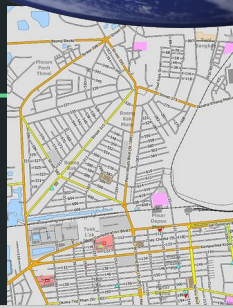
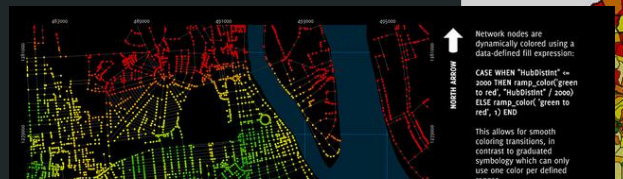
# Introduction to Georeferencing

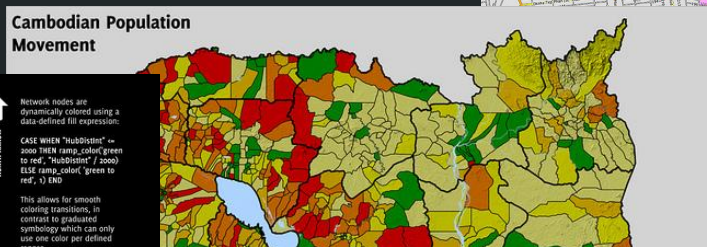
Turning paper maps to interactive layers



## DMDS Workshop

Jay Brodeur
2019-02-29



# Today's Outline

- Basic fundamentals of GIS and geospatial data
  - Vectors vs. rasters
  - Coordinate reference systems
- Introduction to Quantum GIS (QGIS)
- Hands-on Problem-Solving Assignments

# Quantum GIS (QGIS)

- Free and open-source GIS software
- User-friendly, fully-functional; relatively lightweight
- Product of the Open Source Geospatial Foundation (OSGeo)
- Built in C++; uses python for scripting and plugins
- Version 1.0 released in 2009
- Current version: 3.16; Long-term release (LTR): 3.14

OSGeo Project

**GDAL** - Geospatial Data Abstraction Library


www.gdal.org

**SAGA** - System for Automated Geoscientific Analyses

saga-gis.org/

**GRASS** - Geographic Resources Analysis Support System


www.grass.osgeo.org

**QGIS** - Quantum GIS

qgis.org

**GeoTools**


www.geotools.org

# Helpful QGIS Tutorials and Resources

- QGIS Tutorials: http://www.qgistutorials.com/en/
- QGIS Quicktips with Klas Karlsson: https://www.youtube.com/channel/UCxs7cfMwzgGZhtUuwhny4-Q
- QGIS Training Guide: https://docs.qgis.org/2.8/en/docs/training_manual/

# Geospatial Data Fundamentals

Representing real-world geographic information in a computer

# Task 1: Compare vector and raster data layers

**Objective:**

Download some openly-available raster and vector data.
Explore the differences.

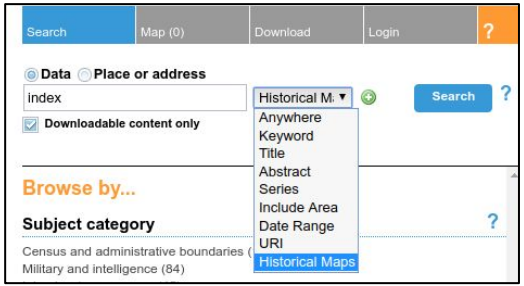
**Topics Covered:**

- The QGIS Interface
- Geospatial data
- Layer styling
- Vectors vs rasters

Online version of notes:

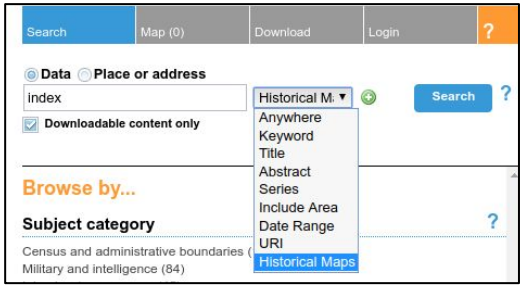
https://goo.gl/H5vqNs

# Task 1.1: Downloading vector raster data & adding it to your map




1. Navigate a browser to Scholars Geoportal: http://geo.scholarsportal.info/
2. Search for ‘index’ using the ‘Historical Maps’ category
3. Load the 1:25,000 topo map index
4. Use the interactive index to download the 1972 map sheet of Hamilton
5. Unzip the sheet
6. Load the file into QGIS using the ‘Add Raster Layer’ button

# Task 1.2: Downloading vector raster data & adding it to your map




1. Navigate a browser to Hamilton Open Data: http://open.hamilton.ca
2. Search for '**Buildings**'
3. Open the top selection (named 'Buildings')
4. Click >Download>Shapefile
5. Download it to the same directory as the topo map sheet
6. Unzip the data
7. Load the file **buildings.shp** into QGIS using the Browser, or 'Add Vector Layer' button, or by dragging it into the layers panel

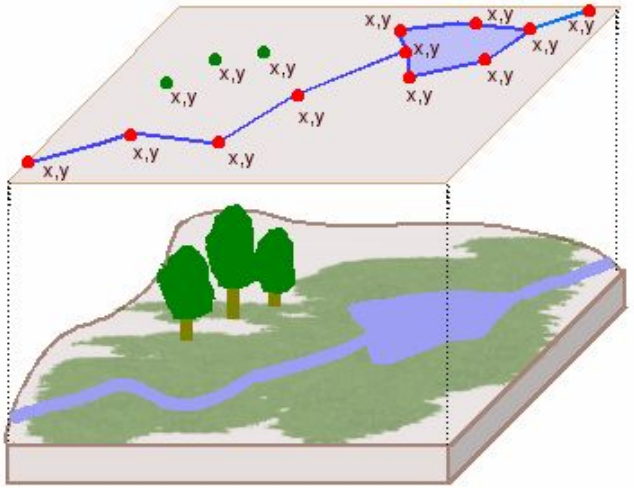
# Data Models

Data models are used to represent real-world geospatial features and objects in a digital format

Most common methods:

- Vectors
- Rasters

# Vector Data Model




www.geography.hunter.cuny.edu

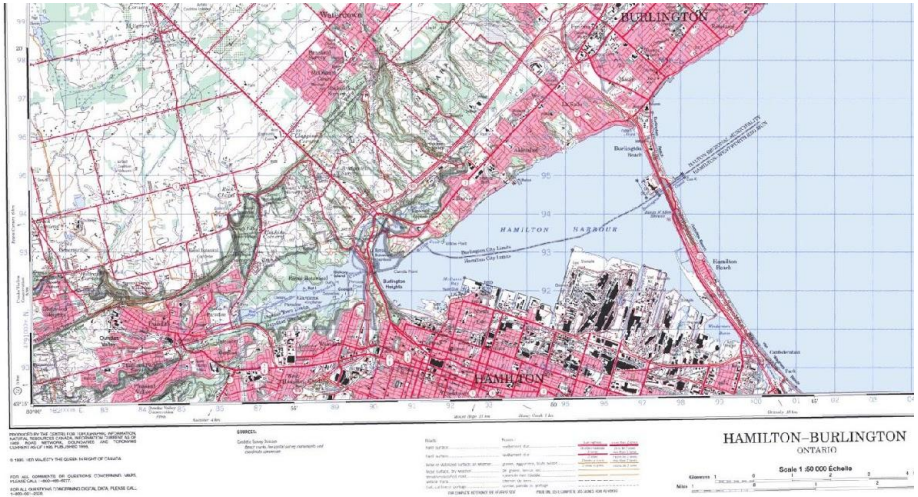
Features represented by:

1. **Points** – (x,y,z) coordinates
    - Hospitals, measurement points, cities
2. **Lines** – Series of connected points
    - Rivers, roads, transects
3. **Polygons** – Areas enclosed by a self-connecting line
    - Lakes, countries, buildings, cities

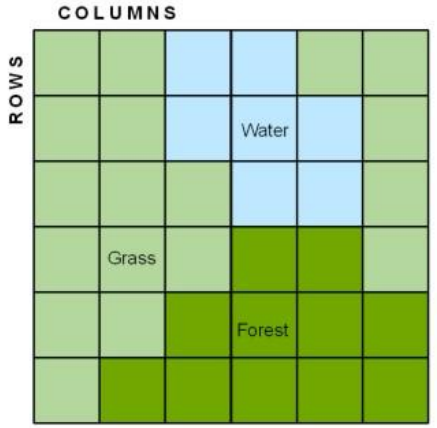
# Vector Data

Courtesy: Harvard Map Collection

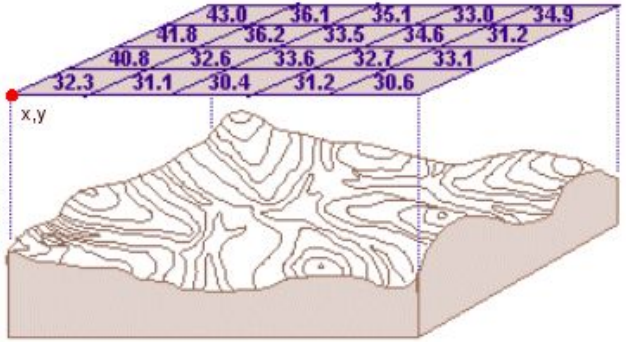
- Useful for clearly-defined objects
- Provides spatial relationships
- Can be scale-dependent



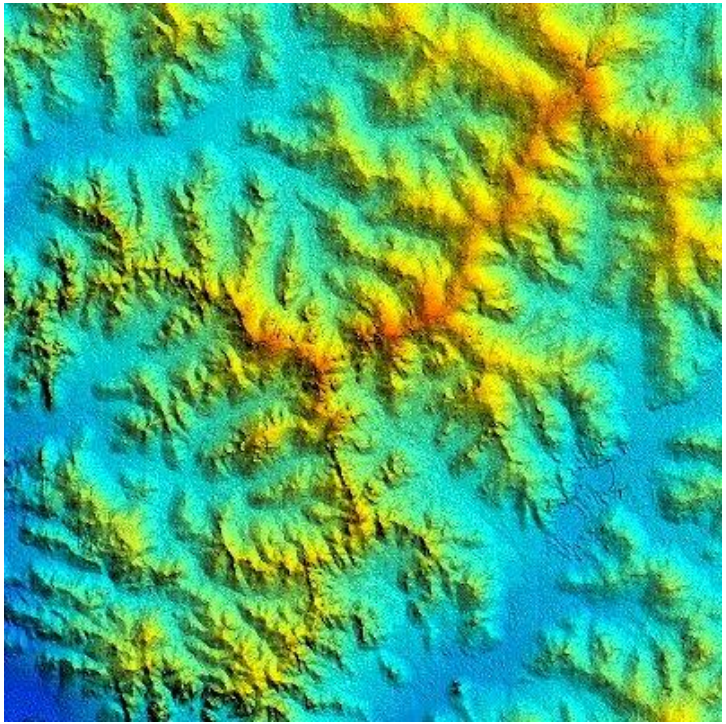
# Raster Data Model

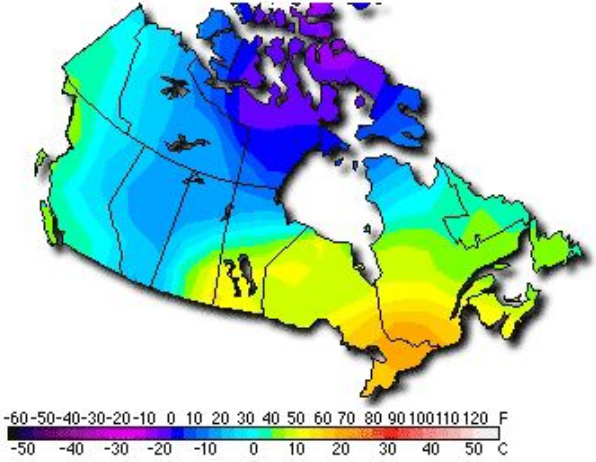



- Regular grid of cells
- Each cell = specified ground area
  - (Spatial resolution)
- Values assigned to cells
  - Categorical (land use, classification)
  - Continuous (elevation, temperature)
- E.g. Satellite imagery,
  digital elevation models (DEMs)



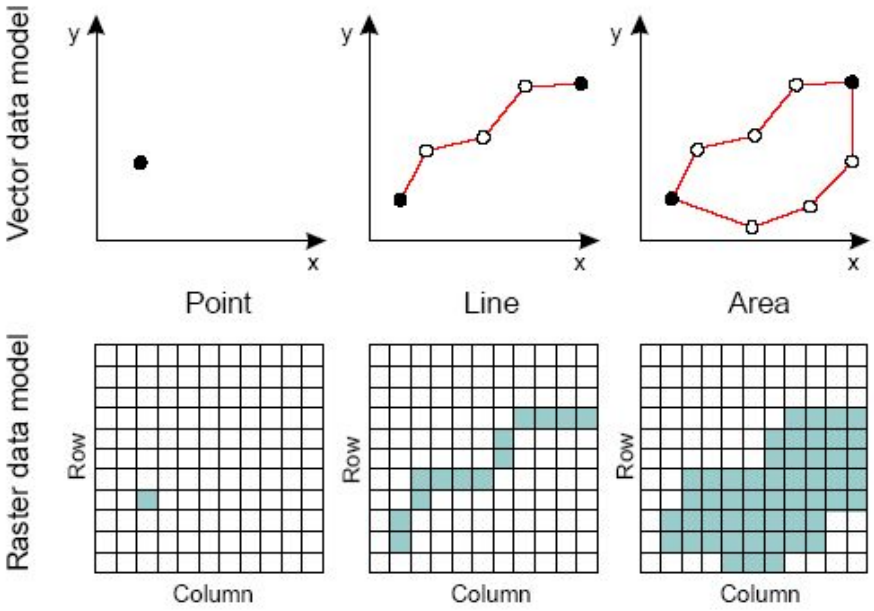
# Raster Data

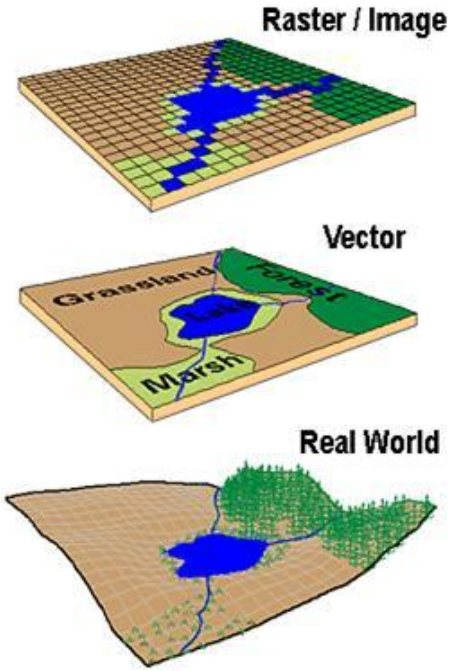



-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 F
-50 -40 -30 -20 -10 0 10 20 30 40 50 C


Google

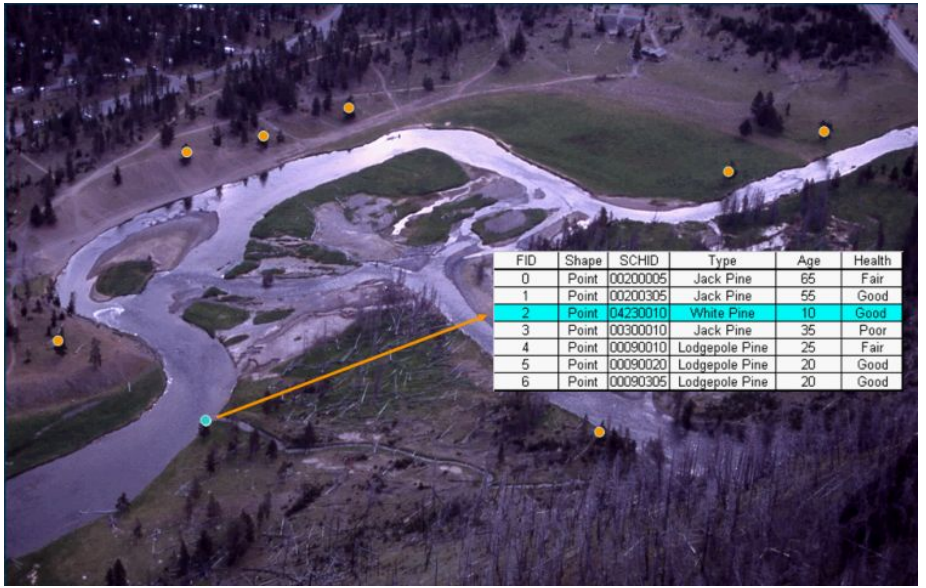
# Raster vs. Vector



# Attributes

- Link non-geographic information to geographic data
- Provide supplementary and contextual information



| FID | Shape | SCHID | Type | Age | Health |
|---|---|---|---|---|---|
| 0 | Point | 00200005 | Jack Pine | 65 | Fair |
| 1 | Point | 00200305 | Jack Pine | 55 | Good |
| 2 | Point | 04230010 | White Pine | 10 | Good |
| 3 | Point | 00300010 | Jack Pine | 35 | Poor |
| 4 | Point | 00090010 | Lodgepole Pine | 25 | Fair |
| 5 | Point | 00090020 | Lodgepole Pine | 20 | Good |
| 6 | Point | 00090305 | Lodgepole Pine | 20 | Good |

# Coordinate Reference Systems

Referencing the location of objects on the Earth’s surface

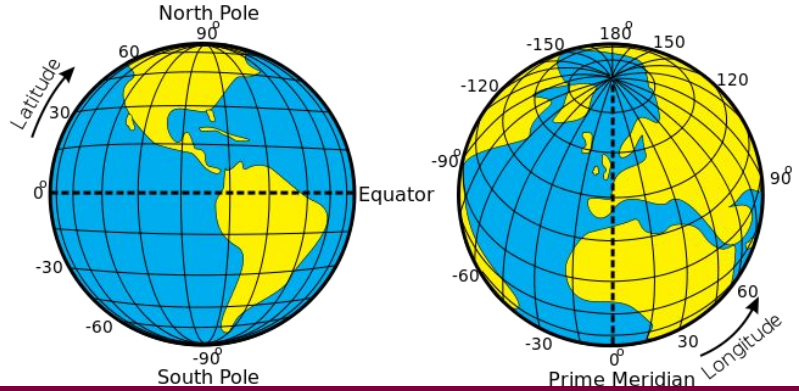
# Coordinate Reference Systems (CRS)

A means of expressing the absolute location of a feature

- **Geographic** – expressed as angles (e.g. latitude, longitude)
- **Projected** – expressed as distances from a reference point on a plane

# Geographic Coordinate Systems

- Locations expressed as angles from an anchor point
- Network of intersecting lines (e.g. latitude, longitude, elevation)
- Reference system for a curved Earth
- Mathematical operations on multiple points are complicated
- Based on a geodetic datum
  - MANY datums exist
  - World Geodetic System - WGS 84
  - North American Datum - NAD 83



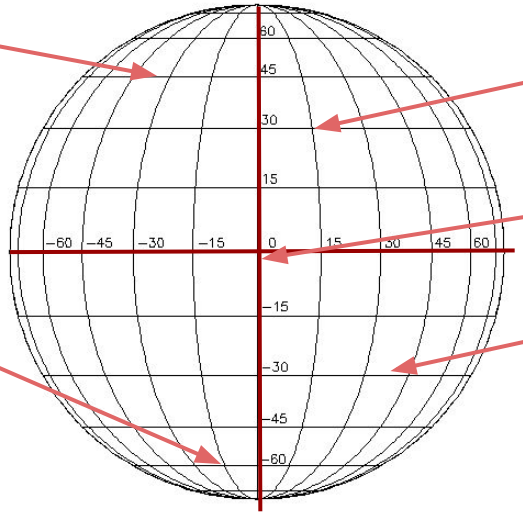
# Geographic Coordinate Systems

1. Reference to a Geographic Coordinate System (lat / long)
   - Degrees East and North of (0°, 0°)

-45° E, 45° N

(-45° E = 45° W)

-15° E, -60° N




15° E, 30° N

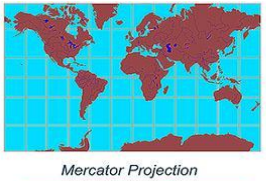
Origin (0° E, 0° N)

35° E, -30° N

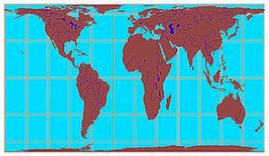
(-30° N = 30° S)

# Projected Coordinate Systems

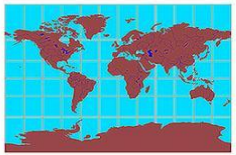
- Projections of the round Earth to a flat surface → Maps
- Express location as distance from an anchor point (origin)
  - Also based on a datum
- All projections preserve and distort some surface features
  - Area, shape, direction, bearing, distance, scale



Mercator Projection



Gall-Peters Projection

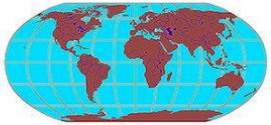


Miller Cylindrical Projection

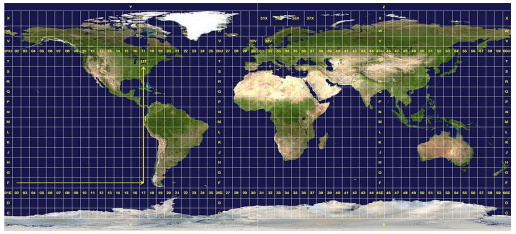
Mollweide Projection

Goode's Homolosine Equal-area Projection

Sinusoidal Equal-Area Projection



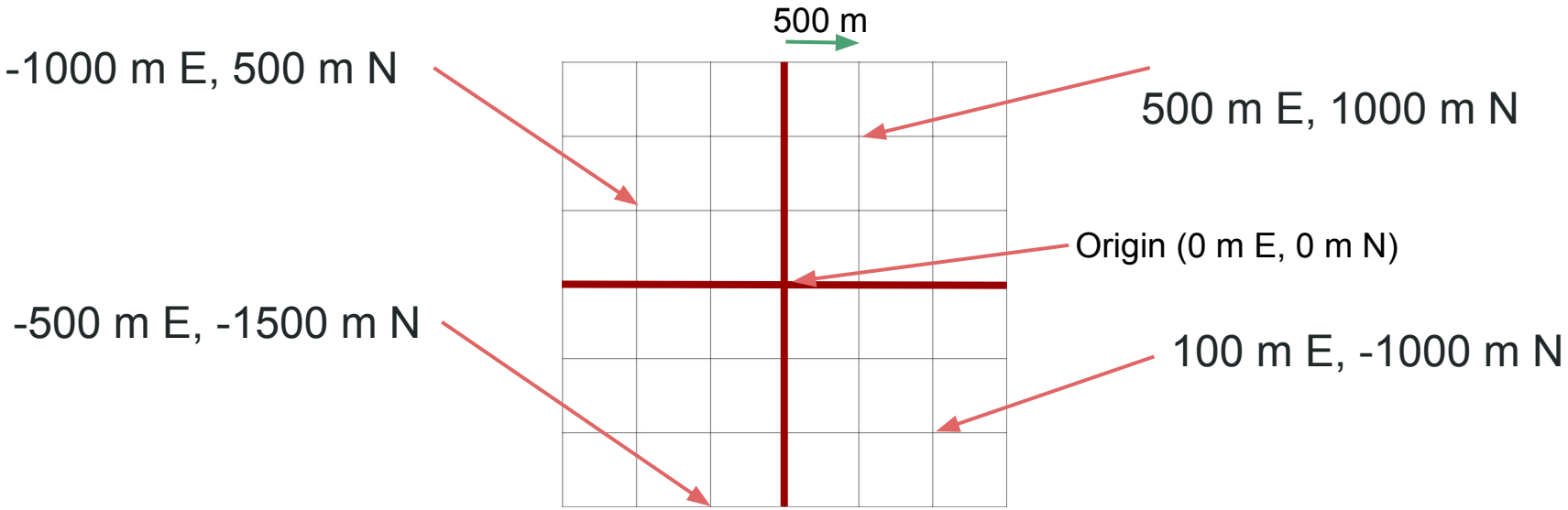
Robinson Projection



Universal Transverse Mercator (UTM)

# Projected Coordinate Systems

2. Reference to a Projected Coordinate System
   - ➢ Distance (e.g. metres) East and North of a selected origin



# Task 2: Georeferencing with Map Warper

**Objective:**

Turn an image with spatial extent (map, aerial photo, etc.) into a geospatial data layer

**Topics Covered:**

- Intro to Map Warper
- What is georeferencing?
- Ground control points
- Image transformation
- Loading into QGIS
- Generating webtiles

# *Georeference*

… “to associate something with locations in physical space”[1]

… [in GIS:] “the process of associating a physical map or raster image of a map with spatial locations”.[1]

[1]Wikipedia
http://en.wikipedia.org/wiki/Georeference

Aligning geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data.[2]

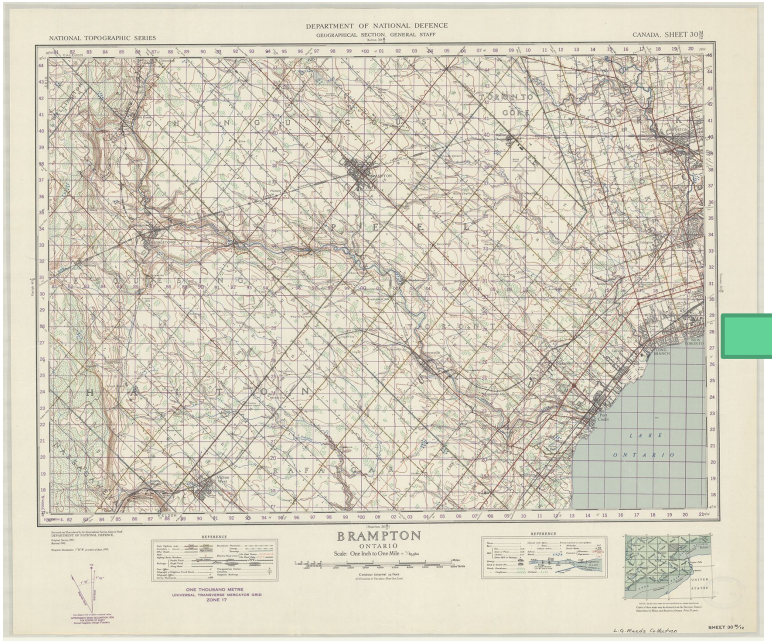
[2]ESRI GIS Dictionary
http://support.esri.com/sitecore/content/support/Home/other-resources/gis-dictionary/term/georeferencing

# *Georectification*

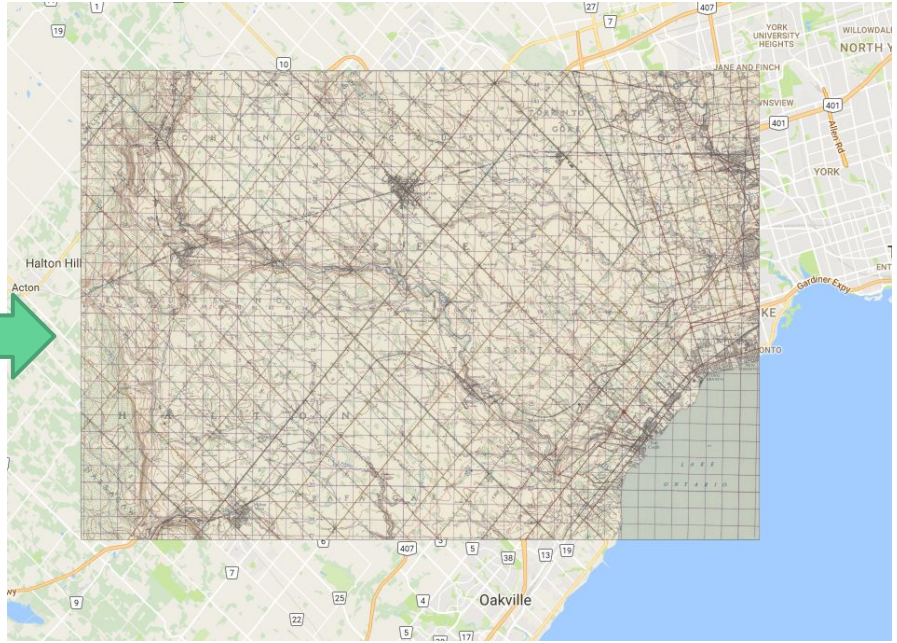
The digital alignment of a satellite or aerial image with a map of the same area. In georectification, a number of corresponding control points, such as street intersections, are marked on both the image and the map. These locations become reference points in the subsequent processing of the image.[1]

[1]ESRI GIS Dictionary
http://support.esri.com/sitecore/content/support/Home/other-resources/gis-dictionary/term/georectification

# Target image




# Projected image in a web map




http://perec.mcmaster.ca/maps/OCUL/300ppi/

# Target image


http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A33284

# Projected image in GIS software


http://perec.mcmaster.ca/maps/apindex/

# Why georeference/georectify maps and images?

Analyze

- Use GIS to evaluate spatial characteristics and relationships
- e.g. land-use change; boundary mapping; image processing

Visualize

- Explore information in a spatial context
- Explore & “mash-up” multiple information layers

Generate new data

- e.g. vectorizing georeferenced imagery

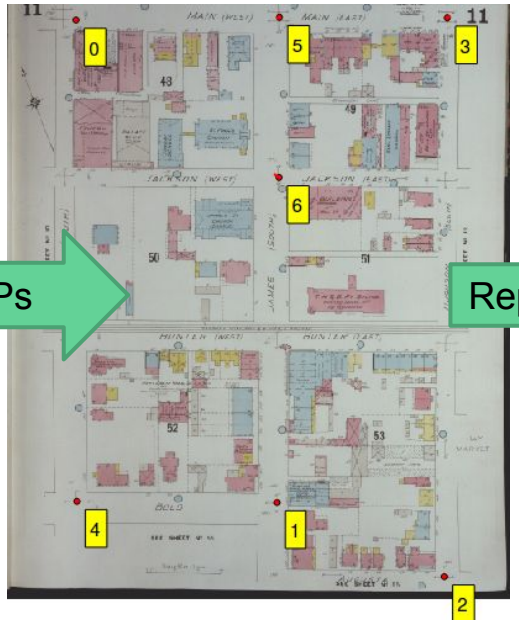
# The process

Target image

Georeferenced image with ground control points (GCPs)

Georectified (projected) image in GIS software

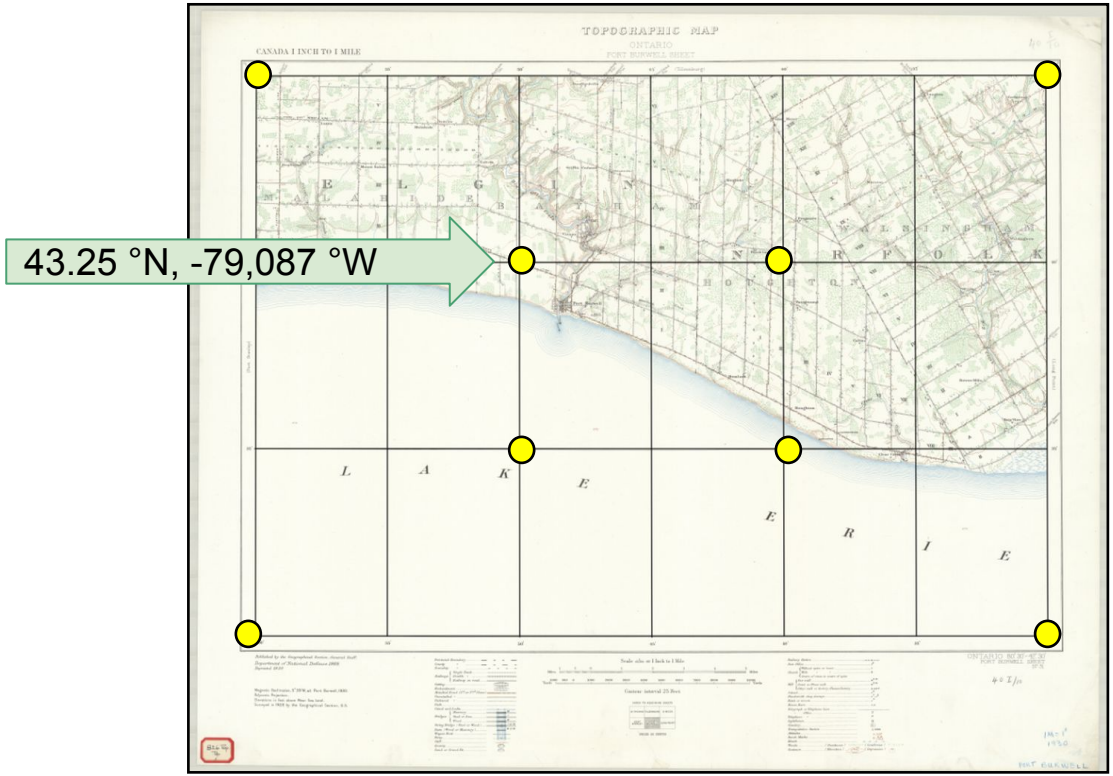

Add GCPs




Reproject

# Setting GCPs using embedded coordinates

Map is georeferenced to its native coordinate reference system (CRS)



# Setting GCPs using georeferenced map / data


Map is georeferenced to the reference data's coordinate reference system (CRS)

# Transformation model and # of GCPs

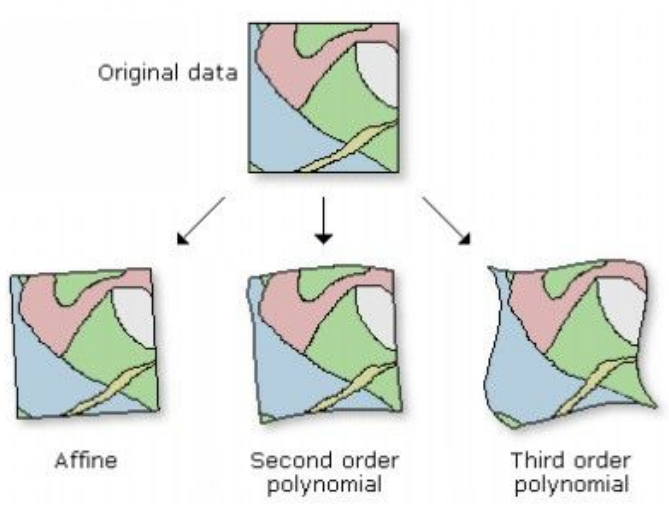
The # of GCPs required depends on your need for accuracy and the transformation model
(i.e. the flexibility for warping the map)

**You can use:**

Polynomial 3 if you've found 10 or more control points

Polynomial 2 if you've found 6 or more control points

Polynomial 1 if you've found 3 or more control points



# Map Warper


“...is an open source map geo-rectification, warping and georeferencing application. It enables a user to upload an image, a scanned map or aerial photo for example, and by placing control points on a reference map and the image, to warp it, to stretch it to fit.”

Tim Warner’s Map Warper Github Page
https://github.com/timwaters/mapwarper

# Step 1: Sign up, Sign in

Navigate to http://mapwarper.net/

- New users: Click on CREATE ACCOUNT
  - Create an account
  - Click on activation link in your new email message


- Registered users: SIGN IN

# Step 1: Log in

Navigate to http://mapwarper.net/

SIGN IN with these credentials:


- Login: libgis@mcmaster.ca
- Pass: mapwarper

# Step 2: Browse the maps

Click “BROWSE ALL MAPS”


Browse maps for our exercise

➢ Search Tags for ***DMDS-2019***

# Step 3: Getting familiar

Jay will introduce the site and demonstrate the process.

# Step 4: Getting Started

Claim a map to georectify with Map Warper in this shared Google Sheet:

https://goo.gl/7yFqRf

Give it a try!

# Task 3: Create web tiles from your GeoTiff

**Objective:**

Turn a georeferenced raster into a series of tiles that display well on the web

**Topics Covered:**

- Using other toolboxes
- Generating webtiles

# Task 4: Vectorizing

**Objective:**

Use a georectified image as source data to create new vector layers.

**Topics Covered:**

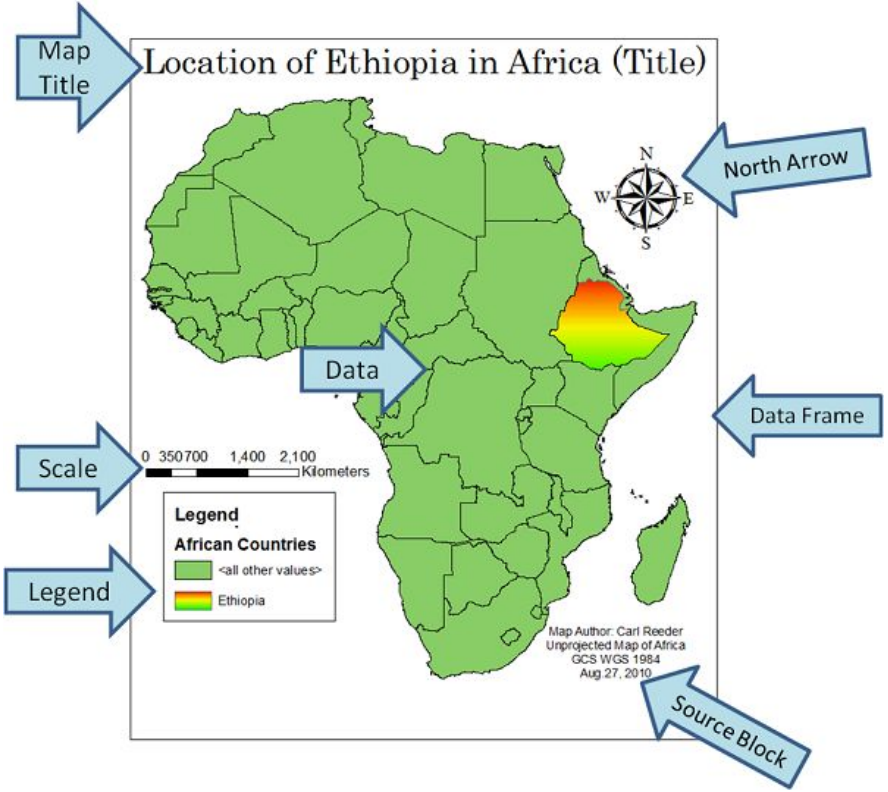
- Vectorization

# OTHER MATERIAL

# Introduction to QGIS

# Fundamental Map Elements

1. Data
2. Title
3. Frame (Neatline)
4. Scale
5. Legend
6. North Arrow
7. Source Information
8. Author, date, projection, ©,etc.



# What is GIS?

- **G**eographic **I**nformation **S**ystem
- A system to assemble, store, manipulate, analyze, manage and present ***geographically referenced data***
  - Data associated with or identified by their location
- A digital representation of real-world geographic attributes:
  - Location
  - Attributes
  - Spatial relationships

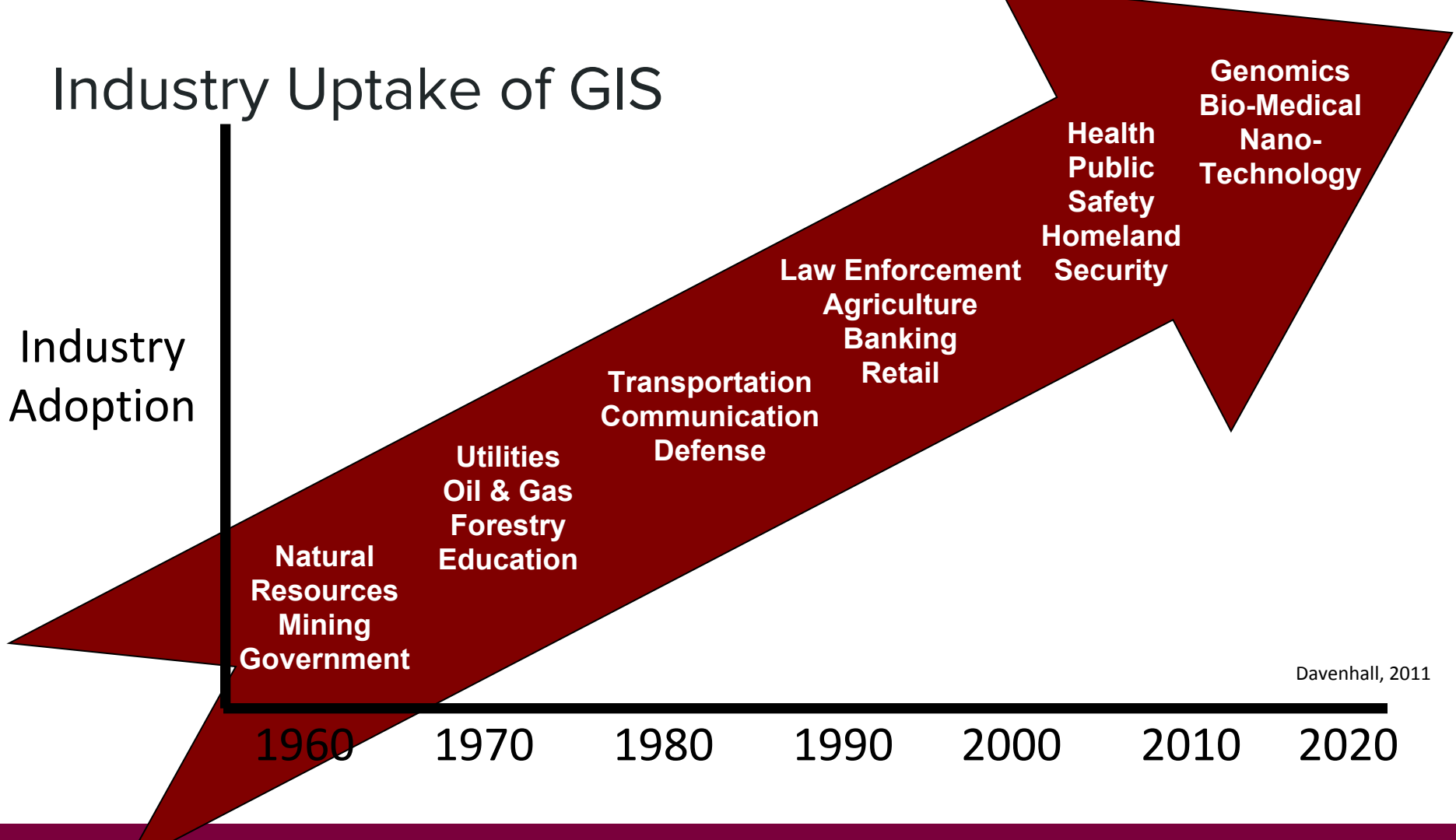
# GIS Components

1. Hardware
2. Software
3. Data
4. Applications & Methods
5. People (developers and users)

# History of GIS

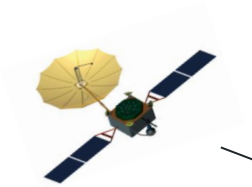
- Made in Canada!
  - 1960 by Dr. Roger Tomlinson for CLI data
  - Canada Geographic Information System (CGIS)
- Developed for wider use through ‘70s & ‘80s
  - CAD, ESRI, MapInfo – commercial software
  - MOSS, GRASS – open-source (public domain)
- Rapid growth and extension of use in ‘90s & ‘00s

# Industry Uptake of GIS




Davenhall, 2011

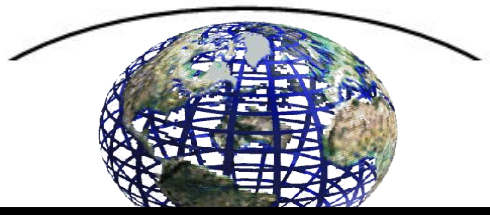
# Geospatial Technology (AKA Geomatics)



**Global Positioning Systems**
(location and navigation)

**Geographic Information Systems**
(map and analyze)

**Remote Sensing**
(measure and classify)



One of the three "mega technologies" for the 21st century and promises to forever change how we conceptualize, utilize and visualize spatial relationships in scientific research and commercial applications, and general usage (U.S. Dept of Labor)

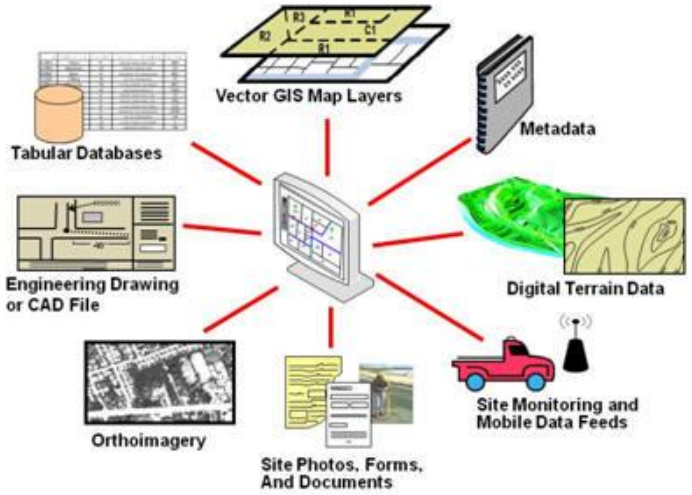
For more: http://en.wikipedia.org/wiki/Geomatics

# Applications for GIS

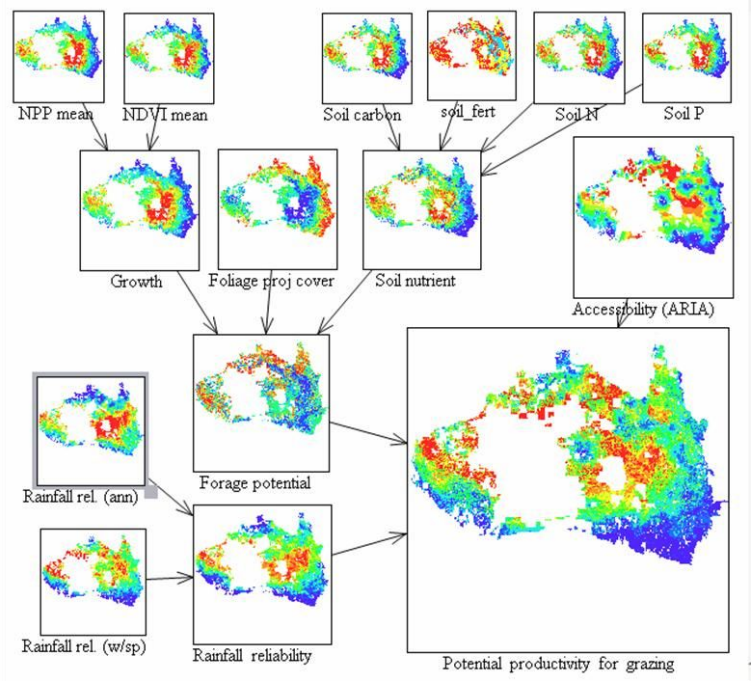
Using GIS to solve ‘real-world’ problems

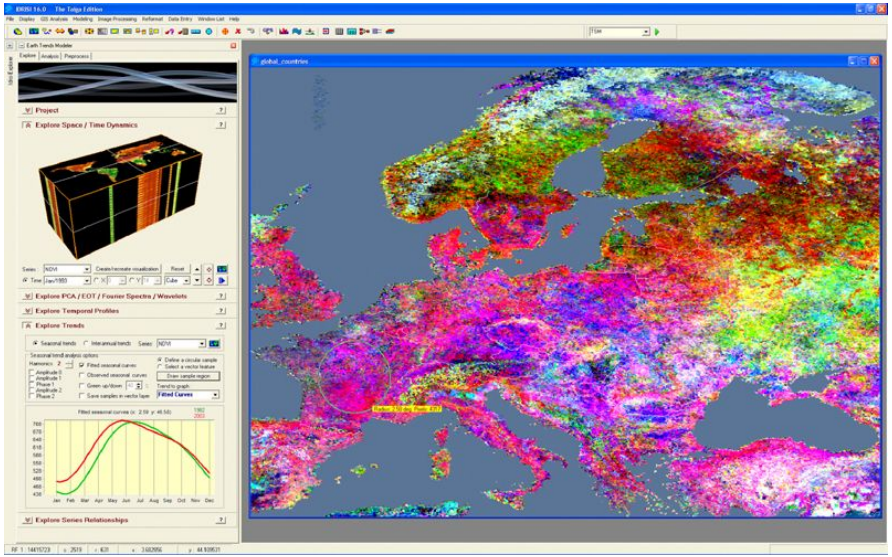
# Data Management

- Collecting geospatial data
- Compiling diverse types of geographical & non-geographical data
- Searching / Querying / Retrieving data from databases

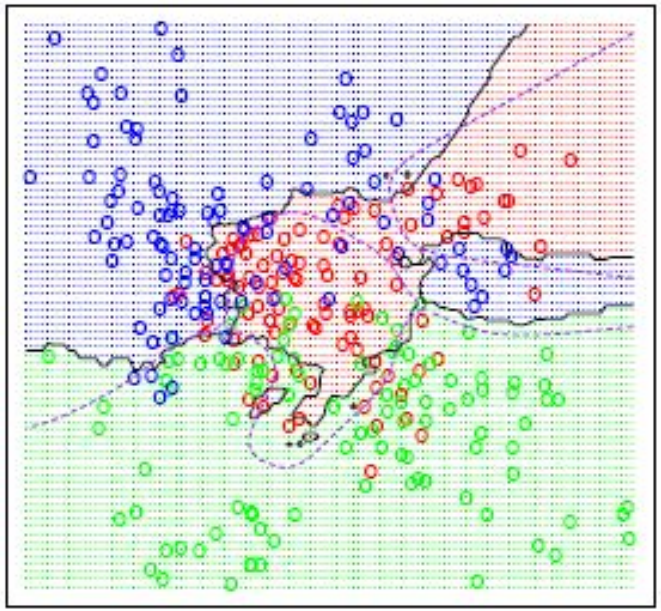


# Multi-Criteria Analyses & Decision-Making

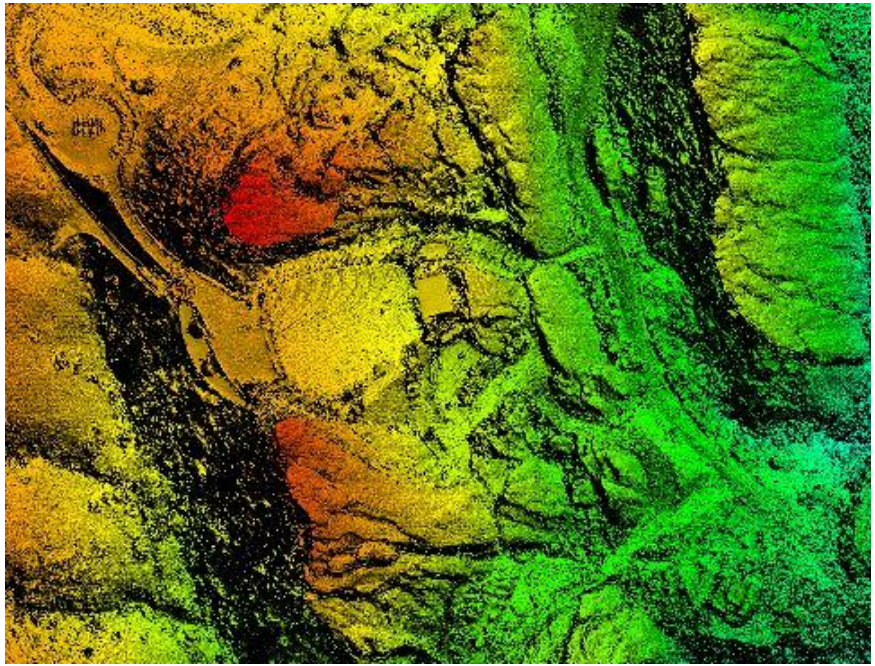


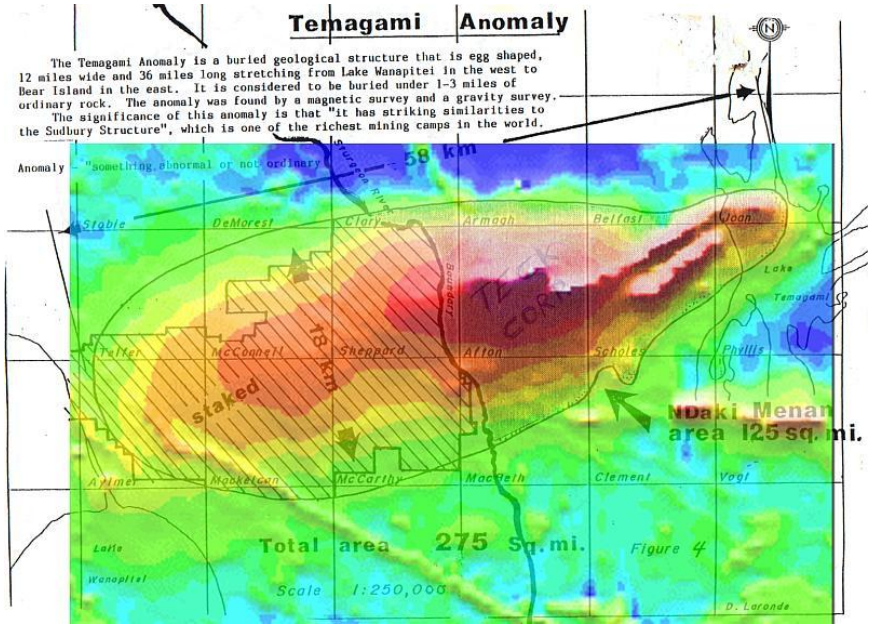
# Geospatial Analyses / Geostatistics

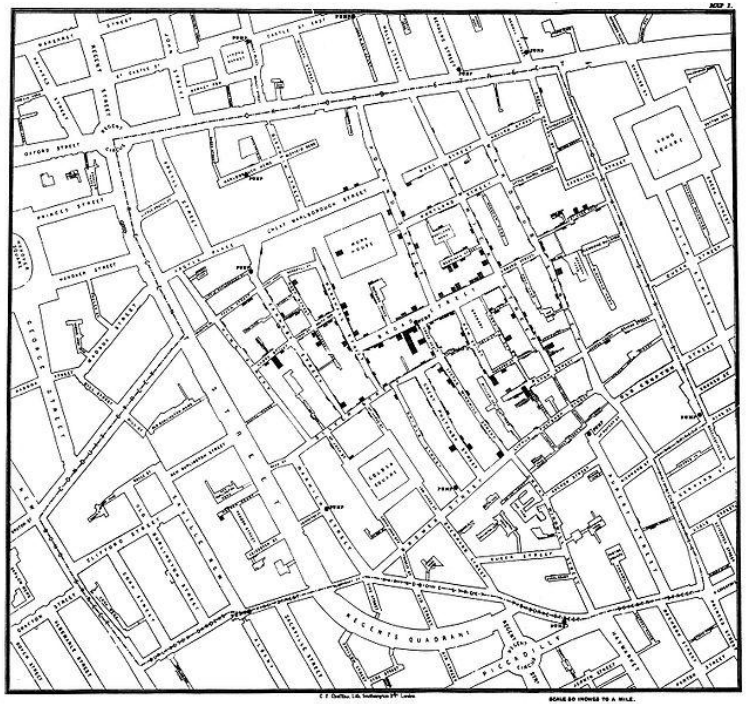


PSU, 2013

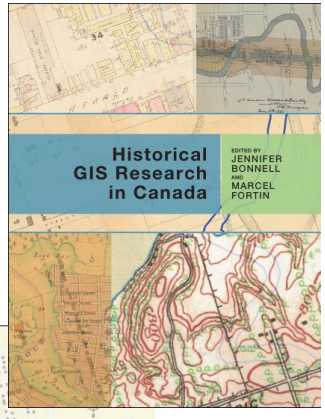


# Data Visualization and Exploration



# Historical GIS




http://uofcpress.com/books/9781552387085

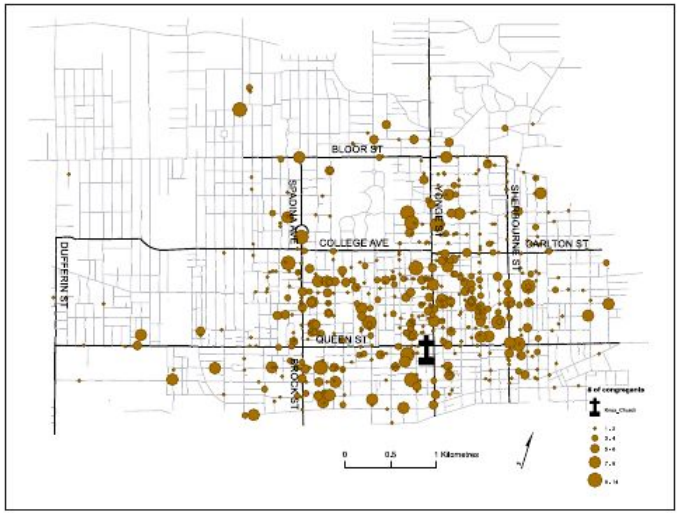



*Fig. 4.3. Number of Knox congregants by address, 1887. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)*

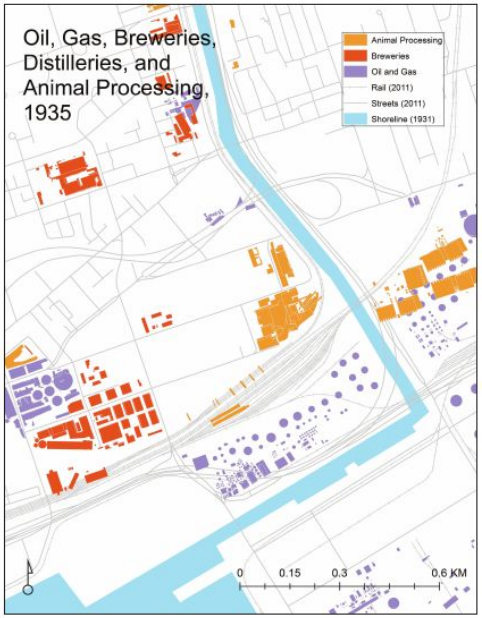



*Fig. 3.5. Oil and gas, breweries, and animal processing, 1935. (Roads and Railroads from DMTI Spatial Inc. CanMap RouteLogistics 2011.3.)*

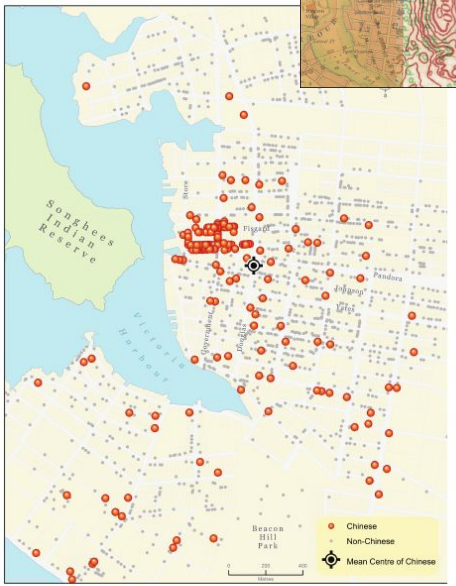
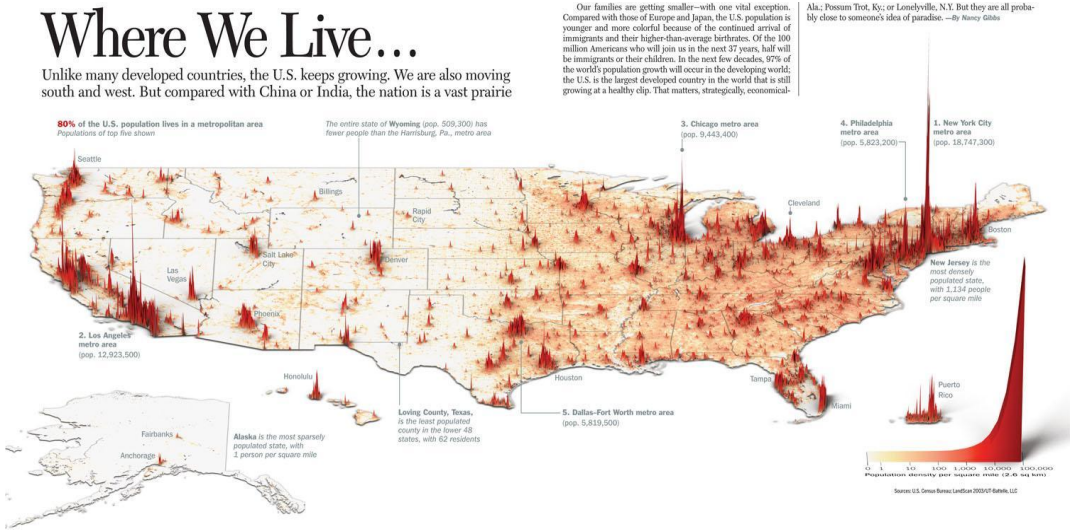
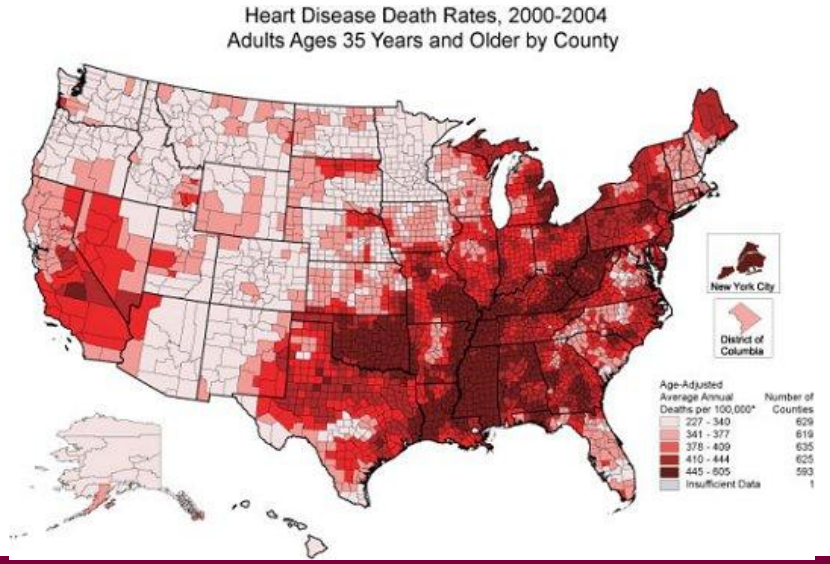



*Fig. 1.9. Victoria population, 1891, showing residences of Chinese and non-Chinese. Source: Canada Census, 1891 with addresses provided by the City of Victoria 1891 Check Census in the BC Archives (Add Mss 1908) and* Williams' Illustrated Official British Columbia Directory for the Cities of Victoria, Vancouver, Nanaimo and New Westminster, 1892 *compiled by the firm of R. T. Williams of Victoria. The directory was compiled in the fall of 1891. Both the census and directory are available on line at www.vihistory.ca.*

# Mapping / Information Dissemination



# Common GIS Software

- Many, MANY types of GIS software
- Different tools for different purposes
  - Full-featured vs. specialized
  - Open-source vs. closed-source
  - Free vs. licensed
  - User-friendly vs. technical
  - Online vs. standard desktop

# Getting Data

Consortial/subscription data is made available through Scholars Geoportal

- http://geo.scholarsportal.info/

Municipal open data portals:

- City of Hamilton Open & Accessible Data
  - http://www.hamilton.ca/city-initiatives/strategies-actions/open-accessible-data
- City of Toronto Open Data Catalogue
  - http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=1a66e03bb8d1e310VgnVCM10000071d60f89RCRD
  - http://goo.gl/o0slUt

# Where to Find Geospatial Data