Geography 222

Laboratory 2

Introduction

In lab 1 you had a brief introduction to map projections and scale. In Lab 2 you will examine these concepts in more detail.

The objectives of this lab are to:

- Use a map scale to understand how the size of an object on a map is related to the size of an object on the Earth's surface
- Be able to convert latitude and longitude coordinates between degrees, minutes, seconds and decimal degree format
- Calculate UTM zones from latitude and longitude coordinates
- Create a point shapefile from latitude and longitude coordinates
- Use the **Project** tool to change layer projections
- Use the **Add X,Y Data** tool to convert between geographic and Cartesian coordinates

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Exercise

Map Scale

A map scale is the ratio between the size of the object on the Earth (river length) and the size of the object on the map. Map scales are represented in one of three ways:

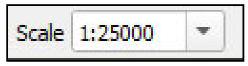
1. **Verbal**: one centimetre on the map represents one kilometre on the ground

2. **Representative Fraction (RF)**: 1:100,000 or (1/100,000)

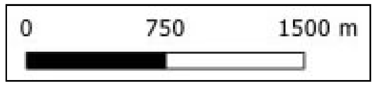
3. **Graphic (Bar)**: 

You used both the Representative Fraction and Graphic Bar in Lab 1.

The representative fraction was used to zoom in and out of the map:



and the graphical bar that was created for the recreation map:

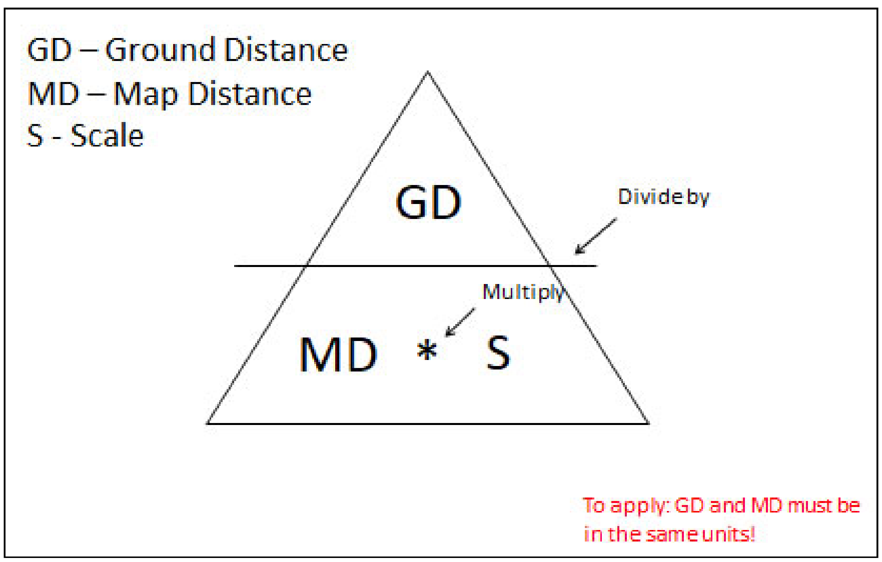


Using a representative fraction you can start to understand how the ground distance (length of river in real life) is related to the map distance (length of river on the map). For example, a scale of 1:100,000 means that 1 unit of distance on the map represents 100,000 of the same units on the ground. When using representative fractions, you can assign any units you want to the scale, as long as you keep them the same on both sides of the ratio when conducting your calculations.

Think of the scale equation as:

map distance : ground distance

A helpful way to understand how the map distance is related to the ground distance, is to review basic algebra:



A. To calculate scale from a given map and ground distance apply:

Scale = GD/MD

B. To calculate a ground distance from a given map distance and scale apply:

GD = MD * Scale

C. To calculate a map distance from a given ground distance and scale apply:

MD = GD/S

Metric Conversions

Before starting any calculations, you need to ensure that your map distance (MD) and ground distance (GD) are in the same units. For that reason, it is a good idea to review your metric conversions:

10 mm = 1 cm

100 cm = 1 m

1000 m = 1 km

Significant Figures

When calculating MD, GD, or a map scale it is also essential to round your answers to significant figures to ensure the precision of your answer.

For rounding, use the following rules:

- **Trailing zeros are significant if the decimal point is specified**. For example: 12, 1200, and 12000 all have 2 significant figures, whereas 12.0 has 3
- **Leading zeros are never significant**. For example: 0.04 has only 1 significant figure, whereas 0.04000 has 4
- **The answer can contain no more significant figures than the least accurate measurement** (i.e., the smallest number of significant figures).

How to calculate scale from a given map and ground distance.

As an example, you will calculate the scale of a map from an object measuring 12.0cm on the map and measuring 3.5km on the ground.

You always round to the least amount of significant figures presented in your measurements. The map measurement of 12.0cm has three significant figures, while the ground distance measurment of 3.5km has two. Therefore, your answer must have 2 significant figures.

1. Present the ratio MD : GD

12.0cm : 3.5km

2. Convert units

3.5km * (100*1000) = 350,000cm

3. Apply the formula: S = GD/MD

350,000cm/12.0cm = 29166.6667

4. Round answer to significant figures

1: 29,000

In this example 9 is the second significant figure, so we look to see what number is behind the 9 to determine if you will round up or not. Since 1 does not round 9 to 10 you are left with 29,000.

How to calculate a ground distance from a given map distance and scale.

When rounding the ground distance in this type of question, **use the number of significant figures in the map distance - ignore the significant figures in the scale**.

For example, given a map distance of 1.2cm and a scale of 1:53500, what is the ground distance of the object in meters? In this case you would round the ground distance according to the significant figures in the map distance.

1. Present the ratio MD : GD

1 : 53500

2. Convert units

1.2cm/100 = 0.012m

3. Apply the formula GD = S * MD

53500m*0.012m = 642m

4. Round answer to significant figures

640m

How to calculate a map distance from a given ground distance and scale.

When rounding the map distance in this type of question, **use the number of significant figures in the ground distance - ignore the significant figures in the scale**.

For example, given a ground distance of 6.71km and a scale of 1:203,500 what is the map distance of the object in millimeters? In this example, you would round the map distance according to the significant figures in the ground distance.

1. Present the ratio MD : GD

1 : 203,500

2. Convert units

6.71km*(10*100*1000) = 6,710,000mm

3. Apply the formula MD = GD/S

6,710,000mm/203,500 = 32.97237297mm

4. Round answer to significant figures

33.0mm

Coordinate Systems

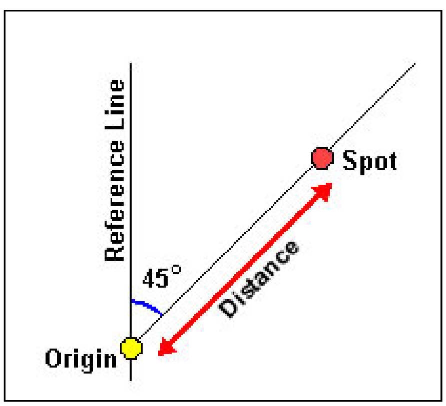
Coordinate systems (CRS) establish a starting point on the earth (origin), and a way to measure distance and directions from that point. By applying coordinate reference systems to data we can line up multiple datasets on a 2D plane, or 3D globe. Components of CRS consist of the:

- **Coordinate System -** an x, y grid use to define where a point is located in space
- **Horizontal and vertical units -** units used to define the grid along the x, y (and z) axis
- **Datum -** a modeled version of the shape of the earth (e.g., sphere or ellipsoid) which defines the origin used to place the coordinate system in space
- **Map projection -** the mathematical equation used to flatten objects that are on a round surface (e.g. sphere or ellipsoid) so we can view them on a flat surface (e.g. our computer screens or a paper map)

Measuring locations on the earth surface

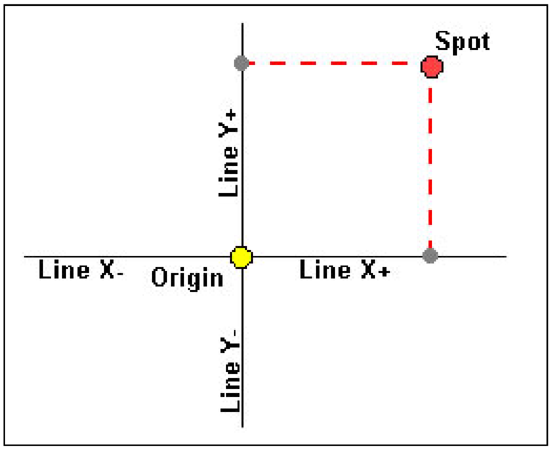
On a flat surface there are two ways to measure distance from an origin in units (ft, meters, kilometers).

- Using an origin, a reference line (north), and angle from that directs to the location:



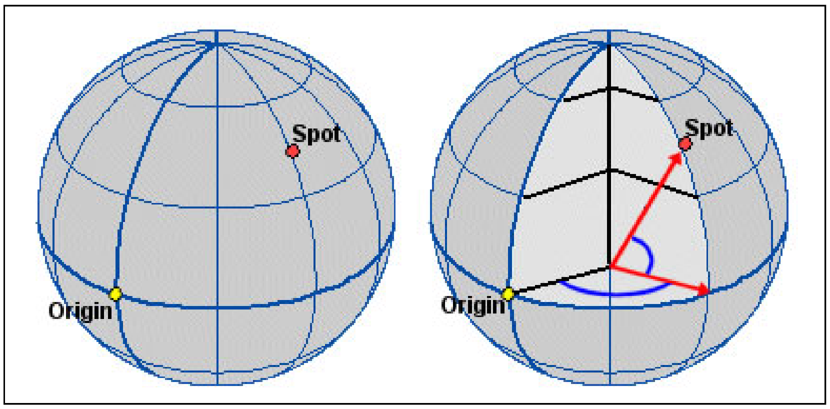
Source: ESRI e-learning "GIS for Humanitarian Mine Action: Coordinate Systems and Map Projections"

- or using an x,y grid system with a 90 degree intersection:



Source: ESRI e-learning "GIS for Humanitarian Mine Action: Coordinate Systems and Map Projections"

If the surface is not flat (e.g., sphere or ellipsoid) locations are not measured by distance. Instead they are measured by interior angles from the centre of the sphere.



Source: ESRI e-learning "GIS for Humanitarian Mine Action: Coordinate Systems and Map Projections"

This leads us to the fundamental difference between geographic and projected coordinates systems.

Geographic coordinate systems reference locations on the earth's surface using angular measuresments off the sphere or ellipsoid, while **projected coordinate systems** reference locations on the earth's surface using straight line distances off a grid.

Geographic Coordinate Systems

Components of the Geographic Coordinate System (e.g., WGS_1984) used to reference locations off a 3D sphere include:

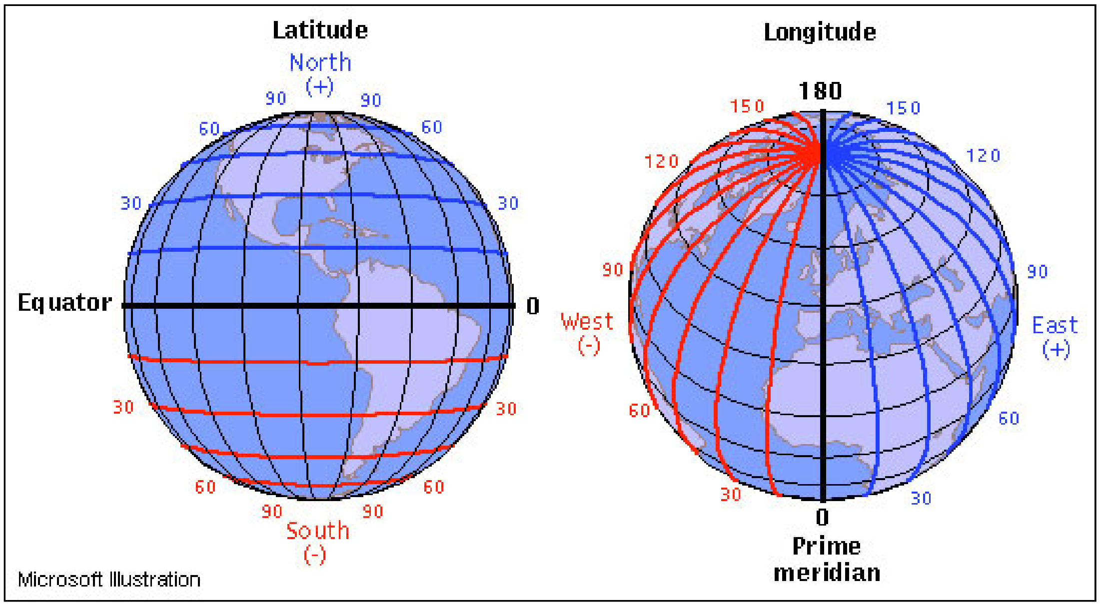
- The angular unit of measure - usually measured in 360 degrees
- A prime meridian - the zero value of longitude (Greenwich England)
- A datum - position of the sphere relative the centre of the earth which defines the origin and orientation of the latitude and longitude lines

Latitude and Longitude

Locations in a geographic coordinate system are measured using an angular unit in the following formats:

- decimal degrees: 48.2006°
- degrees, minutes, and seconds: 48° 12' 02" N
- or in degrees and decimal minutes: 48° 12.03' N

Latitude and longitude coordinates are measured in one of the formats above.



Source: Illinois State University

Latitude (*or Lat)* states a position North or South (0° to 90°) from the equator. Lines of latitude can be referred to as *parallels* because they run parallel to the equator. Lines of latitude have different lengths: the equator (0°) has the longest length, while at the poles (90° N and 90° S) the lengths shrink to a point.

Longitude (*or Long*) states a position East-West (0° to 180°) from the Prime Meridian, which is located at Greenwich, England. Lines of longitude are called meridians also because each one is the same length as the Prime Meridian.

Together, latitude and longitude form a grid network referred to as the Graticule.

Both latitude and longitude use degrees (°), minutes (') and seconds (") to state a position.

For example, the coordinates for this lab are (approximately):

48° 27' 53" N, 123° 18' 47" W

(48 degrees 27 minutes 51 seconds North) (123 degrees 18 minutes 46 seconds West)

When stating lat/long coordinates, it is convention to state latitude before longitude, so that the N/S position is given before the E/W position.

Also, when stating latitude and longitude in degrees, minutes, and seconds, only whole numbers are used and the N,S,W,E directions is included. Decimals are used with the decimal degree format only, which converts minutes and seconds into [decimal] degrees.

The conversion is straightforward using the following ratios: **60 seconds in 1 minute** and **60 minutes in 1 degree**.

For example, to convert the 48° 27' 51" N into decimal degrees:

1. You will convert the seconds to minutes: 51" / 60" = 0.85' [do not round the number at this stage]

Then add that decimal to the minutes: 27' + 0.85' = 27.85'

So now you have: 48° 27.85' N

B. Next, you want to convert the minutes to degrees: 27.85' / 60' = 0.464166666°, which you will round to four decimal places.

Then add that decimal to the degrees: 48° + 0.4642° = 48.4642°

48° 27' 51" N = 48.4642°

In a GIS the latitude would be represented as 48.4642 because the location is North of the equator (i.e., positive value)

Using the same ratios, you can convert a decimal degree format back into degrees, minutes, seconds.

For example, you will convert -123.9858 longitude into the degrees, minutes, seconds format.

A. Take the decimal portion of the degrees and multiply it by 60 [minutes]:

0.9858° x 60' = 59.148', so now you have 123° 59.148

B. Now you need to convert the decimal portion of the minutes to seconds:

0.148' x 60" = 8.88" (rounds to 9")

You end up with **123° 59' 9" W = -123.9858°**

Notice the negative sign before the longitude coordinate in the decimal degree format. The negative denotes that the coordinate is west of the Prime Meridian.

Also, note that when calculating decimal degrees, you round to FOUR decimal places if minutes and seconds are present and TWO decimal places if minutes are present. For example, a longitude coordinate of **123° 59' W** would convert to **-123.98°**, while a **123° 59' 00" W** would convert to **-123.9833°**.

Projected Coordinate Systems

Projected coordinate systems reference a geographic coordinate system. In contrast to using angular measurements for location points on the earth surface, projected coordinates systems use linear measurements in familiar units such as feet or meters. The fundamental components of a projected coordinate system include:

- a geographic coordinate system
- a map projection type
- any parameters needed by the map projection
- a linear unit of measure (feet or meters)

Here are some of the reasons behind why you would want to use a projected coordinate system to map your spatial data:

- You want to take accurate distance measurements from your map
- You want to view, query, or analyze maps with consistent area, shape, distance, or direction properties
- You want to make a map that preserves a specific spatial property: area, shape, distance, or direction

Cartesian Coordinates

Cartesian coordinate systems are based on an x,y grid. The grid intersects at a perpendicular angle with an origin point. There is a fixed unit of distance (m), and the coordinates are positive from the false zero reference point.

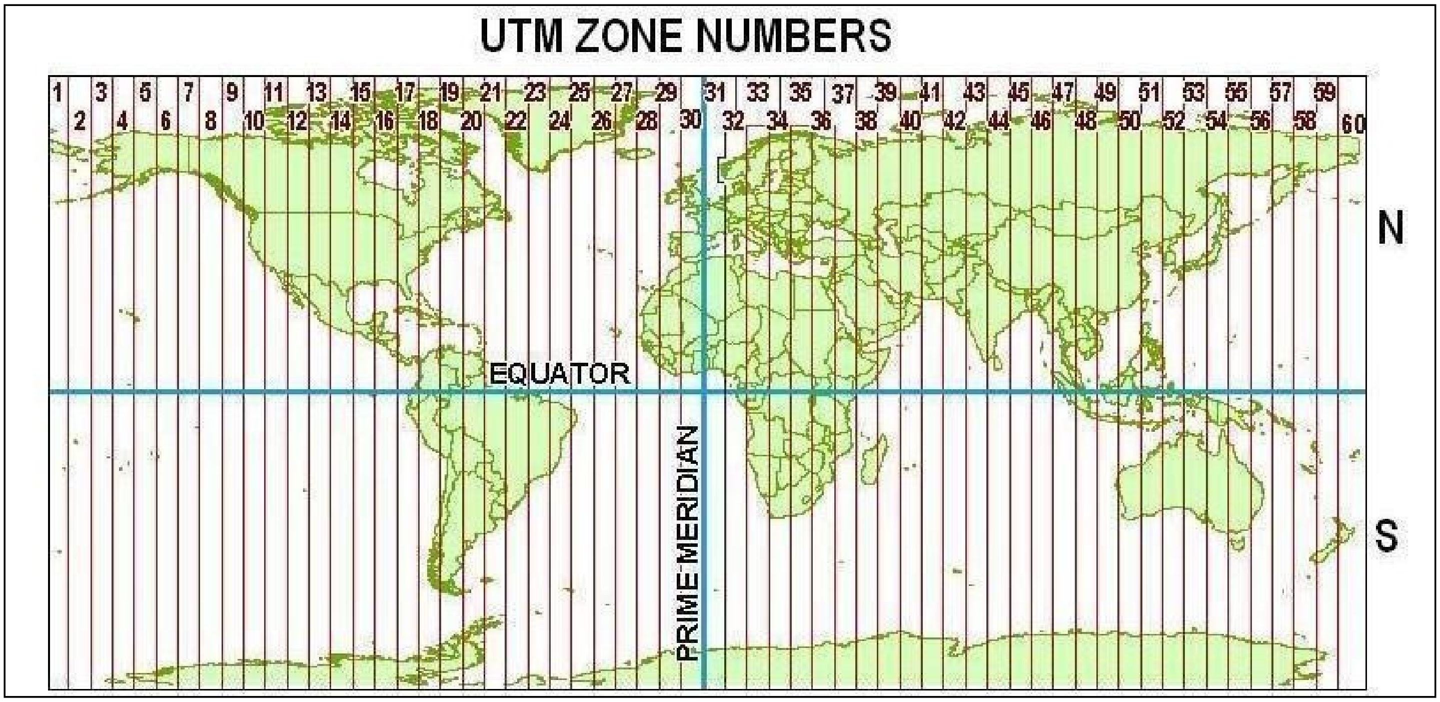
The **Universal Transverse Mercator** projection uses a grid system designated by Eastings (vertical lines referenced from the zone's central meridian) and Northings (horizontal lines measured from the equator) to locate coordinate pairs.

Eastings are sometimes referred to as "false Eastings" because the central meridian is assigned, arbitrarily, a value of 500,000m. This is done so that an Easting of zero will never occur; a 6° wide zone is never more than 674,000m wide.

Universal Transverse Mercator (UTM) Zones

The UTM system divides the world into 60 north-south zones, each covering a longitude of 6° (because the earth is 360° in circumference, a division into sixty vertical zones gives each zone the width of 6° of longitude).

These 6° longitudinal zones are numbered from 1 to 60, starting at 180° west and proceeding to 180° degrees east.



Source: GIS stack exchange

UTM zones extend from 80° S to 84° N. In the polar regions, the Universal Polar Stereographic (UPS) grid system is used.

To calculate which zone a point resides in, use one of the following formulas:

West (W) of Greenwich : (180° – longitude of city) / 6°

East (E) of Greenwich : (180° + longitude of city) / 6°

UTM Zones are **discrete**, which means you can only be in one zone at a time. **This means that you always round up when calculating UTM zones**.

For example, you will calculate the UTM zones for Victoria and Paris.

Victoria: 123° W (West of Greenwich)

(180° - 123°) / 6° = 9.5 = Zone 10

Paris: 2° 20' E (East of Greenwich)

(180° + 2° 20') / 6°

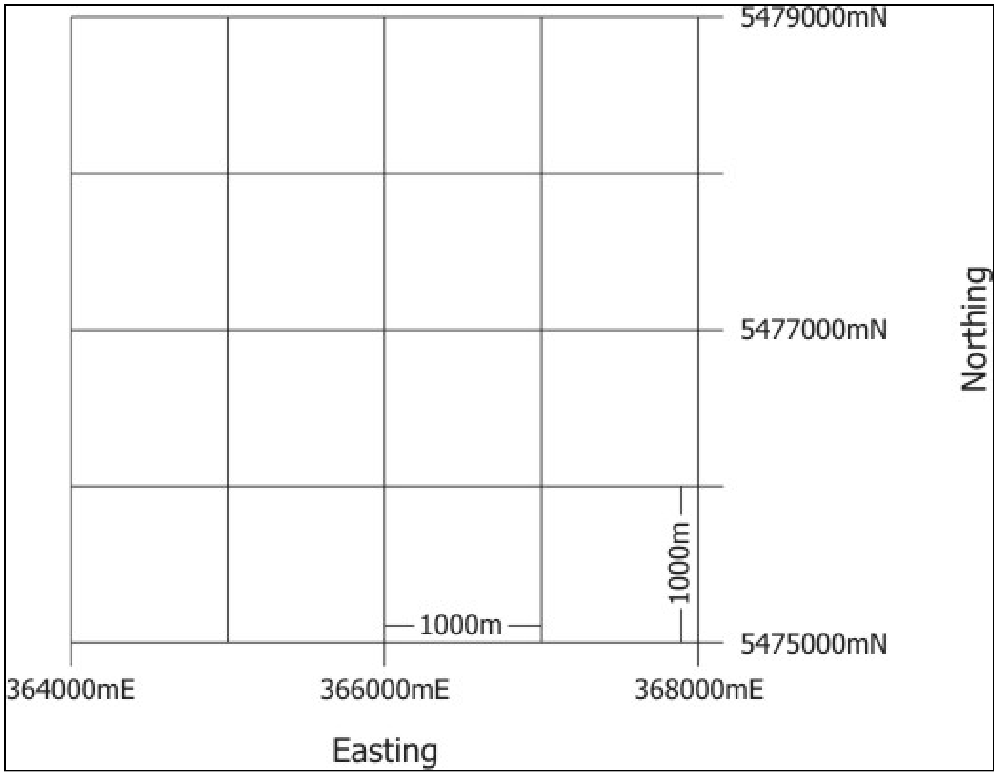
Before you can do the calculation, you need to convert the minutes to degrees:

2° + (20' / 60') = 2.33°

(180° + 2.33°) / 6° = 30.39 = Zone 31

Within the UTM Zones, easting and northing coordinates are measured. The UTM Grid uses Eastings and Northings (given in metres) to determine position. As shown in the image below, Eastings increase to the right (East) and Northings increase to the top (North).

On a 1:50,000 map, the UTM grid is comprised of 1000m x 1000m squares (shown below); on a 1:250,000 map each square is 10,000m x 10,000m.

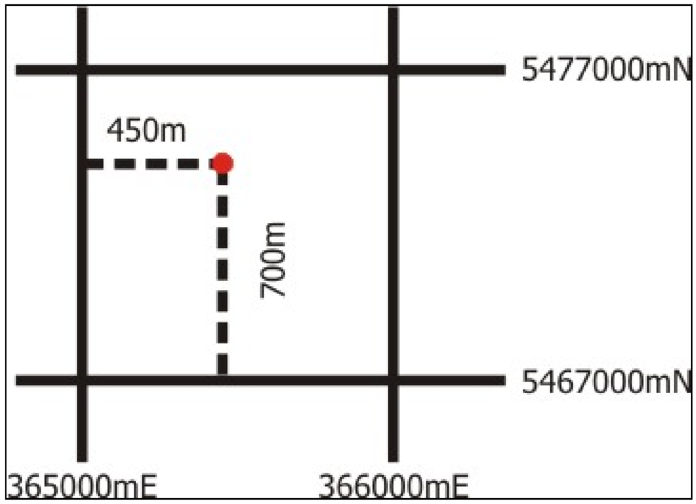


When stating a position, the six digit Easting is stated before the seven digit Northing.

For example, the UTM coordinates for this lab are (approximately): 476849mE, 5367991mN (obtained from GPS).

Combining your scale and coordinate skills you can calculate new coordinates using the UTM grid and the map scale.

In the example below, you want to determine the coordinates for the red dot.



From the map scale (1:50,000), you can determine what each cm or mm represents. On this map sheet,

1 cm represents 500 m OR 1 mm represents 50 m

Using a ruler you find that the dot is 9.0 mm to the right of Easting 365000. Using either of the ratios above, we can calculate this ground distance and add it to the 365000m Easting.

1. Present the ratio MD : GD

1 : 50,000

2. Convert units

9.0mm/(10*100) = .009m

3. Apply the formula GD = S * MD

.009*50,000 = 450m

4. Complete coordinate

365000mE + 450mE = 365,450mE

We also find that the red dot is 1.4cm or 14mm North of the 5467000mN line.

1. Present the ratio MD : GD

1 : 50,000

2. Convert units

1.4cm/100 = .014m

3. Apply the formula GD = S * MD

.014*50,000 = 700m

4. Complete coordinate

5467000mN + 700mN = 5467700mN

The coordinates of the red dot are: 365450mE, 5467700mN

Coordinates and QGIS

QGIS has the ability to convert latitude and longitude geographic coordinates into easting and northing coordinate pairs automatically.

Let's explore the steps, and practice your coordinate conversion skills.

In the following example you will map the locations of various GIS employers in the City of Victoria. Below you will find the coordinate dataset with a Description, Latitude, and Longitude headers which will form the headings of the attribute columns for your new shapefile. Commas are used to separate the columns (known as comma delimited data) and coordinates are represented in decimal degree format. Since we are mapping locations to the west of Prime Meridian the longitude coordinates have a negative sign.

Description, Latitude, Longitude

GeoBC, 48.454802, -123.379756

Latitude Geographics, 48.426674, -123.369971

ESRI Canada, 48.424681, -123.364735

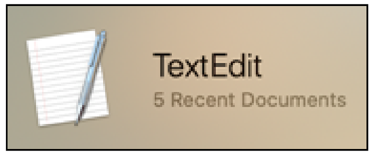
Forte Consulting, 48.469387, -123.363540

Foundry Spatial, 48.466438, -123.361171

Steps:

1. Open notepad from the start menu

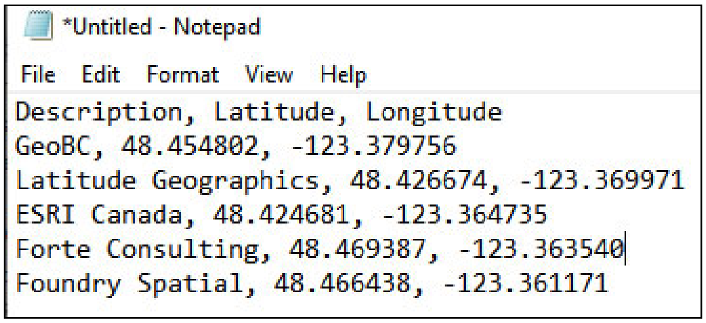
On a mac open:



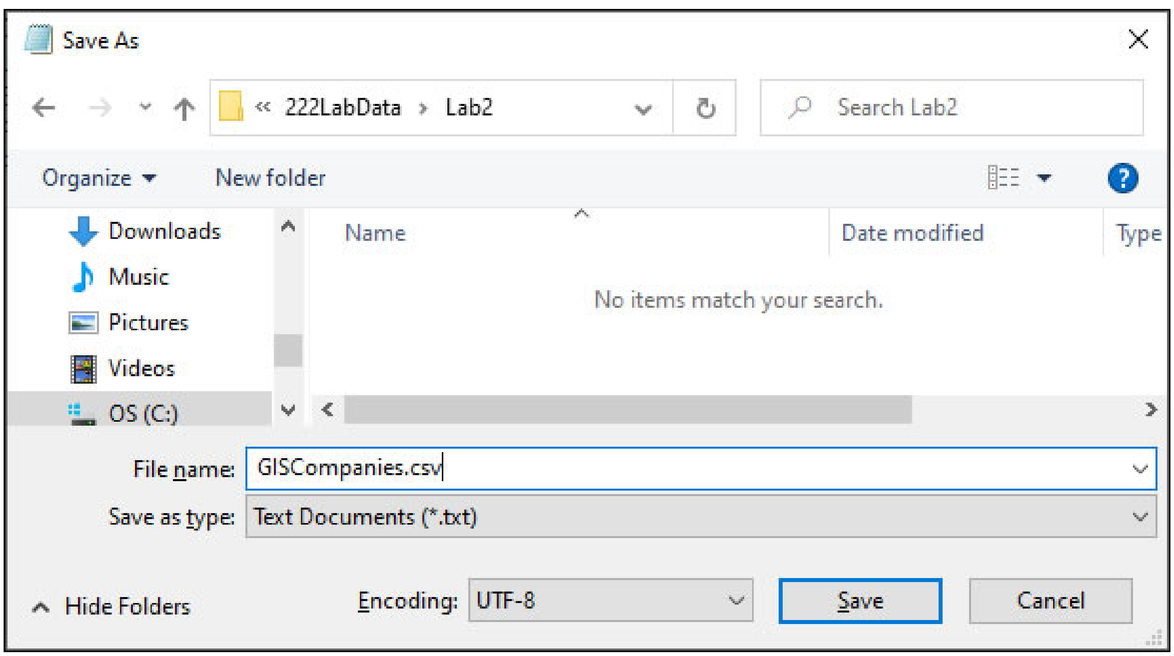
2. Copy the coordinate dataset above (highlight text → right click → copy)

3. In Notepad, right click → paste

4. Remove any extra rows left over from the website formatting

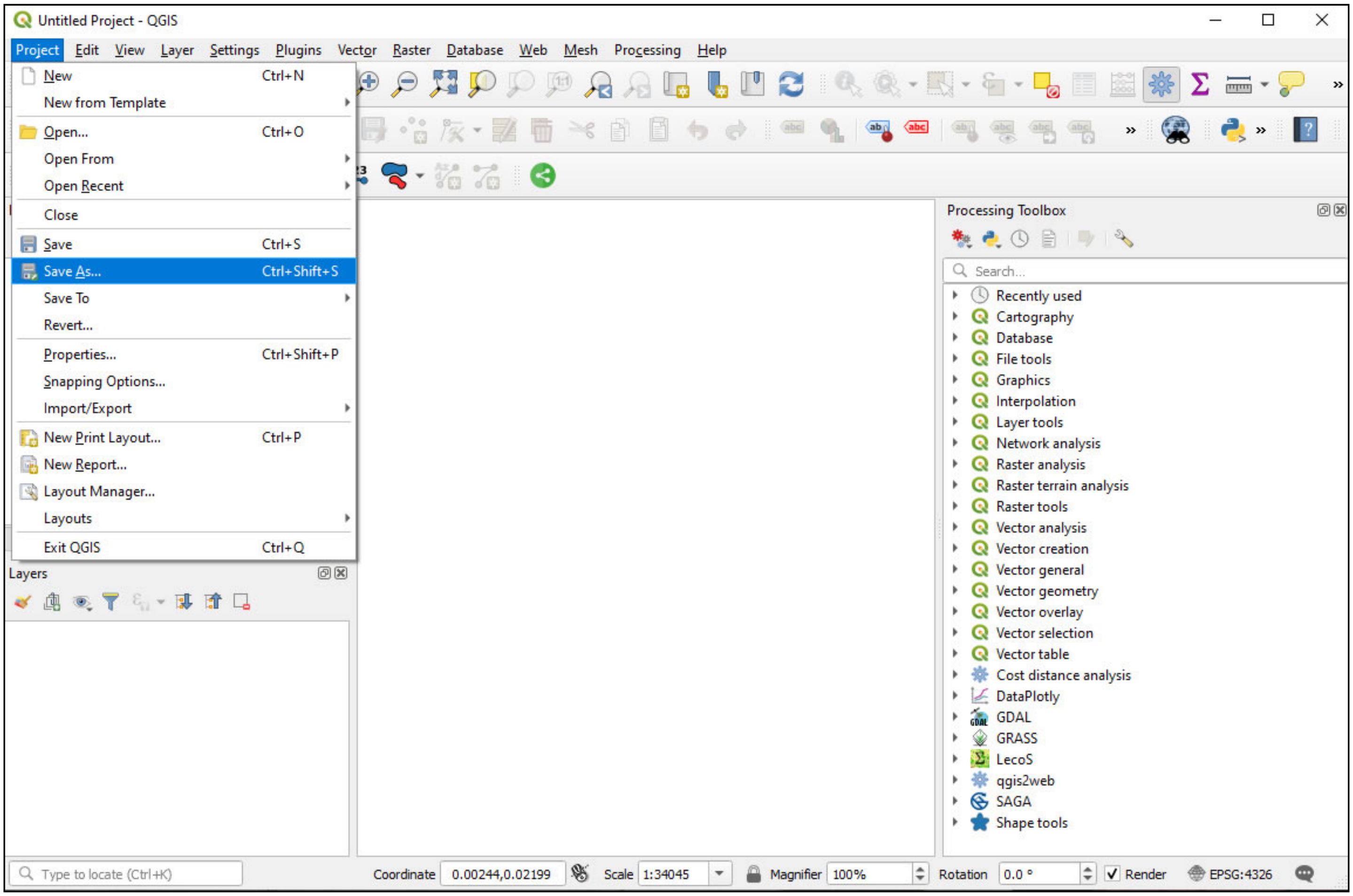

*Untitled - Notepad
File Edit Format View Help
```
Description, Latitude, Longitude
GeoBC, 48.454802, -123.379756
Latitude Geographics, 48.426674, -123.369971
ESRI Canada, 48.424681, -123.364735
Forte Consulting, 48.469387, -123.363540
Foundry Spatial, 48.466438, -123.361171
```

5. File → Save As: **GISCompanies.csv** **(ensure you include the csv extension that stands for a comma separated values)**



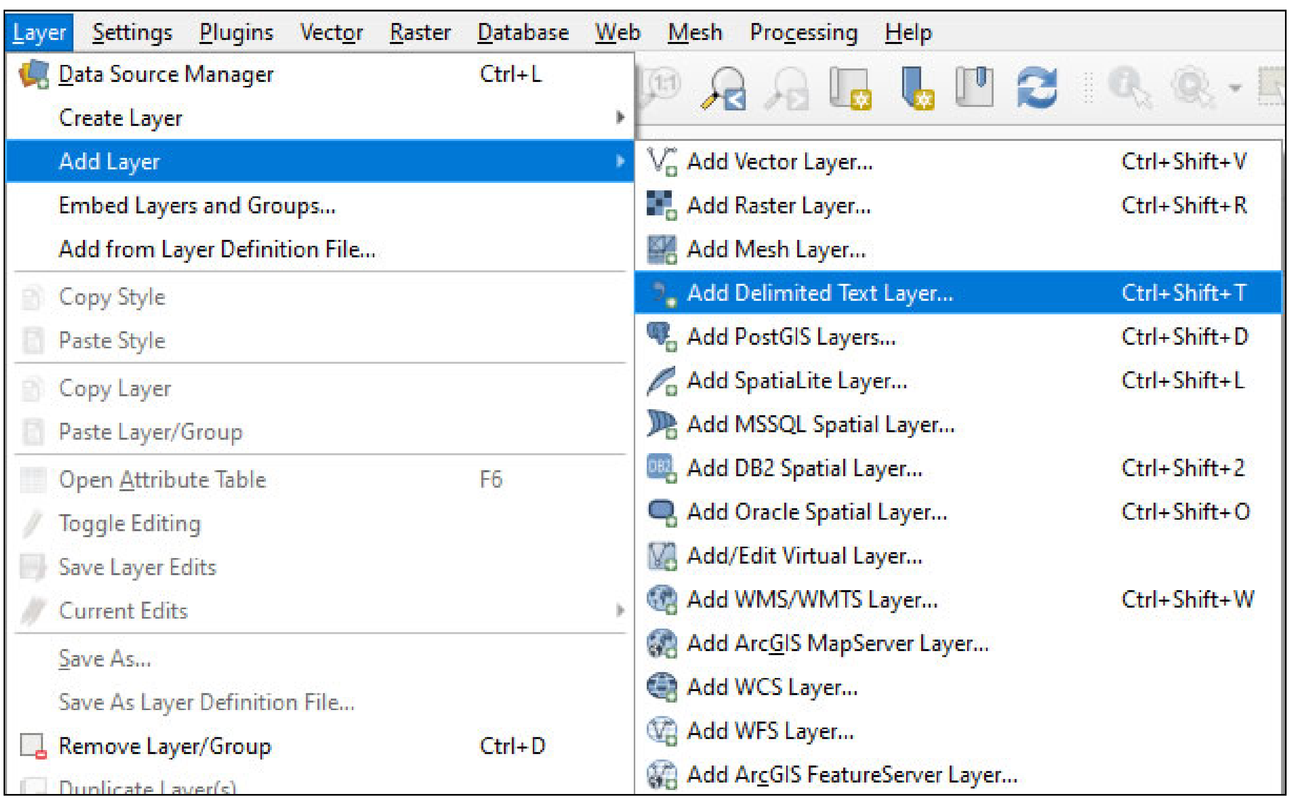
Now you will add the points to QGIS

1. Open QGIS and save your project as Lab2 in your Lab2 folder.

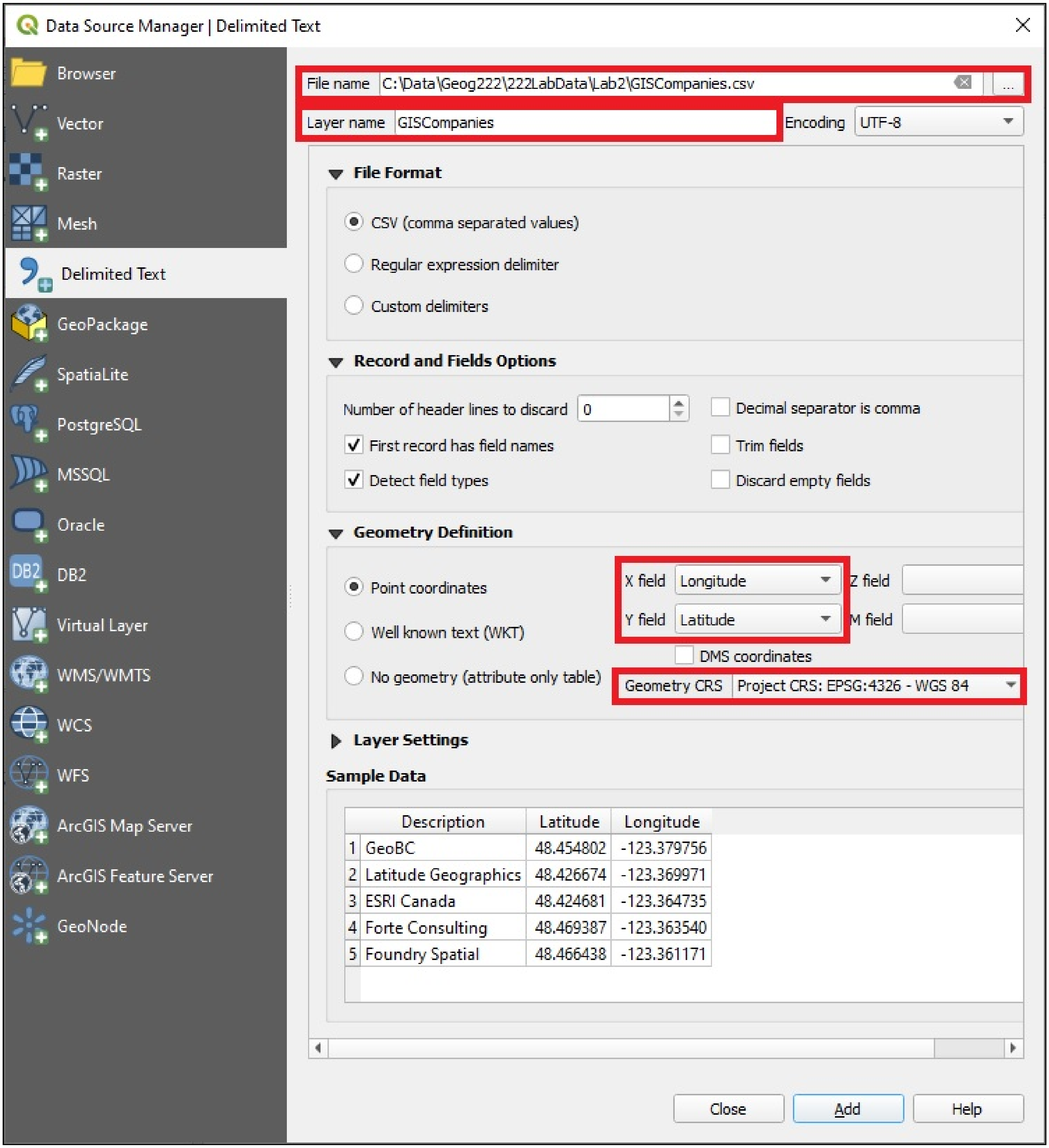


Now you will add the coordinates to QGIS via the GISCompanies.csv file

2. The from the Layer menu → select **Add Layer** → **Add Delimited Text Layer...**



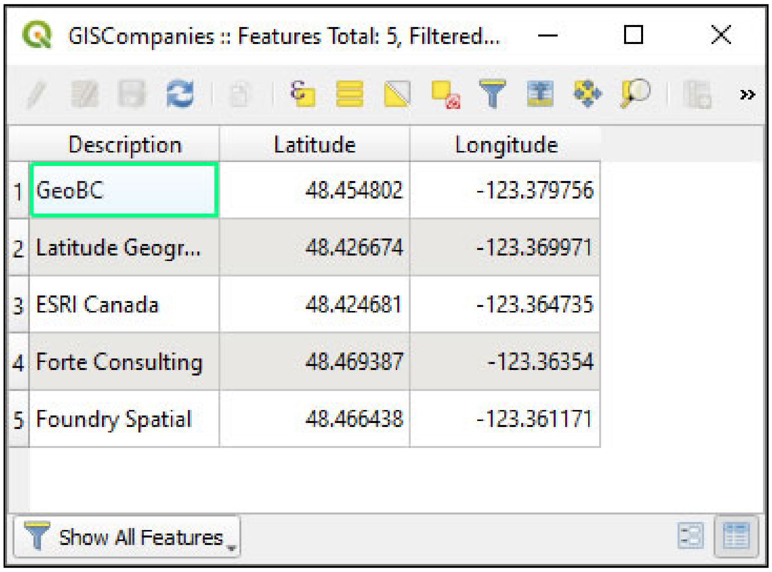
Set the parameters as follows:



- Press **Add** and close

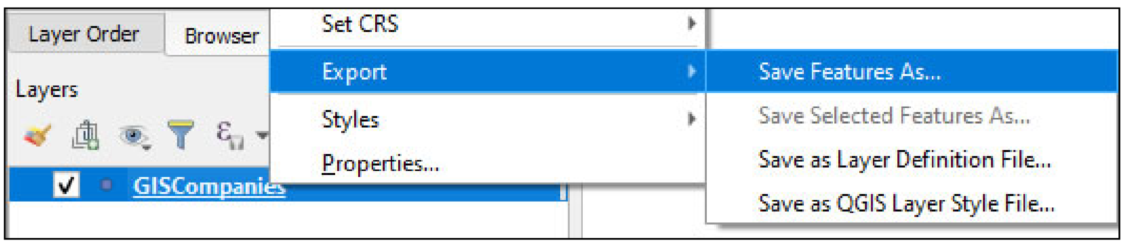
3. Right click on the GISCompanies layer in the Layers menu → choose the **Open Attribute table**.

Notice that the software has created ID column to index the new file. The description, and coordinate columns you created are also visible.

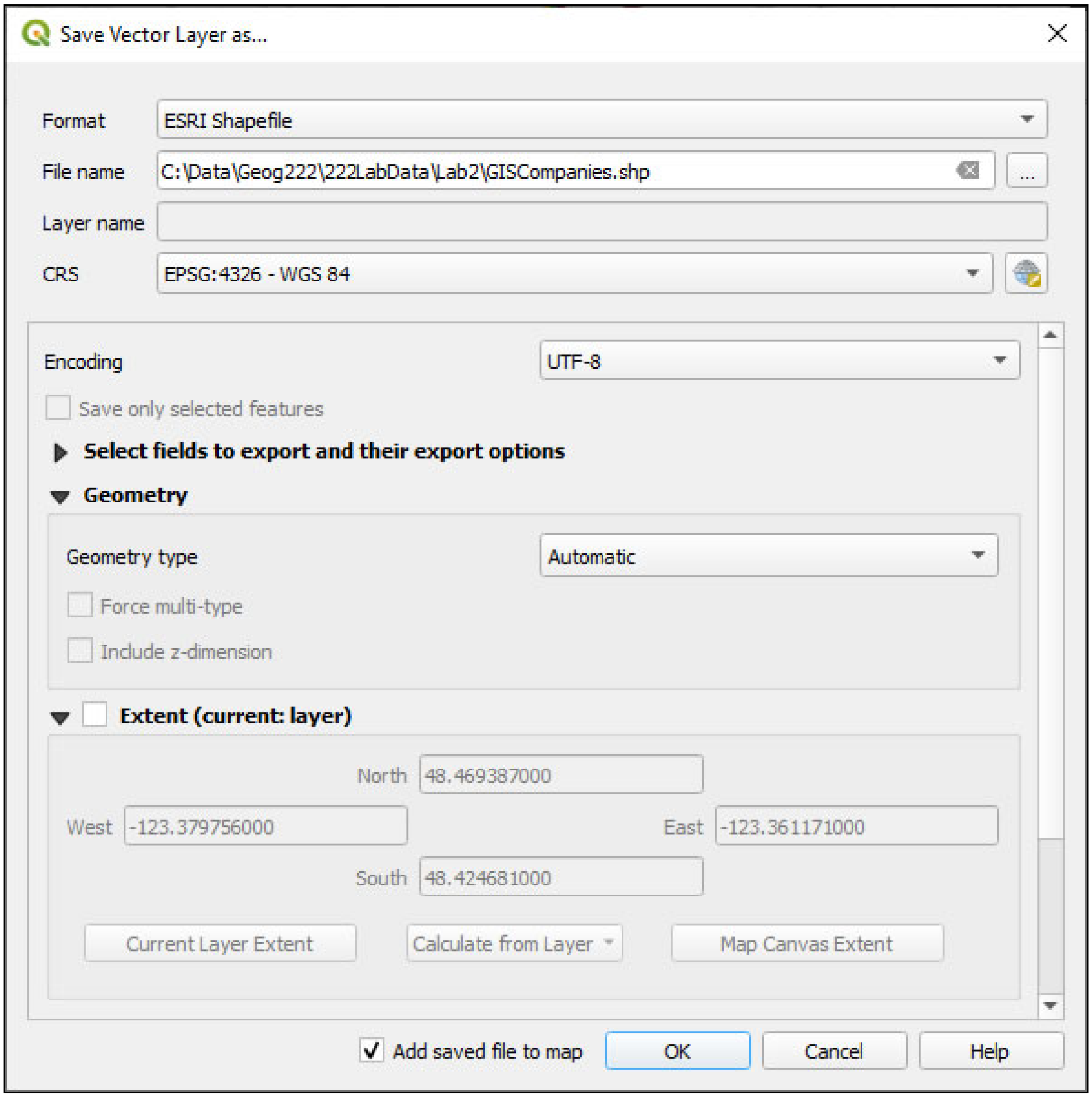


Now you can save the layer as a permanant shapefile.

4. In the Contents pane → select GISCompanies → Export → Save Feature As...



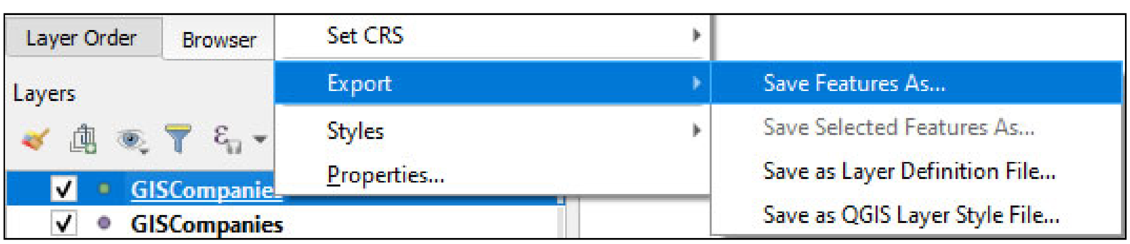
Set the parameters as follows:



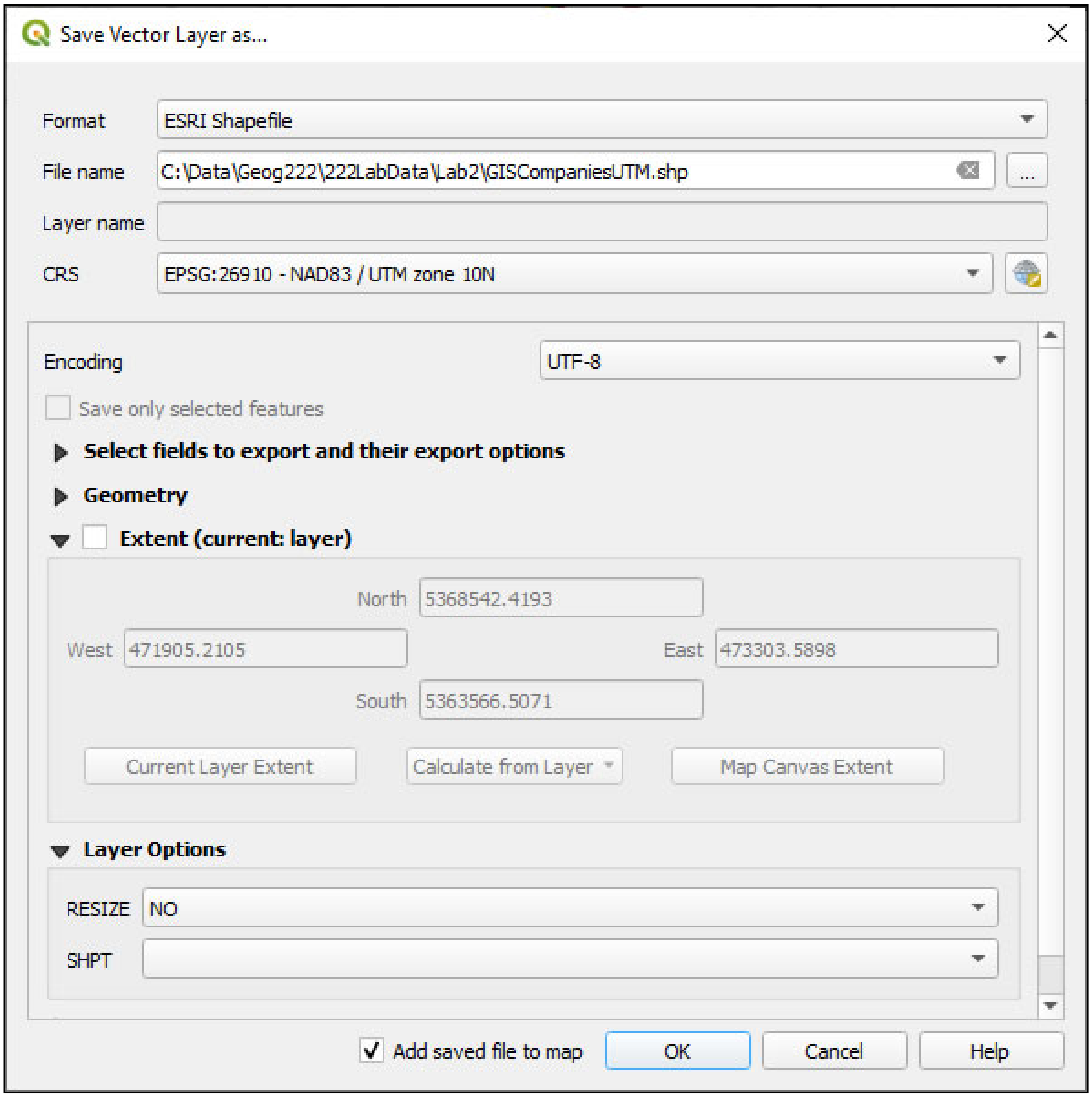
Press **OK**

Now you will transform the GISCompanies shapefile into an equal area projection so you can add easting and northing coordinates to the file.

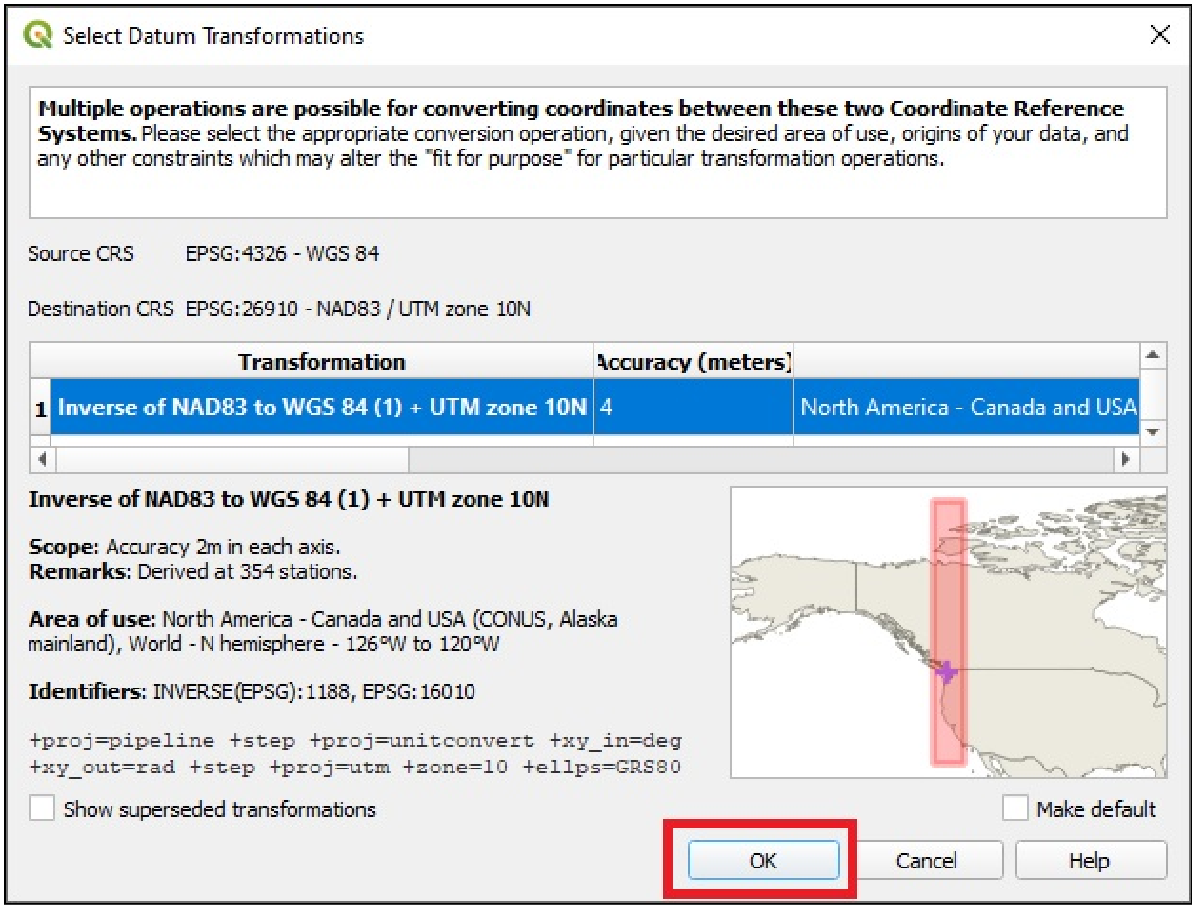
5. In the Contents pane → select the first **GISCompanies** layer in the list → select **Export** → **Save Feature As...**



Set the parameters as follows:

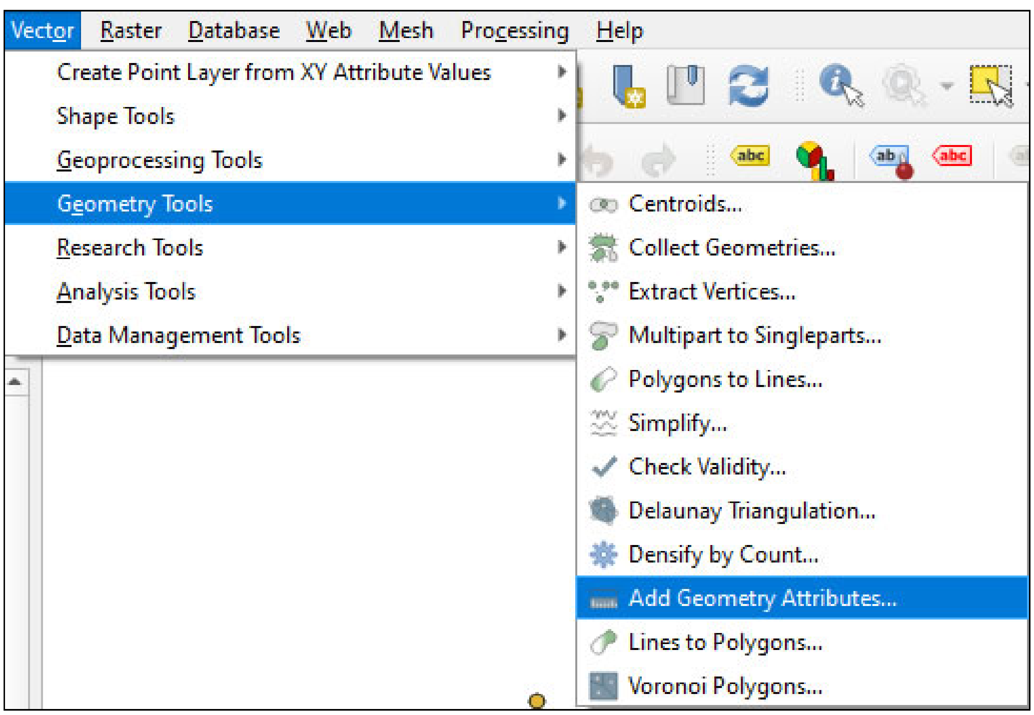


- Press **OK** and then press **OK** for the **Transformation**

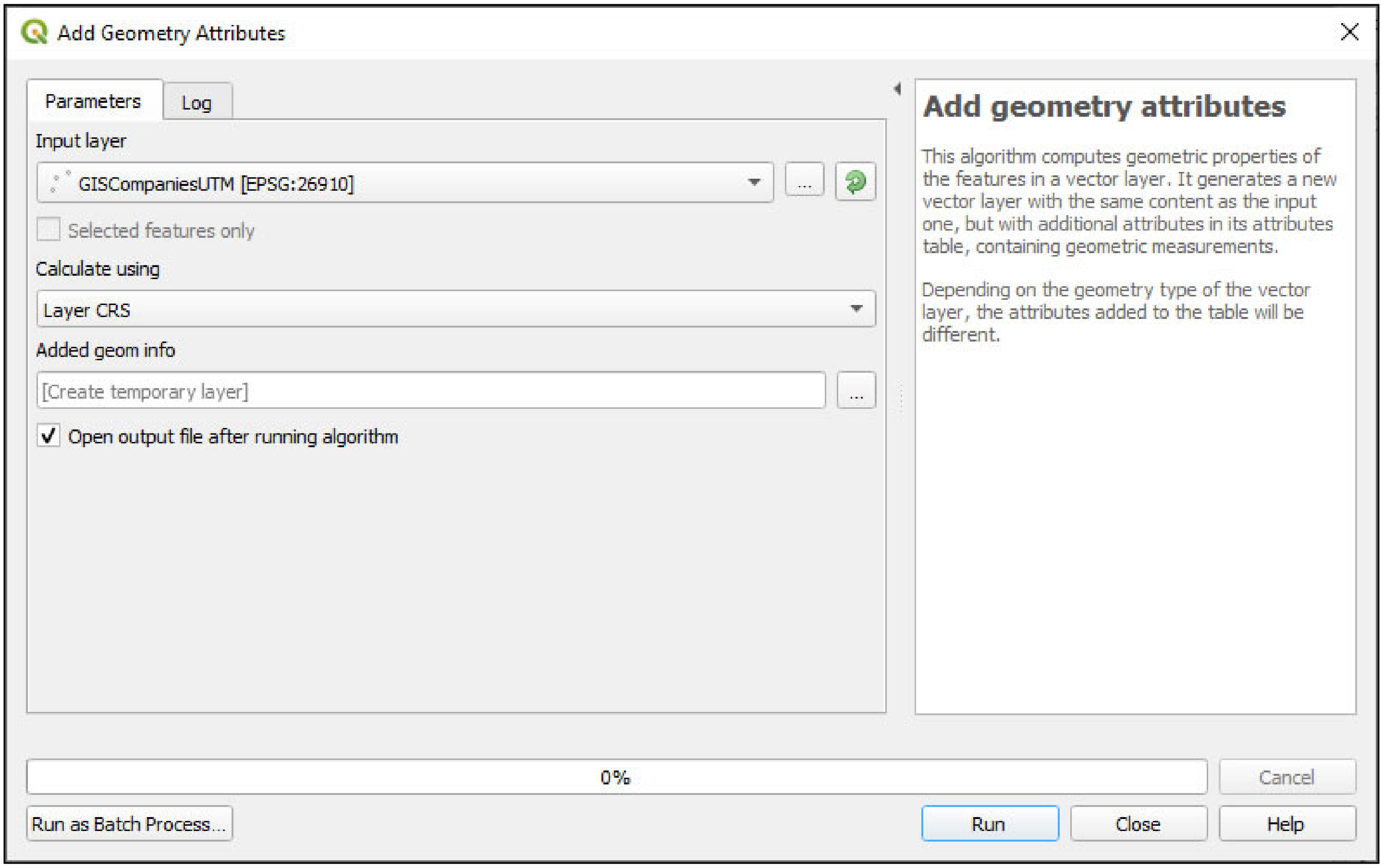


Now that the dataset has been trasnformed into the **NAD_1983_Zone_10N** projection you can add new X,Y coordinates to your dataset.

6. Select the **Vector** menu → **Geometry Tools** → **Add Geometry Attributes...**



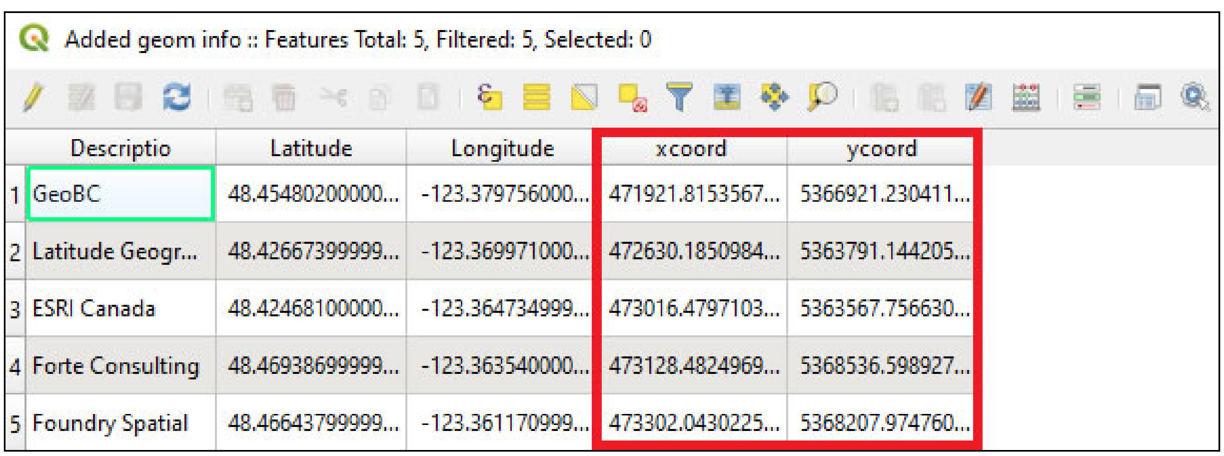
- Set the parameters as follows:



- Press OK

7. In the contents pane right click on the "Added geom info" → Open Attribute Table

Observe the new easting and northing coordinates:

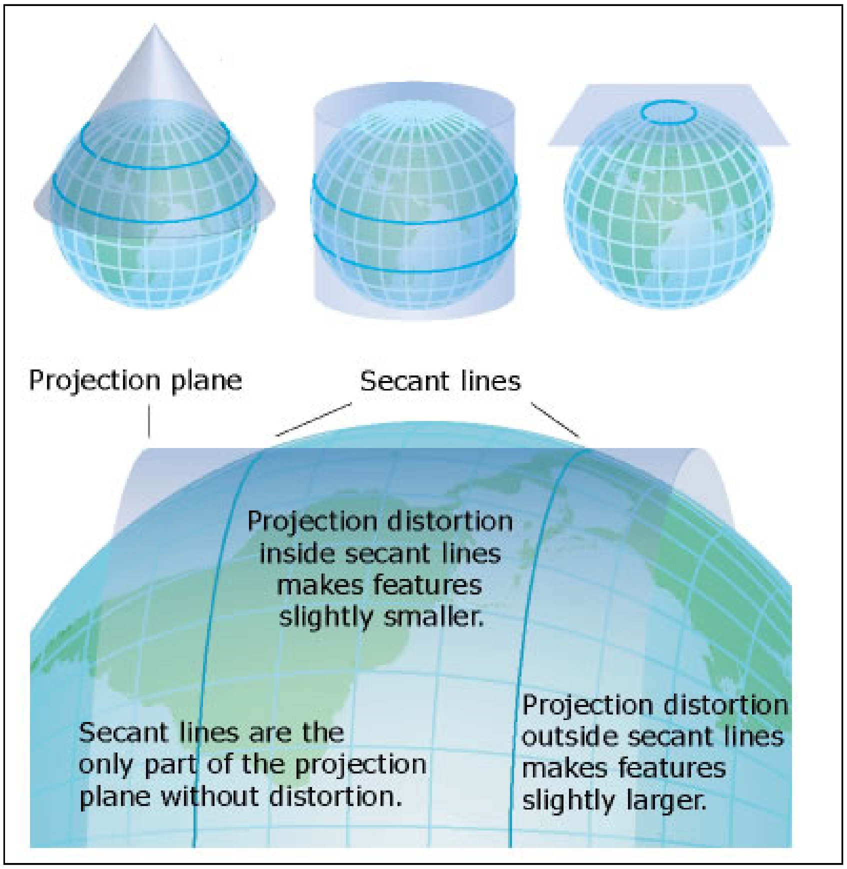

Added geom info :: Features Total: 5, Filtered: 5, Selected: 0

	Descriptio	Latitude	Longitude	xcoord	ycoord
1	GeoBC	48.45480200000...	-123.379756000...	471921.8153567...	5366921.230411...
2	Latitude Geogr...	48.42667399999...	-123.369971000...	472630.1850984...	5363791.144205...
3	ESRI Canada	48.42468100000...	-123.364734999...	473016.4797103...	5363567.756630...
4	Forte Consulting	48.46938699999...	-123.363540000...	473128.4824969...	5368536.598927...
5	Foundry Spatial	48.46643799999...	-123.361170999...	473302.0430225...	5368207.974760...

Map Projections

In the next section, you will upload a world map and convert between different map projections to see distortions across the globe.

To review, a **map projection** is a transformation of coordinate locations from the surface of a sphere or ellipsoid onto a 2D surface **(plane, cylinder, or cone)**.

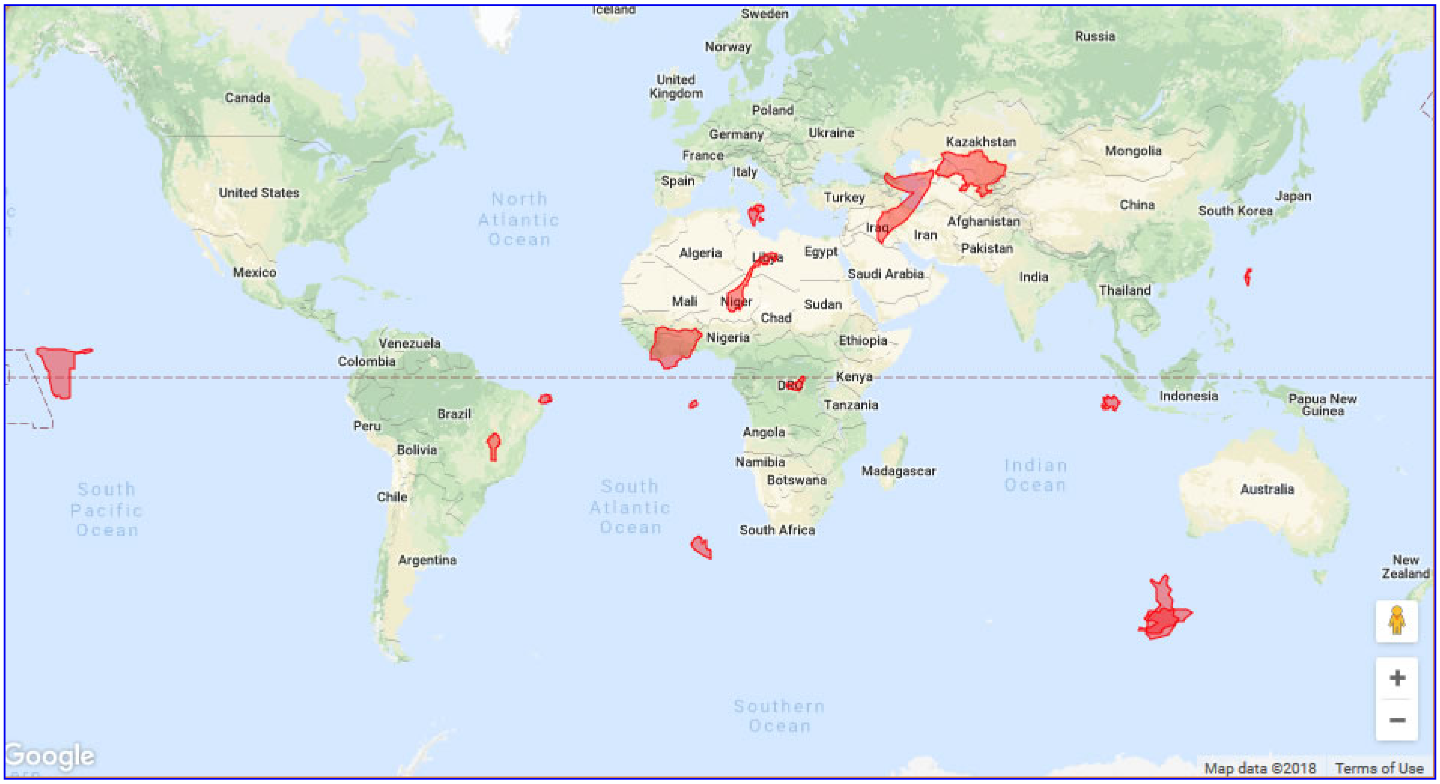


Source: http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?topicname=what_is_a_map_projection?

Different types of projections preserve different spatial properties (area, distance, shape, direction). However, the only point or line on a projected map that holds true for area, angle (shape), distance or direction is the point or line where the cylinder, cone, or plane touches the earth in the theoretical process of the projection creation (i.e., at the Secant Lines). As one moves further from that point or line, distortion increases.

- **Equidistant** map projections preserve distance between selected locations
- **Azimuthal** projections preserve the direction from a central point to all other points on the map
- **Equivalent / Equal Area** projections preserve area while distorting shape
- **Conformal** projections preserve shape across small areas

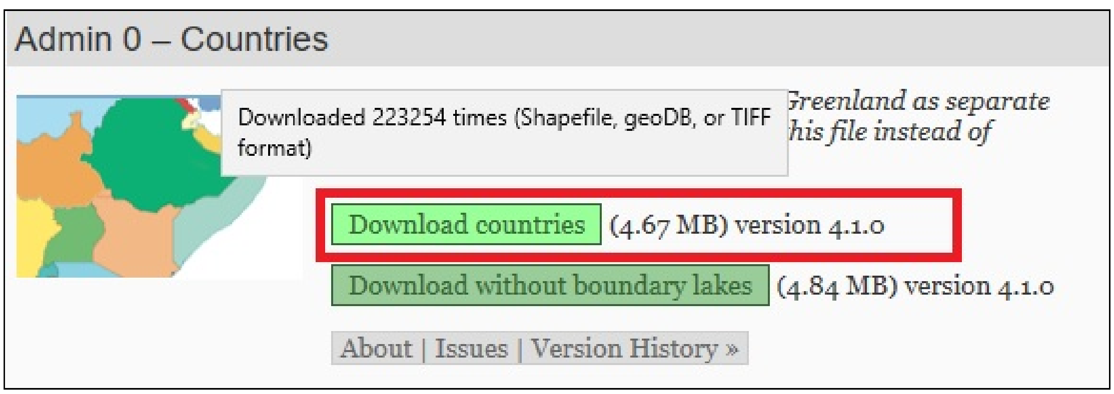
A fun way to explore just how much a Mercator projection skews the size of countries visit the **Mercator Puzzle — by Bramus!**



Now you will explore distortions of various projections using QGIS.

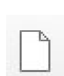
1. To download the world map, visit the Natural Earth website

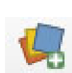
- Press the download countries button → save the zipped folder into your Lab2 folder

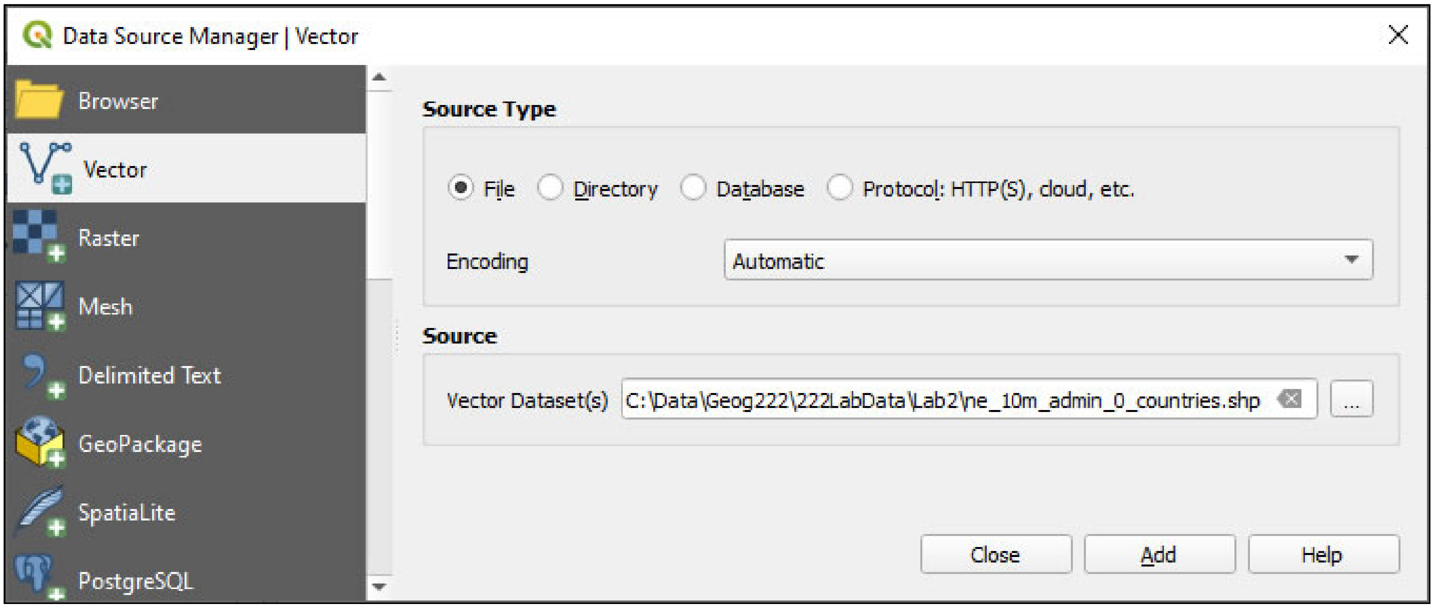


- Navigate to your Lab2 folder → and right click on the **ne_10m_admin_0_countries** folder → select **Extract All...**

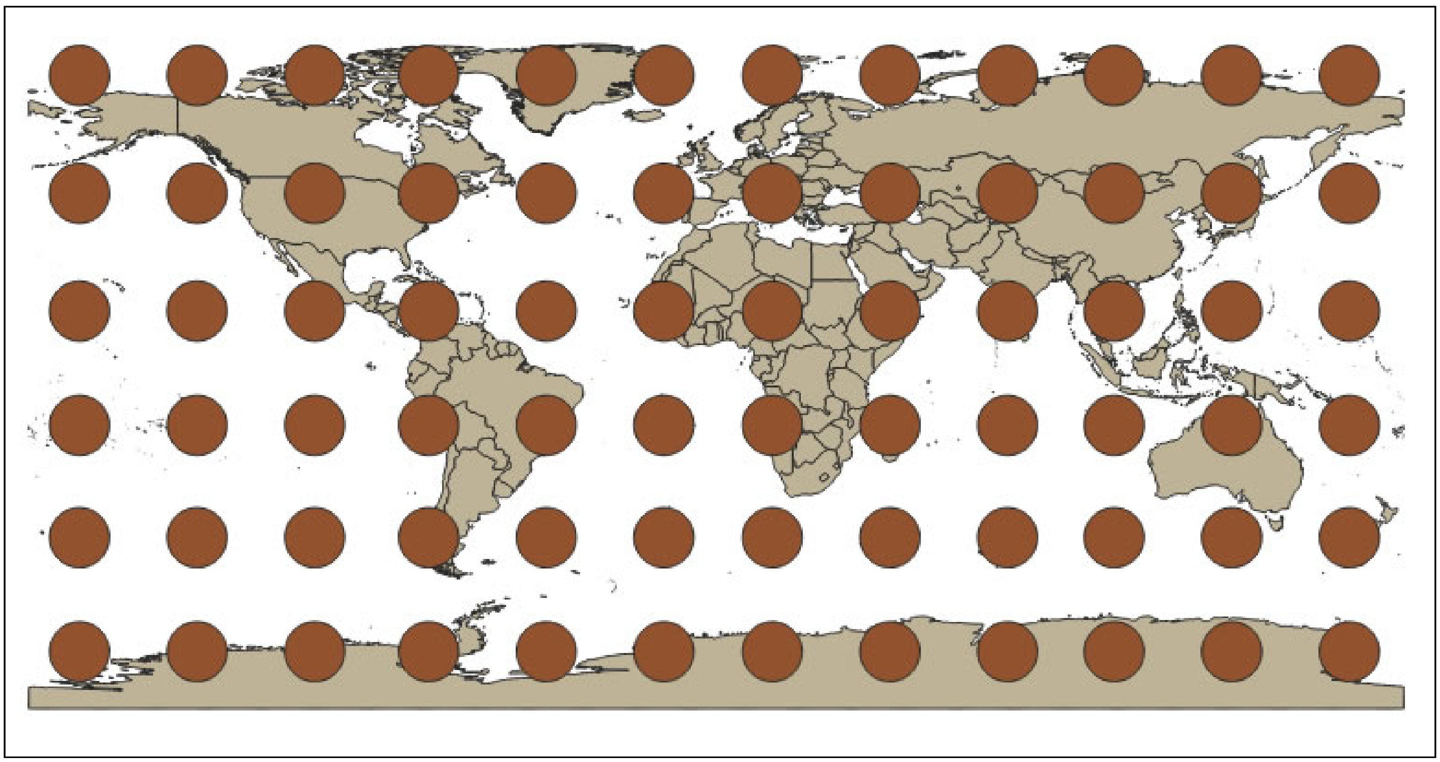
2. Download the Tissot's Indicatrix (Circles.shp) to your Lab 2 folder → right click → and **Extract All...**

3. Open a new QGIS document 

4. Use the add data button  to open the the **ne_10m_admin_0_countries.shp** and **circles.shp** files



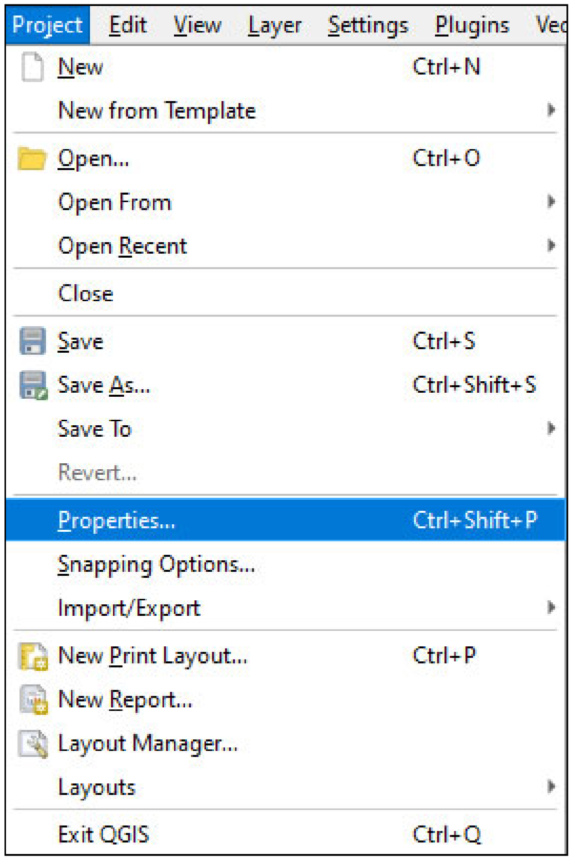
You map should look like the following:



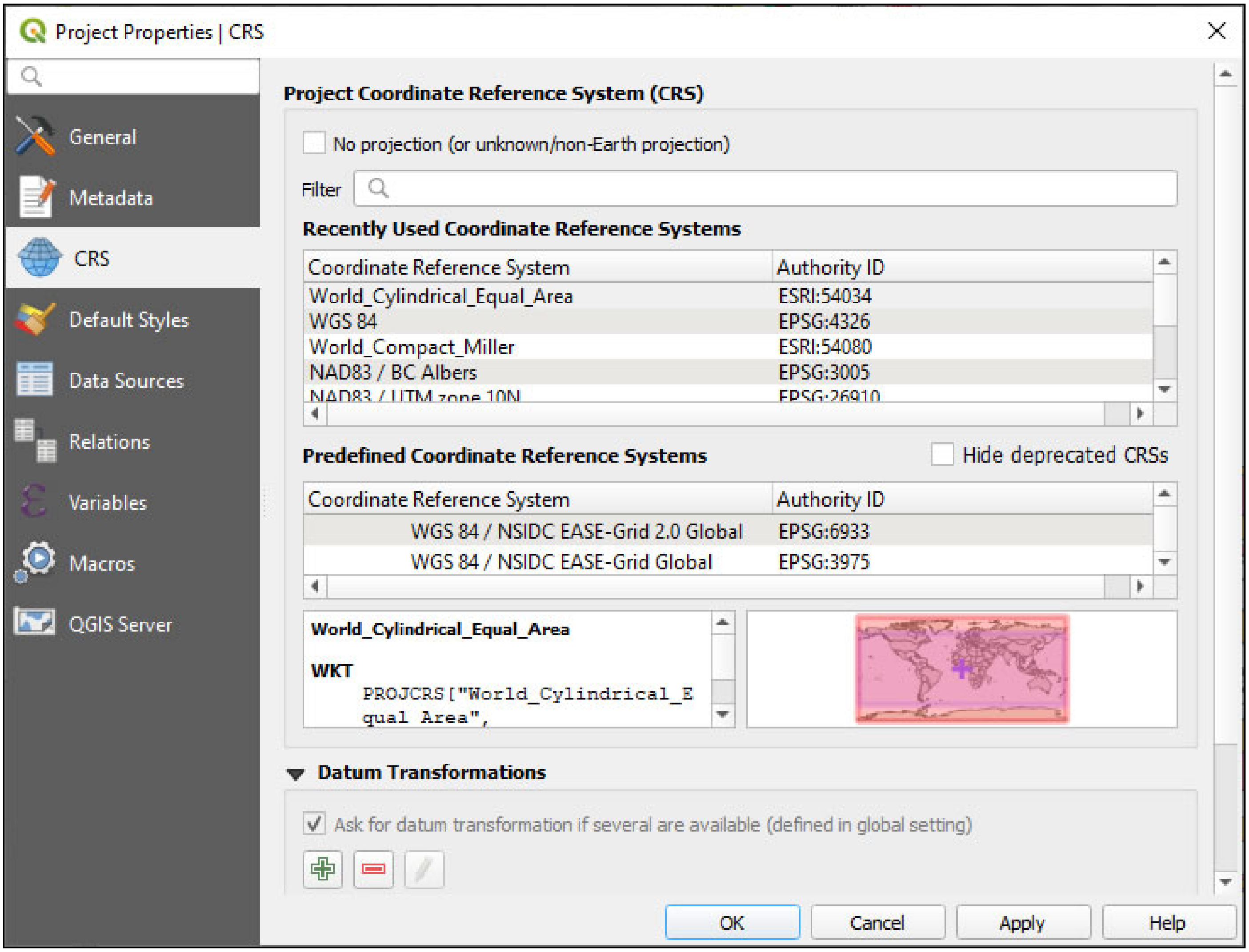
Now you are going to change the map projection, but before you do, take note of the circles. Particularly notice that the circle's shape and area are uniform across the plane in this geographic coordinate system.

When you change to a projected coordinate system the circles are going to change shape and/or size depending on the property the projection is trying to preserve.

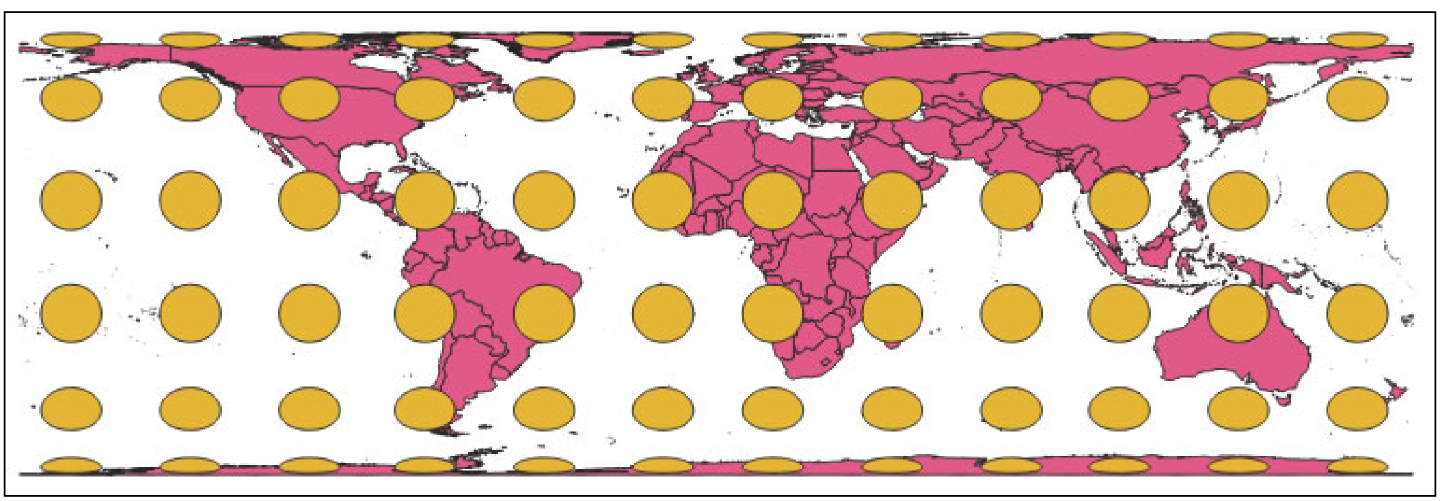
6. Go to the **Project** menu → select **Properties**



In the Project Properties box, search for **World_Cylindrical_Equal_Area** in the filter option and then select the Coordinate Reference System



- Press **Apply** and **OK**



The Cylindrical Equal Area projection has no distortion at the equator, but becomes compromised in shape, area, and size at the poles (i.e., the circles are no longer the same shape, size, or orientation).

Assignment