Lecture 9: Reference Maps & Aerial Photography

I. Overview of Reference and Topographic Maps

There are two basic types of maps?

Reference Maps - General purpose maps

&

Thematic Maps - maps made for a specific purpose

A major type of reference map is a topographic map. The main producer and distributor of topographic maps in this country is the United States Geological Survey (USGS). The USGS has develop different series of topographic maps based on common fractional scales such as:

1:24,000	1 inch = 2,000 ft
1:62,500	1 inch ≅ 1 mile
1:250,000	1 inch ≅ 4 miles

These maps cover that following geographic area, respectively (7.5', 15', 30' X 1^{o}, 1X2^{o}) and can be visualized in Figure 1. **Also, hand out paper copy maps to students**. Note that in the US Quadrangle maps tend to be longer in the N-S direction than the E-W direction. In Laredo 7.5' of latitude covers 7.6 miles; whereas, 7.5' of latitude covers about 8.6 miles Additionally, with increasing latitude the distance covered by 1^{o} of latitude and longitude decreases. To visualize this concept, look at the latitude and longitude lines on a globe.

I invite, **actually I insist**, you to go to the USGS map locator website at (type USGS Map Locator in google and select the first record). You have a Google Earth type interface within the USGS map locator website. Use the zoom tool until Laredo occupies the whole map. The select the MARK POINTS button on the right of the browser. Now click on the map application. Notice there is now a red marker located where you clicked on the map. Click on this marker. A pop-up menu will appear that will give you the option of downloading files. The topographic maps have been converted into a Digital Raster Graphic (DRG) and are saved in a PDF format that you can open with Abode Reader. Click download (select 7.5' quadrangles for both 1980 and 2010; to see how Laredo has grown in the last thirty years). Once downloaded is selected, it may take a few minutes these are big files, you will have to unzip the files and then you can open them in Abode Reader. Make reference to these files as we go through this lecture.

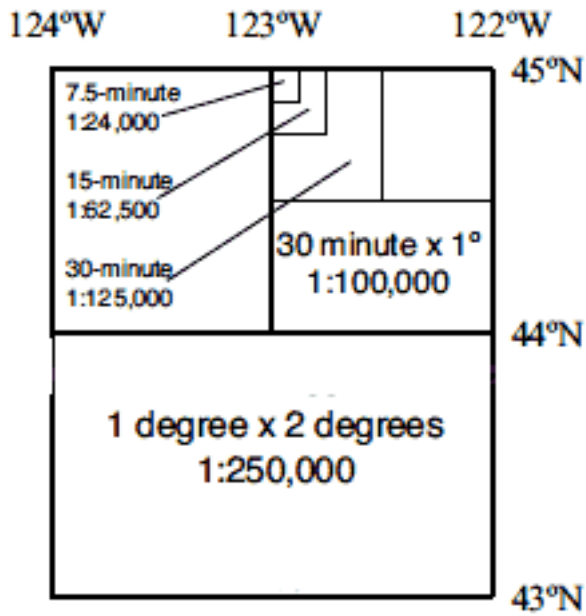

Figure 1. Map series and geographic extent covered.

You need to think about the following concept in detail and understand! A map with a large fractional scale covers a small geographic area and vice versa. For example,

1:24,000	Large-scale map; 1 inch on map grounds 2000 ft on ground
1:62,500	Smaller-scale map; 1 inch on map grounds 1 mile on ground

What are some of the geographic entities plotted on a topographic map? Typically, the USGS will only map permanent man-made features as well as significant naturally occurring features. The USGS topographic maps are printed with a 5-color printing process with different colors for different entities?

Blue for hydrography

Black and red for man-made objects like buildings, roads, and railroads

Brown for hypsography (contour lines)

Yellow for certain boundaries

Green for vegetation

These features are described in more detail in the USGS Topo Map Symbols document (PDF), which you should download from the following website:

nationalmap.gov/ustopo/images/US_Topo_Map_Symbols.pdf

Most modern topographic maps are based on a projection that corresponds to the State Plane System and will the most recent datum, which f**or South Texas is:**

Projection - Lambert Conformal Conic (South Texas zone) Datum - NAD 1983

Finally, these maps have a specified spatial and temporal accuracy. The stated spatial accuracy of a 7.5' USGS topographic map is that 90% of the features plotted on the map must be within 0.02 inches on there actual position. As we determined previously this will represent 40 feet of real world distance? However, in rapidly growing regions one needs to consider not just spatial accuracy but also temporal accuracy. The Laredo East 7.5-minute quadrangle from 1980 would not be a useful reference map navigating around Laredo; whereas, the 2016 map would be more suited to this purpose. As I mentioned previously, maps and GIS data sets have finite shelf lives that will control the length of time in which a resource can be effectively utilized as a reference map. Check out the animation from DiBiase (Figure 6.5.1).

II. USGS Digital Data

The USGS has two different base digital products based on the topographic maps, which are available at a base fractional scale of 1:24,000.

Digital raster graphic (DRG; Figure 2)
Digital line graphic (DLG; Figure 3)

A third type of USGS digital product is a Digital orthophoto quadrangle (DOQ; Figure 4).

Digital raster graphic (DRG) - Is basically a scanned raster image of the topographic map. DRG's are scanned at 250 pixels per inch. So, one pixel reflects 8 ft on the earth's surface; this is the resolution of this product. As you learned from previous assignments the fundamental geometric element any raster data, including a DRG, is a pixel. Each pixel in a DRG is associated with a single attribute with pixel values ranging from 0 to 12. Therefore, there are 13 standard DRG colors present in a DRG.

Digital orthophoto quadrangle (DOQ) - DOQ's are raster images of rectified aerial photos. A DOQ has the same geometric characteristics as a topographic map. The nominal scale of DOQ's is 1:12,000 (3.75'). DOQ's have a resolution of 1 meter. Applying the National Map Accuracy Standard to this data type indicates that 90% of well-defined points must appear within 20 ft of their actual position in the real world. Each pixel in a DOQ is associated with a single attribute: a number from 0 to 255. This is a 8 bit grayscale raster. Check out the following website to see what I mean by bit (http://en.wikipedia.org/wiki/Grayscale).

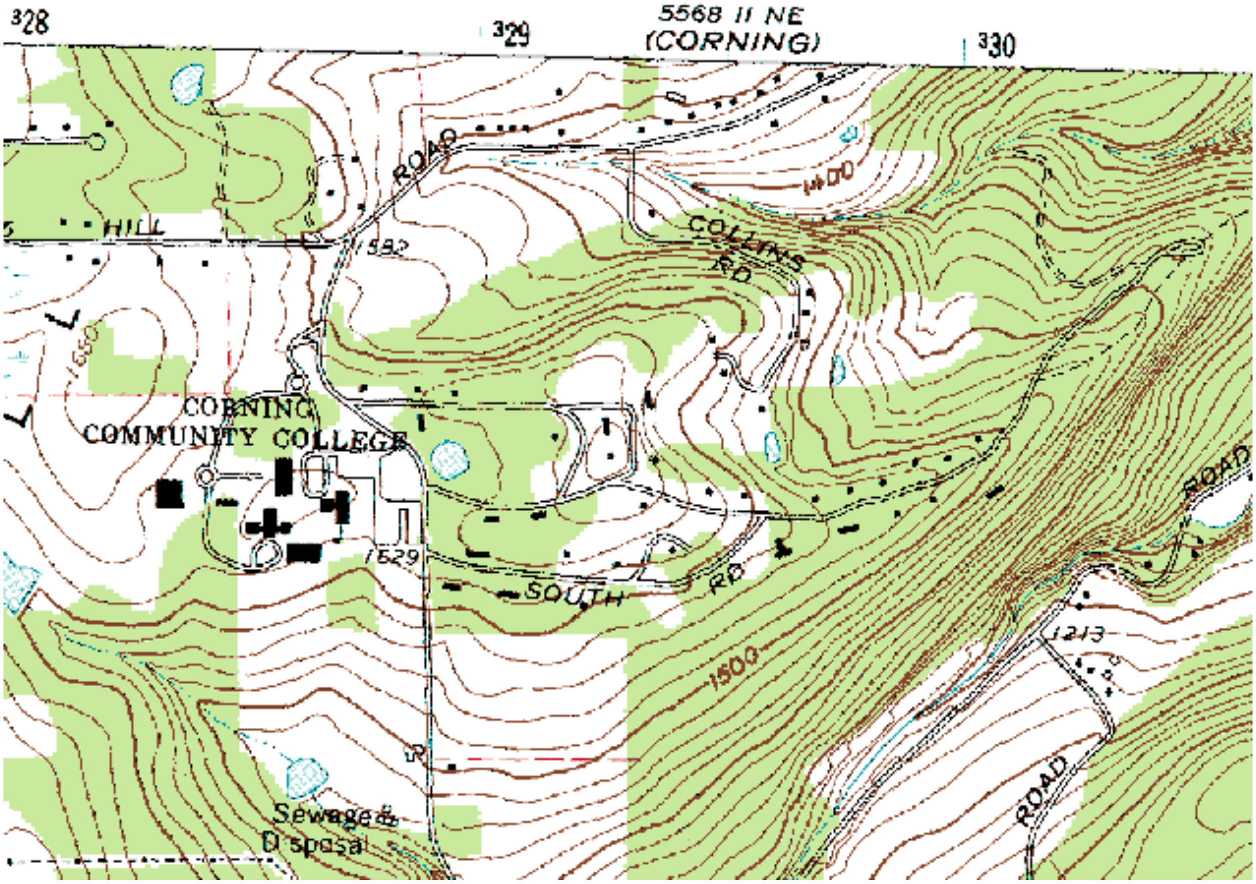

Figure 2. Sample DRG which is basically a scanned topographic map.

Since both DRG's and DOQ's are raster-based data individual entities cannot be selected in a GIS system. Typically, both DRG's and DOQ's are used as a background layer (*i.e.* reference maps) in a GIS system where other layer can be superimposed on top of the DRG.

<u>Digital line graphic</u> (DLG) - DLG's are vector layers that define the various entities present in a topographic map. Individual feature categories present in a DLG include (Figure 2):

Boundaries (city and county boundaries)
Hydrography (rivers, streams, lakes)
Transportation (roads, rail line)
Hypsography (elevation – contour lines)

These features are stored in different layers and since these vector data entities can be selected and much more attribute data can be related to each entity. Additionally, these layers that define a DLG are **topologically** interconnected. The USGS maintains DLG's at three scales.

Small	1:2,000,000
Intermediate	1:100,000
Large	1:24,000

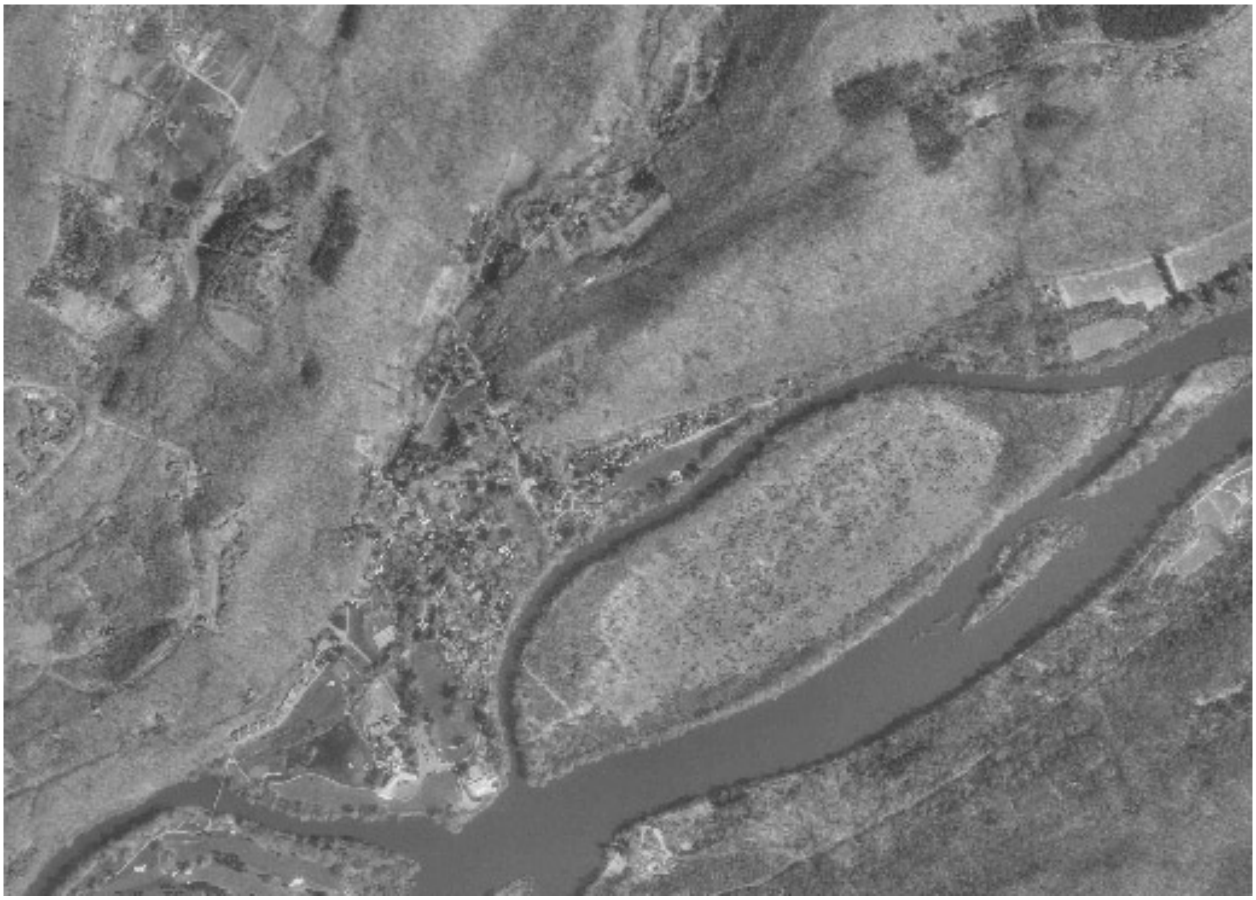

Figure 3. Image of a sample DOQ, which is raster based aerial photo that is georeferenced and has a constant scale across the photo.

III. Aerial Photography and Orthophotos

In Texas, beside the USGS DOQ, aerial photography is available from two other different sources, which include the Texas Department of Transportation (DOT) and Agriculture Stabilization and Conservation Service (now known as the US Department of Agriculture). Texas DOT data is referred to as Level 2 (L2) orthoimagery. USDA imagery is today acquired through the National Agriculture Imagery Program (NAIP, https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/). Download some orthoimagery from the NAIP website and import these images into your Map view. Explore how this data can be potentially used as a reference map. Start to think about how you could utilize some of this data in your final project?

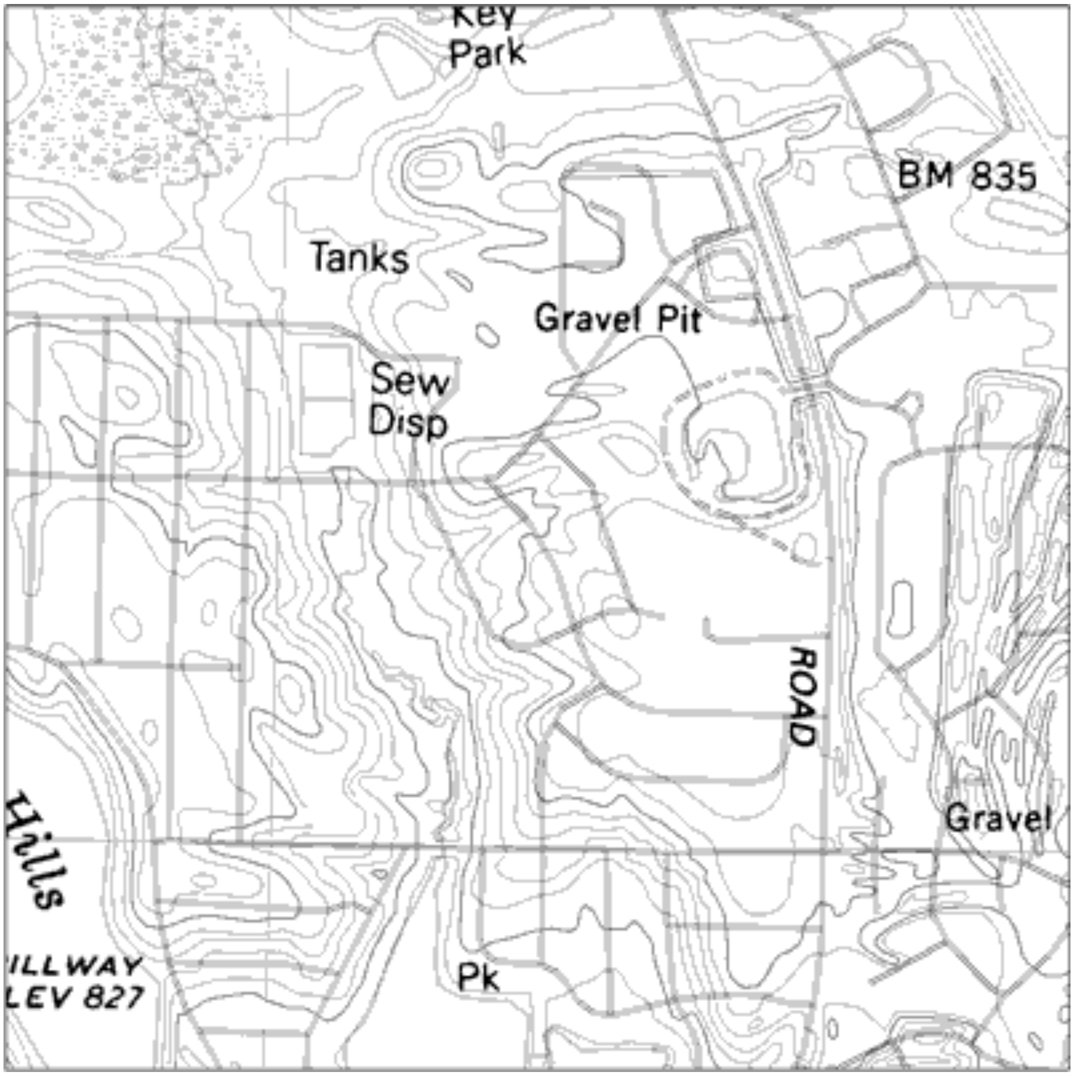

Figure 4. Image of a sample DLG, which has vector-based features such as roads and contour lines.

Aerial photographic is the easiest method of tracking how land use changes through time. TNRIS maintains the most extensive archive of historical aerial photography covering the entire state of Texas, which goes back to the dawn of aerial photography in the 1920's. Today NAIP imagery is obtained on an annual basis allowing users and researcher the ability to track land use changes.

Note that aerial photography we have been discussing, which is used in GIS systems, are orthophotos such as the DOQ's developed by the USGS. An orthoimage is a special type of aerial photograph that is geometrically corrected ("orthorectified") such that the scale is uniform across the entire photo allowing the user to use this photo as a reference map. If you think about it an aerial photo will have distortions because features across the photo will be at a different angle relative to the camera (Figure 5). The next section on photogrammetry, the science of adjusting aerial photos, will discuss how aerial photographs can be corrected.

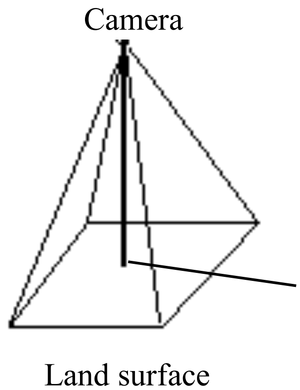

Figure 5. An illustration of the spatial relationship of the aerial camera and land surface in an aerial photo. Distortion will exist throughout the aerial photo except for at the principal point in the center of the photo, which is a point that is perpendicular relative to the center of the lens of the camera and the land surface.

Unlike an uncorrected aerial photograph, an orthophotograph can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt. Therefore, orthophotographs are commonly used as reference maps in GIS projects. GIS software can not only display the orthophotos but can allow users to digitize features creating new data layers such as streets and buildings that are vector-based. Created vector data can be related to extensive attribute information. Now you can begin to see how reference layers can be used to generate additional layers that are customized for an individual user. Finally, some GIS software can process the orthophoto and produce the vector-based linework automatically.

IV. Photogrammetry

Photogrammetry is the profession concerned with producing precise measurements of objects from photos. Why can a topographic map not be made by simply tracing features off a single aerial (or satellite) photo? The only point on a photograph that is distortion free is the point immediately below the lens - called the principal point (Figure 5). The only place on the photo where the horizontal scale is constant is at the principal point with increasing distortions away from the principal point towards the edge of the photo causing a changing scale.

There are also problems with distortion in the vertical direction. Points on the photo that have above average elevation will be displaced away from the principal point. Points on the photo that have below average elevation will be displaced towards from the principal point. Example: Lets imagine we have three side-by-side photos of a straight road (Figure 6). Because of distortions when we lay these photos next to each other we do not have a straight road but a zig-zag highway. Aerial photos can be corrected digitally to account for both horizontal and vertical distortions through a process called rectification.

Figure 6. Relief displacement of pipeline in the center of the aerial photo associated with three unrectified aerial photos compared to actual location in topographic map.

The primary method of rectification that corrects distortions in aerial photos is by Stereoscopic (3-D) viewing. In the old days this was done manual with an analog stereoscope. Today, rectification is facilitated digitally using a device called a stereoplotter.

An orthophoto is an aerial photo that has been completely corrected for distortions. This means that every pixel in the photo is as it would have been if its location were at the principal point. Even with significant corrections there still can be problems especially when matching up two adjacent orthophotos. Commonly, there can be significant offsets between two adjacent orthoimages meaning that your images commonly will not quite match up seamlessly.

Readings

DiBiase, D., 2014, Nature of Geographic Information Systems. Sections 6.2 to 6.16.

Terms

DRG	DLG	DOQ	NAIP
Reference Map	L2	Orthorectified	Principal Point
Thematic Map	Photogrammetry	Stereoplotter	Orthophoto

Concepts

Know about the different scale maps offered by the USGS

Check out the USGS Map Symbol PDF

How are different colors used to represent diverse features on a USGS map

What are the three main mapping products offered by the USGS

What steps are needed to transform an aerial photo into an orthophoto

HOMEWORK

1. Which of the following USGS products is not a raster?

(a) DRG (b) DLG (c) DOQ (d) None of the above

2. A digital line graphic lacks topology? True or False

3. The following scale represents the smallest scale typically used by the USGS.

(a) 1:24,000 (b) 1:62,500 (c) 1:100,000 (d) 1:250,000

4. In you own words explain why you cannot use an uncorrected aerial photography to make measurements in ArcMap.

5. Discuss the significance of the principal point in an aerial photograph.