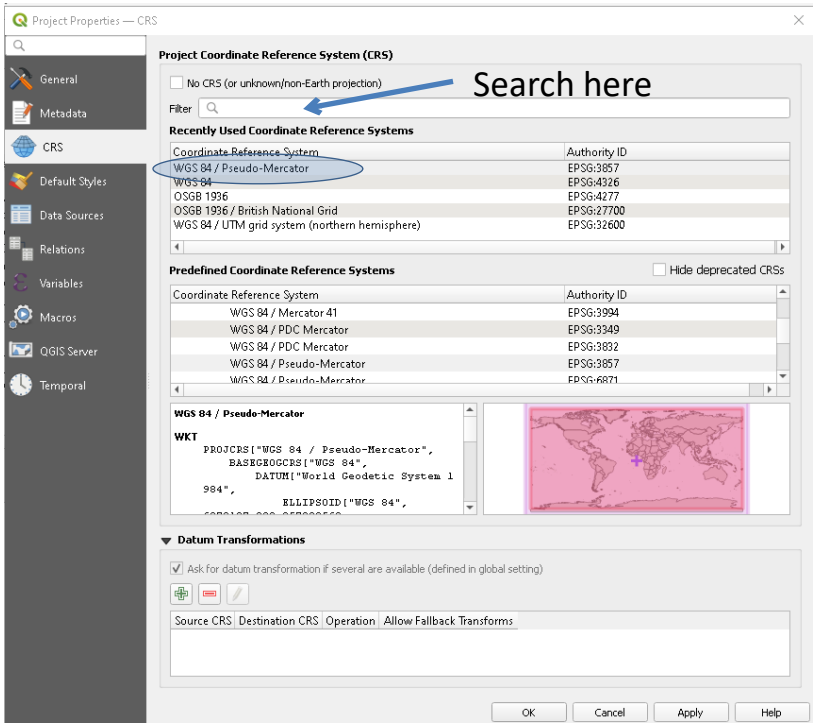
News outlets have become big fans of maps in recent months



COVID-19 infection rates plotted via a shapefile of English Local Authorities (Daily Mail, 7/10/2020)

A shapefile of Cumbria and (later) the lakes

- Click: Project / New.
- Click: Project / Properties – set CRS to WGS 84 (EPSG: 3857); use the "Filter" function if necessary to track it down as there are lots of CRSs. Click Apply.
- Save as "Cumbria" in your projects folder. This creates Cumbria.qgz.
- Click of XYX tiles and select (double click) Open Streetmap.
- A map of the world will appear.
- Zoom in to Northern England using the  or the mouse-wheel – resize until Cumbria fills the map area. You can move the map around by clicking the hand icon  and using your mouse.
- The county boundary is just visible as a purple dotted line. We are going to trace this and create our first shapefile.



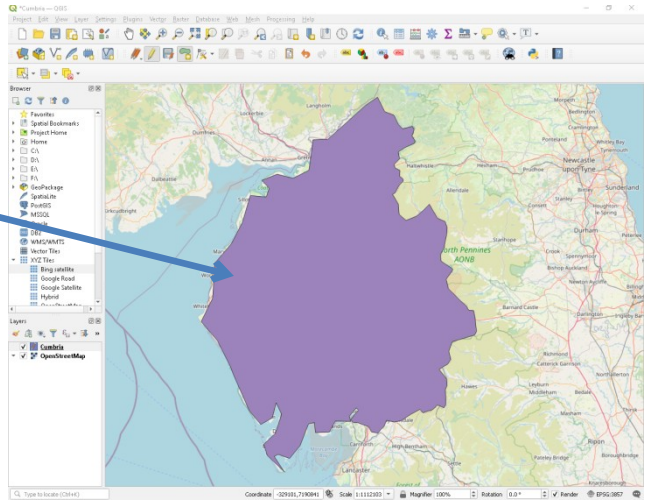
Cumbria shapefile

- Click Layer/Create/New Shapefile Layer
- Name the file “Cumbria” and set Geometry Type to “Polygon” - leave everything else as is.

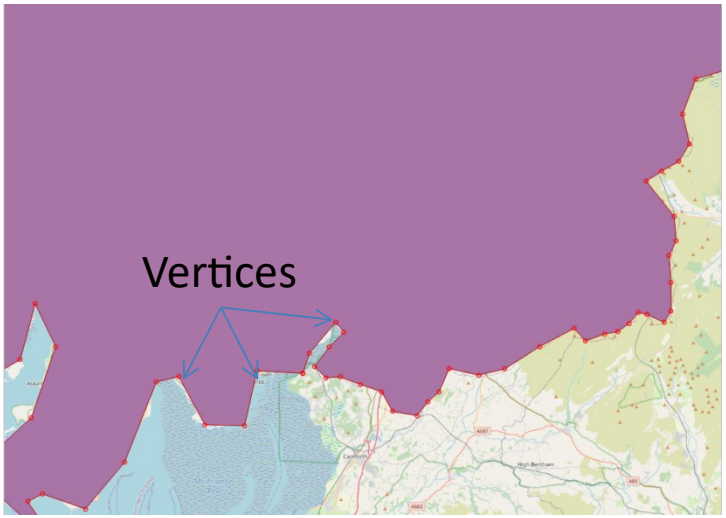
Click here and navigate to your “Shapefiles” folder. If you do not do this it may get lost in the wrong folder

- Press Apply and a new layer will appear in the layers box at the bottom left of the screen.
- On the tool bar ribbon press the Toggle editing pencil icon  .
- Then press the Add polygon button  .
- The cursor will change to crosshairs. Click on the map and you will now be able to trace the outline of Cumbria. Each click creates a point and the polygon will grow around these points. Don’t worry if you make a mistake – we will fix later.

Cumbria Shapefile: Shaping it up



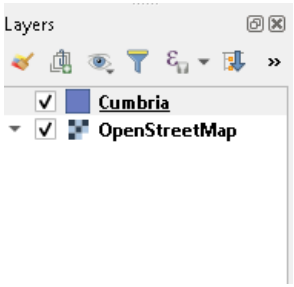
- Your polygon should look a little like this.
- When you have finished right click on mouse and, when prompted, assign “1” for the ID (this can be left empty).
- To tidy things up press the Vertex Too button. The little points (vertices) you created each time you clicked will appear in red (see bottom image).
- Use the mouse to move the vertices into the right place – click on a point once then click where it should move to. A red cross appears between each vertex – these can be similarly moved and will add new vertices.
- Click anywhere on the outline to add a new point (vertex) by double clicking.
- But you may have difficulty seeing the base map so let’s alter the “Cumbria” layer transparency to help us...



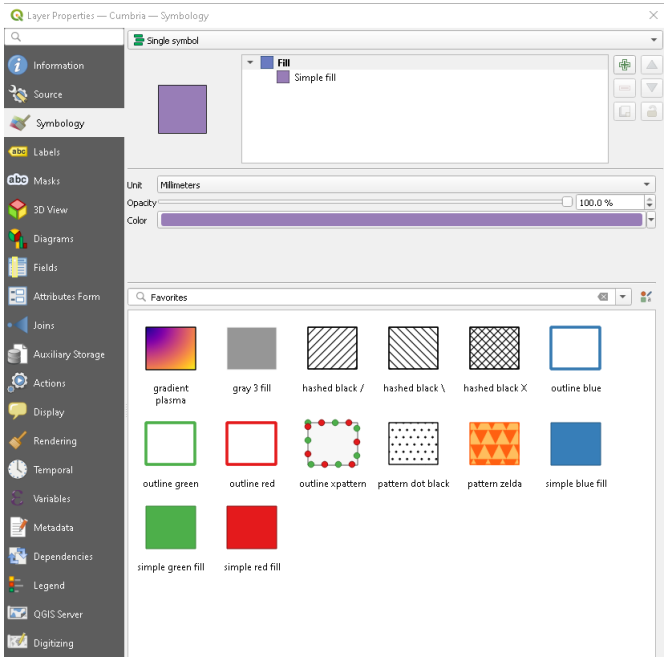
If you cannot edit, remember to toggle editing on

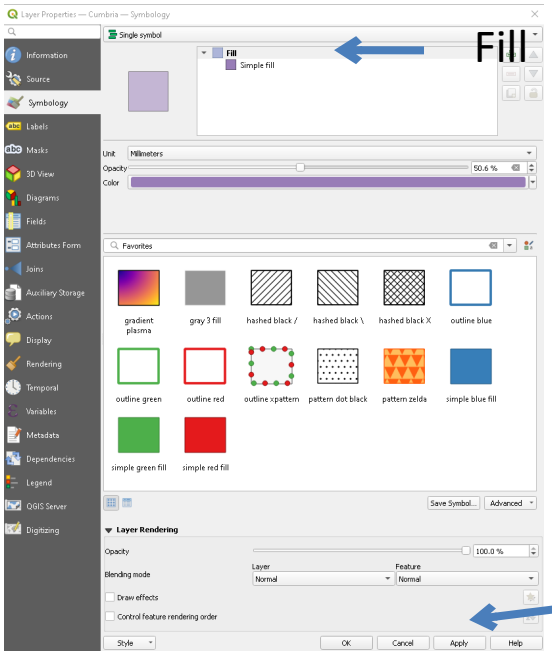
Cumbria shapefile: Transparency adjustment

- To adjust transparency double click on "Cumbria" layer here (bottom left panel).
- A box like the one below (left) comes up – choose "Symbology" then click on "Fill" and set Opacity to 50% - click Apply to see what it looks like. Click OK if happy with transparency.



Symbology





Press apply to see what it looks like

Cumbria shapefile: Crude and improved

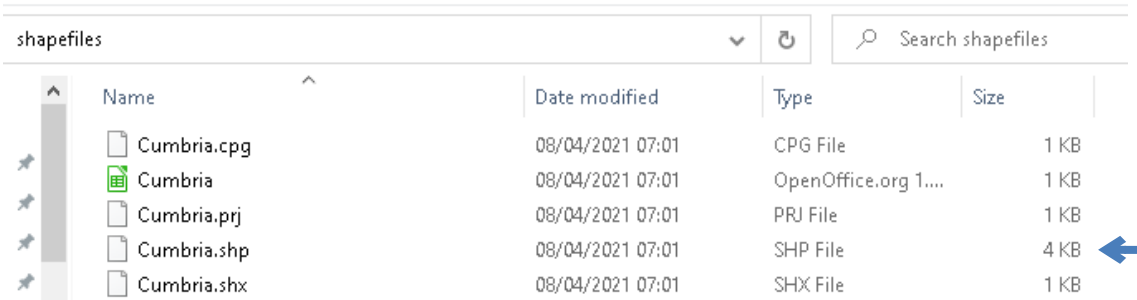
Crude polygon 50% transparency

More accurate, additional vertices to better track county boundary

- Press disc icon to save  and pencil icon  to stop editing

We now have a shapefile of Cumbria!

- Navigate to you “shapefiles” folder.
- As you will see, there are five files associated with the polygon you have created (a shapefile is actually 5 files!), each with different portions of information (spatial info, character encoding etc.).



Import this

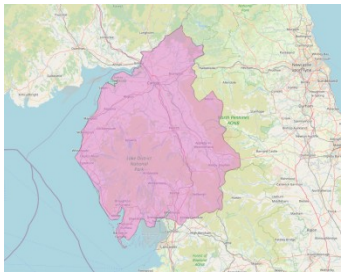
- To import the file into a project choose the *.shp file – this can be simply dragged and dropped into the QGIS workspace or opened by Layer/Add layer/Add Vector Layer (remember to set CRS of project first).
- The five files can be zipped together and still imported into QGIS but cannot be edited unless unzipped. [<u>It makes sense to keep each unzipped shapefile set of files in its own folder.</u>]
- Later on we will store our files in a database to make things much, much tidier and easier.

Let’s look at some basic QGIS functions using our Cumbria shapefile

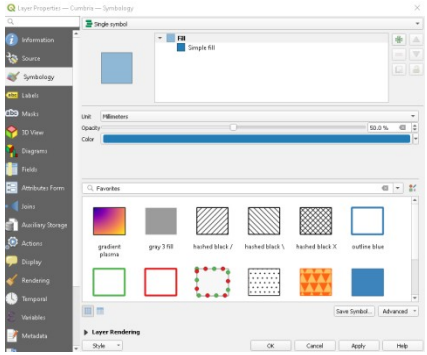
- Changing its appearance
  - Colour
  - Border
- Calculating area
- Adding attributes

Change the appearance of the vector shape

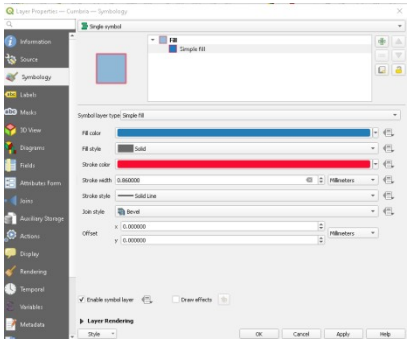
- Open "Cumbria.qgz" – The project should open with your shapefile overlaying the Gooogle satellite image (Note – in the Layers panel (bottom left) you can drag the layers into the order you want).
- Ensure the "Cumbria" layer is selected and then double click on it.
- The Layer Property dialogue box opens
- Click on Fill and use the Color option to change the colour to a blue colour. A colour wheel will appear. Set Opacity to 50% in not already done
- Now click on Simple Fill and more options appear. Change Stroke color to red and increase stoke colour to, for example, 0.86 mm and the Stoke style to Dash line.
- Press Apply to see the changes and OK if happy or change to something else.



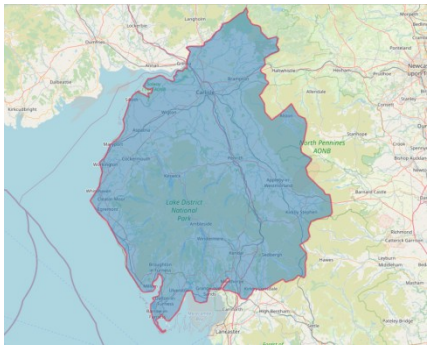
1. On opening



2. Fill – change to blue

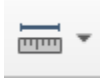


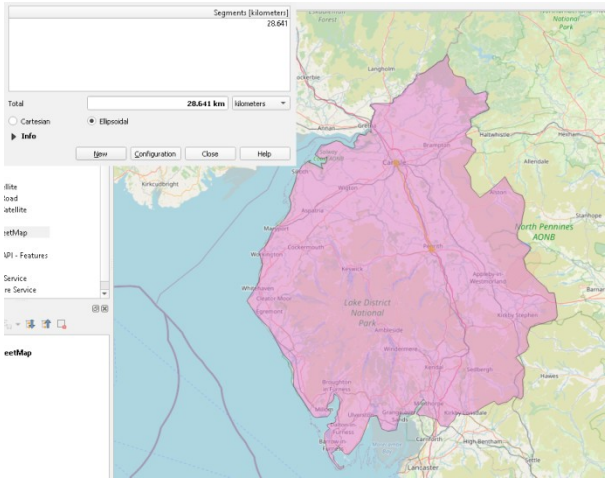
3. Simple fill – change stroke attributes

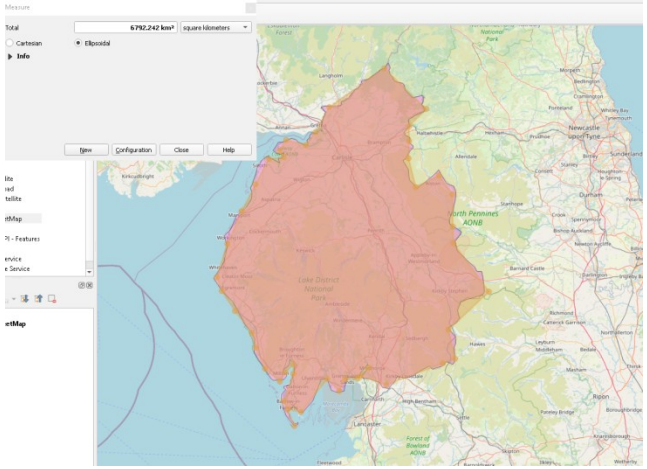


4. Changed appearance

Simple distance and area calculations

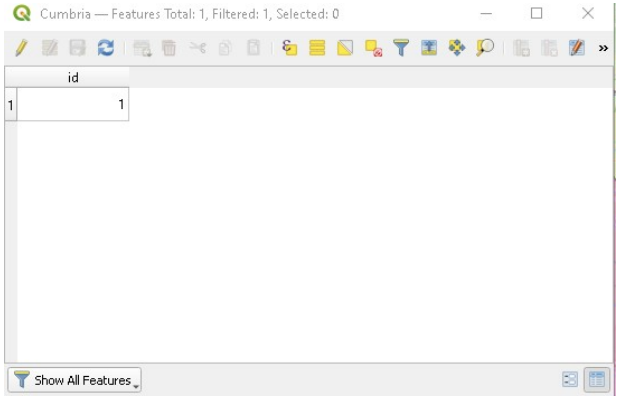
- On the top ribbon you will see this icon 
- This drop down to give three options.
  - Measure line
  - Measure area
  - Measure angle
- Choose Measure line and drag line out from Carlisle to Penrith .
- A box will appear giving the distance in meters. The dialogue box below allows the units to be changed, in this case to kilometres. Here we measure around 28 km.
- Now choose Measure area and drag-out a crude outline of Cumbria and right click when done. Change the units to square kilometres if necessary. Here we measured approx 6792 km^2.
- Distance on Google Maps = 28.6 km, area in Wikipedia = 6768
- WE ARE ACCURATE – OUR SHAPEFILE IS GOOD



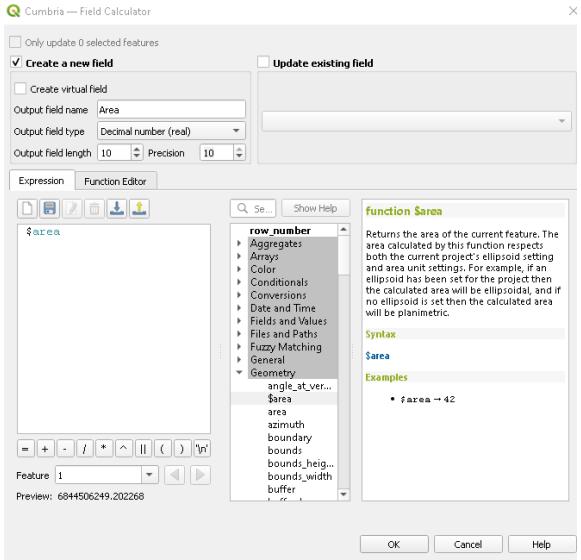


Adding attributes - Area

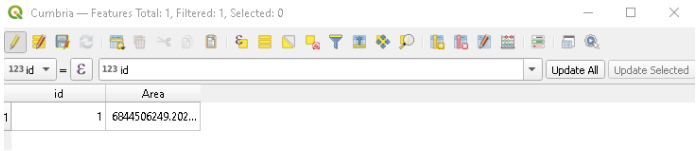
- Right click the "Cumbria" layer in the layers pane and choose Open attribute table. As you see there is not much here!
- Click the pencil  (Toggle editing) icon so we can start editing the attribute.
- Click the abacus icon (Open field calculator)  This allows us to add fields and do calculations . This opens the Field Calculator dialogue.
- Fill out the dialogue box like this.
  1. Tick Create a new field
  2. Output field name call it "Area"
  3. Output field type – choose Decimal number (real)
  4. Set Precision 10 (for very big calculations this may need to be set lower)
  5. From the central grey box of functions choose Geometry and double click $area
- The $area expression will appear in the left hand box. Press OK and a new column will have appeared in the attributes table with the exact area in m^2 of our shapefile polygon.
- Here our polygon is 6844506249.2 m^2.
- But we may want to change our units to something more convenient so we will do some more calculations...



1. Our almost blank attributes table



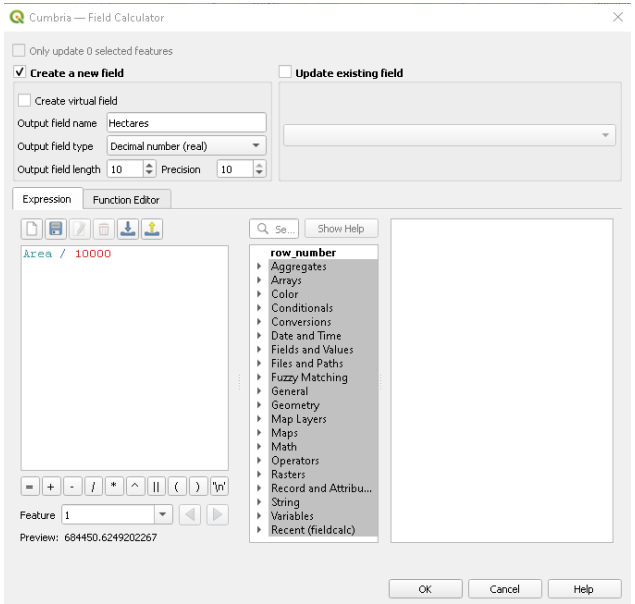
2. Fill out the field calculator like this



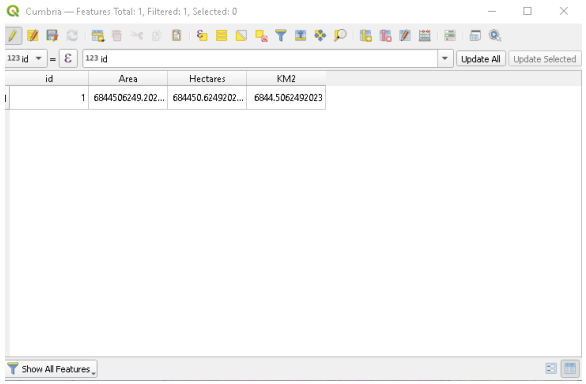
3. The attributes table has been updated with the area

Adding our own expressions to the attributes table via the field calculator

- Open up the Attributes table and Field Calculator as described previously.
- Click the  icon again.
- Create new field with the Output field name “Hectares”.
- Set Output field type to Decimal number (real) and Precision to 10.
- In Expression box type expression “Area / 10000”.
- Press OK and the area in hectares will be calculated in column 3.
- Repeat this process creating a field called “KM2” that uses the expression “Ha /100” to calculate the area in square kilometres.
- The attributes table now looks like the screen grab here and contains area in m², Ha and km².
- Press the save button  and then, if finished, press the icon  to stop editing the attributes table.
- Similar procedures can be used for a plethora of calculations.
  - A good one to try next for this shapefile is $perimeter.



1. Fill out Field Calculator dialogue like this to get hectares



2. The final attributes table looks like this

A quick note on the expressions used

- When we chose the area expression we selected $area and not area. Why?
- The $area expression takes into account curvature.
- The same is true for $perimeter as opposes to just perimeter.
- We will look into these nuances later and see how they effect calculations
- Lets make something more complex that gives us more options to investigate QGIS. Go to Lesson 2.