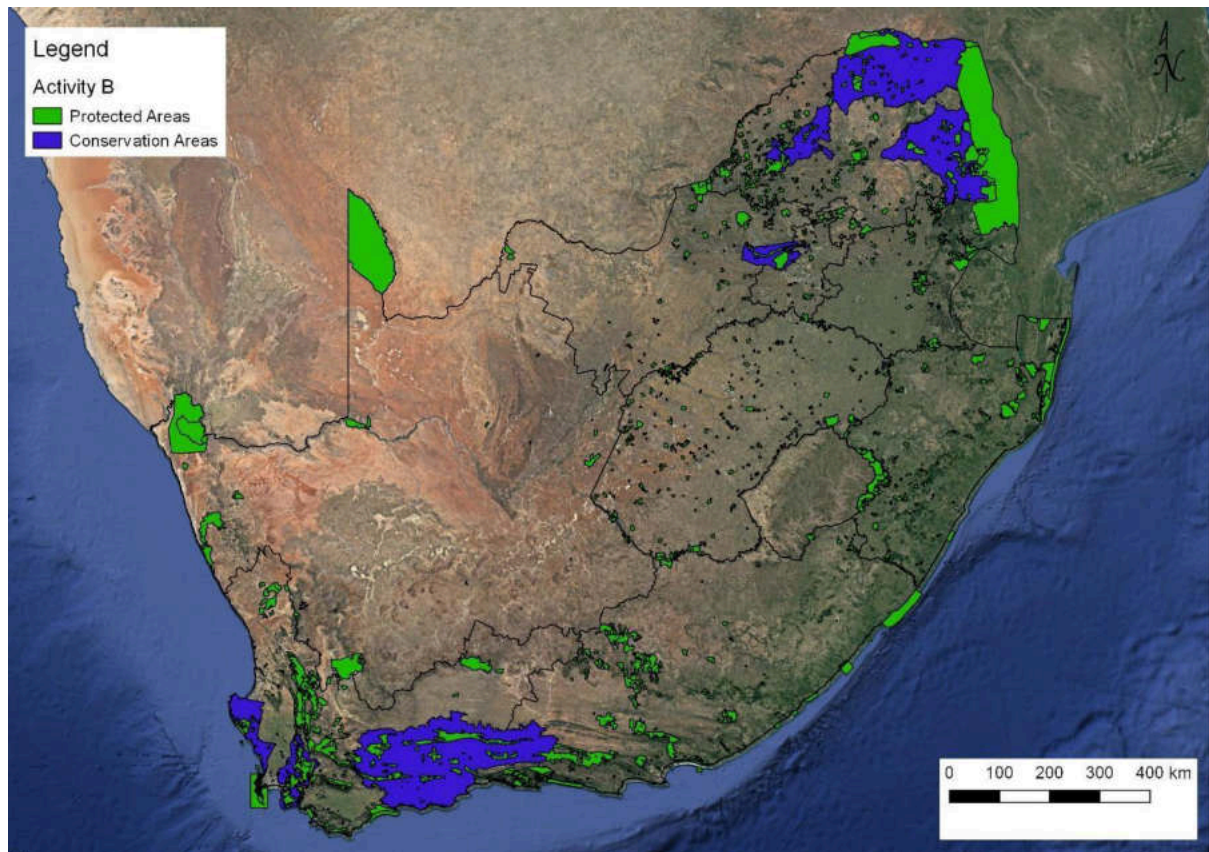# Geographic Information System (GIS) Educator Training Manual

Authors: Hayden Wilson; Kogie Govender, Caitlin Ransom and Bonolo Mokoatsi
Edited by Rion Lerm
Imagery and data sourced by Hayden Wilson and Bonolo Mokoatsi

Contents

Foreword

The South African Environmental Observation Network (SAEON) invests in capacity development programmes for senior grades' educators through their environmental science education programmes (ESEP). These programmes are aimed at enhanced teaching and learning that promote critical thinking. In 2011, Geographical Information Systems (GIS) was introduced into the Curriculum Assessments and Policy Statements (CAPS) in high schools across South Africa. SAEON through its interaction with Geography educators established that educators needed assistance with training in Geographical Information Systems (GIS).

The teaching of new technologies in education such as GIS requires an investment in training to upskill educators in the incorporation of hardware and software. In developing this GIS training programme, SAEON conducted a needs analysis to determine what resources are available in a school setting for a GIS capacity building programme to be effective. The underwhelming availability of resources particularly at rural schools prompted SAEON to firstly create an educator capacity development programme in GIS that uses paper plotting activities to provide meaningful learning opportunities for learners who do not have access to computers. This GIS training manual thus incorporates learning-centred activities to educators that they can use or adapt to promote inquiry and paper-based teaching strategies.

Despite the obvious challenges, the Department of Basic Education is promoting the integration of technology into the South African classroom. Through the first edition of this training manual, SAEON will also support senior Geography educators who have access to computers to develop the necessary skills in the use of QGIS open software. Training in the use of the software will allow them to implement technology-based teaching activities and to have open access to the latest data and computing technology.

We wish all educators and trainers a rewarding journey when adopting this manual. Your feedback will be essential for the improvement of further editions.

Moreover, we wish the high school learners who will ultimately benefit from their newly upskilled Geography teachers, great success in applying the power of GIS technology across a wide range of careers.

Managing Director: South African Environmental Observation Network (SAEON) of the National Research Foundation (NRF)

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SAEON is a comprehensive, sustained, coordinated and responsive South African environmental observation network that delivers long-term reliable data for scientific research and informs decision-making; for a knowledge society and improved quality of life

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Introduction

The science of Geography is one of the oldest professions in the world. For as long as people have been aware of the world around them, we have tried to describe the way that one place is related to another. This has been achieved through verbal descriptions of where to go, through stories, paintings, and legends. These have all served as a way of describing how one place relates to another and provides us with information about that place. This means that they provide spatial information or spatial data about a place.

More recently, maps were used to create a simplified representation of the world, which enabled people to navigate the land and oceans and told people what to expect about their eventual destination. As science has progressed, our ways of describing our world have become more and more complex, with tools being able to provide us with detailed information about a place in both space as well as time through technologies such Global Positioning Systems (GPS) and Databases. These technologies and the rise of personal computers and smartphones have enabled everyone to be able to use spatial information in order to understand the world around them.

Linking GIS concepts to Curriculum and Assessment Policy Statements (CAPS)

Subject content knowledge as per CAPS	Grade	Term	Page	Assessment (To assess learner's skills on:)	Assessment activities	Activity in manual
Concept of GIS.	10	1	10, 11	Defining GIS	● Describe GIS.	
Reasons for the development of GIS.	10	1	7, 11	Identifying GIS applications	● What are some of the uses of GIS? ● Think of a question that GIS can help answer	
Concept of remote sensing.	10	1	20	Defining remote sensing and Identifying its applications	● Describe remote sensing? ● Identify remote sensing applications	
How remote sensing works?	10	1	20 -21	Comparing, differentiating between and giving an example of the types of remote sensing techniques (passive and active) and data (raster and point cloud).	● Differentiate between active and passive remote sensing ● Differentiate between point cloud and raster images Give examples of each	
GIS concepts: spatial objects, lines, points, nodes and scales.	10	4	13 – 15	Defining, identifying, differentiating between and giving an example of different types of vector data	● Define the different types of vector data (point, line and polygon/shape) Give examples of appropriate features that each could represent ● Calculate the distance on a map using a scale Between two points; or distance of a river/road	2
Spatially referenced data.	11	2, 4	1, 10	Defining spatially referenced data and contrasting the different types of data (spatial verse attribute data)	● Define the spatially referenced or geographic data ● Compare spatial and attribute data	1

Topic						
Spatial and spectral resolution.	11	2, 4	21 -2 3	Defining resolution	● Define resolution Define spatial resolution Define spectral resolution	5
Different types of data: line, point, area and attribute.	11	2, 4	13 - 15	Defining, identifying, differentiating between and giving an example of different types of data	● Define the different types of vector data (point, line and polygon/shape) Give examples of appropriate features that each could represent ● Define attribute data	1 and 2
Raster and vector data	11	2, 4	15	Defining, identifying, differentiating between and giving an example of raster and vector data	● Define vector data Give examples of what features this type of data could appropriately represent ● Define raster data Give an example of what type of data would be most appropriate as a raster data	
Capturing different types of data from existing maps, photographs, fieldwork or other records on tracing paper.	11	2, 4	9, 13	Interpreting maps/photograph and identifying features on a map/photograph	● On a map/photograph identify an example of a polygon, line or point Using string or a whiteboard marker on blank transparency to represent a polygon Using string or a whiteboard marker to represent a line Using a pin or a whiteboard marker to represent a Point	2 and Appendi x B
Application of GIS by government and the private sector, relate to weather and settlement topics above.	12	2	13 -1 5			

Developing a "paper GIS" from existing maps, photographs or other records on layers of tracing paper.	12	1, 2, 3		Interpreting maps/photograph and identifying features on a map/photograph	● Identify features on an aerial photograph or map that could be represented as a polygon, line or point.	2
GIS concepts: remote-sensing and resolution	12	2, 3	20 -2 3	Defining remote sensing and Identifying its applications. Defining resolution	● Describe remote sensing? Identify remote sensing applications ● Define resolution	
Spatial and attribute data; vector and raster data.	12	2, 3	15	Defining, differentiating between spatial and attribute data. Defining, identifying, differentiating between and giving an example of raster and vector data	● Contrast spatial and attribute data ● Define the different types of vector data (point, line and polygon/shape) Give examples of appropriate features that each could represent ● Define raster data Give an example of what type of data would be most appropriate as a raster	1 and 2
Data standardisation, data sharing and data security.	12	2, 3	16 -1 7		● Why is data standardisation important? Can you compare data in different formats? ● Why is data shared? ● Why is data security important?	
Data manipulation: data integration, buffering, querying and statistical analysis.	12	2, 3	17 -1 9	Applying GIS concepts, investigating and extracting information to answer a question.	● What do you need to consider before integrating data from different sources?	3 and 4

Spatial data

In order for us to understand GIS, we need to understand a bit about spatial data. Spatial data is information that has some form of geographical location associated with it. For example, a street address, place name, GPS co-ordinates, geotagged photos, tweets, location tags on Facebook or Instagram and Census data all are spatial data, even your cell phone photos can have a location attached to it.

Photo by Patrick Brinksma on Unsplash   Photo by ShareGrid on Unsplash

Examples of tools that we use to understand and record our world.

As most people are very visually orientated, we like to represent the world around us in some sort of visual way and in order for us to easily represent what we see in a way that other people can understand where something is. How things relate to each other spatially, we may use maps in our day-to-day lives like Google Maps on your cell phone or topographic maps for your learners in Geography.


Examples of an Oblique (Side view) Aerial Photograph and a vertical (Bird's eye view) Aerial photograph.

Maps

A map is a way of telling us information about an area. Often it is a vertical photograph of a place with additional information added (such as labels of place names) or it can be a representation of a place that has been simplified for it to be easier for us to understand.

In the example below, we can see two maps, one with place information on an aerial photograph, and another with street and place names. As we can see, the types of information we receive from these two different kinds of maps varies however, both are useful!
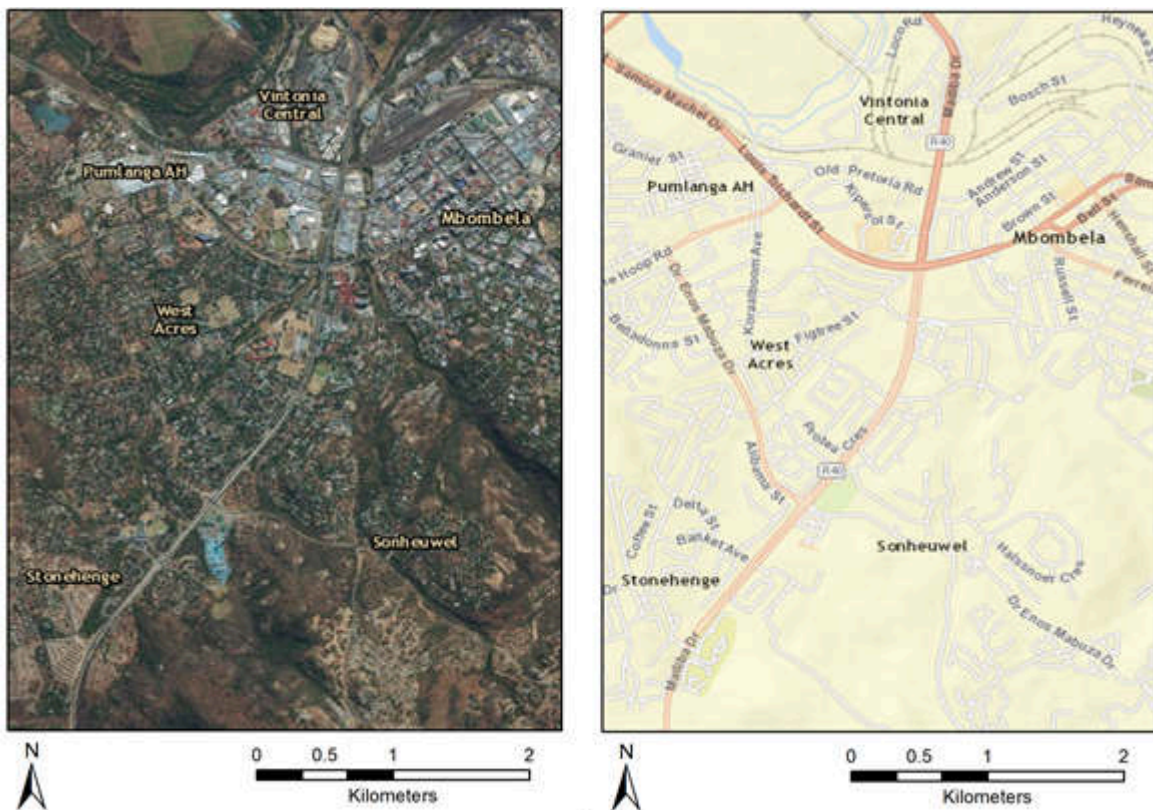
Two different maps of the same place (Nelspruit/Mbombela)

Why do we create Maps?

•   Shows us the important physical features
•   Features are both natural and man-made e.g. rivers, mountains, school, church
•   Assists in finding a particular location
•   Quite simple to use
•   It can be customised to suit the audience e.g. tourist map vs. map of a town

Type of Feature	Description
Cultural Features	Airports, roads, buildings, infrastructure
Hydrography features	Rivers, streams, lakes, dams,
Relief and Mountains	Mountains, valleys, cliffs, contours
Vegetation	Forests and Nature Reserve

Different types of Maps

Shaded relief map
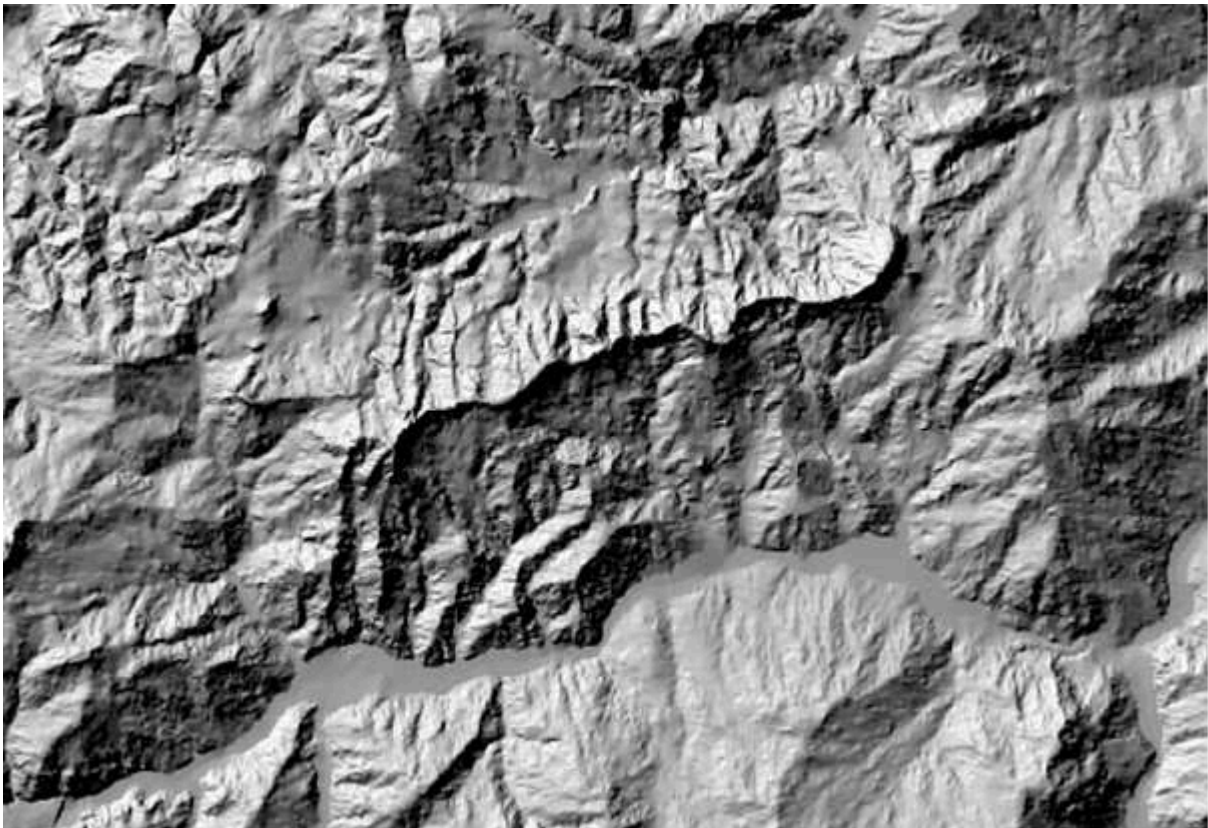
A shaded relief map that shows us features such as mountains, slopes, etc. with the flat areas appearing smooth and steep areas appearing rough on the map.

Topographic Map: Luchaba Wildlife Reserve
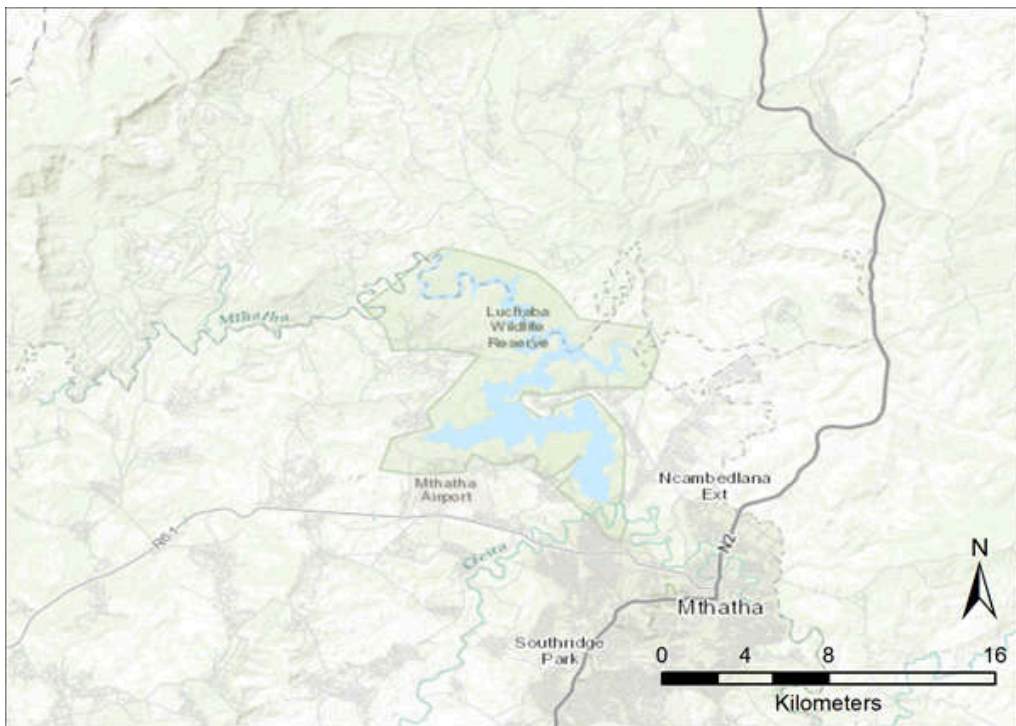
Road Map: roads of a city and a town
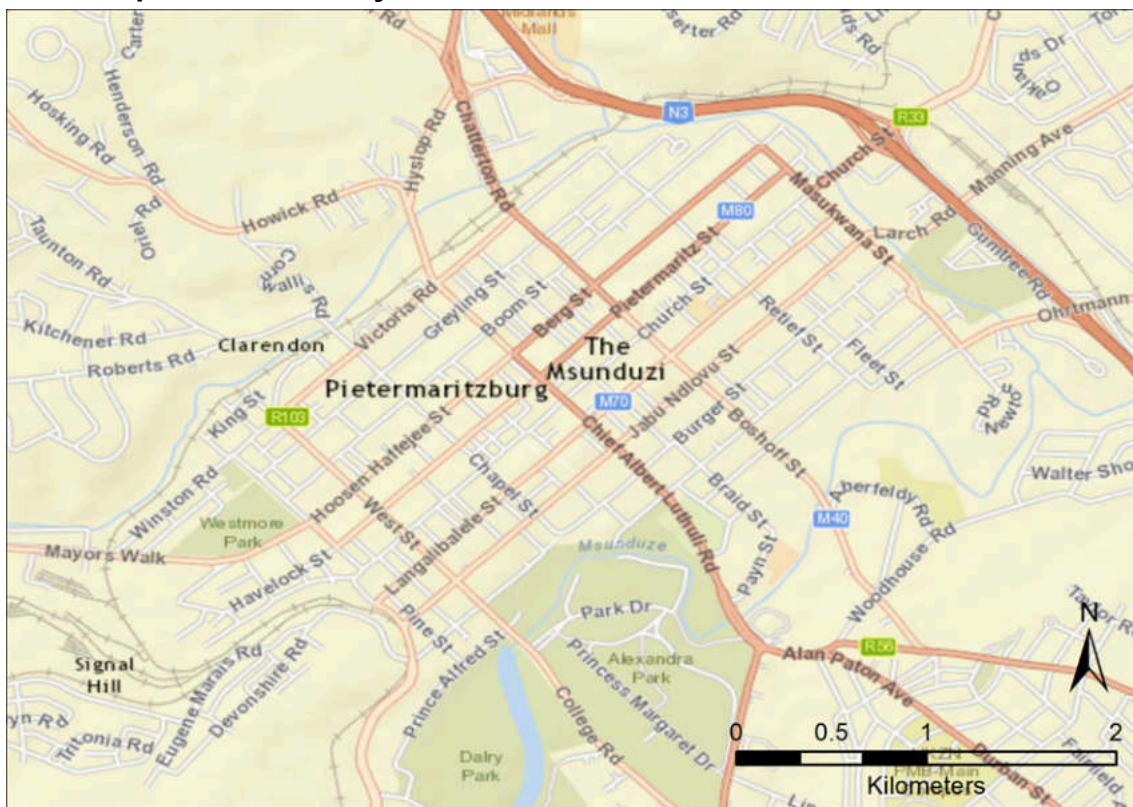
Tourist Map: features such as tourist's monuments or places of interest for tourists.

3D Maps: information in three dimensions showing the features such as the elevations of a landscape.

Use of Maps

Use of Maps
Improves the understanding of a place

Location:
Where are we?
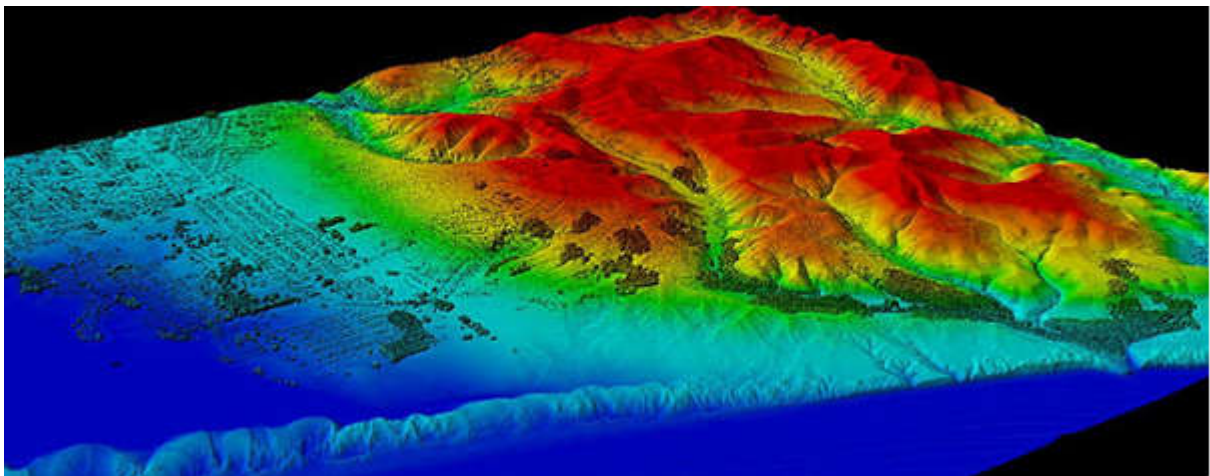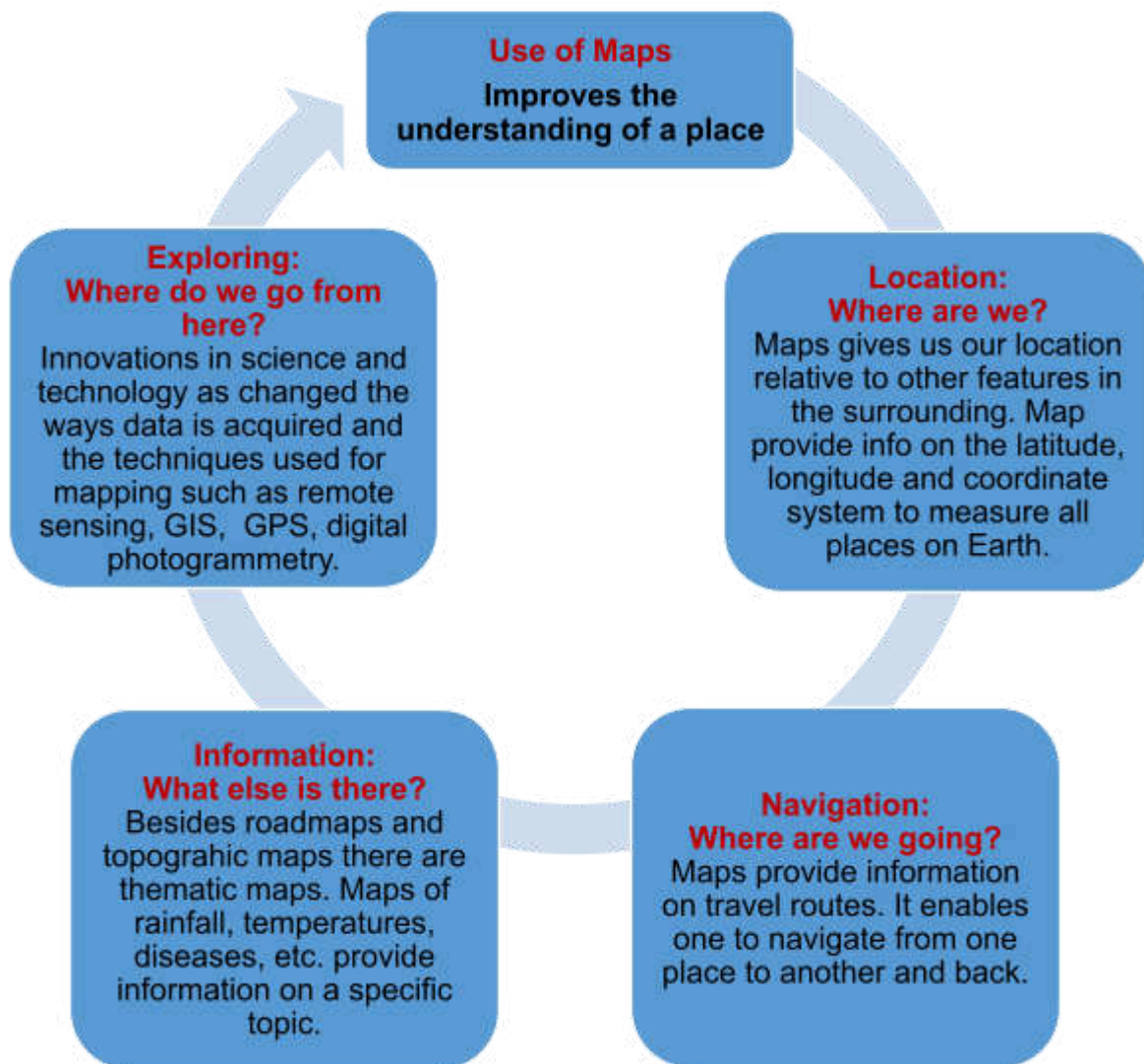Maps gives us our location relative to other features in the surrounding. Map provide info on the latitude, longitude and coordinate system to measure all places on Earth.

Navigation:
Where are we going?
Maps provide information on travel routes. It enables one to navigate from one place to another and back.

Information:
What else is there?
Besides roadmaps and topograhic maps there are thematic maps. Maps of rainfall, temperatures, diseases, etc. provide information on a specific topic.

Exploring:
Where do we go from here?
Innovations in science and technology as changed the ways data is acquired and the techniques used for mapping such as remote sensing, GIS, GPS, digital photogrammetry.

Interpreting a Map

When a map is analysed, the features can be distinguished through colours, lines and other symbols. Features are shown as points, lines or areas. The size and type of the feature depends on whether a feature is represented as a point, line or area - these types of data are called Vector Data and we will explain these concepts in detail in the GIS section.

As all maps are a representation of something in the real world, a true map will always have the following:
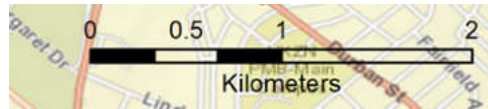
The scale of a map controls the amount of information that a map contains. The scale defines the relationship between the mapped magnitude and the actual magnitude. On the map, the linear distances are shown as a ratio of the actual ground distance. In the example below, the scale bar shows that the distance represented by the length of the scale bar represents 2 km in real life.

Orientation for positioning a map so the top, for example, points either magnetic or true North. When you orient a map and know where you are on the map, you can look in a certain direction, see a real landmark, and find it on the map.

A symbol on a map is defined by the map's <u>legend</u>. An area feature represented by green illustrates vegetation, blue is for water and the built up area is grey or red. Lines such are curved, dotted or dashed or a mixture of them are used to indicate different features.

WHAT YOU SEE
ON YOUR MAP

3-D VIEW
OF LANDMARK
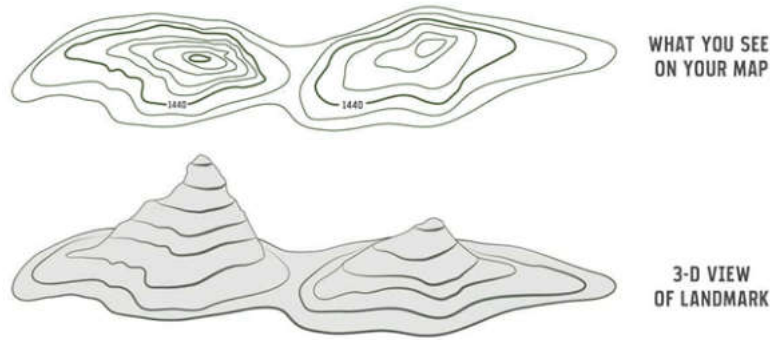
Additionally, maps can provide you with information about the landscape surface, for example, contour lines can tell you about the shape and slope of landscape features such as hills, valleys, and mountains. These are called three dimensional surfaces: 3 D surfaces are illustrated in three-dimensions to ensure that the elevation value is not lost on the map. An example of a three-dimensional surface is a terrain that is shown by contour lines that have an elevation value.

Geographic Data

Activity One
Each participant is given a card that has information on the card. The participant will describe the information on the card and the other participants will determine the point of interest.

Card 1	Card 2
A rest camp: 24.9948° S, 31.5969° E	33.9628° S, 18.4098° E
A National Park in South Africa that lies across two provinces. This park was open in 1927 and is home to approximately 93 mammal species, 518 bird species and 118 reptile species.	A flat topped mountain forming a prominent landmark overlooking a city in South Africa. Tourists use the cableway or hike up this mountain. This mountain is home to fauna and flora, most of which is endemic.
● **Who am I?** ● **What is the name of the province/s that you would find me in?**	● **Who am I?** ● **What is the name of the province/s that you would find me in?**

Card 3

Photo: Caitlin Ransom

28.7391° S, 24.7585° E
Thousands of prospectors with picks and shovels came here and created what claims to be the largest hand dug excavation in the world. People are contesting that I am not the largest hand dug excavation in the world.

● **Who am I?**
● **What is the name of the province/s that you would find me in?**

Card 4

Photo by South African Tourism on Flicker

33.8076° S, 18.3712°E
I am an island in Table Bay, 6.9 kilometres west of the coast of Bloubergstrand. My shape is roughly oval 3.3 km long north-south, and 1.9 km wide, with an area of 5.08 km^2.

● **Who am I?**
● **What is the name of the province/s that you would find me in?**

Card 5

Photo by South African Tourism on Flicker

25.9254° S, 27.7674°E
Just 50km away from Johannesburg, there is a complex of limestone caves. In these caves, scientists have discovered fossils that date back to the birth of humankind. The most famous among the fossils are the skull 'Mr. Ples' (which is a 2.1 million-year-old skull) and the skeleton 'Little Foot' (which is 3 million-years-old).
● **Who am I?**
● **What is the name of the province/s that you would find me in?**

Card 6

Photo by FrancoisMalan on Flickr

34.0169° S, 23.8574° E
A National Park in an area of the Garden Route on South Africa's southern coast. It encompasses a marine reserve, deep gorges and local vegetation like the Big Tree, a towering yellowwood. The Mouth Trail crosses a suspension bridge over Storms River.

● **Who am I?**
● **What is the name of the province/s that you would find me in?**

Card 7

23.6362° S, 30.3463° E

This reserve is situated in Lobedu Mountains, home of the Modjadji rain queens. In this reserve, you would find the highest concentration of a single species of cycad with featuring some of the oldest and largest cycad specimens on earth.

- **Who am I?**
- **What is the name of the province/s that you would find me in?**

Card 8

29.0967° S, 26.2362° E

Gaze up at the mysteries of the universe in the first digital planetarium in Sub Saharan Africa. Opened in 2013, this digital planetarium provides a digital experience from the smallest atomic particles to the largest cosmological scales.

- **Who am I?**
- **What is the name of the province/s that you would find me in?**

Card 9

26.2348° S, 27.9827° E

This is the largest stadium in South Africa which seats 87 436 spectators. The unique design of this stadium is often referred to as the "Calabash" or "African Pot".

- **Who am I?**
- **What is the name of the province/s that you would find me in?**

Card 10

29.8672° S, 31.0463° E

The aquarium is the 5th largest in the world, with 32 tanks totalling 17,500 m^3 of water. The underground aquarium is designed around five shipwrecks, with its entrance through the above-ground "Phantom Ship". The fantastic dolphin stadium can seat 1,200 visitors, and the seal stadium can seat about 450.
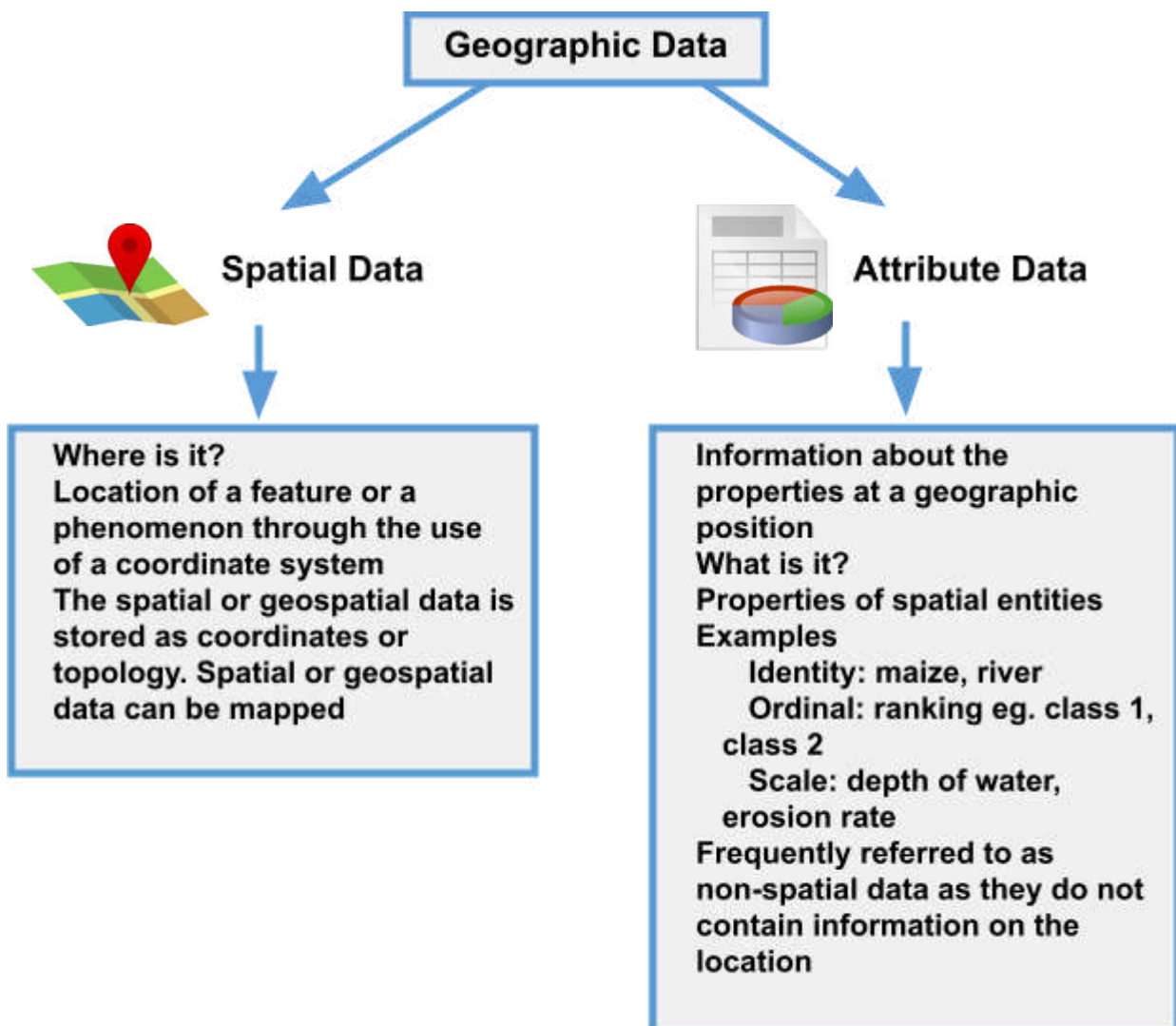
- **Who am I?**
- **What is the name of the province/s that you would find me in?**

At the end of the activity, the concepts of spatial data and attribute data is introduced which leads us to the next section of this training manual.

Geographic data is the information that we gather about the world around us.

- It can be the name of a place (point).

- The length and direction of a road or river (line).

- The size and shape of a farm, school ground, province, mountain (polygon - a flat figure consisting of connected straight lines).

All geographic data has a position and attributes which describe to us what that data is.

Geographic Data

Spatial Data

Where is it?
Location of a feature or a phenomenon through the use of a coordinate system
The spatial or geospatial data is stored as coordinates or topology. Spatial or geospatial data can be mapped

Attribute Data

Information about the properties at a geographic position
What is it?
Properties of spatial entities
Examples
    Identity: maize, river
    Ordinal: ranking eg. class 1, class 2
    Scale: depth of water, erosion rate
Frequently referred to as non-spatial data as they do not contain information on the location

Concept: GIS

GIS is the abbreviation for Geographical Information Systems.

Basically, it is a tool that enables us to analyse information and spatial relationships between different geographic datasets, it enables us to take the information that we gather about the world around us and use it to answer questions and solve problems, enabling us to make our own maps.

For example, you could use a GIS in order to answer this question: How many emergency services are there that are within 10 minutes' drive from your school?
In order to answer this question, we would use the location of the different emergency services in a region, and see how far away they are from the school by plotting the routes that a car or ambulance would take in order to get from the school to the emergency service point (hospital, fire station, clinic, etc.). Thereafter we could then calculate how long each of those routes are (distance) and then calculate the time it would take for an ambulance to get from the school to a hospital. We can then discard any routes where the time taken takes longer than 10 minutes. We can then see how many of those routes wind up at different hospitals and we would have our answer!

Now, answering the above question using a pen and paper map would take a long time, but it is easy to do when using a GIS on a computer system.

GIS brings together layers of information about a place so that we can better understand that place. The types of analyses we will perform will vary depending on the types of problems we are trying to solve. When bringing together the different layers of information, the purpose of the analysis will determine how datasets are combined and analysed. GIS is a computer based programme that collects, stores, manipulates and displays geographic information, but the techniques and concepts that we will be applying date back to the first cartographers making maps.
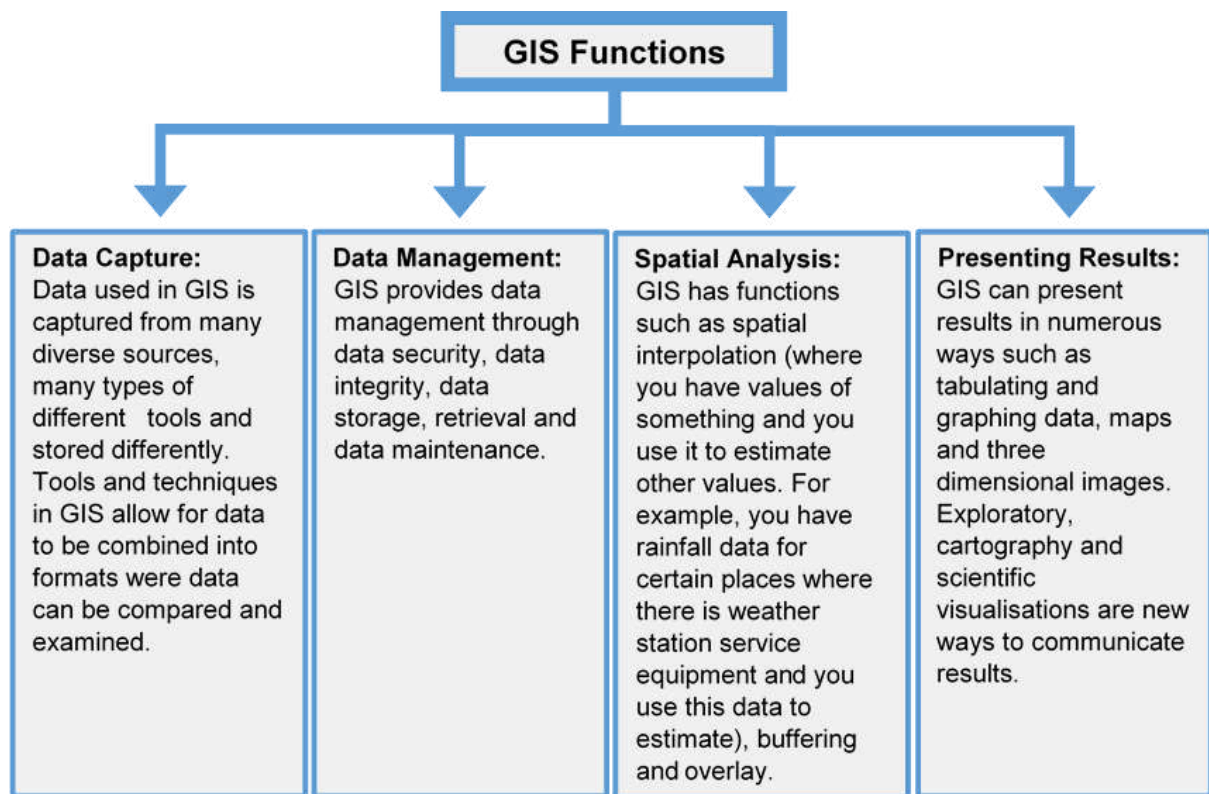
History of GIS

GIS is an extension of cartography and the concept began through trying to understand cholera outbreaks in Europe during the 19th century. In 1854 John Snow discovered that London cholera outbreaks were concentrated around a water pump, by marking outbreaks on a map. This was the beginning of spatial analysis. GIS has since evolved from paper maps to the concept of layers, through the use of transparencies, and now to computers. Roger Tomlinson pioneered GIS through his role in developing the Canada Geographic Information System (CGIS). The CGIS aimed to integrate natural resource data to create a Canadian national land use management program. The improvement in computers and the advantages of GIS lead to commercialisation of software in the 1980s. Today GIS gives people the ability to solve real world problems by creating their own maps by combining different sets of data relevant to each problem.

Key Components of a GIS

- Hardware
    A computer is the hardware from which the GIS is used.
    Examples include: CPU, monitor, keyboard and drivers, scanners and digitisers
- Software
    GIS software makes available the functions and tools to store, analyse and display geographic information
    Tools for input of data and manipulation of data
    Database Management Systems (DBMS)
    Tools that support geographic query, analysis and visualisation
    Graphical user interface (GUI) to access the tools easily
- Data Processing
    The most crucial factor that is costly for GIS is data. Building a database costs money, time and requires lots of planning and management. GIS can work effectively if data is readily available at an affordable cost.
- People
    GIS technology cannot be utilised without people to manage the system.
    The technical specialists design and maintain the system.
    Others users are people that use it to help them in their work eg. scientists, engineers, town planners.
    Skills needed by people who use GIS is that they need to think spatially.
- Policies and Procedures
    Well-designed plan and business rules are important in making decisions such as choosing the right GIS for a particular implementation

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                    ┌─────────────────┐
                    │  GIS Functions  │
                    └─────────────────┘
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Data Capture:	Data Management:	Spatial Analysis:	Presenting Results:
Data used in GIS is captured from many diverse sources, many types of different tools and stored differently. Tools and techniques in GIS allow for data to be combined into formats were data can be compared and examined.	GIS provides data management through data security, data integrity, data storage, retrieval and data maintenance.	GIS has functions such as spatial interpolation (where you have values of something and you use it to estimate other values. For example, you have rainfall data for certain places where there is weather station service equipment and you use this data to estimate), buffering and overlay.	GIS can present results in numerous ways such as tabulating and graphing data, maps and three dimensional images. Exploratory, cartography and scientific visualisations are new ways to communicate results.

What can GIS do?

- **Location**: GIS can provide information on what can be found at that specific location. A location is described by using different methods eg. postal code, name of the place, longitude/ latitude or x and y.
- **Condition**: Given a certain condition, such as an area of 2 000 square metres of forest, you can use GIS to find the location for that particular condition.
- **Trends**: What has changed in an area with time? Has the forest cover changed over the past ten years?
- **Patterns**: What spatial patterns are there?   At which intersections are accidents happening most often?
- **Modelling**: GIS uses specific models to answers questions. What would the impact be if a new road is added?

Activity Two

2.1.1. Create a map of Africa using the string.

2.1.2. Use string or raffia to illustrate any river that you know of in Africa on the map that you have drawn from the string.

2.1.3. Place the drawing pin on a location of a country in Africa that you have visited or that you would like to visit.

Participants would then be given an A4 map of Africa on a transparency to determine if the map that they have created is the correct shape, the river is placed correctly and their pin is on the country they have visited or would like to visit. The shape that has been created from the string of Africa is called a polygon or shape in GIS. The river has a start and finish point and in GIS this is known as a line. Other examples of lines on a map would be roads, trails, and pathways. The location of a place that they have visited or intend to visit, in GIS we call this a point and it is given by a single set of x and y coordinates. This activity links to the concepts of vector data which is defined in the next section of this training manual.

The above activity was adapted from National Geographic Website:
https://www.nationalgeographic.org/activity/introduction-gis/

Picture of a Map showing Points, Lines and Polygons
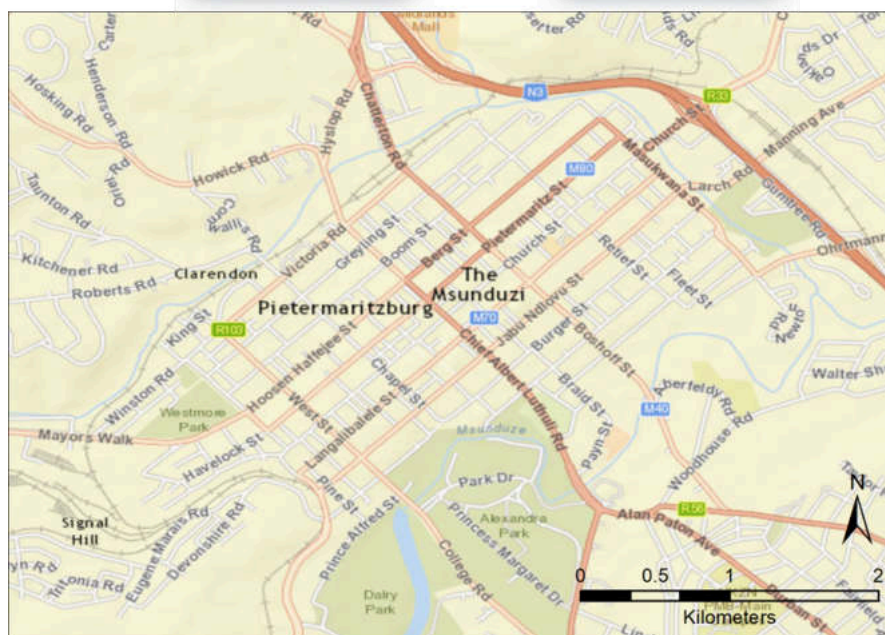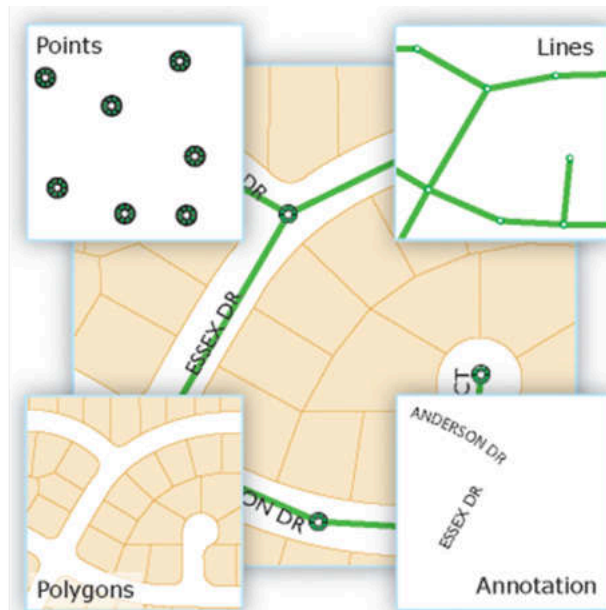
Raster and Vector Data

The spatial features in GIS are stored either in vector or raster form (data).

Vector Data

The position of map features is stored in coordinates x (longitude), y (longitude) and occasionally z (Height). The vector format indicates the location and shape of features and boundaries accurately.

Point: A single location that illustrates the location of a feature. A point feature location may be characterised by a single x, y or x, y, z location. Points have no linear or area dimensions. Examples of point features are a point were something occurred or a single point showing a monument or a place of interest.

Line: A line joins two points to illustrate the start and finish of a feature. There is no area in a line feature. An example of a line feature is the centre line of a road or a river.

Shape or **Polygon** or Area: A shape that has three or more sides and is on a plane (flat) is defined as a polygon in mathematics. In GIS a polygon or shape is a figure that are on a plane were the first and last coordinate pair is the same. The shape / polygon / area feature is characterized by two dimensions that is enclosed by a boundary line that contains the area.

Raster Data

Data that has a grid-based format in which map features are shown as cells or pixels in a grid matrix. Pixels are the smallest unit in which raster data is stored. The space is defined by points or cells that are arranged into rows and columns. The position of each element can be given if the rows and columns are numbered. The row number and the column number can be linked to coordinate positions that form the coordinate system. Every cell or pixel has an attribute value (a number) that represents a geographical phenomenon or nominal data e.g. rainfall or elevation.

The size of the grid will determine the level of detail in which map features can be specified.

Sensors from satellites and airborne instruments provide raster data which is made up of pixels. Raster data is used to illustrate elevations using pixels. The resolution of an image is the pixel size in raster data. The "minimum mapping unit" is the smallest object that can be identified.

Raster

Rows

Columns
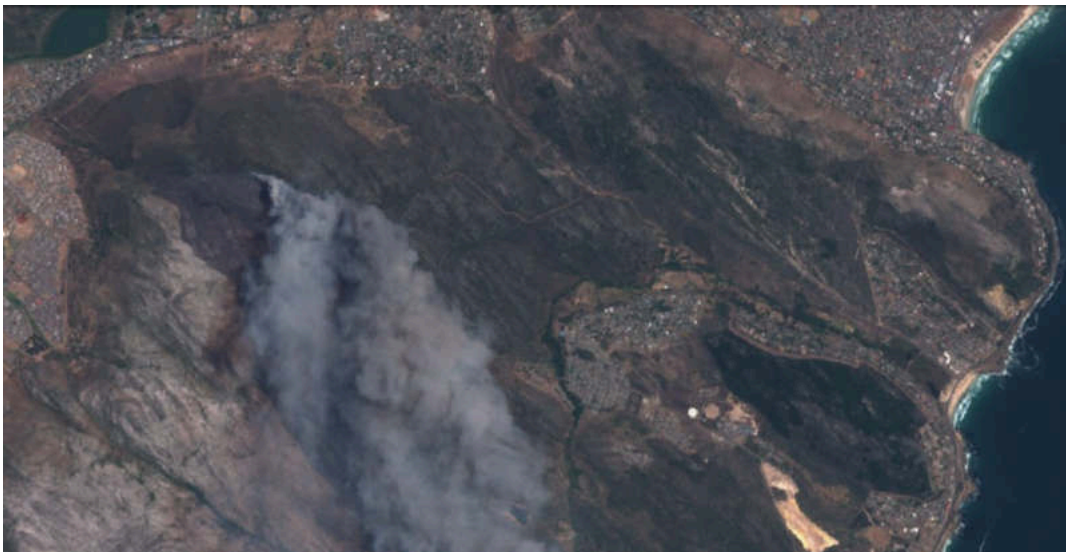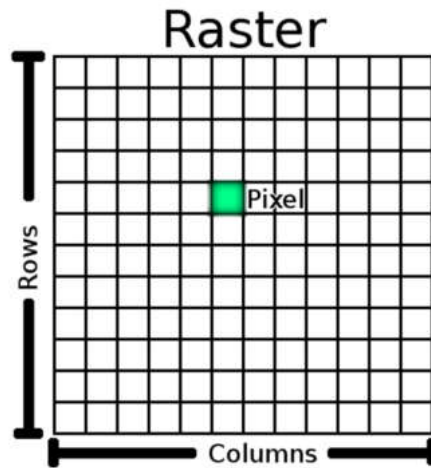
Raster image from a satellite of a veld fire near Simonstown in the Western Cape.

Activity Three

3.1.   Use the set of transparencies provided and answer the questions below:

   3.1.1.   Set the layers.

   3.1.2.   Identify which province has the most number of district municipalities?

   3.1.3.   Identify which province has the least number of district municipalities?

3.2.   QGIS is an open source GIS software, meaning that it is free for anyone to download and use. Now use QGIS to answer the questions in 3.1. Appendix B (page 40) is a user guide for you to follow.

Data standardisation

When you look at the ID number of a South African citizen, the ID number starts with the first two digits being the year in which you were born, the next two digits being the month in which you were born and the next two digits being the date on which you were born. All ID numbers in South Africa have 13 digits. Did you ever wonder why this is so? The data for the ID is put in a format that has meaning to any person reading the ID number and this is known as data standardisation.

When data is sourced you will find that there are different formats in which data is stored. When data is shared, it is problematic for users if the data is in different formats. Geography Markup Language (GML) is the standard for spatial data for the South African Government's Minimum Interoperability Standards (MIOS). Interoperability is the ability of different systems to work together.

Data sharing

Data is collected from different sources such as local government, provincial government, and national government. The benefits of sharing data can reduce costs amongst different government departments.
The most effective way to share data would be through the internet. Data can be shared through:
• 	Shared folders or directory
• 	Use URLS to download full data sets as files
• 	Email for small data files
• 	Web services such as Web Map Services (WMS) and Web Feature Services (WFS)
• 	Connect to a database where the spatial data is stored
• 	Application Programming Interface (API) which the developer gives access to the user for the content

Data security

Data security refers to the confidentiality and integrity of the data. In South Africa, certain government data is accessible to the general public. Security measures are put in place to ensure data security. Some of the security measures are database or file system, web services or application. There are numerous ways that data security is applied eg. read-only access, write or edit access, access to delete data sets or create new ones.

Data manipulation and application of GIS Techniques

Data is manipulated by changing or reorganising the data to make it more beneficial for the user.
- Editing by changing the features or moving the features around
- Linking of data sets for integration
- Simplifying the data
- Adding or removing attributes

Data integration

Data integration is combining data from different sources and providing an integrated interpretation of the data to the user. The questions that need to be answered when doing a GIS project is:
- What type of data do I need?
- Where can I get the data?
- What map layers do I need?

Prior to integrating data, you need to ensure that:
- Data is in the correct format
- The data is cleaned and the data is of high quality
- The projection and coordinate reference system is chosen

Data standards for quality
- The data fields or attributes contain the content that is needed for the GIS project
- The geometry is correct. For example, if a polygon is not closed, it means that the coordinates of the polygon at the start and finish are not the same and this polygon cannot be used. A polygon cannot be used if it is intersecting itself.

When data is integrated it is crucial that the map layers are overlaid accurately. The alignment needs to be correct so that all layers provide correct information. The layers must align themselves in their rightful geographic positions.

How can you make sure that layers are aligned?

- Coordinate reference system (CRS) refers to how your map that uses coordinates is drawn in GIS is viewed in relation to the places on earth.
  Using different CRS between layers is the main culprit if layers are not aligned. The type of CRS to use depend on where you want to work and the analysis you want to do.
- Here are some ways you can make sure your layers are aligned:
  - CRS of the geometry needs to be defined accurately.
  - Geometry should be in CRS defined above
  - CRS for the project should be understood by GIS software or the GIS software should change the data to the CRS that is being used

Analysis – Buffering

Buffering is when you make a zone of which the distance is specified from the original feature's edge and that zone is called the buffer zone. The buffer zone is made around features such as a point, line or polygon feature. Buffer zones are created for environmental protection, protection of people from natural disasters, etc. In the following exercise, we are going to use buffers in order to solve a problem.

Activity Four

4.1.   When farmers use river water to irrigate their fields, the further away from the river the field is the more expensive it is to water that field. Using the imagery given to you, answer the questions in the below activity.

   4.1.1. How many circular fields are within 500m of the river?

   4.1.2. How many circular fields are within 1km of the river?

   4.1.3. Which Buffer (500m, 1km or 2km) contains the most circular fields?

   4.1.4. The fields of which Buffer are going to be the cheapest to pump water to?

   4.1.5. The fields of which Buffer will be the most expensive to pump water to?

4.2.   Appendix B is a user guide for you to follow the steps to be able to answer activity 4.1 using QGIS.

Querying

Querying is to retrieve the attribute data that has been specified by the user and this attribute data must satisfy the criteria set by the user. Eg. data that show rivers that are less than 10 000m in length.

In the example below all Fields within 500m of the river were selected using the following SQL query:

SELECT 'fields' WITHIN 500 of river

Statistical Analysis

The data in a spreadsheet or database field is the same as spatial data attributes or fields. Statistical functions used to analyse data in a spreadsheet can be used in GIS. Statistical techniques that can be used in GIS are:

•   Distribution: eg. Distribution of fish species in the ocean
•   Classification: eg. Urban or Rural
•   Patterns: eg. Rainfall patterns in different provinces
•   Aggregation or summaries: eg. The elevation of the catchment area

Remote Sensing

We use our five senses to understand the world around us. The sense processes are:

Seeing

Hearing

Smelling

Touching

Tasting

Close contact with objects allows one to touch and taste. However, to see or hear we do not need close contact with an object and in this instance, we are remote sensing as we are gathering information about an object without physically coming into contact with it.

Remote sensing can be defined as collecting information through recording, observations, sensing objects or events without direct contact. Remote sensing allows for information about the Earth to be collected from a distance. Remote sensing is done from aircrafts and from satellites that are orbiting at distances from a few hundred to 36 000 kilometres above the Earth.

Image of a satellite collecting data
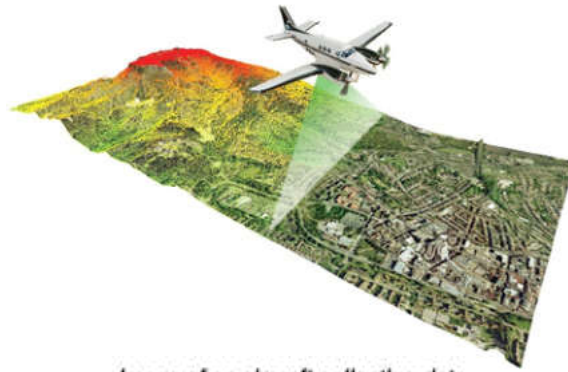
Image of an aircraft collecting data

Types of Remote Sensing

Passive Remote Sensing	Active Remote Sensing
The source of energy is the sun or earth/atmosphere	The source of energy is part of the remote sensory system called Radar
Wavelengths of the sun are 0.4-5µm. Wavelengths of the earth or atmosphere are 3 µm-30 cm	Wavelengths of the radar are in mm-m. These include ultraviolet, visible, and near infrared wavelengths.

Remote sensing data types – raster and point clouds

Remote sensing datasets come in 2 types. Point clouds or as raster images.
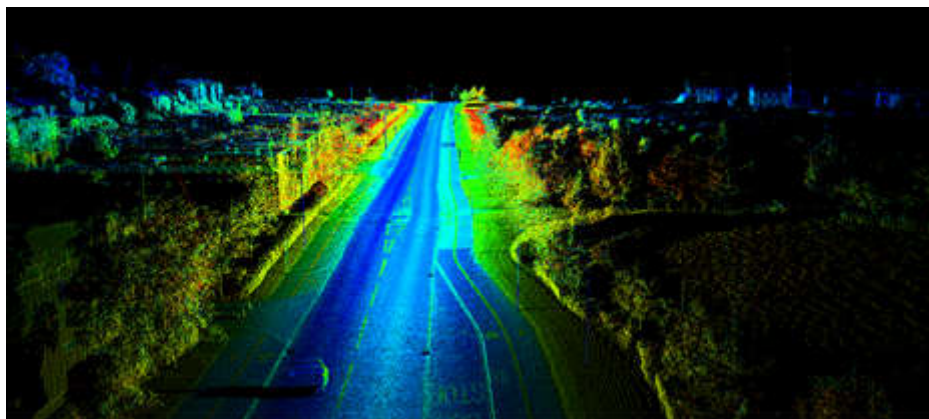
Point clouds are three-dimensional (3D) datasets that get created by scanning the world with a laser range finder or LIDAR system. Each place that the laser scans is then added to a dataset that gives us the GPS co-ordinates and height above sea level for each point. This enables us to build 3D models of the world.

This type of data is not very common as it is expensive to generate, however as sensors become cheaper we will probably see more and more uses for this information.

Resolution

Resolution is defined as the size of the unit of measure. It can be broken up into different classes, being spatial, temporal and radiometric resolution.

Spatial resolution: is the smallest object that a sensor can resolve. Spatial resolution refers to on the ground linear dimension of each pixel or grid cell. Spatial resolution indicates the amount of detail that is found in a map or image. In the example below, the first image has a coarse resolution, i.e. one pixel of the image represents an area 17km long by 17km wide! As you can see, with coarse resolution images it is difficult to see detail in the picture. The far right image has a resolution of 1km so one pixel of the image represents an area 1km by 1km. This enables us to see a lot more detail. Some satellites have a resolution of 3cm. But, the problem with working with very high resolution images is that the images take up a lot of storage space on a computer and are difficult to process due to their size.

Activity Five
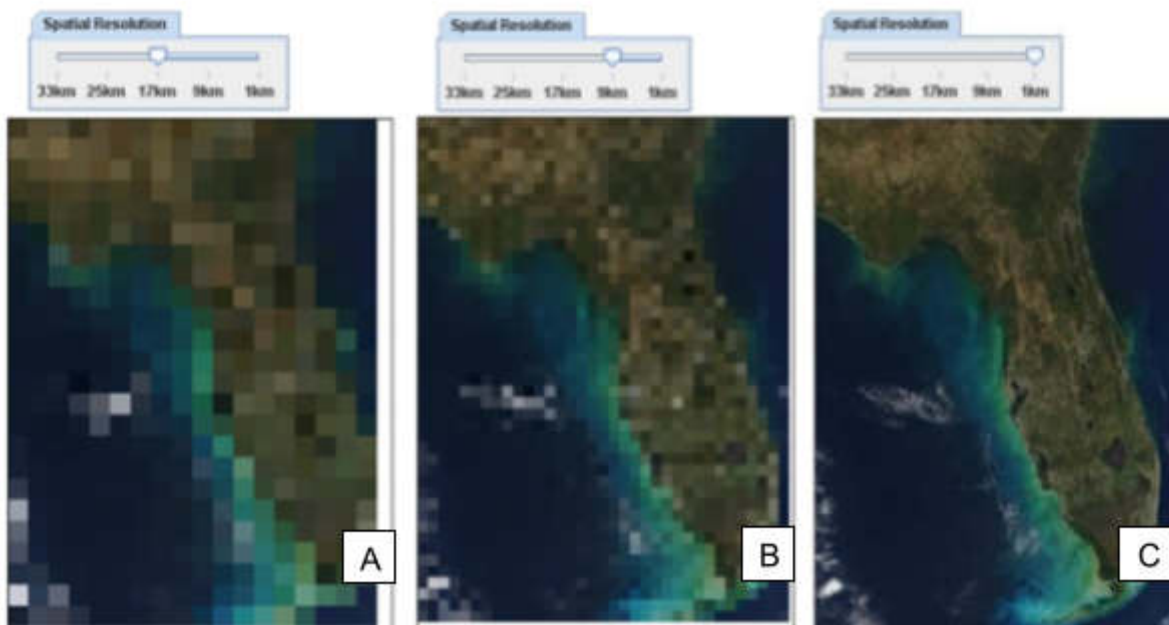
Which picture (above: A, B or C) has the highest spatial resolution? Give a reason for your answer.
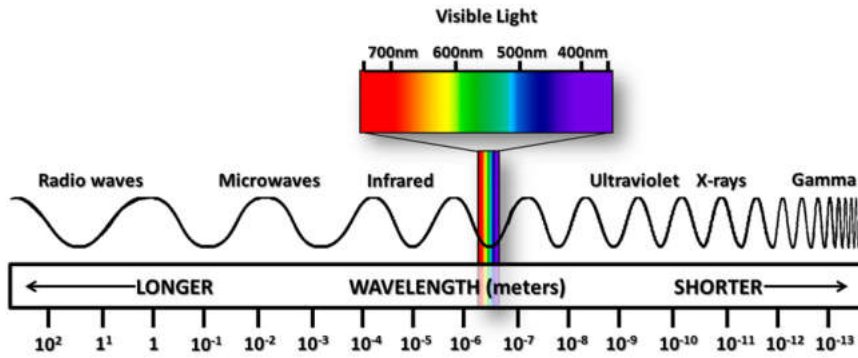
Spectral resolution: tells us the specific wavelengths within the electromagnetic spectrum that the sensor can record as information.
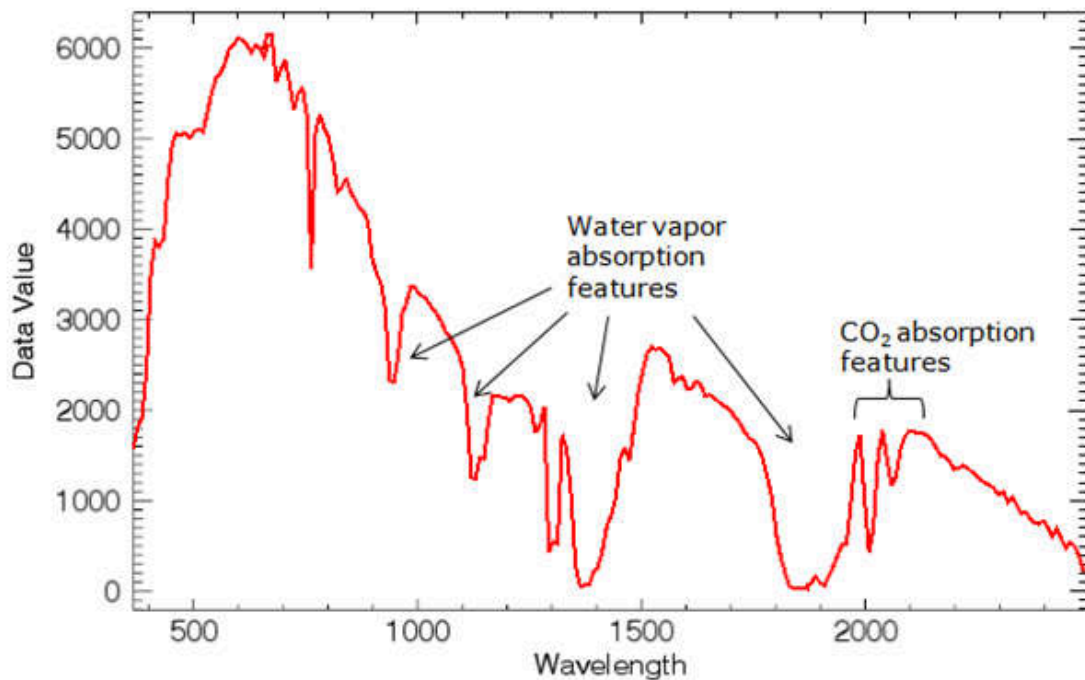
Temporal resolution describes how a sensor can get an image of a particular place of interest. Eg., a satellite passes a certain location every 48 hours and images are only processed every 48 hours.

Radiometric resolution tells us the amount of brightness values that is likely in every band of data and is calculated by the number of bits into which the recorded energy is divided into.

Conclusion

This manual in conjunction with the appendices can be used to teach GIS using paper based activities. The link for the QGIS software has been provided together with the data for the activities 2 to 4. We suggest that when teaching each section, start with the paper based activity. Thereafter get learners to implement the same activity using QGIS (if your school has access to computers).

We encourage you to use QGIS to teach GIS in your classrooms as this is free software and can be installed on computers in your lab.

Appendix A: Creating your own spatial datasets in Google Earth Pro

Google Earth is a geospatial software application that combines satellite images, aerial photography, and GIS data. Google Earth allows users to explore the globe, using a computer and the internet.

The Google Earth Pro desktop application can be downloaded at: https://www.google.com/earth/versions/download-thank-you/?usagestats=1.

Please note that you need to be connected to the internet for the images to load.

Manual Digitising in Google Earth

Google Earth offers high resolution imagery that can be used for digitising land features and for ground truthing (validation of land cover classification).
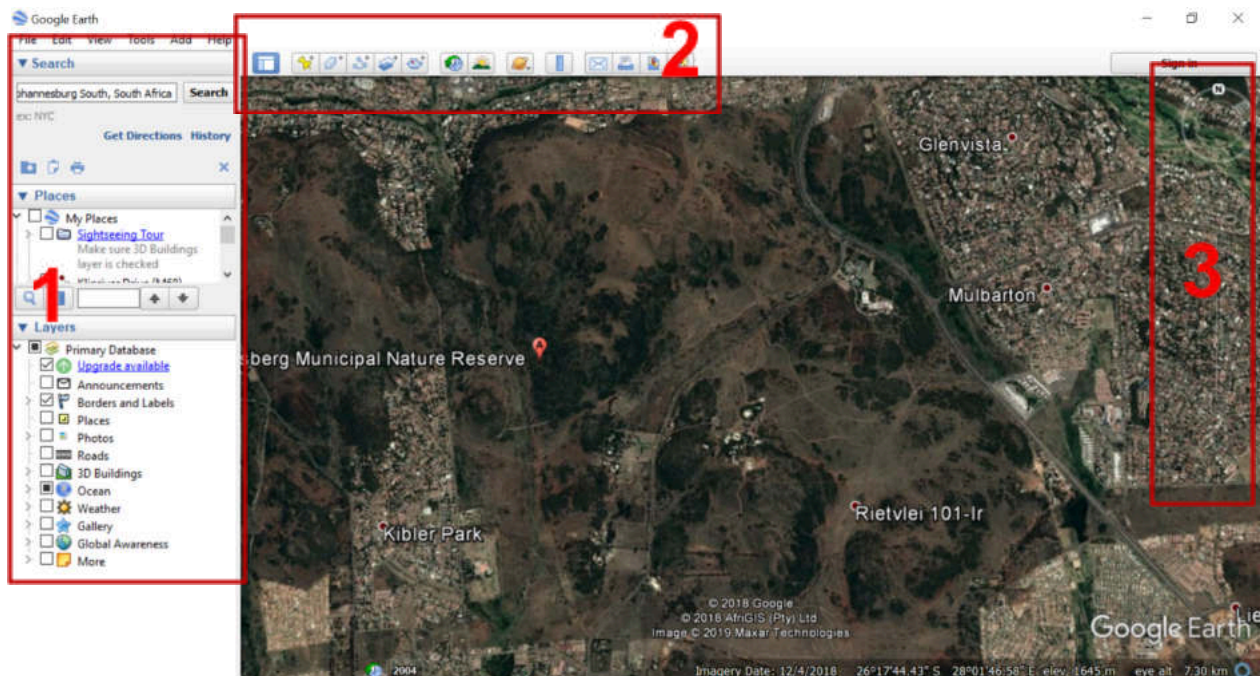
1 – The left panel contains "Search" (for searching locations), "Places" for locations that have been digitised or saved, and "Layers" for layers of information and features that Google Earth offer – you can switch them on and off by clicking the small check-box next to each feature.

2 – The top panel of the Google Earth interface includes 14 buttons which allows you to do various tasks. Hover (the cursor) over each button to see what it does.

3 – The top right corner is a navigation panel, which lets you navigate around the map and move it in all directions and angles. The bigger navigation circle with an eye

in the centre and "N" on top (denoting "North"), allows you to **tilt** the map up, down, left and right. Clicking the "N" will bring the map back to its "true North" position. The second and smaller navigation circle with a hand in the centre lets you **pan/move** the map up, down, left and right. The orange standing man icon shows a street view – in other words, it allows you to zoom all the way in on the feature as though you were on the ground. Lastly, the vertical slider bar with plus (+) and minus (-) signs is also used for zooming in and out.

Ditigitsing a point feature

To digitise a point feature, simply select the "Add Placemark" button. A New Placemark dialogue window will appear, while the placemark flickers on the map. In the dialogue window, you can give the placemark a name and below it is the geographic coordinates of the point (longitude and latitude).
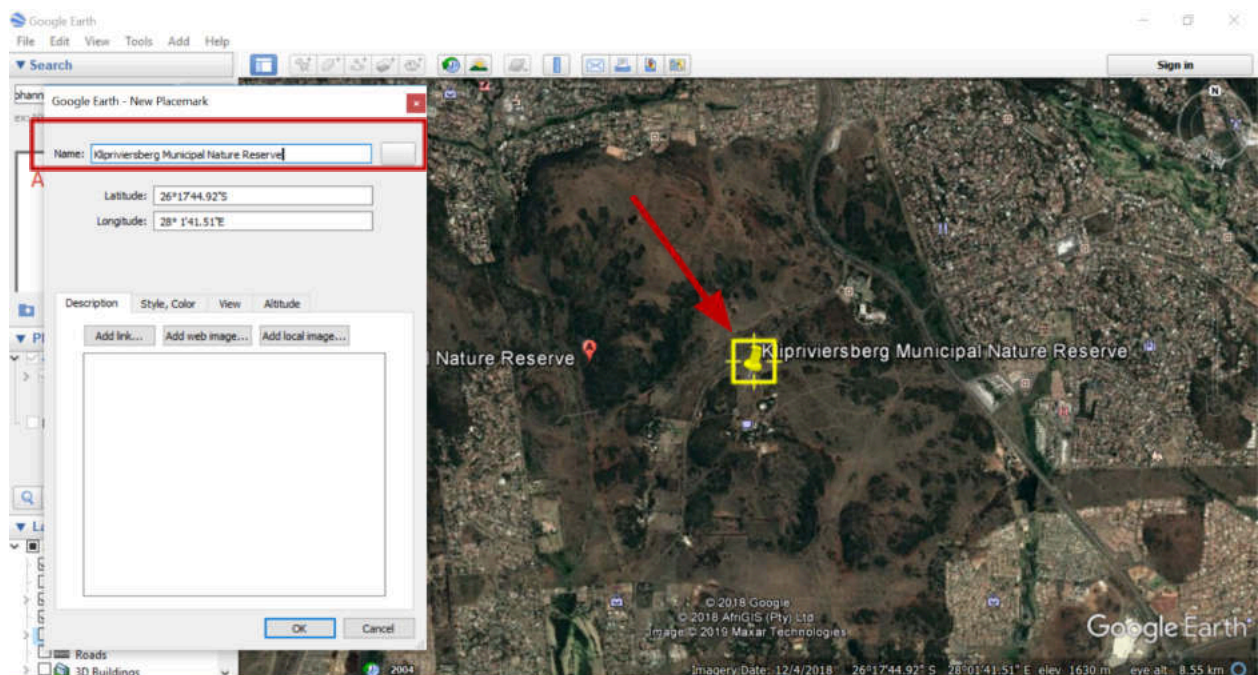
At bottom of the "New Placemark" window there are 4 tabs – **Description**; **Style, Colour**; **View** and **Altitude** – which can be altered to your preference. Under "Description", you can type in any information relating to the feature in question. You can also add a link, a web image, or a local image as references for the point you are creating. The "Style, Colour" tab allows you to change the colour, scale (size) and opacity (%) of the point label as well as the icon (symbol).
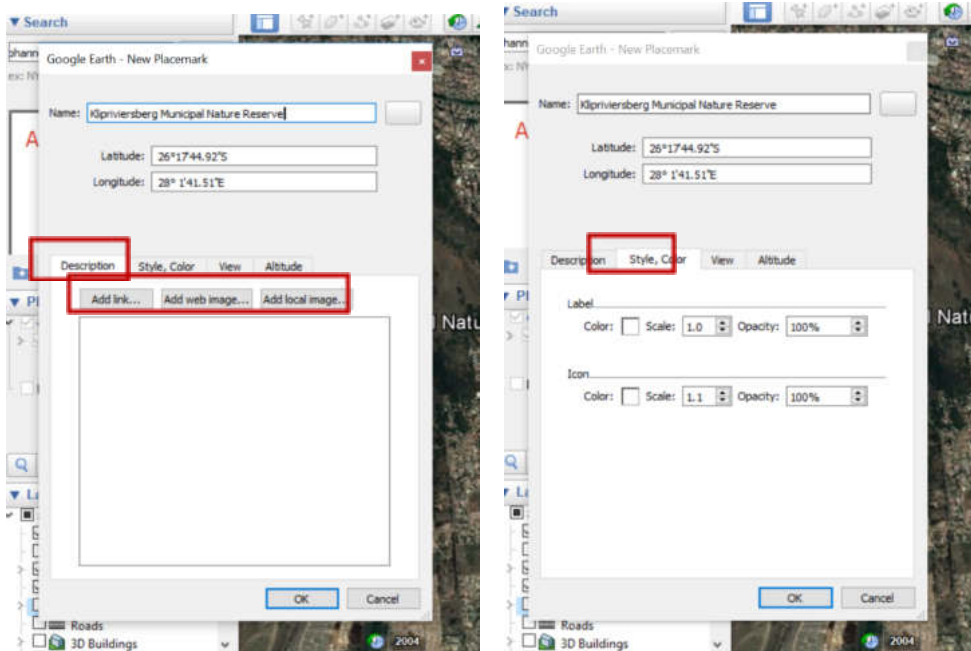
The "View" tab shows metadata such as longitude and latitude of the point, range, heading, tilt as well as date and time. The "Altitude" tab shows the altitude of the point - the drop-down menu next to altitude lets you choose whether altitude is measured from the ground, sea floor, relative to ground, relative to sea floor or absolute. Do not click OK or cancel on the dialogue window until you have named the feature and placed it in the right position. Use the mouse to move the placemark to its appropriate position while the dialogue window is open.
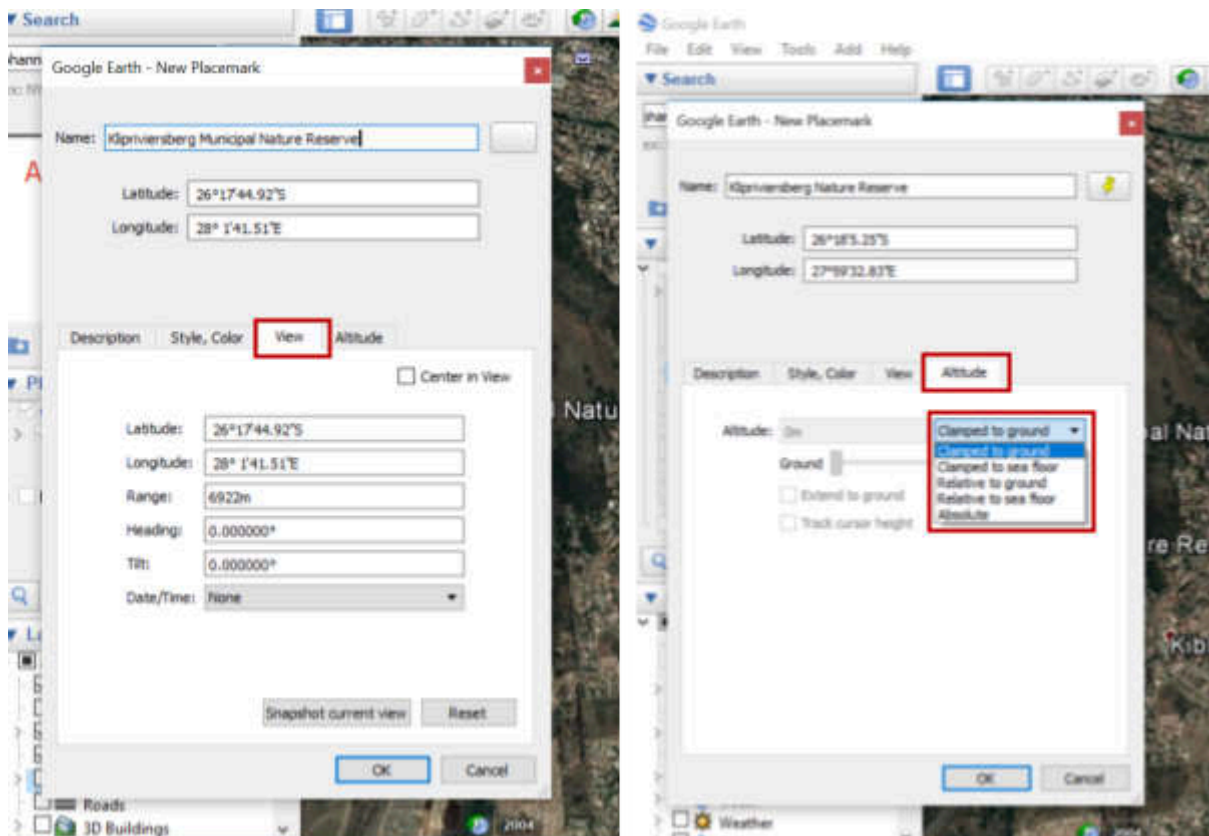
Digitising a line / linear feature

Lines are made of a series of connected points from the starting to the finishing point. To create a line feature, select the "Add Path" button and a "New Path" dialogue window will pop up. Follow the steps above to give the path a name, change symbol colour, and view metadata. When drawing a line, use one left click to place a point. If you wish to remove a point that is misplaced, right-click on the point and it will be removed. Place points subsequently along the linear feature until the end, before clicking OK on the New Path dialogue window. Red dots show how far you have come, and the blue dot shows the last point digitised (so you know where you left off). To end, double-click on the last point. The spacing between your points will depend on the shape of the line feature. Sharp curves require more and closely spaced points for a smooth curve. Straighter lines can have fewer points.
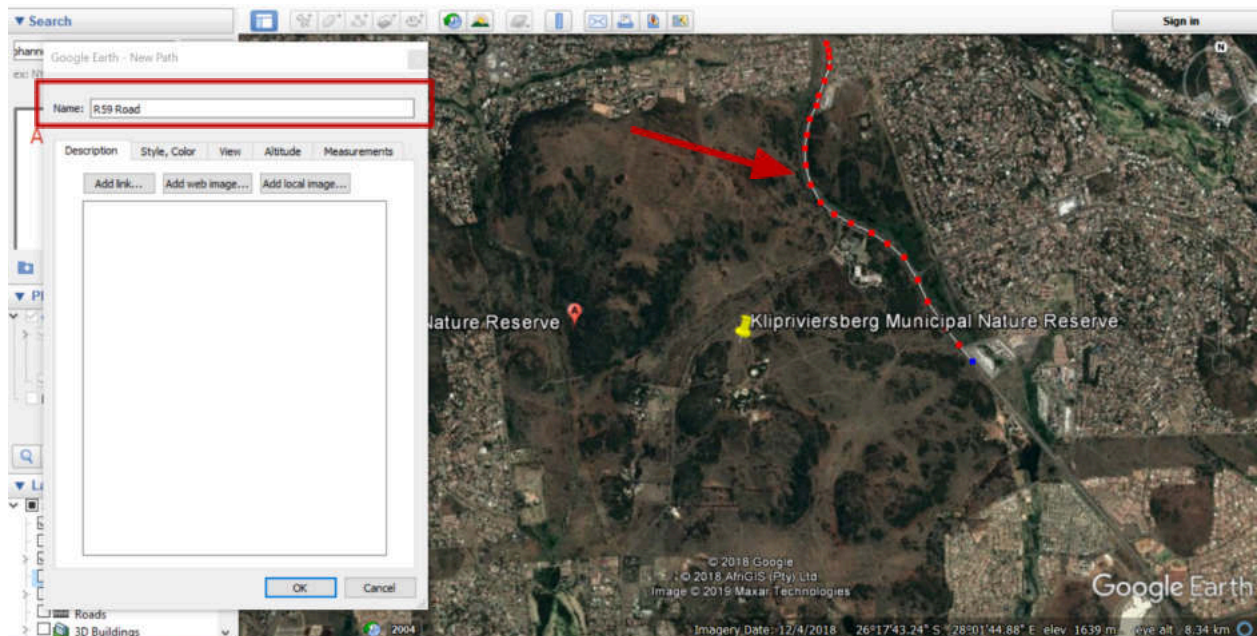
Digitising a polygon

Polygons are made of a series of points that are connected sequentially and such that the last point meets the first point. To create a polygon feature, select the "Add Polygon" button and a "New Polygon" dialogue window will pop up, follow the steps above. Follow the steps above to give the polygon a name, change symbol colour, and view metadata, it is the same as for a line or point. Change the opacity of the fill to 0%, this will allow you to see what you are trying to digitise on the satellite image. Remember to double-click to end digitising.
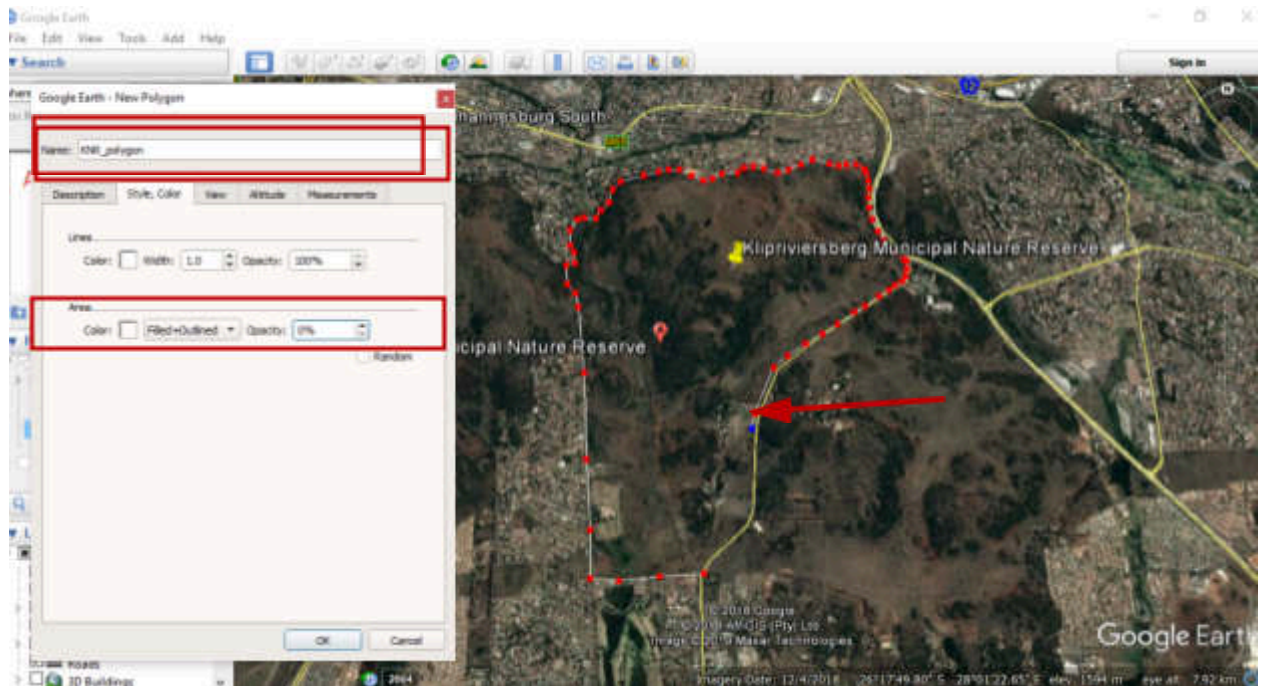
Once you have digitised all of your desired features, you can view them together using different colours, as shown below. In case you closed the properties dialogue before you finish digitising, you can edit it later by right clicking on the feature ("Places" tab) and select "Properties".
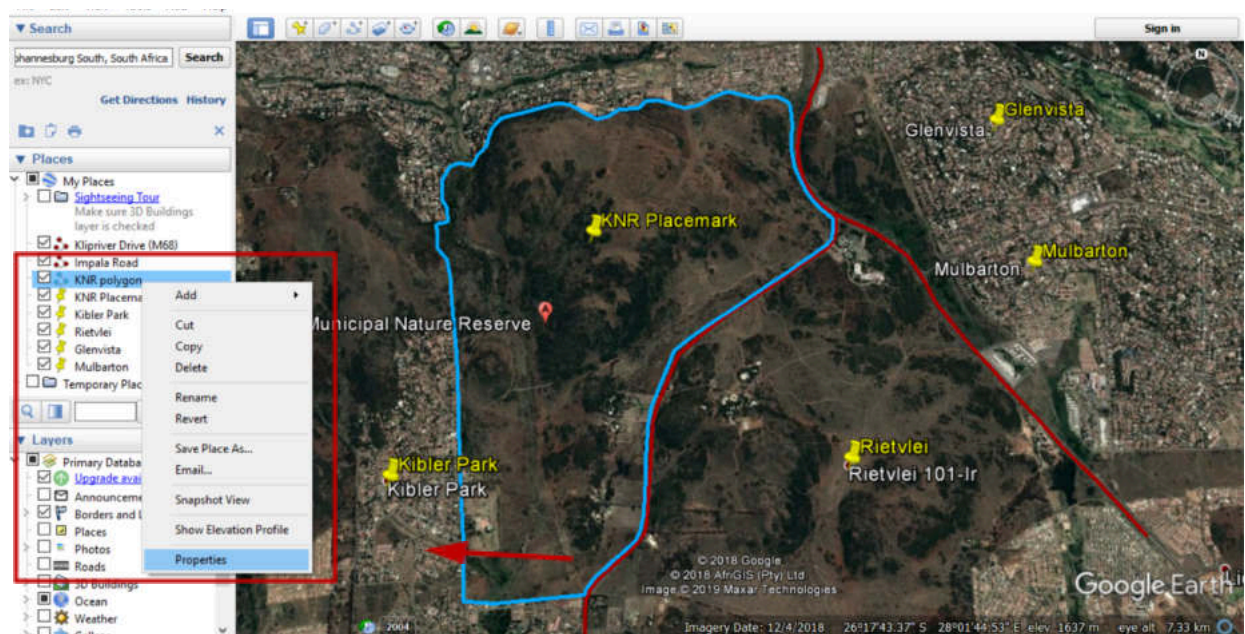
Saving Digitised / saves places as KMZ/KML files

To save your newly digitised places, go to "Places" on the left panel, scroll to your desired place, right click on it and select "Save Place As". A windows file explorer will pop
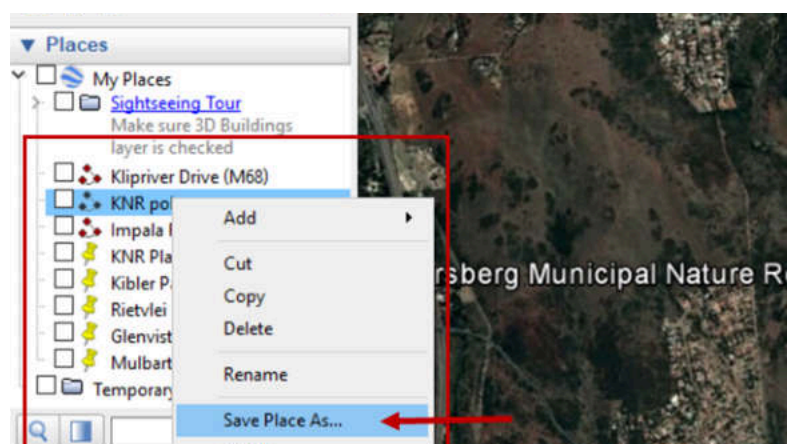
up so you can navigate to the location where you wish to save your data. Note that the format of the file is "Kmz(*.kmz). This is a standard format for all Google Earth features.

Importing KMZ/KML files into QGIS

Simply drag the (kmz) file and drop it onto QGIS window! ☺

Appendix B: How to use QGIS

What is QGIS?

QGIS is an Open Source Geographic Information System. This means QGIS is free software, making GIS available to anyone with access to a computer.

This user guide takes you through the step by step process needed to complete the activities in SAEON's Training Manual for Geographic Information System (GIS). If you wish to learn more than what is in this training manual there are many user guides and training manuals on QGIS at **https://docs.qgis.org/3.4/en/docs/**

Installing QGIS

You can download QGIS using the following link: https://www.qgis.org/en/site/forusers/download.html. Download the QGIS Standalone Installer from the long term release repository. This manual is based on Version 3.4.

After downloading the setup file, open the file and install the software simply clicking "Next" for all dialog options.

QGIS is open source software and is therefore continually updated. Different versions may look slightly different, but the basic processes remain the same. You can download older versions through the "all releases tab".

Download data for these activities

Download the Google Drive folder below, to get the shapefiles.

You will need to unzip the folder to get the shapefiles. Once you downloaded the activity folder to your computer, **right click** on the folder and click **Extract All....**

Activity Three

Activity 3.1 demonstrates the concept of layers using transparencies.

3.2. Now perform the same tasks using QGIS software on a computer instead of using transparencies.

    3.2.1.   Set the layers.

    3.2.2.   Identify which province has the most number of district municipalities?

    3.2.3.   Identify which province has the least number of district municipalities?

Think about what information you need to answer the questions of which province has the most and least number of district municipalities.

Information you will need:
- Provinces of South Africa
- District Municipalities of South Africa

You can also freely download many of these spatial data sets for yourself if you want to create different maps.

3.2.1 Set the layers

Before adding a layer, you need to decide whether your data is represented as a raster or a vector. The vector format indicates the location and shape of features and boundaries, in the form of a point, line or polygon. While raster data has a grid based format or can be a photograph.

What data format do you think the provinces and district municipalities will be?
   a) Both the provinces and district municipalities will be vector data as they represent boundaries in the form of a polygon.

Adding a vector layer for activity 3.2.1:

Once you have opened QGIS, click on **Layer -> Add Layer**, and **Add Vector Layer** or press **Ctrl + Shift + V.**
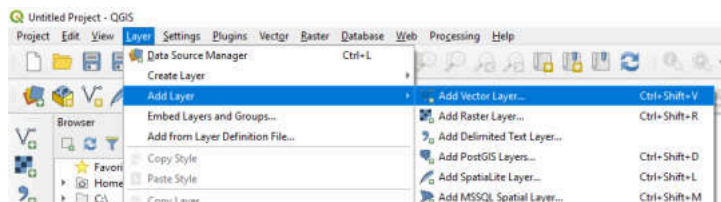
This will bring up the Data Source Manager|Vector dialog box below.
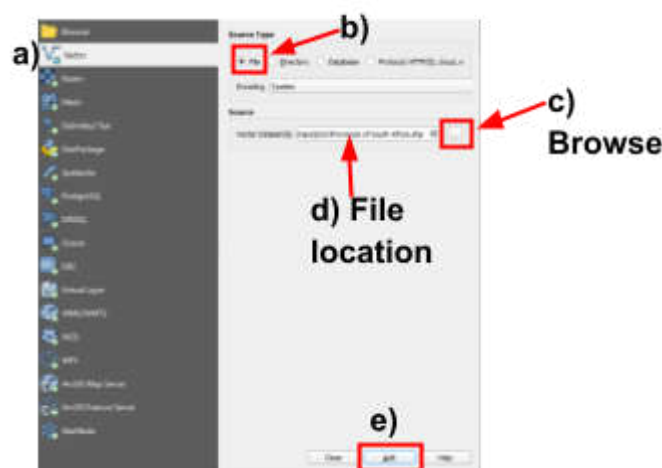
   a) Make sure the **Vector** tab is selected
   b) Select **file**
   c) Click **Browse** [...]
   d) Search for the layer you would like to add (In the case for Activity 3.2, this will be "Provinces.**shp**") and click **open** to on your selected file.

A shapefile, a geospatial vector format, must have at least three extensions (".shp", ".shx" and ".dbf"). When adding your shapefile in QGIS make sure you select the file with the extension ".shp". If you select the wrong file extension you may get an error message "invalid data source". This is because you want QGIS to draw you shapefile and ".shp" is the main file and contains the information about the geometry and shape of the features. Whereas, ".shx" is an index file and ".dbf" stores that attribute information.

e) Once your file/files are selected as the vector dataset(s) click **Add**.
The data you selected will now load. The *Provinces of South Africa* has now
been added to the Layers Panel and its features have been drawn.
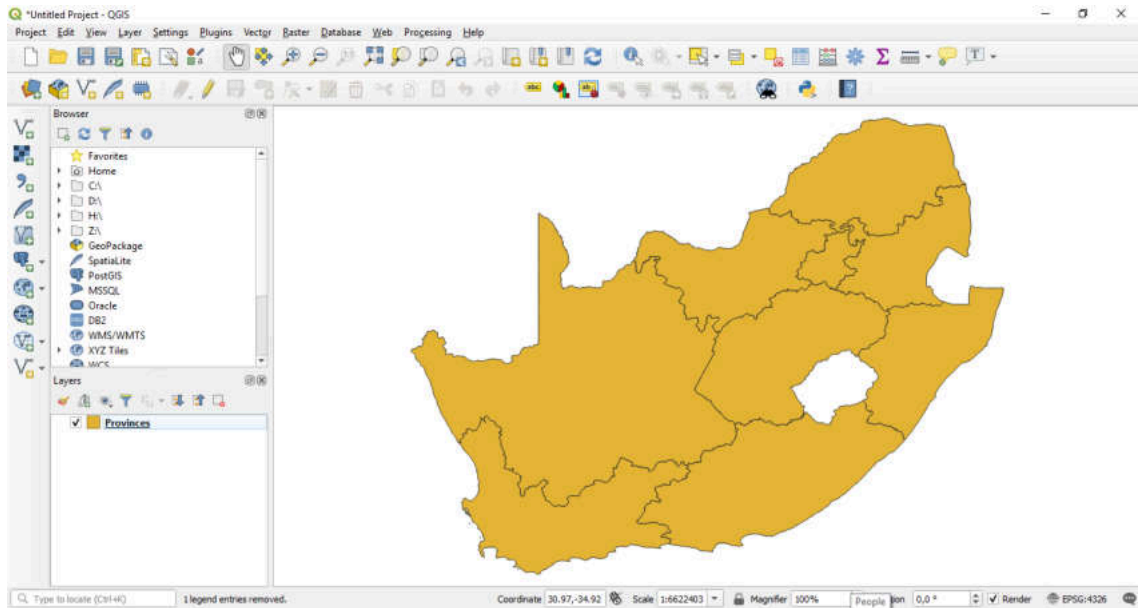
To add the local municipalities' layer, follow the same steps as above to add a vector
layer, **except in step e)** select "District_Municipalities.**shp**".

As you can see there are now 2 layers (District Municipalities and Provinces) in the
layers panel.
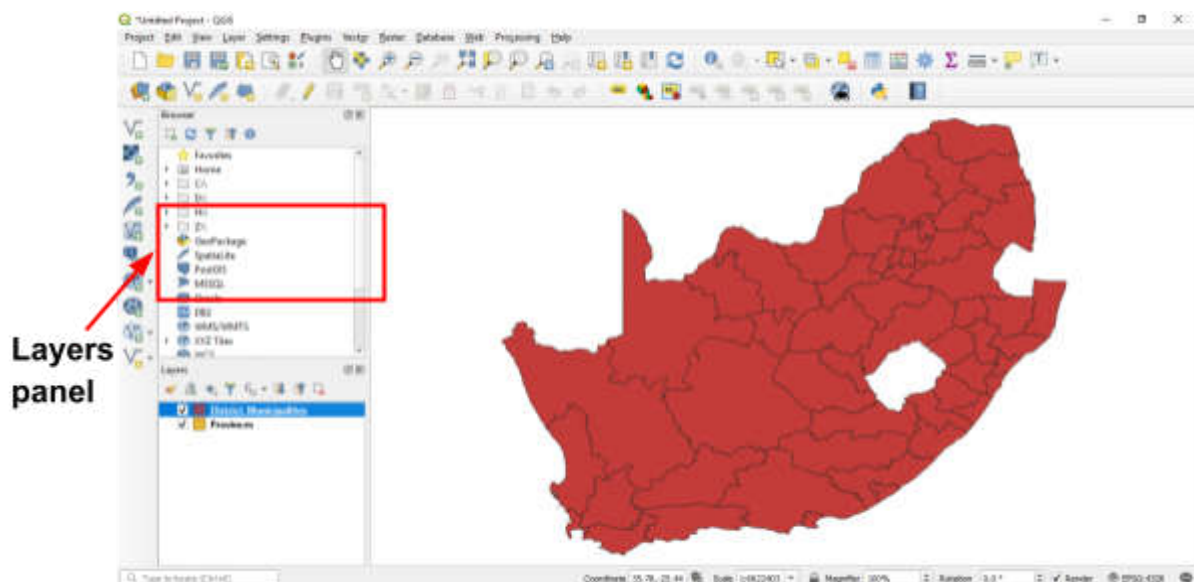
Alternatively, you can simply drag and drop the file that you are wanting to open (eg.
Provinces.**shp**) from File Explorer or your browser onto the QGIS window.

Adding a raster layer:

One of the transparencies you were given is a raster and is a satellite photograph or base map of southern Africa. While we don't need the base map to answer our question, it is nice to know how to add one.

To add a raster layer, click on **Layer -> Add Layer**, and **Add Raster Layer** or press **Ctrl + Shift + R.**

This will bring up the Data Source Manager|Raster dialog box below.
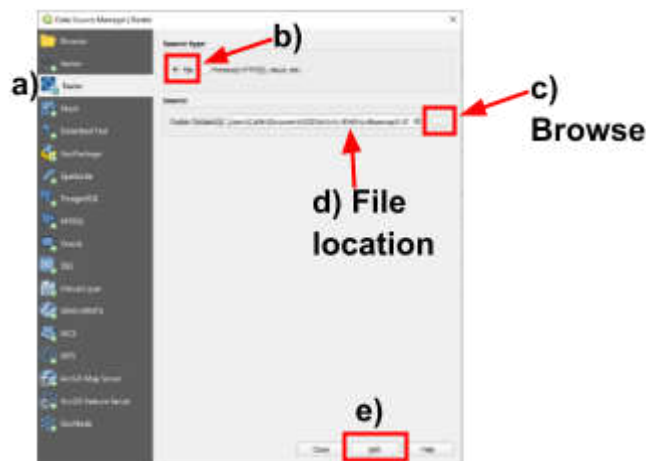
a) Make sure the **Raster** tab is selected
b) Select **file**
c) Click **Browse** ...
d) Search for the layer you would like to add (In the case for Activity 3.2.1, this will be "Africa_basemap") and click **open** on your selected file.
e) Once your file/files are selected as the vector dataset(s) click **Add**.
The data you selected will now load. The *Basemap_Africa* has now been added to the Layers Panel and its features have been drawn.

Changing the order of layers:

As you can see in the Layers Panel you have added the *District Municipalities* and the *Provinces* layers (you may also have added the base map). But you cannot see the *Provinces* shapefile, because it is below the *District Municipalities*.

To fix this problem you can **click** on the *Provinces* layer in the **Layers Panel** and **drag it** above the *District Municipalities* layer.

You should now see the *Provinces* layer above the *District Municipalities* layer in the Layer Panel and *Provinces* drawn on the canvas.
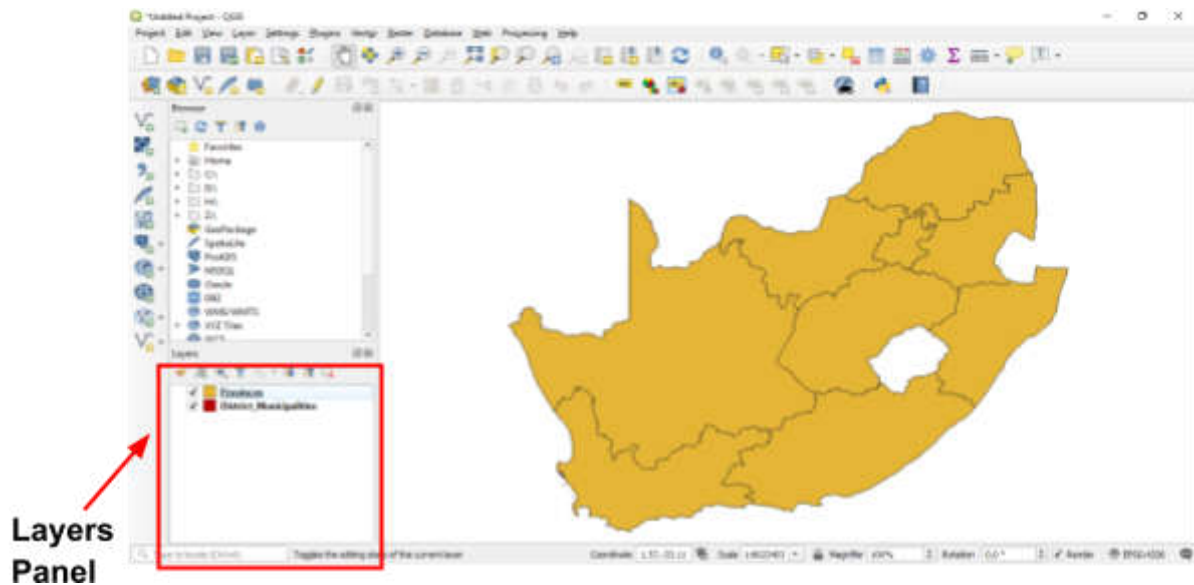
Changing the colours of a layers:

Right click on the layer you want to change the colour (*Provinces*) of and select **properties.** Alternatively, you can **double click** on the layer (*Provinces)*.
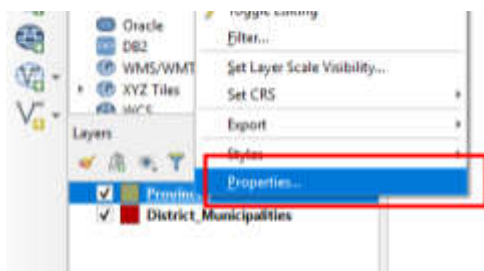
This will bring up the **Layer Properties** dialogue box.
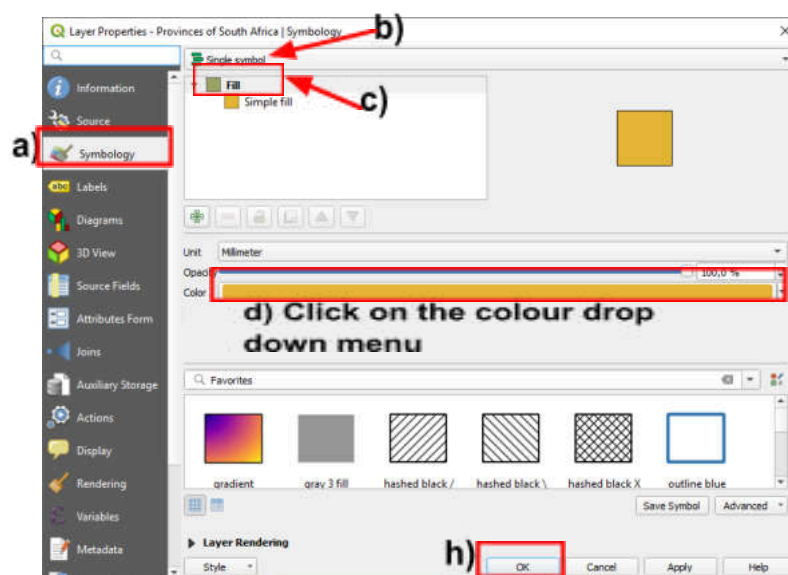

a) Make sure the **Symbology** tab is selected

b) Make sure the **Single Symbol** is selected
c) Select **Fill**. If you select Simple fill you are able to change the fill and line colour.
d) Click on the **Color drop down menu**
e) This will open the **Select Color** dialogue box. You can select any colour by switching between the tabs at the top and the colour options below.
f) For this activity, we want the Provinces of South Africa to have a transparent fill (so we can see the layers below). To do this change the **Opacity** to **0%**.
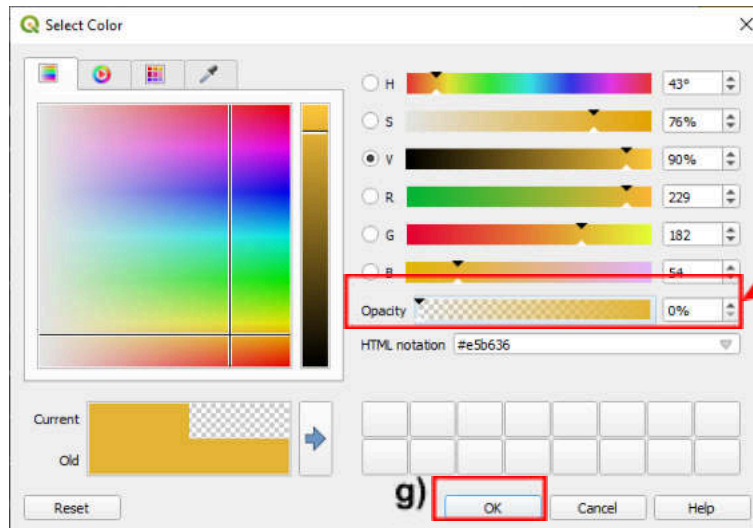
f) Change the opacity to 0% to make the layer fill transparent

g) Once you have selected your colours click **OK**.
h) This will bring up the **Layer Properties** dialogue box again. Click OK to change the colour of your layer.

Now that you have made the fill colour on the *Provinces* layer transparent, you can see the *District Municipalities* layer below. It is difficult to see the outline of the different provinces, as the line (stroke) is the same for both layers.
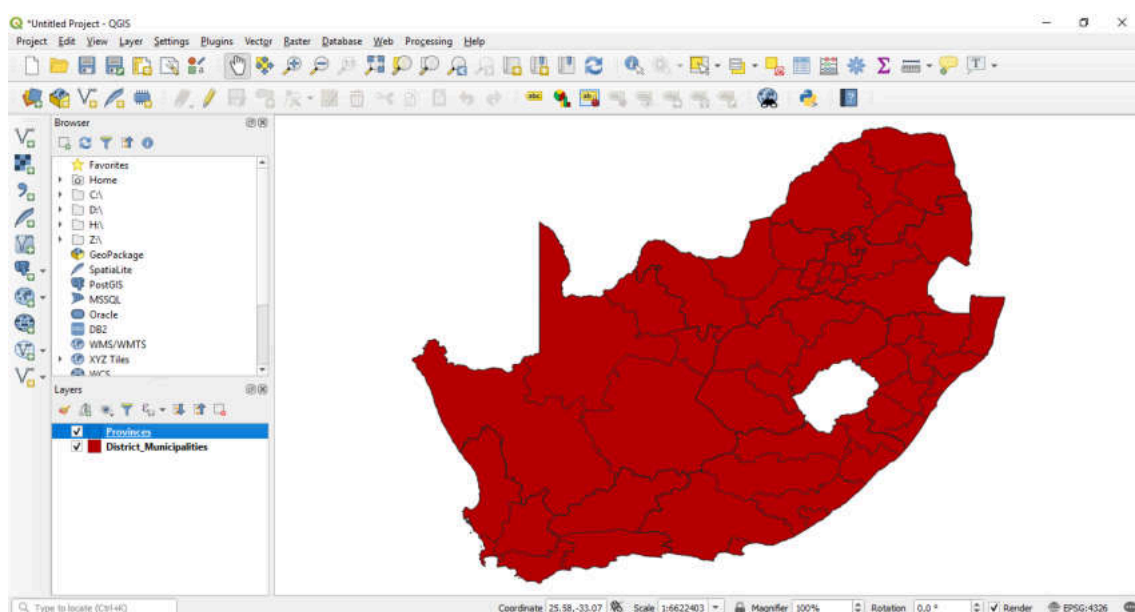
Now that you know how to change the fill colour of a layer change the fill colour of the *District Municipalities* layer to blue. To do this follow the same steps as above, except open the **Layer Properties** of the *District Municipalities* instead of the *Provinces* layer.

To make the province boundaries more clear, we can change the line (stroke) colour, width or style. For this activity, we are going to increase the width of the line to make the province boundaries clear.

Changing the line width of a layer:

This process is very similar to changing the fill colour of a layer above.

Right click on the layer you want to change the colour (*Provinces*) of and select **properties.**

Alternatively, you can **double click** on the layer (*Provinces)*.

This will bring up the **Layer Properties** dialogue box.
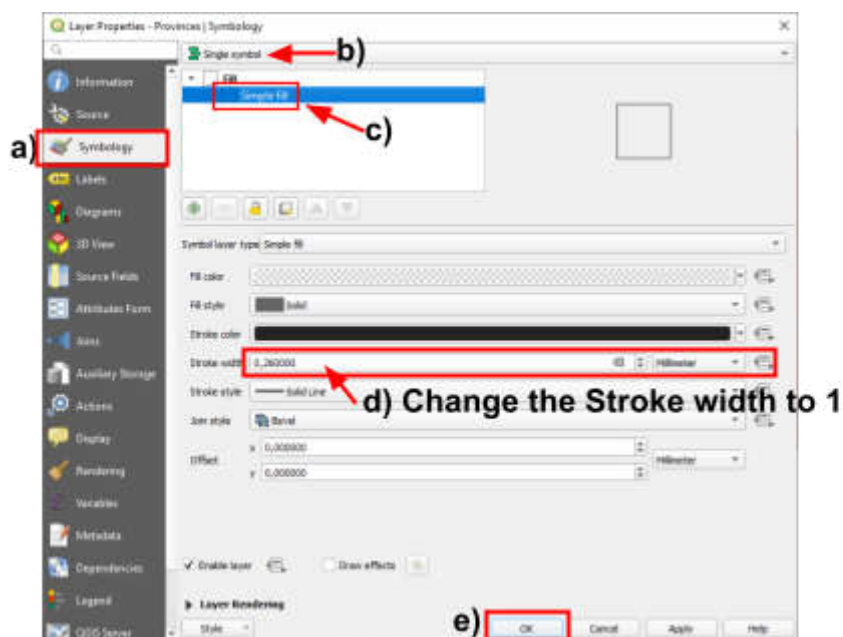
a) Make sure the **Symbology** tab is selected
b) Make sure the **Single Symbol** is selected
c) Select **Simple Fill**. This will give you options to change the stroke (line) colour, width, and style, which were not available under Fill.
d) Change the **Stroke Width** to **1**
e) Click **OK** to change the line width of your layer.

How to zoom in and move around the map:

You may want to move around your map and zoom in or out to specific areas.

To zoom into South Africa only, **right click** on that on the layer (*Provinces*) and click **zoom to layer.**

Alternatively, use the **magnifying glasses** to **zoom in** 🔍 **(+)** by drawing a block

around where you want to zoom into or to zoom **out** using 🔍 **(-)**.

Select the Pan Map icon 🖐 to help you move around the map.
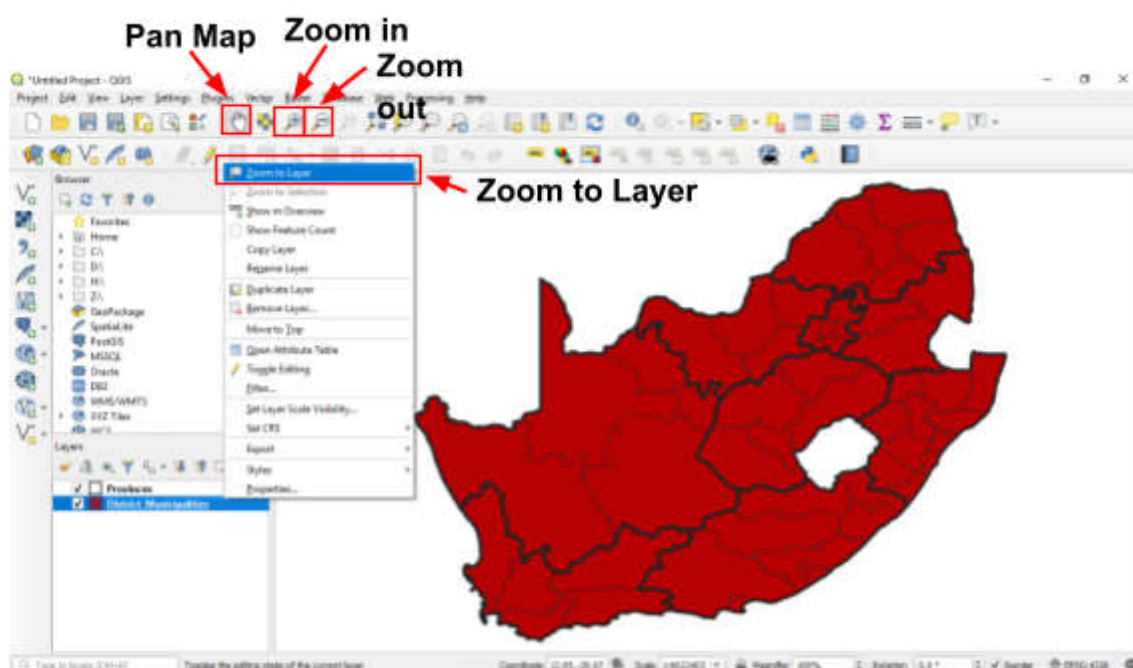
Now that you have set your layers and can draw colourful maps of your choice, we can answer the questions on the number of district municipalities in each province.

Check the coordinate reference system:

Before we start with any analysis we need to make sure that the layers we have added are in the same and an appropriate coordinate reference system (CRS).

The choice of coordinate reference system is dependent on the choice of your region that you are working in and the type of analysis that you intend on doing. A popular CRS is WGS84 (World Geodetic System 1984) which is used in GPS and has great accuracy. Activity 4, where you created buffers at different distances from the river) you need to use a projected coordinate system. Albers Equal Area is a map projection designed to preserve the relative sizes of areas on a map. This map projection is particularly useful when mapping regions with significant variations in

latitude, such as countries or continents. The is an Albers Equal Area specifically for Africa (**Africa_Albers_Equal_Area_Conic**) and is appropriate for the whole of South Africa.

You can find out more at:
https://docs.qgis.org/3.4/en/docs/gentle_gis_introduction/coordinate_reference_syste ms.html

- To check the CRS, **right click** on the layer - > **Properties** to open the **Layer Properties** dialogue box. Select the **Information** tab to view information including the CRS of the selected layer.

Both the *District Municipalities* and *Provinces* Layers are in WGS 84. We will learn how to change.
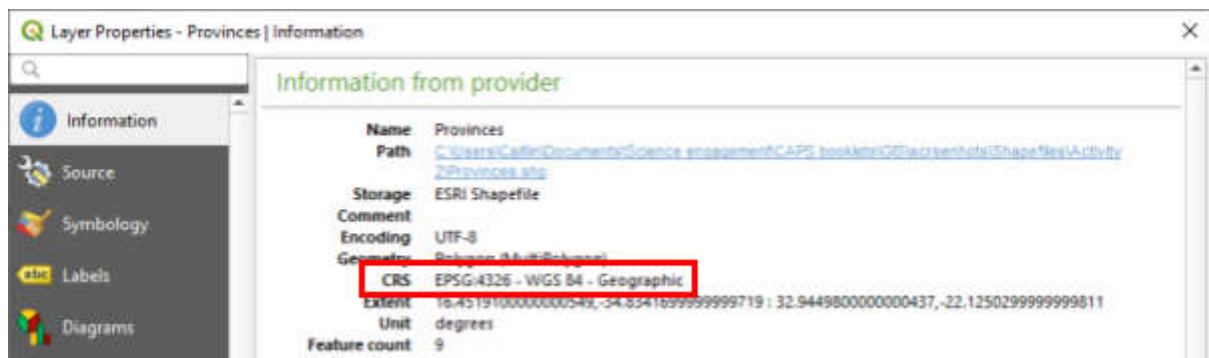
3.1.2) Identify which province has the most number of district municipalities?

To answer this question, we need to know how many districts are in each province. There are multiple ways that we can go about finding the answer.

I.   We could manually count how many districts there are in each province, as was done in 2.1.2.
II.   Alternatively, we could ask QGIS to select the districts within a certain province. This is known as selection by location.
III.   In QGIS you are also able to update the attributes data. We can add a column to the attribute data of the district municipalities to indicate which province each district municipalities are in.

Select by location (within)

Let's start by looking at how many district municipalities there are in the Northern Cape.

a) Select the *Provinces* layer by clicking on it in the Layers panel

b) Select the **Select features by area or single click** icon ⬚ . This icon allows you to select a feature that you click on.

c) Click on the Northern Cape province. The province should go yellow (as in the image below) to indicate that it is selected.

c) Click on the Northern Cape to select it

b) Select features by area or single click

Select the Provinces layer
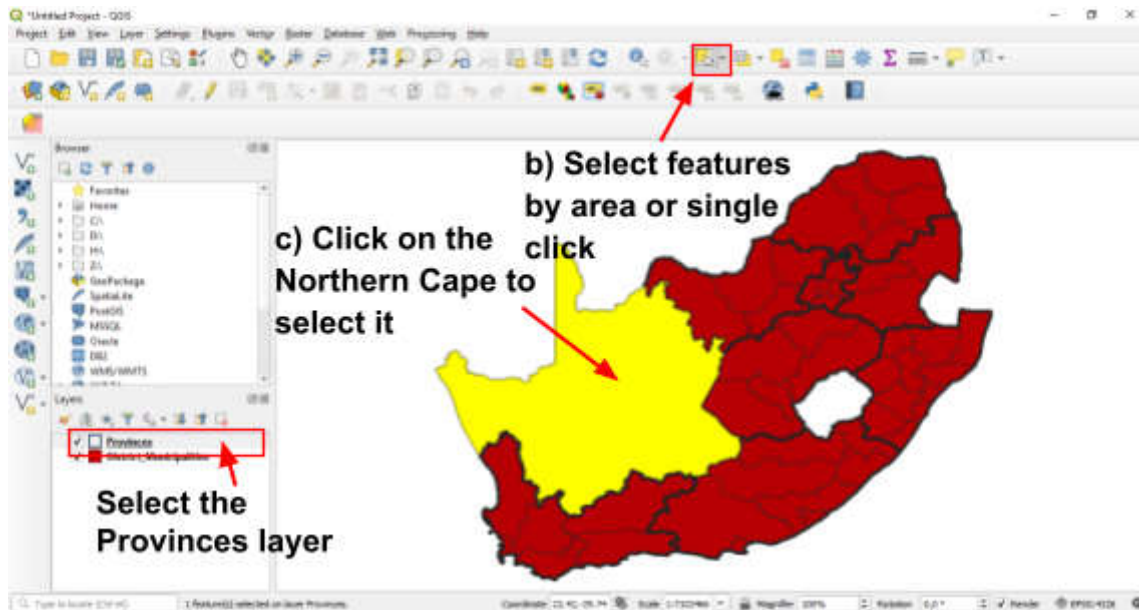
Now that we have selected the Northern Cape province, we want to select all the districts within that province. QGIS has a plugin (a feature) that you can add to do

this job, called **Select Within** .

I. Click on **Plugins** and select **Manage and Install Plugins…**

II. This will open the **Plugins** dialogue box.
III. Select **Install from ZIP**
IV. Click **Browse** [...]
V. Search for the plugin you would like to add (**SelectWithin-0.4** in the ZIP file) and click **open** to on your selected file
   ● Alternatively, if you are connected to the internet. Select the **All** tab. Search for **Select Within**, click on the Select Within.

VI.   Click **Install plugin**.
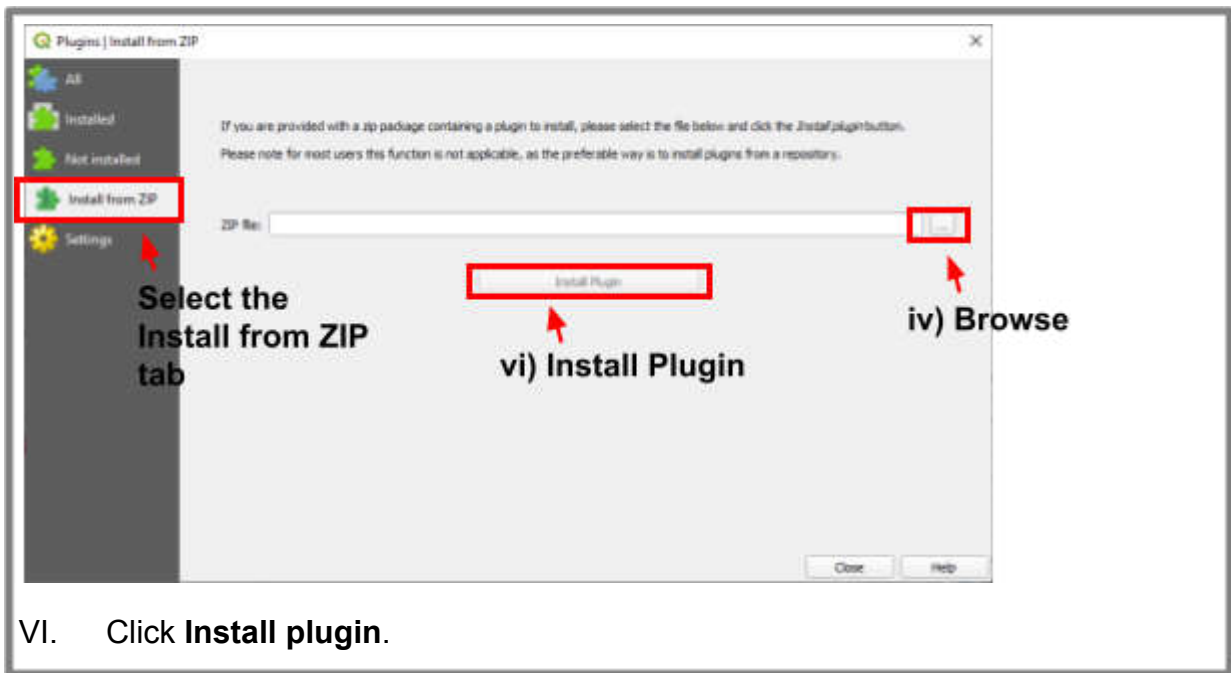
Now that the Select Within plugin is installed, we can use the function to help us answer our questions

d) To use the select within plugin click on **Vector -> Select Within ->**

Select Within
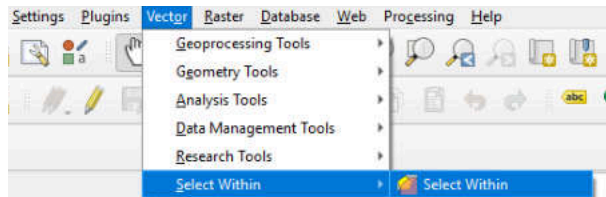

e) This will open up the **Select Within** dialogue box (below).

f) We want to select all features from *District Municipalities* that are within the **selected features** in *Provinces* (the Northern Cape).

    a. You can change what layer is selected by clicking on the drop down menu

    b. Make sure that **Using Selected Features** is selected. If not it will select the district municipalities that fall within will the whole of South Africa, not just the province we are looking at.

g) Click **OK**
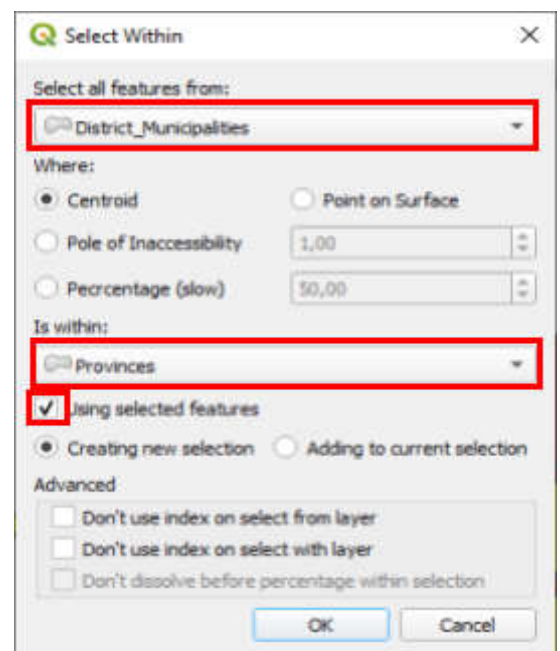
h) To see what district municipalities that have been selected because they are in the Northern Cape, we can open the **Attribute Table** for the *District Municipalities* layer.

    a. Right click on *District Municipalities* layer and click on **Open Attribute Table.**
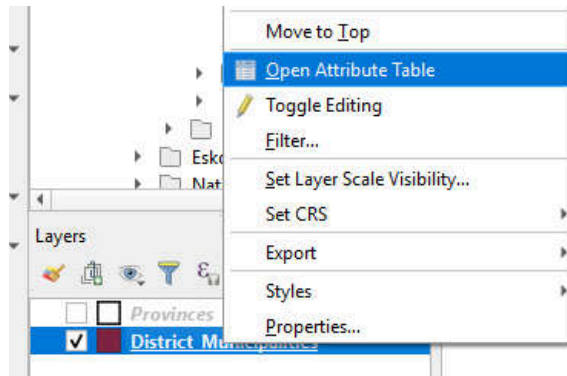
i) The attribute table shows information about each feature in that layer. For the *District Municipalities* layer, the attribute table tells us the district name (District_N). The top of the attribute tells us that there are 52 district municipalities, five of which are selected and within the Northern Cape.

j) From the ▼ filter drop down menu, select **Show Selected Features**. Now we can see which district municipalities are within the Northern Cape. You should only see five rows.
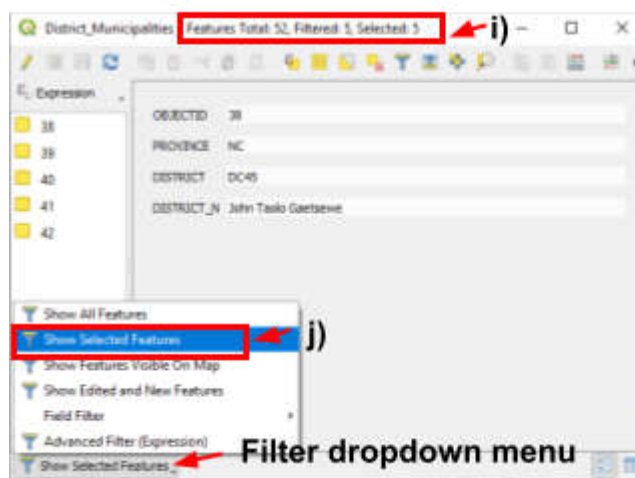

k) Now that you know how to select based on a location (for district municipalities within a selected province), complete the table below and count the number of district municipalities in the other 8 provinces.

    a. Follow steps **a – j**, selecting a different province each time in step **c** to complete the table

Province	Number of district municipalities
Northern Cape	
Western Cape	
Eastern Cape	
Kwa-Zulu Natal	
Free State	
Gauteng	
North West	
Mpumalanga	
Limpopo	

Using attribute data

Now we are going to answer the same question of how many district municipalities are in each province using a different approach. You may have noticed that the attribute table of the **District Municipalities** layer has which province each municipality is in.

a) Open the attribute table for *District Municipalities*. **Right Click** on the layer -> click on **Open Attribute Table.**

b) In the attribute table, select 🔻 the **Select/Filter features using form** (CRL + F). So the attribute table looks similar to below.

c) Next to the Province heading, we are going to search for NC (Northern Cape). Options will appear as you start typing.

d) Click on **Select Features**.

e) You should notice that the top of the attributes table now reads, **Selected: 5**. You can also check on your map if the select features are in the correct province.
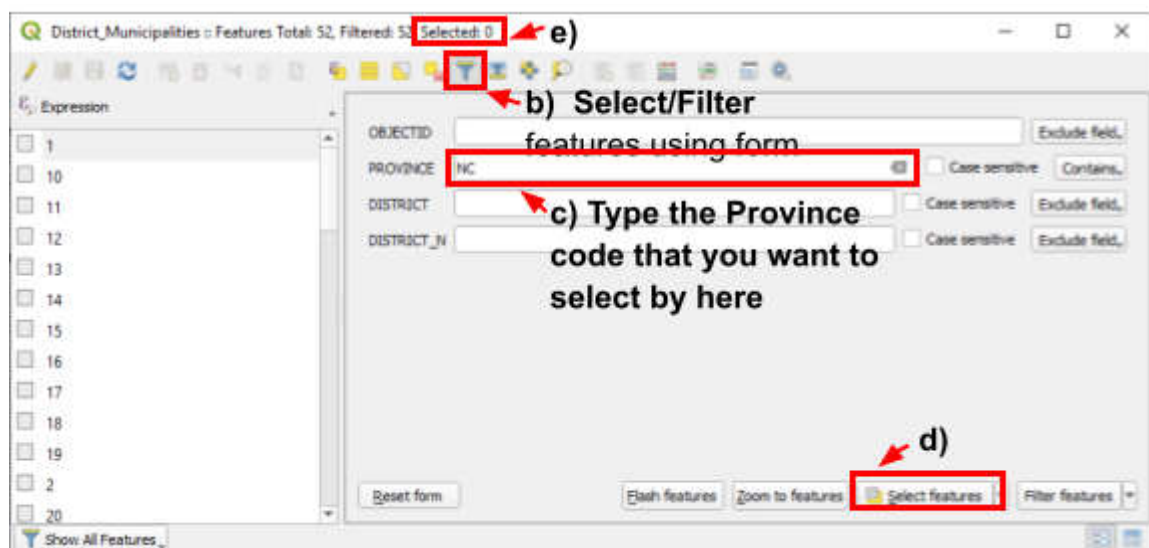
f) Follow these steps to complete the table below and see how many municipal districts are in each province

Province	Province code	Number of district municipalities
Northern Cape	NC	
Western Cape	WC	
Eastern Cape	EC	
Kwa-Zulu Natal	KZN	
Free State	FS	
Gauteng	GT	
North West	NW	
Mpumalanga	MP	
Limpopo	LIM	

Using the table created above answer the following questions:

3.2.2 Identify which province has the most number of district municipalities?

Answer: _____

3.2.3 Identify which province has the least number of district municipalities?

Answer: _____

Activity 4

Activity 4.1 in the Training Manual demonstrates the concept of buffering using transparencies. Now we will perform the same tasks using QGIS software on a computer instead of using transparencies.

4.2. When farmers use river water to irrigate their fields, the further away from the river the field is, the more expensive it is to water that field. Using the shapefiles provided and QGIS answer the following questions.

4.2.1. How many circular fields are within 500m of the river?

4.2.2. How many circular fields are within 1km of the river?

4.2.3. Which Buffer (500m, 1km or 2km) contains the most circular fields?

4.2.4. The fields of which Buffer are going to be the cheapest to pump water to?

4.2.5. The fields of which Buffer will be the most expensive to pump water to?

Think about what information we will need to answer these questions.

Load to following layers: *Activity4_basemap* (raster), *Circular_fields* (vector) and *River* (vector)

Change the symbology to make the **River** blue with a line stroke of 1mm and the fill colour of the *Circular_fields* green.

To answer the questions, we need to create buffers around the river and count how many fields are in each buffer.

We need to make sure that the Coordinate Reference System (CRS) that our layers uses are in the unit meters, as we need to create buffers of 500m, 1km, and 2km. Therefore, it is important to pick the correct CRS.

How to change the Coordinate Reference System (CRS)/ projection?

We are going to change to CRS to **Africa_Albers_Equal_Area_Conic**. This is a CRS/projection that is commonly used for South Africa and the units are in meters.

a) **Right click** on the *River* layer (the layer that you want to change the CRS of). Click on **Export** -> **Save Feature As...** to open up **Save Vector Layer as…**

b) Make sure the Format is **ESRI Shapefile**
c) Make your File name: **River_m**. Use Browser to find a place to save your new shapefile
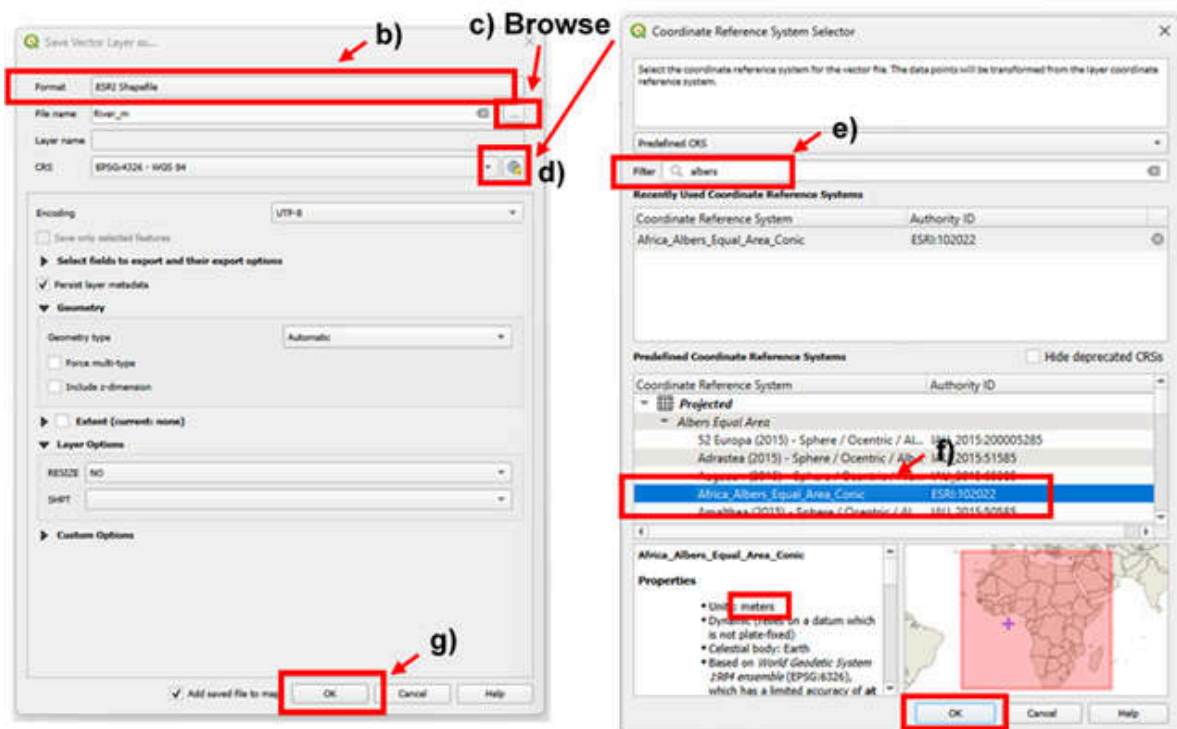
d) To the right of **CRS** click on **select CRS** to open the **Coordinate Reference System Selector**
e) In the filter bar search for **Albers**
f) Select **Africa_Albers_Equal_Area_Conic** (as you can see the units are in m). Click **OK** to select this as the CRS.
g) Click **OK** in **Save Vector Layer as…** to save the Layer with the new CRS.
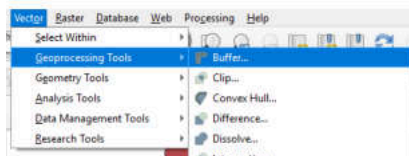h) The new layer will now be added to your layer's panel.

Now convert the **Circular_fields** to the same CRS as **River_m** and name the new shapefile **River_m**.

4.2.1. How many circular fields are within 500m of the river?

Answer: _____

Now that our layers are in an appropriate CRS, we can create a buffer to answer this question.

a) To add a buffer, click on **Vector -> Geoprocessing Tools**, and **Buffer…**

b) Select **River_m** as the Input Layer, as we want to create a buffer around the river.
c) Set the Distance to **500** and make sure the units is in **meters**.
d) Select **Dissolve results**, so the buffer is one feature and easier to work with later.
e) Under buffered, click **Browse** and select **Save to file…**
f) Select where you want to save your new buffer and name it **500m_buffer**. Make sure that you save it as a SHP file (.**shp**).
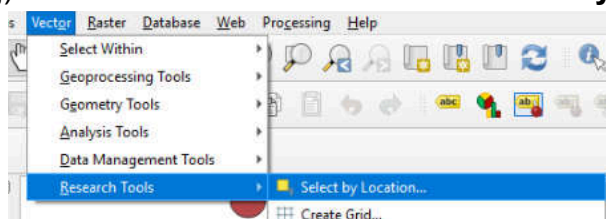g) Click **Run.**
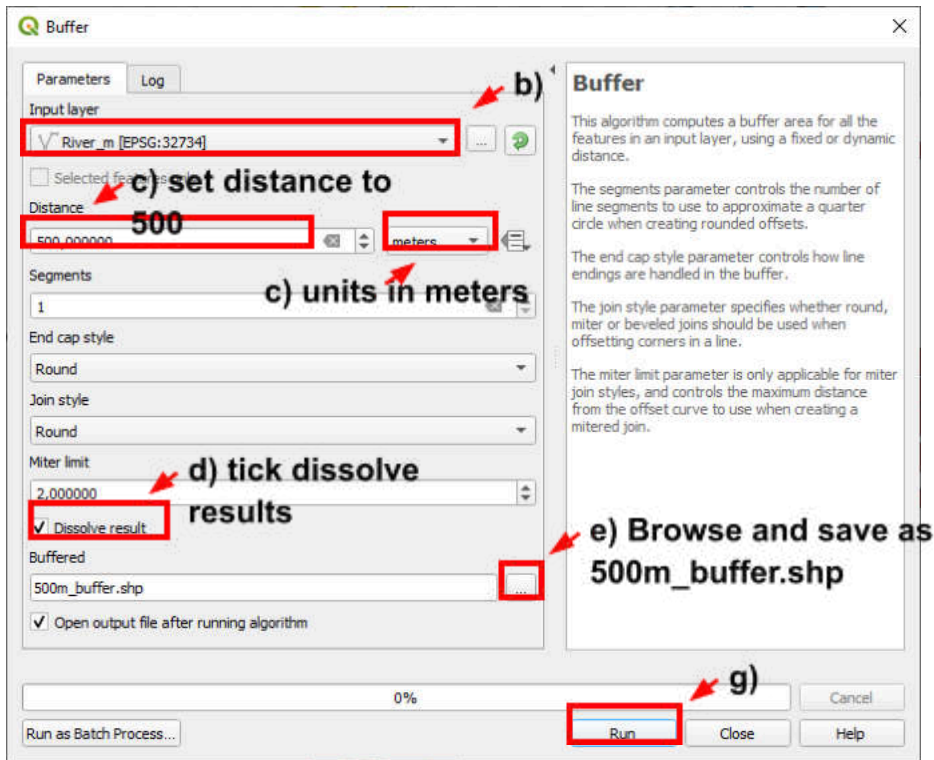
h) If your **500m_buffer** layer is not added to the layer panel, you will have to add it using **Layer -> Add Layer**, and **Add Vector Layer.**

i) Change to opacity of the **500m_buffer** layer to 50%
   Right click on 500m_buffer layer**-> Properties -> Symbology**.
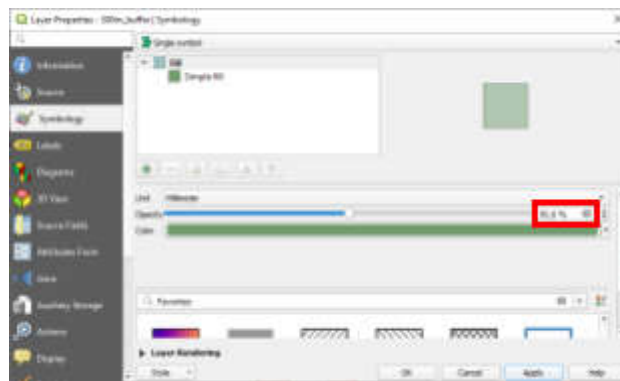
Now that we have created our 500m buffer we need to know how many fields are completely within this buffer. We will use **Select by Location** for this.

j) **Vector -> Research Tools -> Select by location**
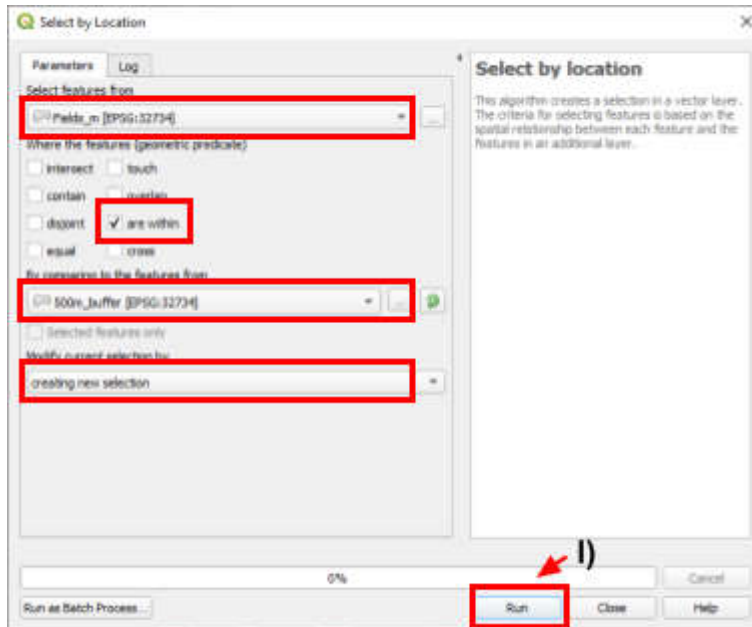
k) In **Select by Location.**
Select features from **Fields_m**
Tick where features **are within**. This will select the fields that are completely inside the buffer.
By comparing to the features from **500m_buffer**
Select **create new selection**

l) Click **Run**

m) Open the **attribute table** of *Fields_m* to see how many fields have been selected.
Right click on the layer (*Fields_m*) - > **Open Attribute Table**

4.2.2. How many circular fields are within 1km of the river?

Answer: _____

Now create a 1km buffer around the river and count how many are found within this buffer. Use the same procedures as above.

- Make sure in **step c** you use **1km or 1000m** as the distance
- Call this layer **1km_buffer**
- Make sure you select the correct buffer when selecting by location

4.2.3 Which Buffer (500m, 1km or 2km) contains the most circular fields?

Answer: _____

Now create a 2km buffer around the river and count how many are found within this buffer. Use the same procedures as in 4.2.1.

Now that you have all three buffers and have the number of fields within each complete the table below. Use this table to help you answer 4.2.4.

Buffer size	Number on fields
500m	
1km	
2km	

4.2.4 The fields of which Buffer is going to be the cheapest to pump water to?

Answer:_____

_____

_____

_____

_____

4.2.5 The fields of which Buffer will be the most expensive to pump water to?
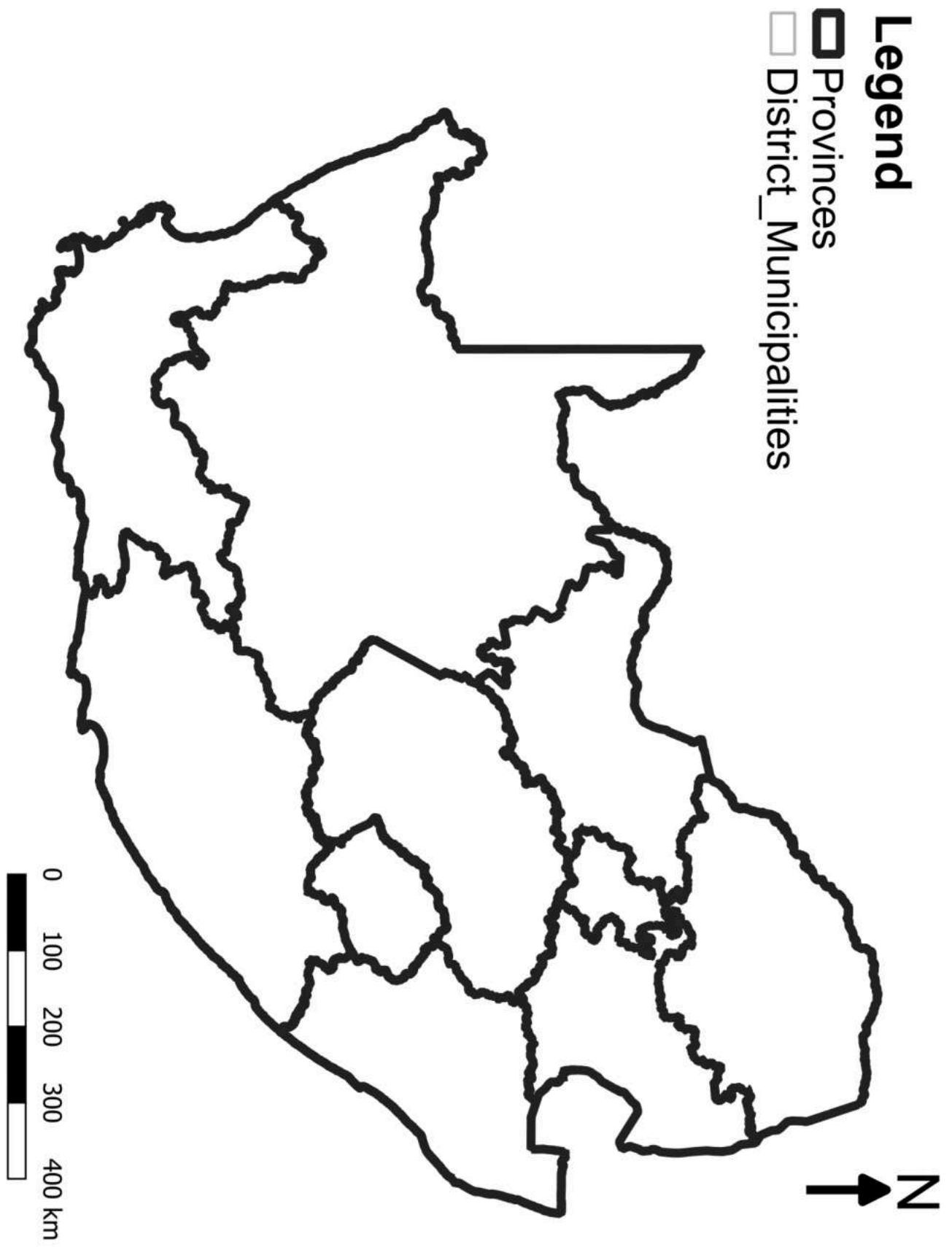
Answer:_____

_____

_____

_____

_____

_____

Appendix C: Images for paper-based activities

Image for activity 2

Images for activity 3

Legend
Provinces
District_Municipalities

0 100 200 300 400 km

N
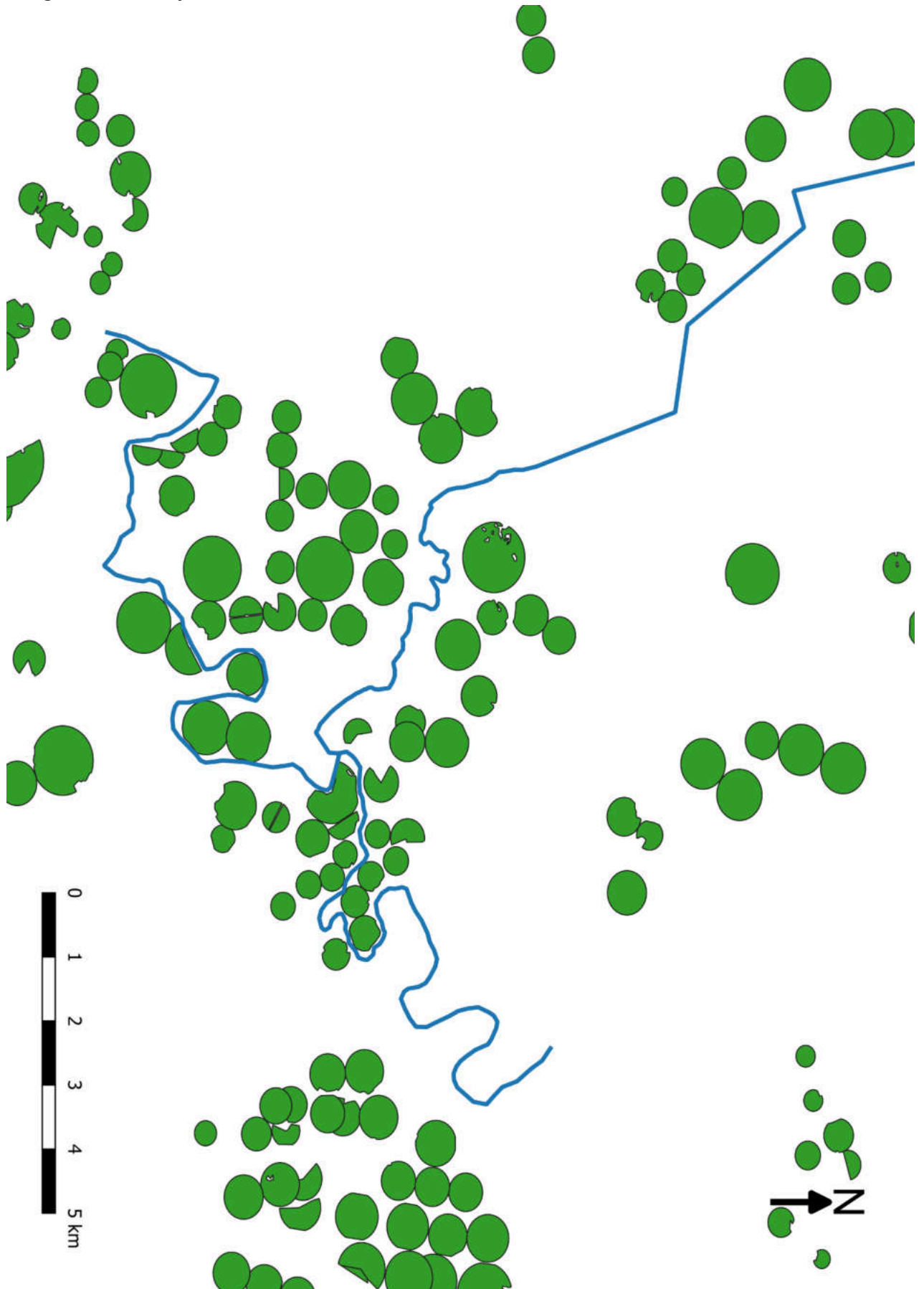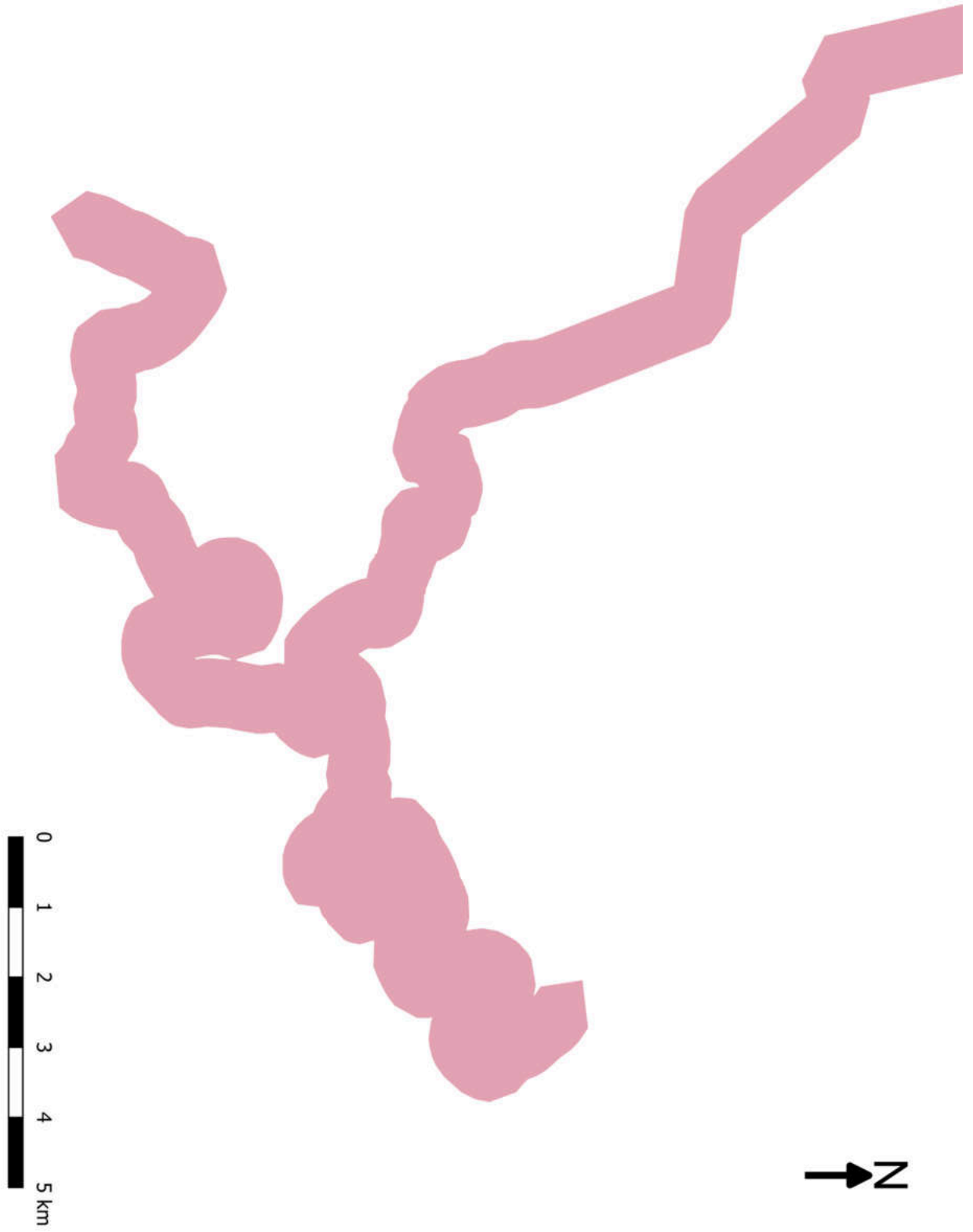
Images for activity 3
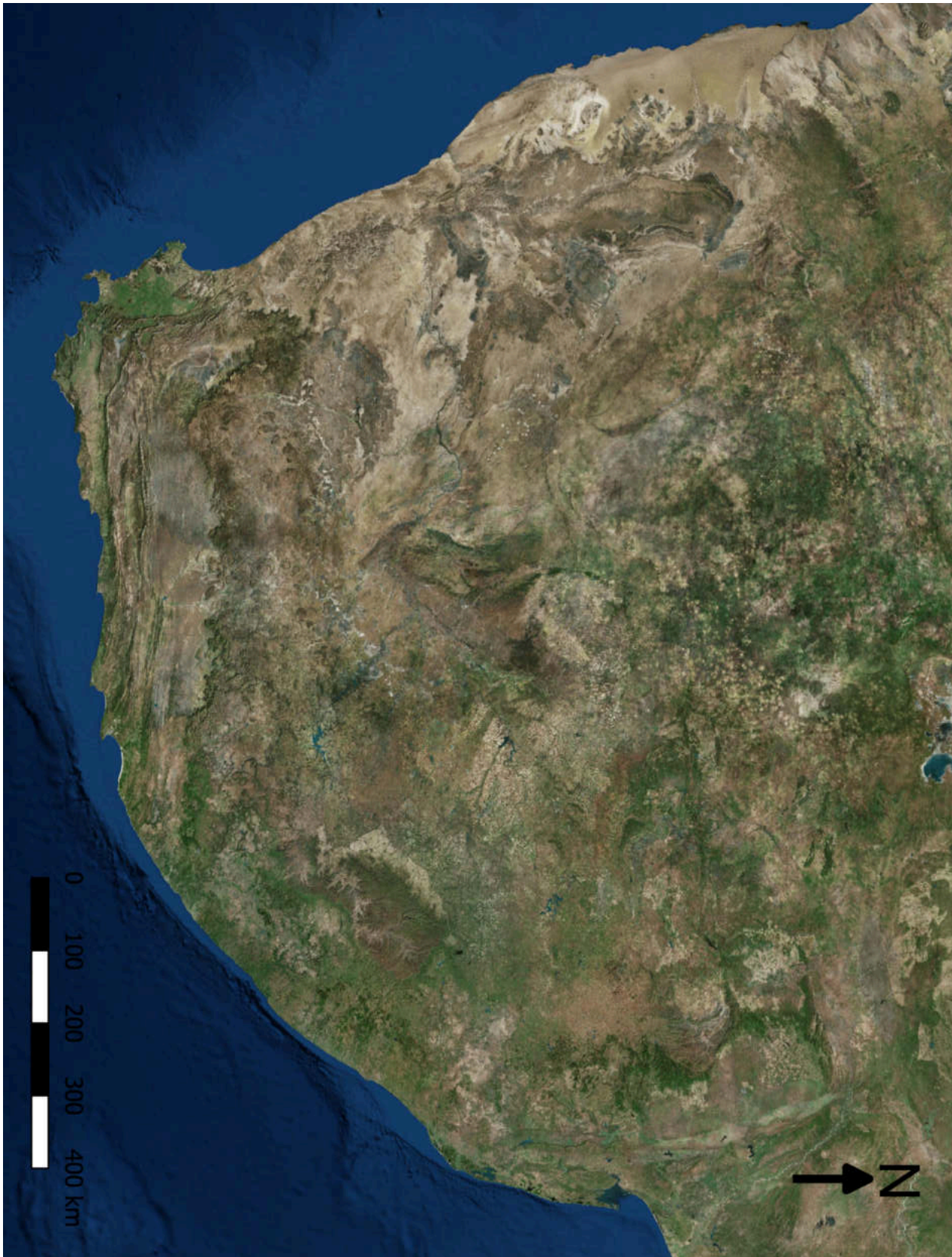
Images for activity 4

Images for activity 4

0 1 2 3 4 5 km

→ N

Images for activity 4

0 1 2 3 4 5 km

N

Images for activity 4

Legend

River

500m buffer

1km buffer

2km buffer

Circular fields