Introduction to GIS in Water Resources
Synopsis of Class 1, GIS in Water Resources, Fall 2014

Welcome to the Geographic Information Systems (GIS) in Water Resources class for Fall 2014. 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 four instructors: David Maidment, David Tarboton, Tony Castronova and Larry Band, distributed among the University of Texas at Austin, the University of North Carolina and Utah State University. We share responsibilities for making up the homework and exams. The course is shared between the three 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.

A geographic information system is designed to capture, store, manipulate, and present all forms of geographic information. A key property of GIS, one that makes it different from other forms of information systems, is the one to one connection between each spatial feature and a record in an accompanying data table that describes its characteristics or *attributes*. A *digital map* consists of a set of layers each depicted using an appropriate symbology, such as for example, green for vegetation, blue for water, and so on. A *relational database* consists of a set of tables connected by a common attribute or *key* field that links one with another. A GIS links map features with data tables, and thus is more than a digital map or a relational database taken alone. A *geodatabase* is a connected set of data tables used to store geographic information.

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 bring together the storage of geographic data in geodatabases, the visualization of geographic information as layers or themes on a display and tools for performing calculations on, or processing of, geographic information to create new information. This geoprocessing functionality connects GIS with computer programming and enables powerful analytic capability that can develop new information and understanding from the combination of multiple geographic information sources.

Perhaps the 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 US federal government has launched an *Open Water Data Initiative* to develop an *Open Water Data Infrastructure* of standardized water data themes shared using water web services, and an Open Water Web to build applications to address water problems. The National Weather Service has opened a new *National Water Center* on the Tuscaloosa Campus of the University of Alabama. A *National Flood Interoperability Experiment* is going to be conducted during the coming year at the National Water Center to use an open water data infrastructure to support flood modeling, forecasting and mapping in the United States.

The Environmental Systems Research Institute (ESRI), the company that makes ArcGIS, has established *ArcGIS Online* http://www.arcgis.com for intelligent web mapping and sharing of GIS information by communities. This system depends on web services for map information at all spatial scales from global to local. We will be using a local version of ArcGIS Online associated with your university to validate your right to access these services. Associated with this is a *Living Atlas* http://doc.arcgis.com/en/living-atlas/ with lots of maps, including a special section on *Earth Observations*, which is especially relevant to this class.

Central to understanding geographic information is to understand geospatial coordinates. 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). *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. 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. Elevation, z, in feet or meters exists in both the Geographic and Projected coordinate systems.

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.