Introduction to GIS in Water Resources
Synopsis of Class 1, GIS in Water Resources, Fall 2018

Welcome to the Geographic Information Systems (GIS) in Water Resources class for Fall 2018. The purpose of this synopsis is to summarize the content of the first lecture in this course, an Introduction to GIS in Water Resources. This course has two instructors: David Maidment and David Tarboton at the University of Texas at Austin and Utah State University, respectively. We share responsibilities for making up the homework and exams. The course is shared between the two universities via video conferencing and shared computer desktops, and the videos are made public so that others can look into the course and follow along as they wish. This is inspired by the idea of a "university without walls", in which the class learning experience is open to all.

The course is taught using the ArcGIS Geographic information system. It is not assumed that you have previous experience with ArcGIS and your capacity to use the software is developed by carrying out five fairly long computer exercises that occur at roughly two-week intervals during the first half of the semester. You will also conduct a term project that deals with some aspect of the subject of personal interest to you, and present your term paper orally and in writing. All the term papers from the two universities will be publicly accessible and part of your final exam will be to write a synthesis of selected sets of these papers dealing with common themes. In this way, you will be learning not only from your teachers, but also from each other. GIS is a technology meant to empower you and others by increasing your understanding of the world around you.

One way of describing how knowledge is developed is to divide this into three mechanisms:

- *Deduction*, which is the classical path of mathematical physics – given a set of axioms, then by a logical process derive a new principle or equation, as in Newton's "Principia Mathematica"
- *Experiment*, a simplified view of the world is replicated under controlled conditions, such as in the laboratory of Louis Pasteur;
- *Observation*, an interpretation of facts and data collected in the natural environment, as Charles Darwin did in his voyages around the world and described in his book "Origin of the Species".

Hydrology uses all of these mechanism but is particularly reliant on observations, that is, data on water quantity and quality collected at gages and sampling sites. GIS is helpful to show where data has been measured and to associate measurement sites with the characteristics of the watersheds that drain to them. Hydrology also uses predictive computer models that are a form of deduction: given a set of input data, use a computational algorithm to derive a new set of results. The National Water Model is a continental scale hydrologic model that continually simulates and forecasts the flow of the rivers and streams of the United States. A robust geospatial information framework is needed as the foundation for this model and as a mechanism to link model predictions in stream reaches with the USGS stream gages located on those stream reaches. Geographic data models provide a vocabulary for describing and reasoning about the things located on the earth.

The core information model of GIS is based around *themes* – layers of geospatial information, where each layer contains information of a particular kind, and all layers share a common spatial extent and coordinate system. Themes can consist of *discrete spatial features* such as points, lines or areas, called *vector* objects in GIS terminology, or *continuous surfaces* such as a raster *grids* or remote sensing *images*. Grids differ from images in that they can have any numerical value, while images have a fixed set of values classified over a range. Surfaces can also be represented by a *triangulated irregular network*, or a continuous mesh of connected triangles.

Geographic information systems can be thought of as comprising three parts:

- *Geodatabase* – a structured set of data that represents geographic information using a generic GIS data model;
- *Geovisualization* – a set of intelligent maps that support interpretation of spatial patterns in the data;
- *Geoprocessing* – a set of transformation tools that develop new geographic datasets from existing data.

A key challenge in GIS in Water Resources is to link the land and water systems. The land system with its hills, valleys, roads, and cities, lends itself to GIS representation. The water system is more subtle – at one level it can be represented in GIS as water features, such as streams, lakes and bays – the "blue lines", or *hydrography* map layer, but at a deeper level what we seek to do is to describe the *properties* of water – its flow, surface elevation and quality, and for this we need *observational* data – time series of data from gages or collections of data from water samples, that collectively describe the character of the water itself. Water properties are dynamic in that they can change continuously in time, so the connection of geospatial and observational data has to be done carefully, recognizing that these are two fundamentally different information types. The data and applications to make this work for the academic community are presented in a system called HydroShare directed by Dr Tarboton

ESRI presents itself as a company centered on the "Science of Where". Central to the creation of this science is to understand how we define location on the earth. We are familiar with (x,y,z) coordinates in feet or meters that describe location in the *Cartesian coordinate system* used in science and engineering. Less familiar are *geographic coordinates* (ϕ, λ, z) that describe latitude (ϕ) longitude (λ) and elevation (z) on the earth. *Latitude* is the measure of North-South location. Latitude has its origin at the equator, where its value is 0, and a range [-90, +90], where -90 is 90°S at the South Pole, +90 is 90°N at the North Pole. Lines of constant latitude are called *parallels* and are oriented East-West. Longitude is the measure of East-West location. Lines of constant *longitude* are called *meridians* and are oriented North-South. The origin of longitude is the *prime meridian* that runs through Greenwich, England, and longitude has the range [-180, +180], where negative longitudes are West of the prime meridian, including the United States, and positive longitudes are East of the prime meridian.

Map projection is a process of transforming geographic information from one coordinate system to another. *Geographic coordinates* (ϕ, λ, z) on a curved earth are transformed onto a flat map to become *Projected Coordinates* (x,y,z), by first shrinking the real earth to a model globe using a *representative fraction,* which is the ratio of globe distance to earth distance (e.g. 1:100,000 scale means 1 cm on the globe corresponds to 100,000 cm or 1 km on the actual earth), then transforming the locations on the globe to corresponding locations on a flat map. There is no way to make a flat surface out of a curved surface without some distortion. In making this transformation, there is an origin location (ϕ_0, λ_0) in the geographic coordinate system, and a corresponding origin location (X_0, Y_0) in the projected coordinate system, which are actually the same point on the earth's surface. We'll learn more about this subject as the semester advances.