Work book

Map Projections

GIS Exercise - 16th December 2003

Information Products for Nile Basin Water Resources Management
www.faonile.org

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Introduction

Requirements

This exercise requires a PC running Windows 95/98, NT/2000/XP, with ArcView 3.x including the projection utility. Internet access is needed. The necessary data are provided.

Objectives

The objective of this exercise is to gain a basic understanding of map projections, and how a projection affects the result of a GIS analysis. After completing this exercise, trainees will be able to:

- Understand the basic principles of map projections;
- View different map projections of the same land area;
- Change the map projection of a data layer;
- Recognize the distortion associated with selected map projections;
- Select the appropriate projection for specific GIS analysis objectives.
- Find useful scripts on the internet and expand the functionality of ArcView.

Task

Locate an avenue script that calculates the area of a polygon and add a button to the interface that executes this script.

Prepare a set of layouts showing the world, Africa, and the Lake Victoria area in various map projections. Select the proper projection

Preparation

Before starting with the projection exercise, we will add a new function to calculate the area of a polygon. Projections affect the distortion of area, scale, local shape, direction, and distance. The new area calculation function will help in assessing the distortion associated with various projections.

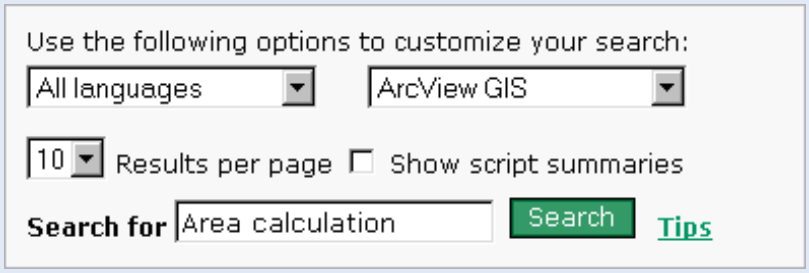
Find script to calculate the area of a polygon.

In this exercise we will explore the online support offered by ESRI to expand the functionality of ArcView, and to tap into a global network of GIS tool and script developers.

Open Internet Explorer and browse to www.esri.com.

Select "Support"; spend ten minutes to check out the "Knowledge Base" and "User forum" topics. Go back to "Support" => "Downloads" => "ArcScripts".

Select "ArcView GIS" in the search interface. Type an appropriate query in the "search for" text box, e.g. "Area Calculation". Activate search by clicking the "search" button.



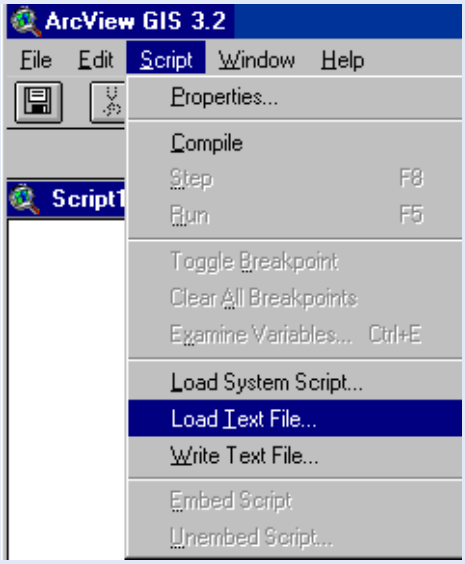
The first 10 results are shown. Select an appropriate script; in this particular case "Area Calculation for Polygon". Double click and read the script summary; download the file to C:\GIS_Work\GISWS\ExProj\AvScript. Upzip the file. This is an avenue script file named "area.ave"..

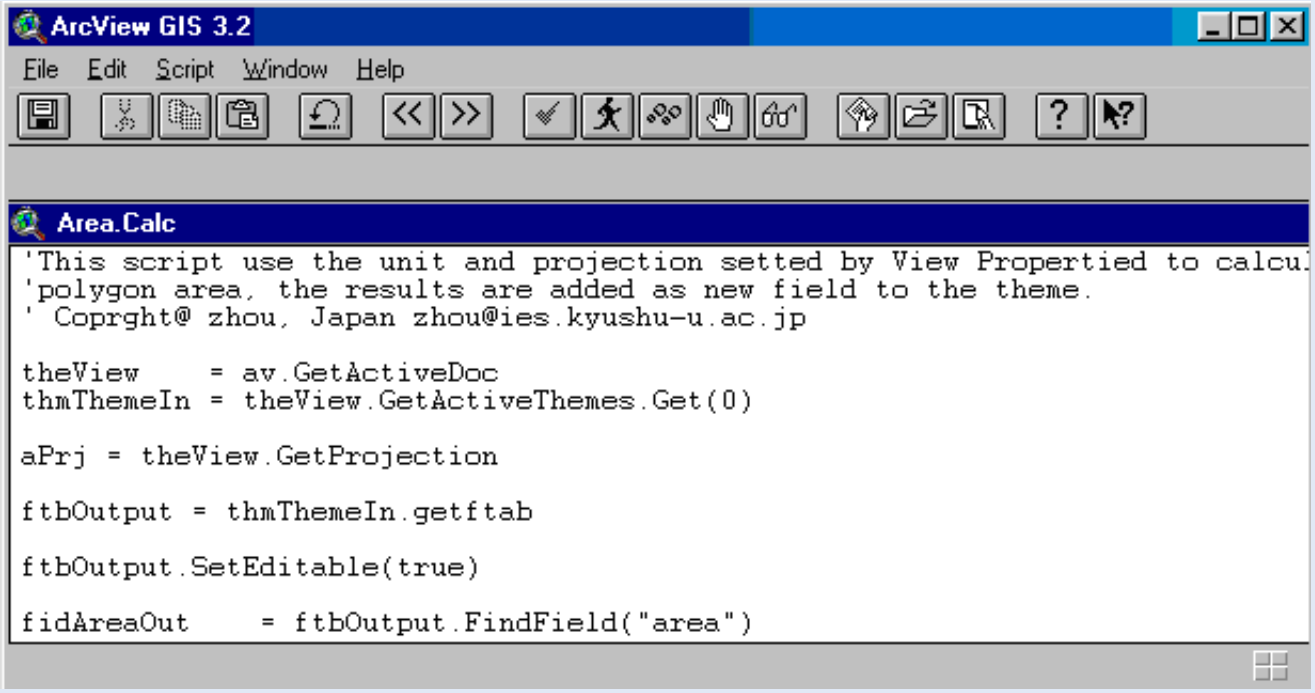
Open ArcView and select Scripts from the project window. Click "New" to begin a new script.

In the "Script" menu, select "Load Text File". Navigate to the appropriate folder and select "area.ave".

Change the name of the script. Select "Properties" in the "Script" menu, and type "Area.Calc" in the "Name" text box.

Compile the "Area.Calc" script by clicking the compile button; the resulting window is shown below.





Leave the script area to return to the project window.

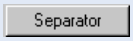
Add a new button to the ArcView interface.

In this exercise we will add a new button to the ArcView interface and connect it to the area calculation script.

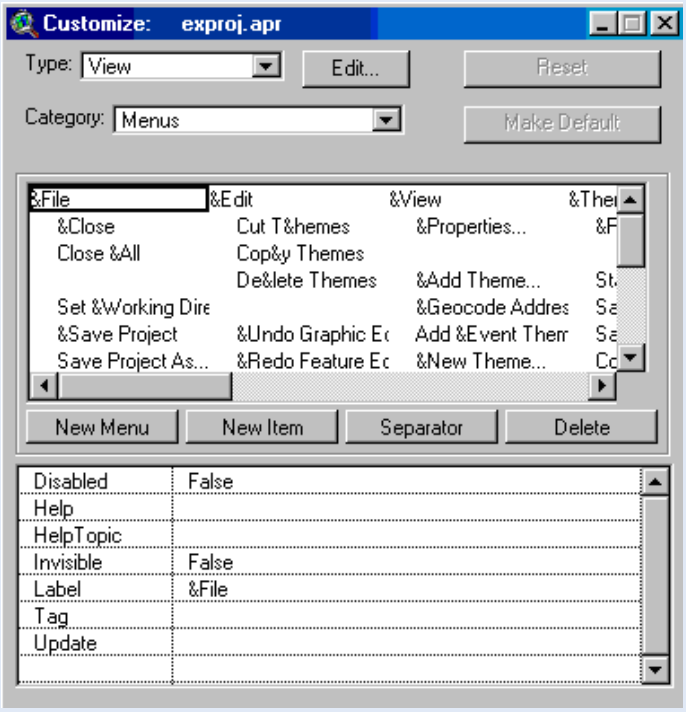
Select Views,  and open a new view. Double click the menu/toolbar area. The following window appears.

From the drop down list in the "Category" box, select "Buttons".

All elements of the current button bar are presented. Move the slide bar to its most rightward position.

Click the separator button 

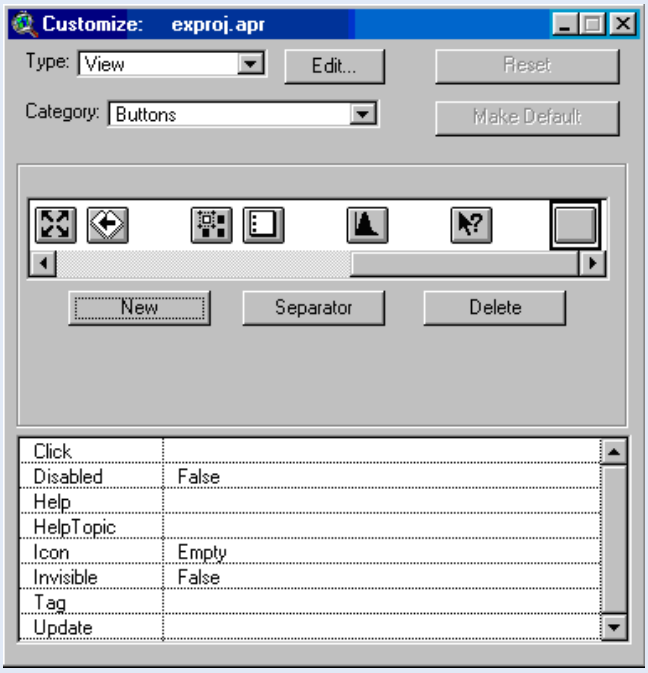
to add a space; then click the "new" button. A new blanc button  is added.



We proceed by setting the properties of this new button, and connect it to the Area.Calc script.

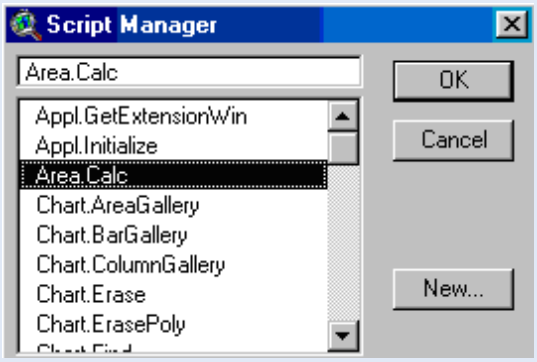
Click the button just added. Its attributes are shown in the window on the left. As you can see, no instructions are connected to the "click" attribute; its field to the right is empty.

Double click this field; it is indicated with an arrow.

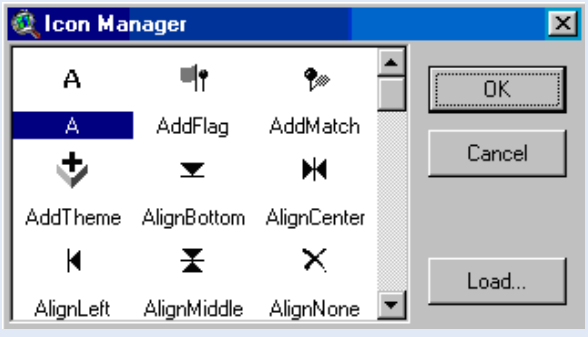


The script manager appears. Select the Area. Calc script and click OK.  The text in the function field has now changed to Area.Calc.

Next we will add an icon to the new button. Double click the field next to "Icon", which now shows "empty". This activates the "Icon Manager", shown on the left



Select A for area, click OK 



This step concludes setting the properties of the new button. The button is now added to the interface and operational; it will calculate the area of a selected polygon.

Save the project if you want to keep the new interface.

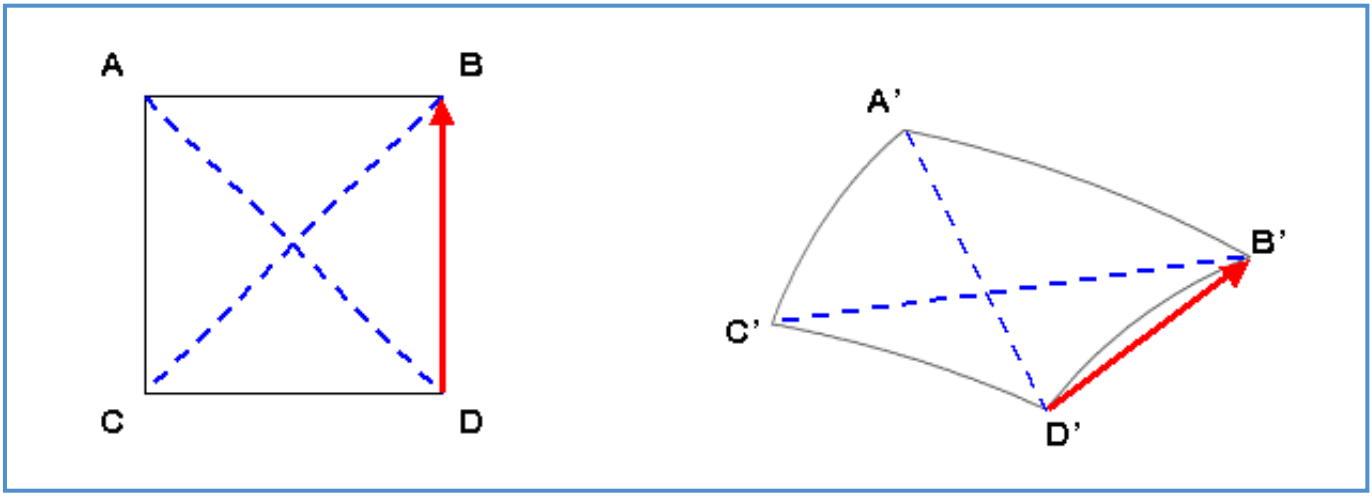
Before starting with the projection exercise, go back to the ArcScript web page and spend some time checking for useful ArcView script that can expand the functionality of this package for water resources assessment, planning, and management purposes.

Procedure

Map Projections of the World

Selecting a map projection is all about managing distortions. The choice of a particular projection depends on the objective of the user. Does he want to calculate an accurate area, or is she more interested in a proper reflection of the local shape of the geographic object.

Projections affect five types of distortions: area, scale, local shape, direction, and distance. This is illustrated by the figures below:



The first figure presents the original square. Angles between horizontals and verticals are 90 degrees. The parallels AC and DB are identical in length and perpendicular.

A different projection leads to 'square' number two, with the following distortions:

- Distance: A'D' ≠ C'B'
- Scale: A'B' ≠ C'D'
- Direction: vector D'B' no longer coincides with the right edge of the box
- Local shape: no 90^0 angles between horizontal and vertical box edges
- Area: implied by 1 & 2

Conformal projections preserve local shape. All angles between arcs are preserved, including those between intersecting arcs.

Equal area projections maintain the area of the geographic object. Shape, angle, scale, or any combination of this may be distorted.

True equidistant projections do not exist. Scale is not maintained correctly by any projection through the entire map. However, there may be lines for which scale is maintained correctly.

True direction projections correctly represent the shortest route between two points.

Project the world in the three major projection classes

Major projection classes are cylinder, cone, and plane.

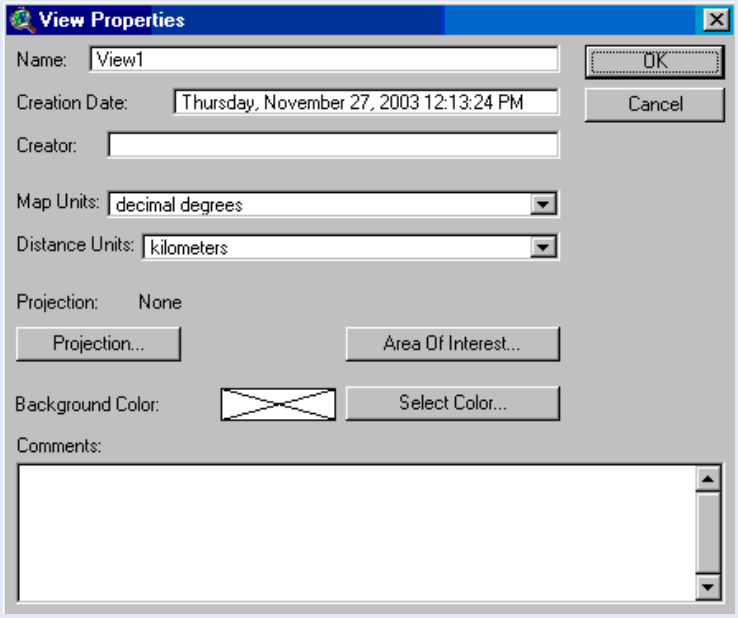
Activate ArcView and open a new view. Add the "Continent.shp" and "Wldgrd05.shp" layers. Data are stored in the "ExProj" folder. Select "Properties" from the "View" menu.

The properties box, presented on the left, appears. Click the Projection button.

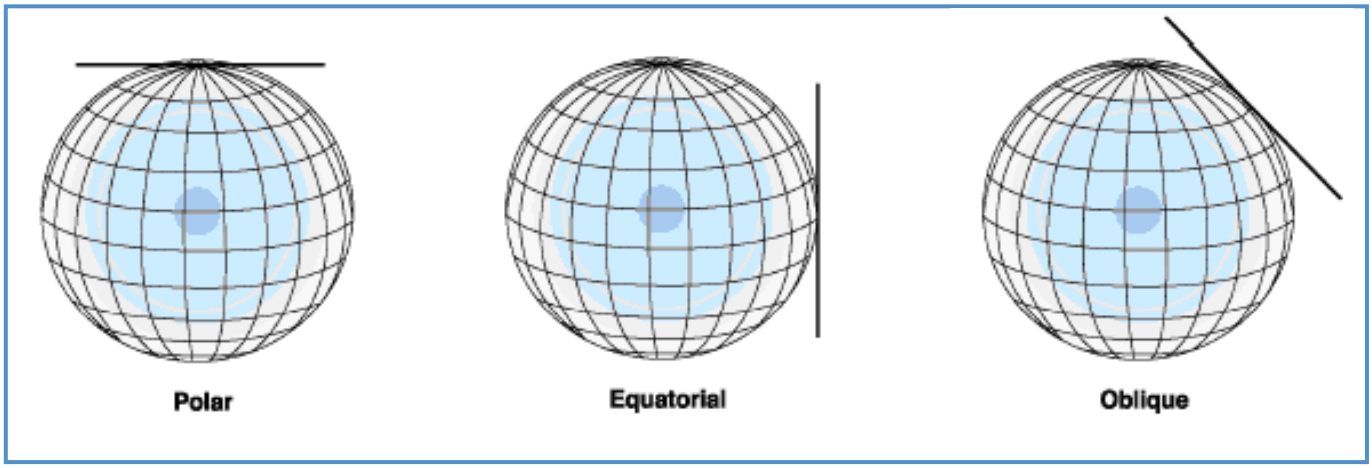
Let's check out the planar projection class first.

The planar projection projects data onto a flat surface touching the globe.

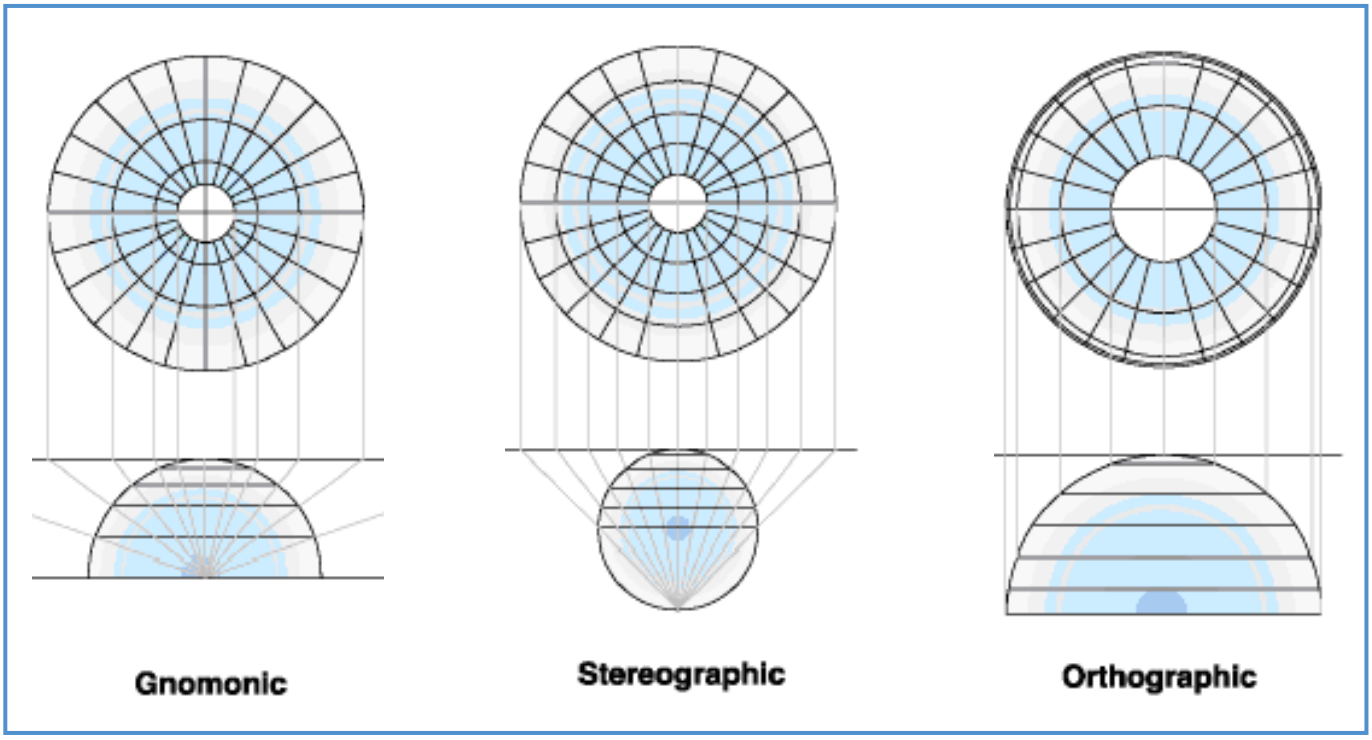
This projection is also referred to as Azimuthal.



The connection point of this plane to the earth determines if we have a polar, equatorial, or oblique Azimuthal projection, as shown below.



Azimuthal projections include Gnomonic, Stereographic, and Orthographic, which have different focus points.

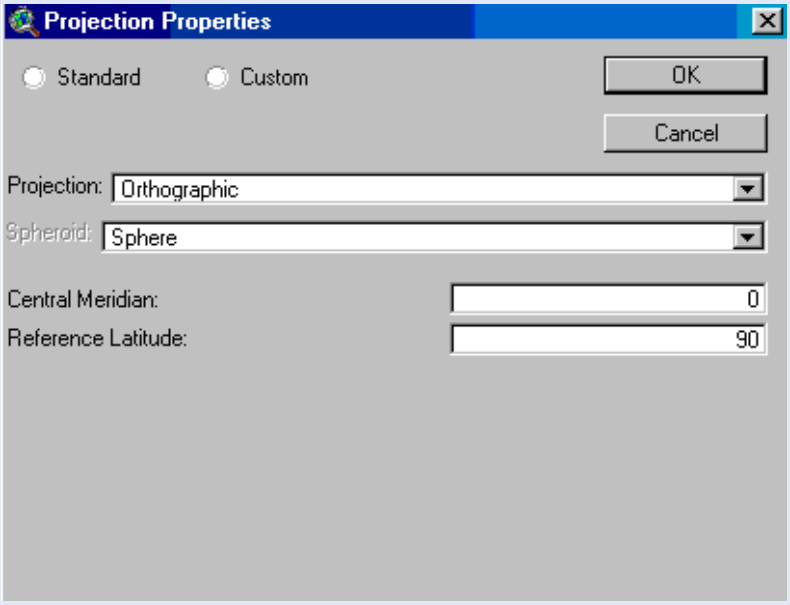


Exercise: Present the world in Gnomonic, Stereographic, and Orthographic projections. Check the various distortions around the pole and the equator. What is the point of least distortion?

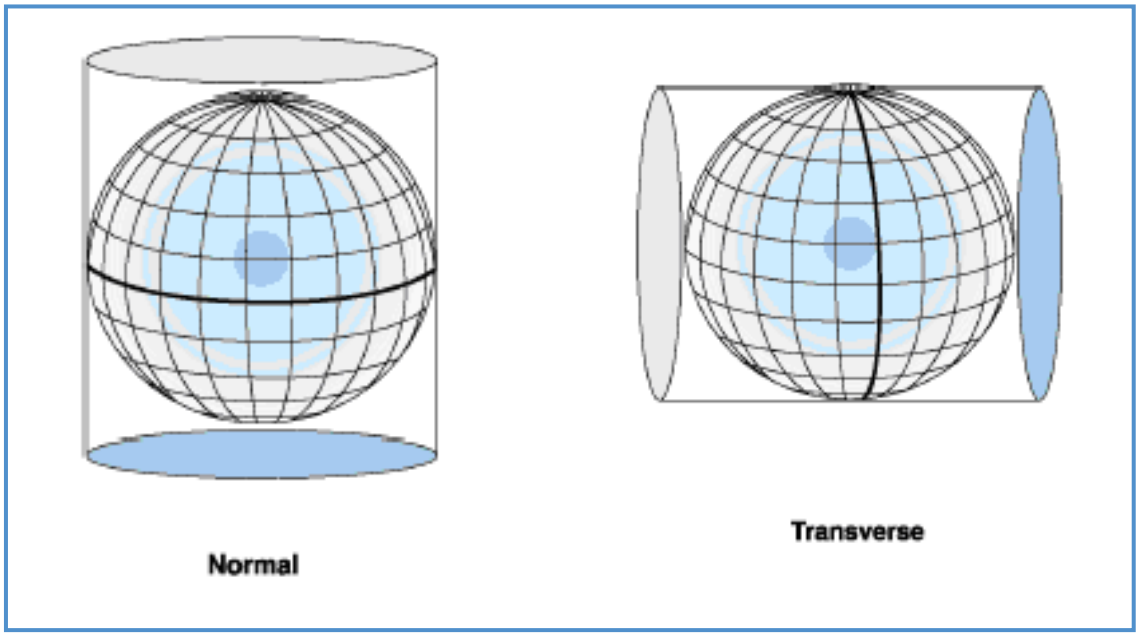
Select the proper projection in the drop down list. Set the Central Meridian to 0, and the Reference Latitude to 90.

Present the world in Gnomic, Stereographic, and Orthographic projection.

Next, repeat the exercise with focus on Africa: Central Meridian = 20, and Reference Latitude = 0.



We will continue with the Cylindrical projection. Two important members of this class are the Mercator (Normal Cylindrical) and UTM (Traverse Cylindrical), both presented below.



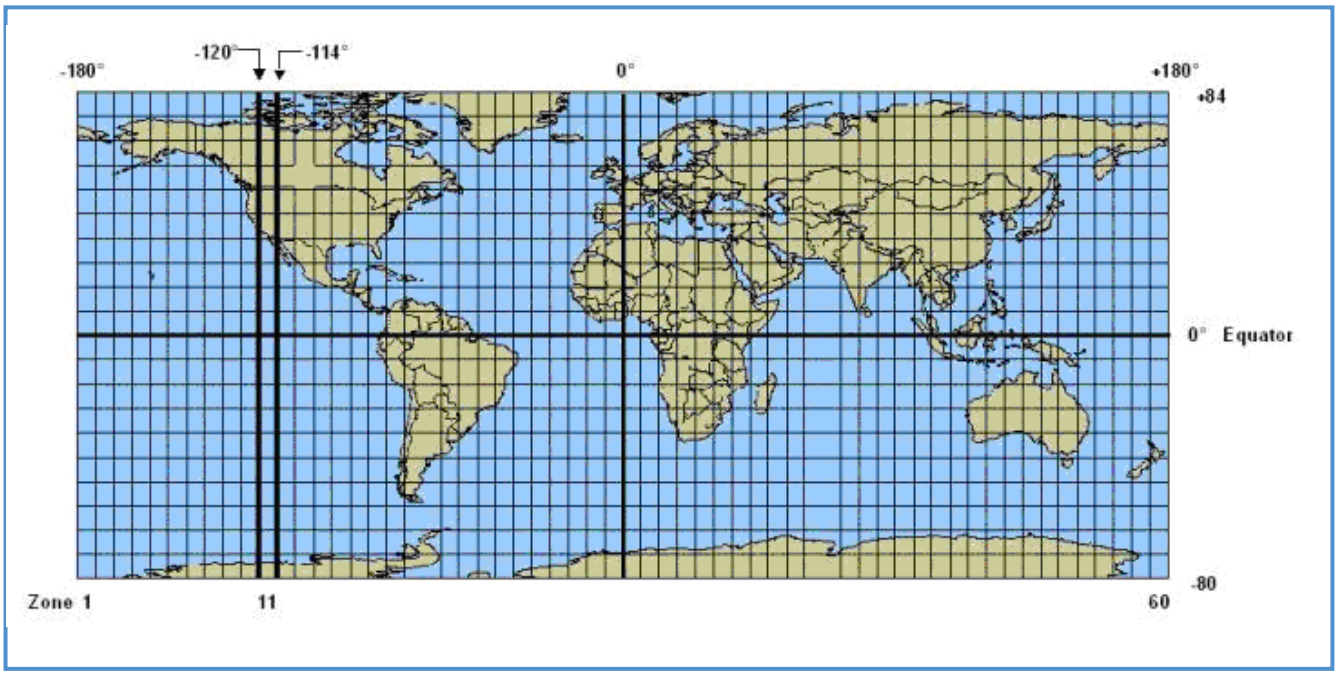
Mercator has a line of no-distortion (called Standard Line) around the equator; areas close to the poles are experiencing significant distortion.

Exercise: present the world in Mercator projection.

Universal Transverse Mercator (UTM) is the de facto world standard for topographic mapping. About 85% of the land area in the world uses this projection.

- UTM divides the world in 60 longitudinal zones of 6^0 each, starting at -180^0, annotated zone 1;
- UTM makes a latitudinal division into 8^0 intervals.
- Each zone has its own coordinate system.
- UTM is inappropriate for large areas, since the area to be mapped has to be part of one UTM zone.

World UTM zones are depicted in the following figure.



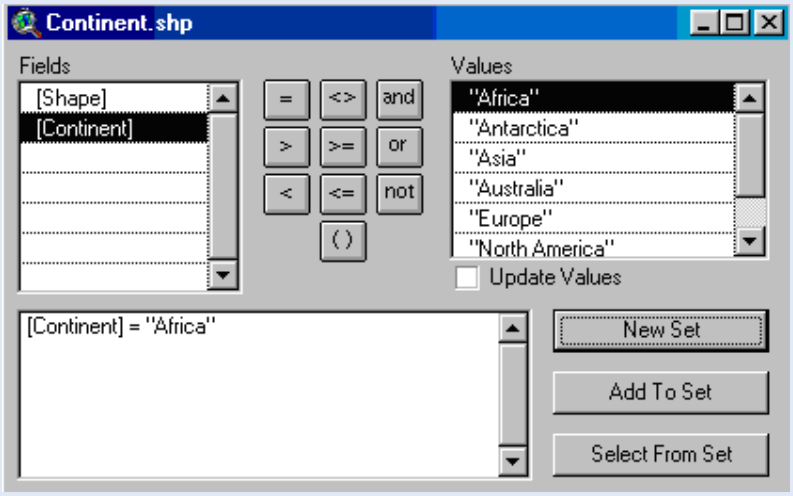
Exercise: select the proper UTM zone for the Lake Victoria region.

Open a new view and add the "Continent.shp". We will use a map query to create a new layer containing the African continent. Select "Query" from the "Theme" menu.

Build the appropriate query. Double click "Continent" from the field list. Click the "=" sign, then double click "Africa". The query window is presented on the left.

Click "New Set"

Activate the View window.

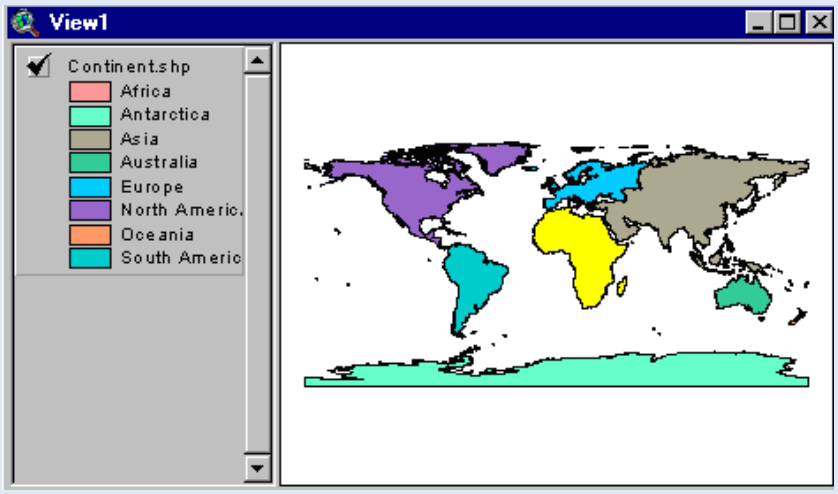


Africa is marked yellow, indicating it has been selected, as shown below.

Create the new shape file. To this end, select "Convert to Shape File" from the "Theme" menu.

Navigate to the "ExProj" folder and name the new shape "Africa.shp".

Click OK. The new shape file is generated.



Close the Query box and remove the "Continent.shp". To this end, activate this layer and select "Delete Themes" from the "Edit" menu.

Add the following layers to the view: "Afgrd02.shp", "Lakevic.shp", and "Africa.shp", which should all be available in the "ExProj" folder. The resulting view is presented below.

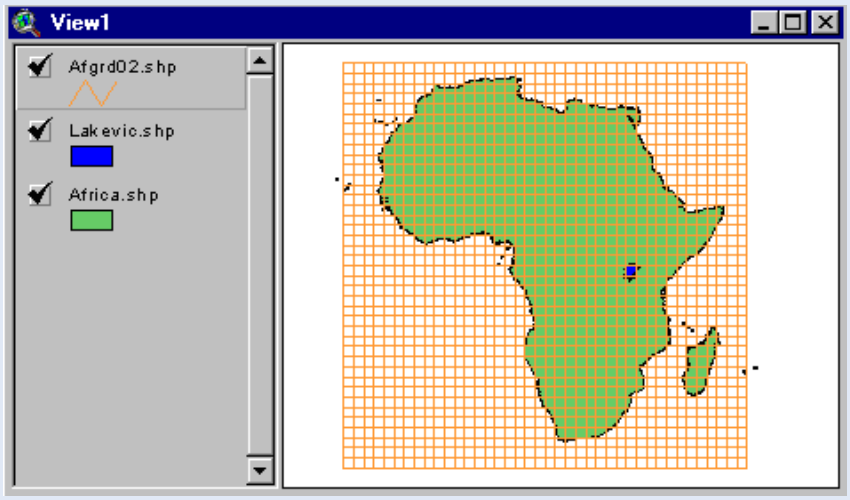
Select the proper UTM zone for the Lake Victoria Area, and project the view in this projection.

Select "Properties" from the "View" menu.

Click the Projection button.

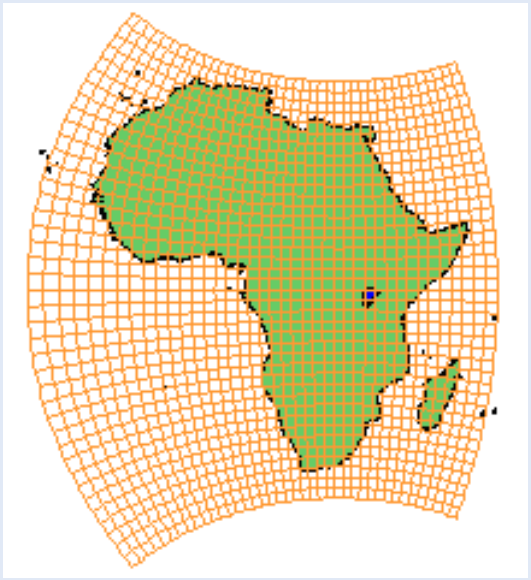
Select "UTM – 1983" and set the appropriate zone. Click OK .

Set the Map Units to kilometers



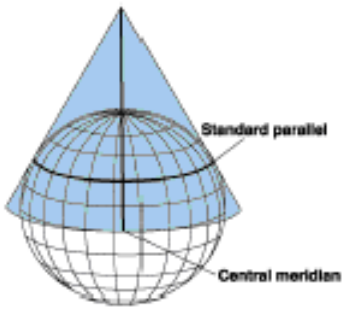
The result is shown below.

Try out various UTM zones and check the difference. Zoom in to the Lake Victoria to see how the graticule changes.

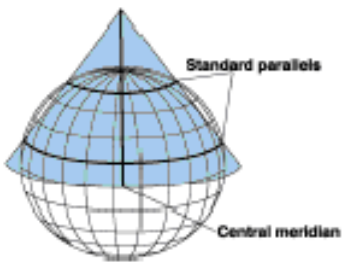


We continue with the last projection class: Conical.

Two important members of this family are "Normal Conical" and "Secant Normal Conical", both presented below.



Normal Conical.



Secant Normal Conical.

The Normal Conical is tangent to the globe along a line of latitude. This line is called the "Standard Parallel" and represents the line of no distortion. The meridians are projected onto the conical surface, meeting at the apex of the cone. Parallel lines of latitude are projected as rings.

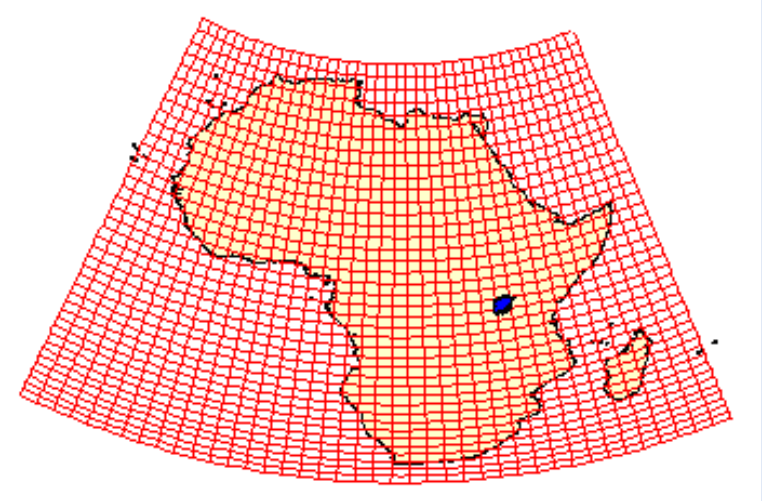
The Secant Normal Conical intersects the globe at two locations, and is thus defined by two Standard Parallels. Generally, a Secant Normal Conical projection has less distortion than a Normal Conical.

Conical projections are predominantly used for the temperate latitudes. A well know member of this class is the "Albers Equal Area" projection.

Exercise: present the Africa shape and grid in the Albers Equal Area projection. The result is shown below.

Adjust the Standard Parallels to facilitate accurate calculation of the surface area of the Lake Victoria.

Spend some time experimenting.



Select a proper projection and calculate the surface area of Lake Victoria

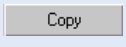
The next exercise is to calculate the surface area of the Lake Victoria for various projections. Select an appropriate Planar, Conical, and Cylindrical projection with minimal distortion of area in the equatorial regions. Then use the Area.Calc script to calculate the surface area.

This Area.Calc script adds a column to the attribute table. To avoid corrupting the original layer, copy the LakeVic.shp to a new coverage, and use this coverage file for the area assessment.

Each spatial layer consists of a number of files, ranging from 3 to 7. One has, therefore, to be cautious when copying a layer. Forgetting a file may result in loosing projection or geo-referencing. A convenient tool for managing spatial layers is the "Source Manager" included in ArcView.

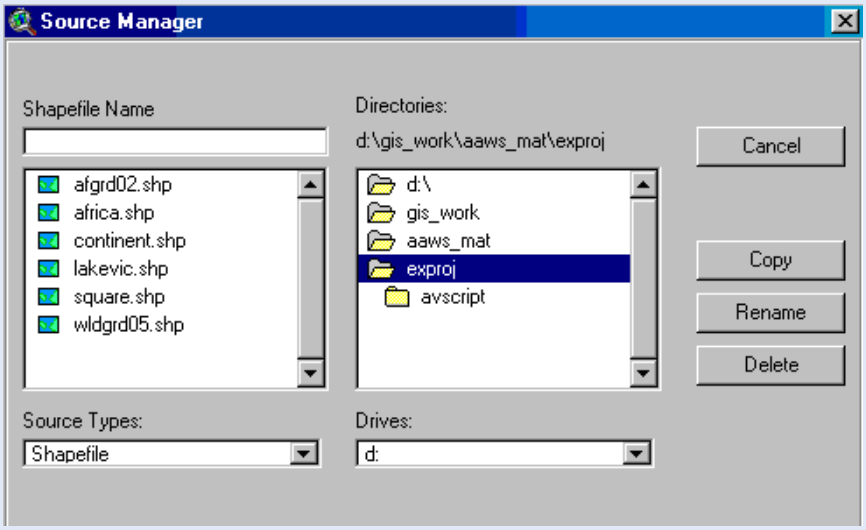
Select "Manage Data Sources..." from the "File" menu.

This activates the "Source Manager", shown on the left.

Navigate to the "ExProj" folder and select the LakeVic.shp file. Click Copy  and select a name (e.g. "LV.shp") and location for the file.

Click OK  to finish.

Close "Source Manager



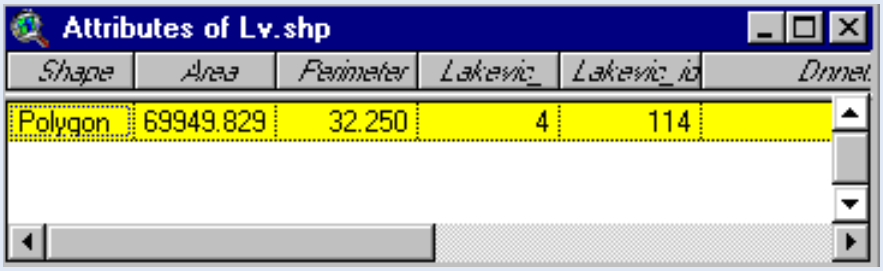
Add the new shape to the view.

Exercise: select a proper projection to calculate the surface area of Lake Victoria.

Set the appropriate projection. Make sure to define the proper map units.

Activate the new layer (i.e. LV.shp)
Then click  to open the attribute table. Select the Lake Victoria polygon.

The result is shown on the left.



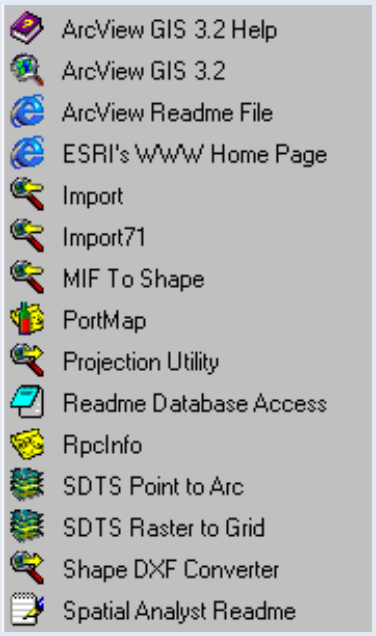
Click the A button to calculate the area of the selected polygon. Compare the surface area calculated with a Planar, Cylindrical (UTM), and Conical projections. For the latter, use Albers Equal Area. While analyzing the results, please keep in mind that the Lake Victoria islands were removed from the polygon.

Use the Projection Utility.

Use the Projection Utility to permanently change the projection of a shape file. If you are dealing with an ARC/INFO coverage, first transfer it to a shape file.

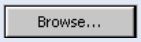
Browse to "Start" => "Programs" => "ESRI" => "ArcView GIS 3.2" and select "Projection Utility" from the menu options, as shown on the left.

The ArcView projection utility is a wizard-based tool that allows you to project shape files, either from geographic coordinates to projected coordinates, or from one projection to the other. The utility also facilitates to convert the datum of your shape files.



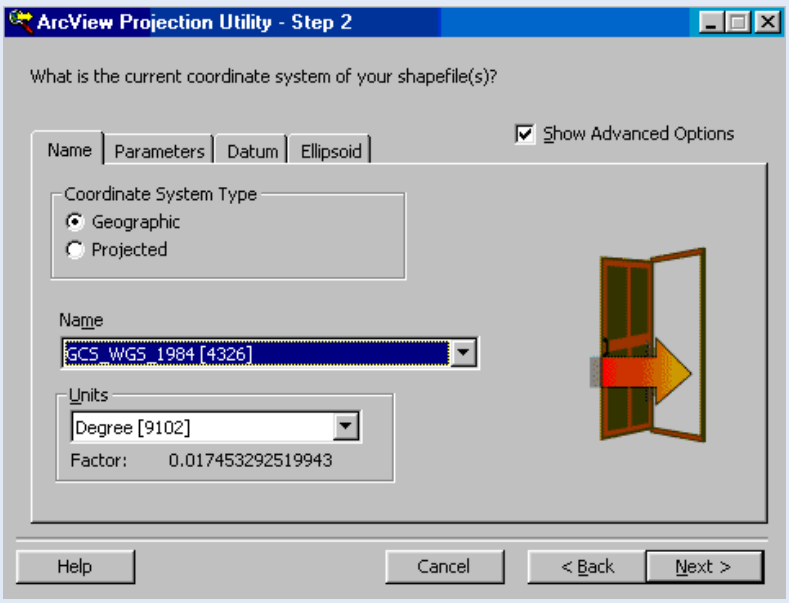
Exercise: Change the projection of the LV.shp file to UTM zone 35, WGS 84 datum.

After activating the wizard, follow the instructions on screen.

Click Browse  to select the "LV.shp" file.

Define the current projection. Set the datum to GCS_WGS_1984.

Click Next 

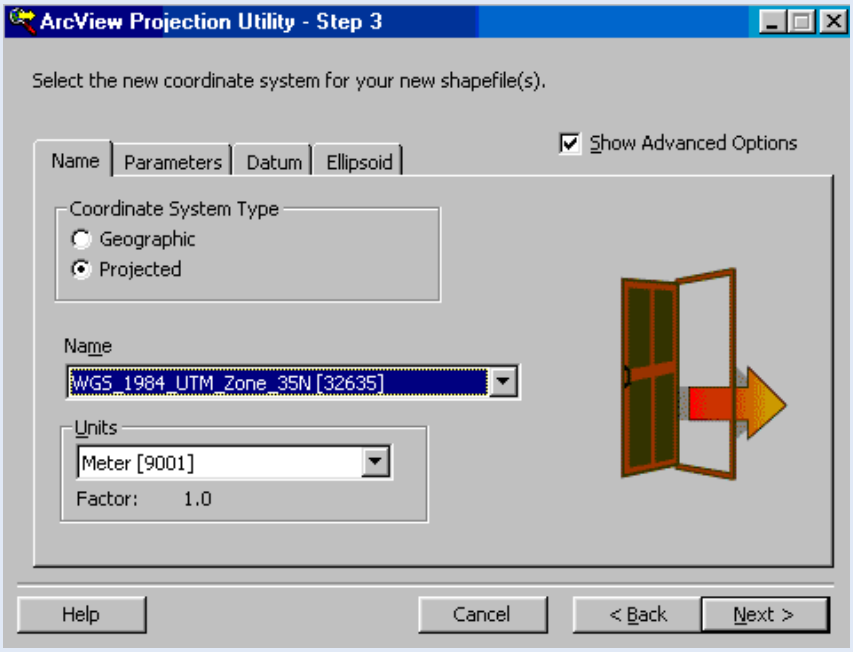


Select the new projection. Activate the "Projected" radio button in the "Coordinate System Type" box.

Select the appropriate UTM projection. Make sure to use WGS_1984.

Set the units to meters.

Click Next 

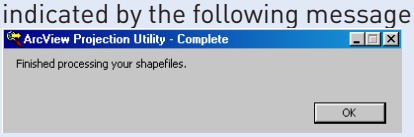


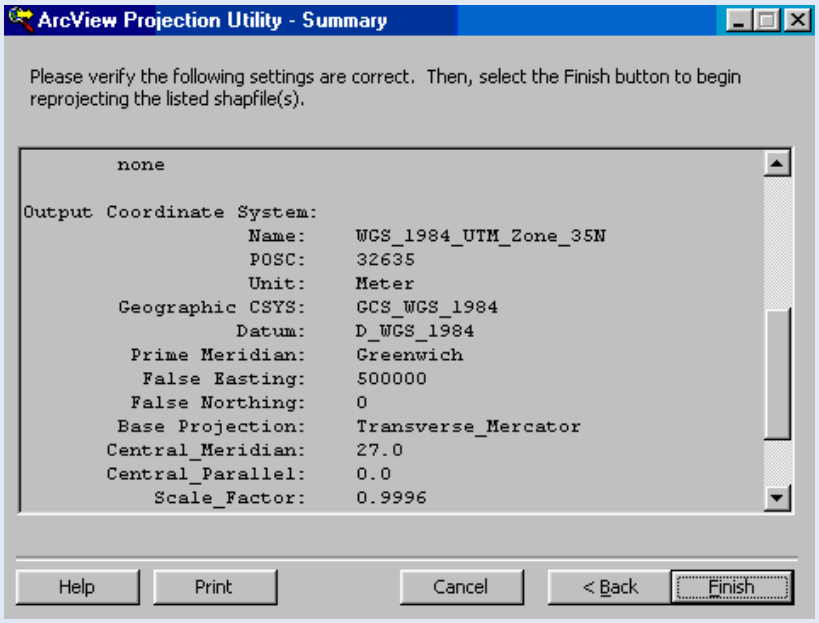
Select a name and folder for the new shape file. Click Next. A summary window appears.

Check the input and output variables.

If correct, click Finish 

The new shape file is generated in the requested projection. Completion is indicated by the following message:





Open new View, add the new shape file, and check results.

This completes today's exercises and course work. Projections are now demystified!

Reference

ESRI Digital Document: Understanding_Map_Projection.pdf