Paper No: 363

Title: GIS for Historic Analysis

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Abstract:

The U.S. Air Force Academy has experienced a great deal of development within surrounding communities. As Colorado Springs continues to grow, commercial and residential developers will continue to acquire desirable land adjacent to the Academy. It is important to understand the historical record of this urbanization in order to project trends and understand potential encroachment concerns as well as impacts to the natural resources of the Academy that will result from this development. This paper will address how GIS will be used to create, visualize, and analyze the data.

USAFA History

In 1954, Congress authorized creation of the Air Force Academy. The ten secretary of the Air Force, Harold E. Talbott, appointed a commission to assist in choosing the permanent site. After traveling 21,000 miles and considering 580 proposed sites in 45 states, the commission recommended three locations. From those, Secretary Talbott selected the site near Colorado Springs. The state of Colorado contributed $1 million toward the purchase of the property.

Figure 1: 1954 Aerial view of the Air Force Academy site before construction.

The staff and faculty of the U.S. Air Force Academy, in the interest of our future national security, molds outstanding young men and women into Air Force officers with knowledge, character, and discipline; motivated to lead the worlds greatest aerospace force in service to the nation. Before its graduates enter various flying and support specialties, the Academy trains them to be, first and foremost, Air Force officers. Of the 34,065 cadets who have graduated in 43 classes, more than 51.2 percent are still on active duty. In addition to the mission to develop outstanding young men and women, the Academy is also an active installation. The 10th Air Base Wing was re-activated activated on Nov. 1, 1994 as the support wing for the U.S. Air Force Academy, Colorado.

Figure 2: Recent photo of the chapel at the Air Force Academy.

The Air Force Academy is located at the base of the Rampart Range on 18,500 acres. The elevation is 7,163 feet above sea level at the Terrazzo level of the installation.

Developing Historic Spatial Data

This project involved the use of Geographic Information Systems (GIS) to develop an historic land use database. GIS has the ability to create, store, edit, visualize, analyze and present data needed to study the historical urban growth of the area. Understanding past land use trends and their environmental impact was crucial to improving current environmental management practices. Historic spatial and tabular data were developed to quantify the changes in area for all water bodies, watercourses, roads (dirt and paved), vegetation and major structures/built up areas (including paved areas), for each selected year.

An Area of Interest (AOI) was defined that included the Academy boundary and several miles in each direction. This ensured that development trends were clearly visible.

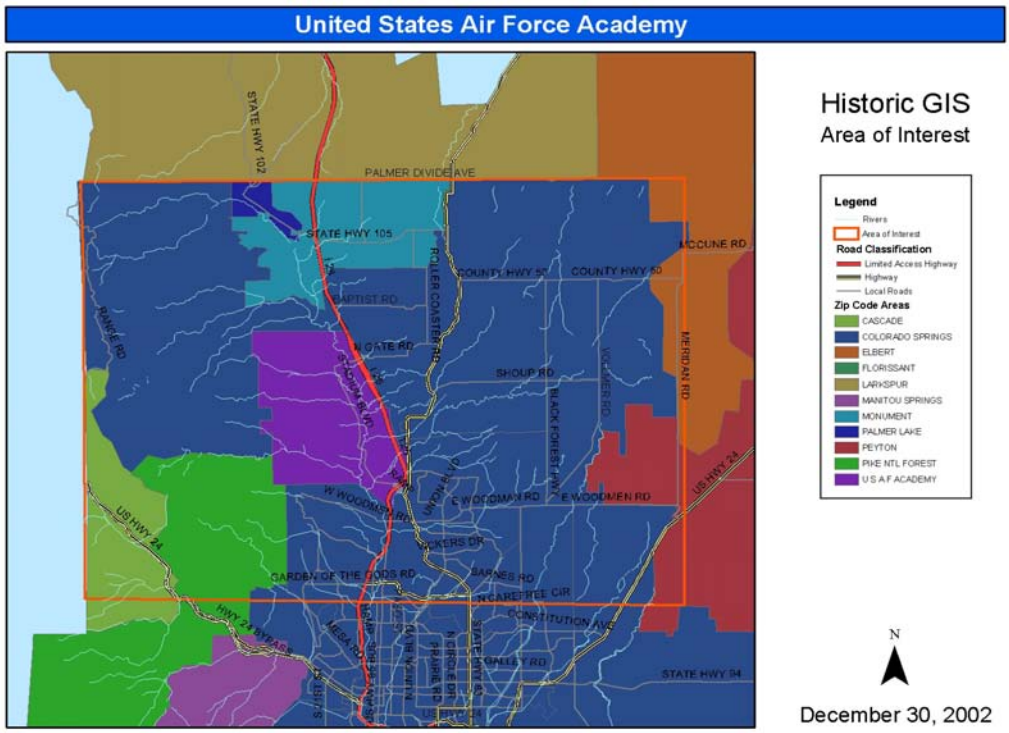


Figure 1: The Area of Interest

The creation of historic spatial data began with a large effort to research all existing resources. The investigation for historic raster or vector data began with federal, state and local agencies. These organizations include USDA, NIMA, BLM, El Paso County, the city of Colorado Springs, the Pikes Peak Council of Governments, USGS, the Army Corps of Engineers and several commercial vendors (including Pixxures, American Reprographics, Intrasearch and Airphoto USA). It was determined that there was no existing historic spatial data that would be of value. Historic raster data was available from a variety of sources.

Year	Format	Resolution	Geo-Referenced	Cost	Cov-erage	No. of Images	Point of Contact
NEW	digital	6"	yes	free or negligible	100%	1	USGS
1956	digital	1:20,000	no	1,140.00	100%	110	USDA ASPFO office- Salt Lake City
1962	digital	1:20,000	no	800.00	75%	76	USDA ASPFO office- Salt Lake City
1967	digital	1:20,000	no	approx. 580.00	70%	54	USDA ASPFO office- Salt Lake City
1983	digital	1:20,000	no	180.00	100%	13	USDA ASPFO office- Salt Lake City

1993	digital	1:40,000	no	300.00	90%	27	USDA ASPFO office- Salt Lake City
1995	digital	1:24,000	no	135.00	10%	7	USDA ASPFO office- Salt Lake City
1979	Digital	1:24,000	No	3,350.00	100%	67	Ron Macke American Reprographic
1999	digital/ DOQ	?	yes	320.00	100%	1	USGS Steve Reiter
1965	analog	bad	no	51.00			USGS corona satellite photo
1988	analog		no	50.00			USGS- NAPP
1953	analog	1:63,299	no	16.00- add'l cost for scanning	50%	1	USGS EROS Satellite
1953	analog	1:53,000	no	16.00- add'l cost for scanning	50%	1	USGS EROS Satellite
1969	analog	1:28,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1969	analog	1:28,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1969	analog	1:28,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1969	analog	1:28,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1969	analog	1:40,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1969	analog	1:40,000	no	16.00- add'l cost for scanning	See map	1	USGS EROS Satellite
1989	analog	?	no	free or negligible	100%	?	El Paso County- Mike Duisey

1994	analog	?	no	free or negligible	100%	?	El Paso County- Mike Duisey

Purchasing Historic Imagery

It was determined that the best source of historical imagery would be through the United States Department of Agriculture (USDA) program, called the National Aerial Photography Program (NAPP), to collect aerial photography. The intent of the imagery was to identify trends in agricultural development. The area of interest for this project extends into the foothills where there is not much farming taking place. These areas had to be augmented with aerial photography provided by the United States Forest Service (USFS). Imagery was located and purchased to represent a historical picture for each decade that the Academy has been operational. This decision was based upon cost and coverage within the AOI.

It is imperative to clearly communicate to the USDA office in Salt Lake City the imagery required. This can be a confusing and time consuming process. It is recommended that anyone needing historical imagery should clearly identify their AOI and communicate that to the USDA office through maps and a concise list of the Sections, Townships and Ranges involved. USDA will return a quote for the imagery that includes a series of photo names. These names are quite ambiguous but can be verified through a map index that the USDA office can mail to you. The local USDA office may have some photo indices on hand for verification. This process can be tedious, but it is critical to quality control the order thoroughly. The time and expense of miscommunication can make a large impact on a project quite quickly.

Decisions regarding the quality of the imagery will also need to be made. The geometric resolution of the scanned imagery varies. This resolution is defined in terms of microns. To put it very simply, the smaller the number of microns the more Dots Per Inch (DPI) and better resolution. The price of the imagery is not affected by the scanning resolution. The cost does increase when considering the CD's and shipping costs as the file sizes grow. For this project we decided on 17.5 microns. Each image is approximately 373 megabytes. A total of 235 CD's were shipped at a cost of $10.00 per CD.

Georeferencing Imagery

As the imagery began to arrive incrementally, we began to compress using Lizardtech software. The process to move the SID files to the accurate location was very simple. We added the USGS 1:24,000 Digital Raster Graphic (DRG) dataset quadrangles to the view with a historic image. Then we made the image the active theme for the georeferencing toolbar and added control points to move the image relatively close to the area of interest.

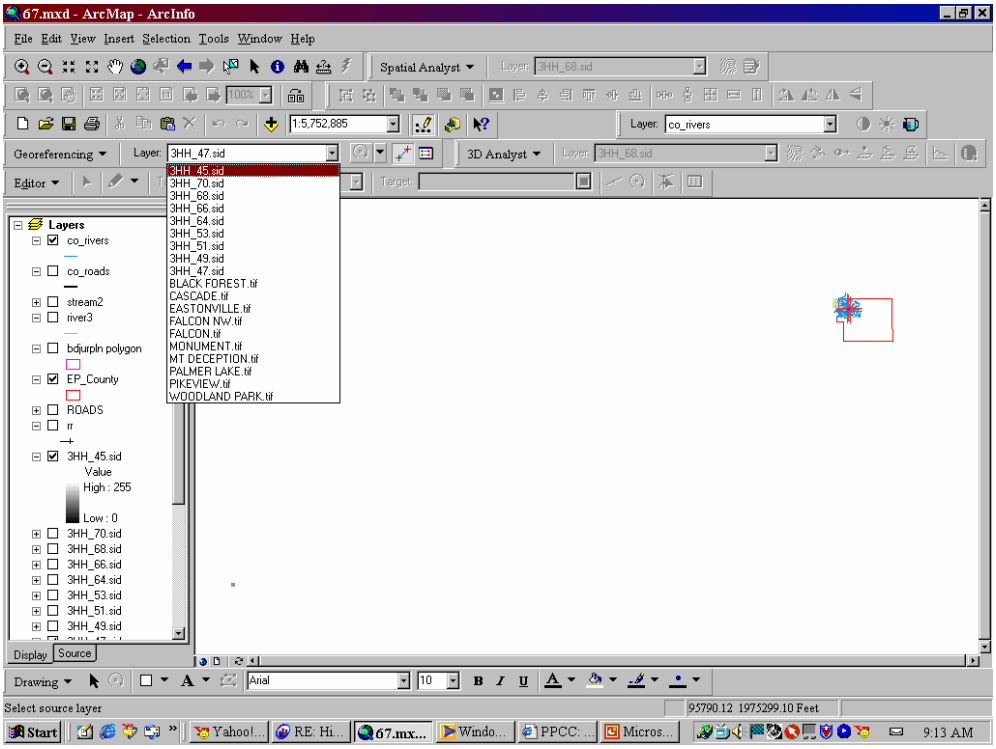


Figure 2: Select the image to move with the georeferencing toolbar.

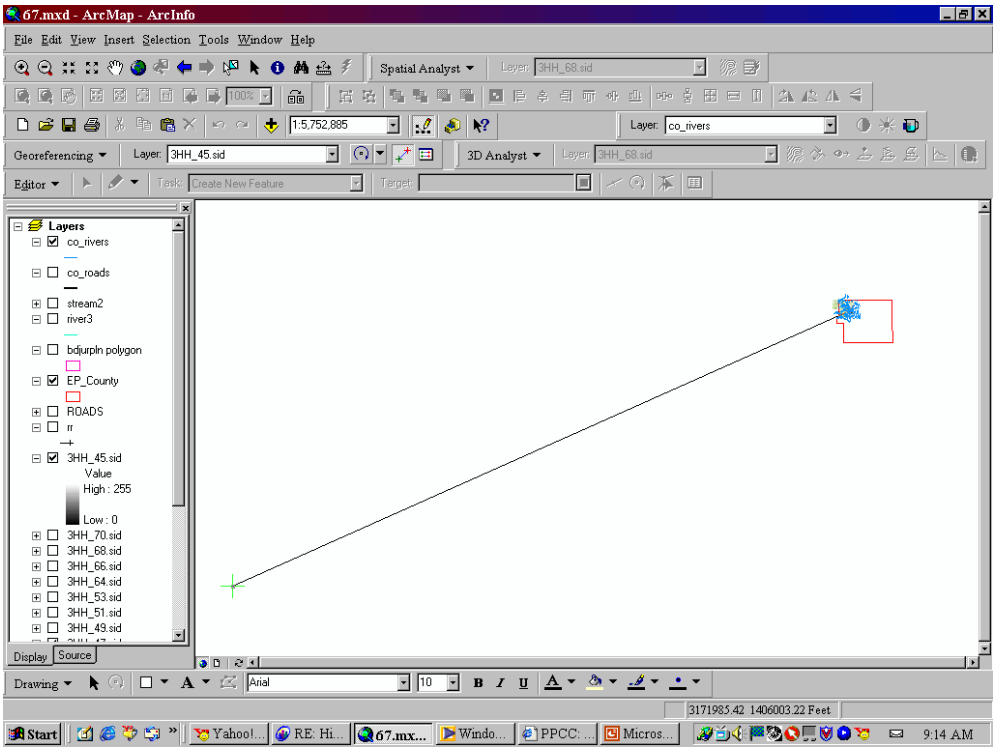


Figure 3: Control points are added first to the point of origin and secondly to the desired location.

There are two very important steps to this process. It is essential to remember to set the

appropriate image as active in the georeferencing toolbar. Without attention to this detail the GIS Technician will find that images are unintentionally warped beyond repair. It is also very important to remove each control point added while moving the image near the appropriate location.

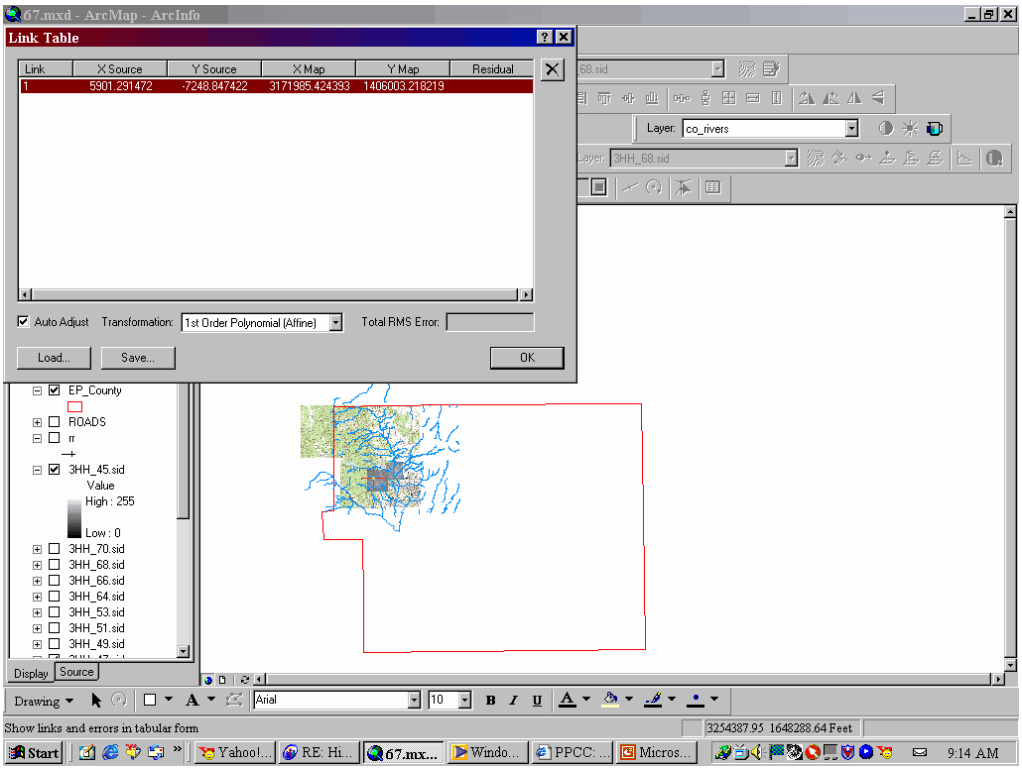


Figure 4: The black X in the upper right corner is used to remove control points.

If the control points are allowed to remain the image will warp considerably. If an error is made in either of these areas, the GIS technician should remove the image from the project and add it again.

Once the image was moved to the area of interest the map index was used to identify the location of the photo for accurate placement. It is very helpful to make the image transparent so that the USGS quads are visible underneath. The magnification window is also extremely helpful in placing imagery.

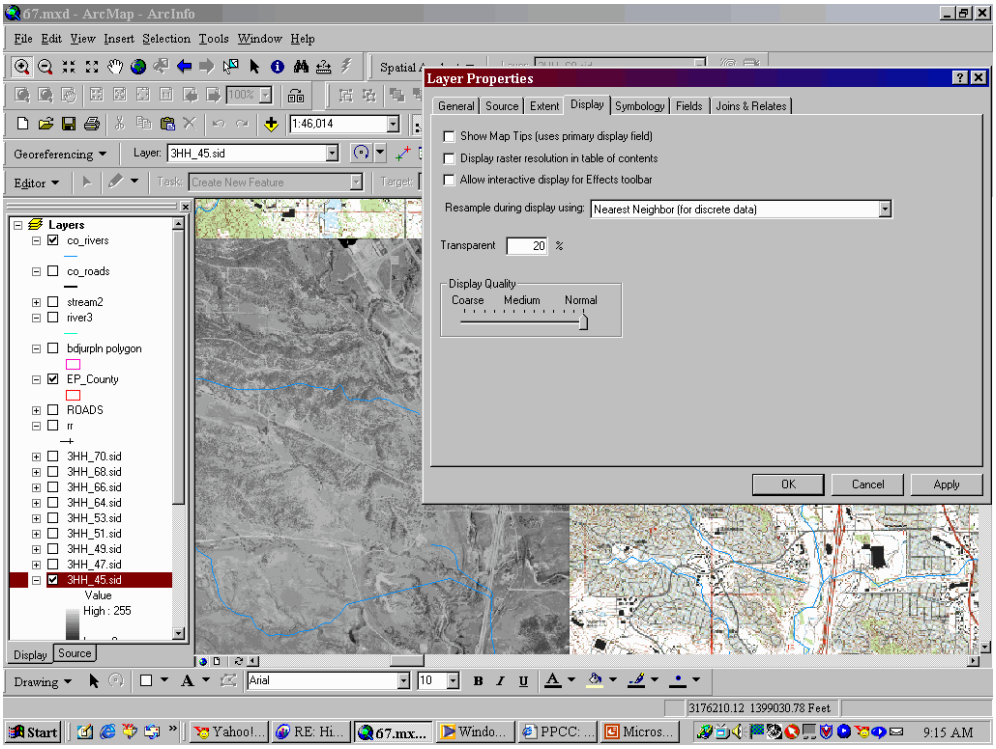


Figure 5: The Layer Properties dialog window can adjust transparency of the image.

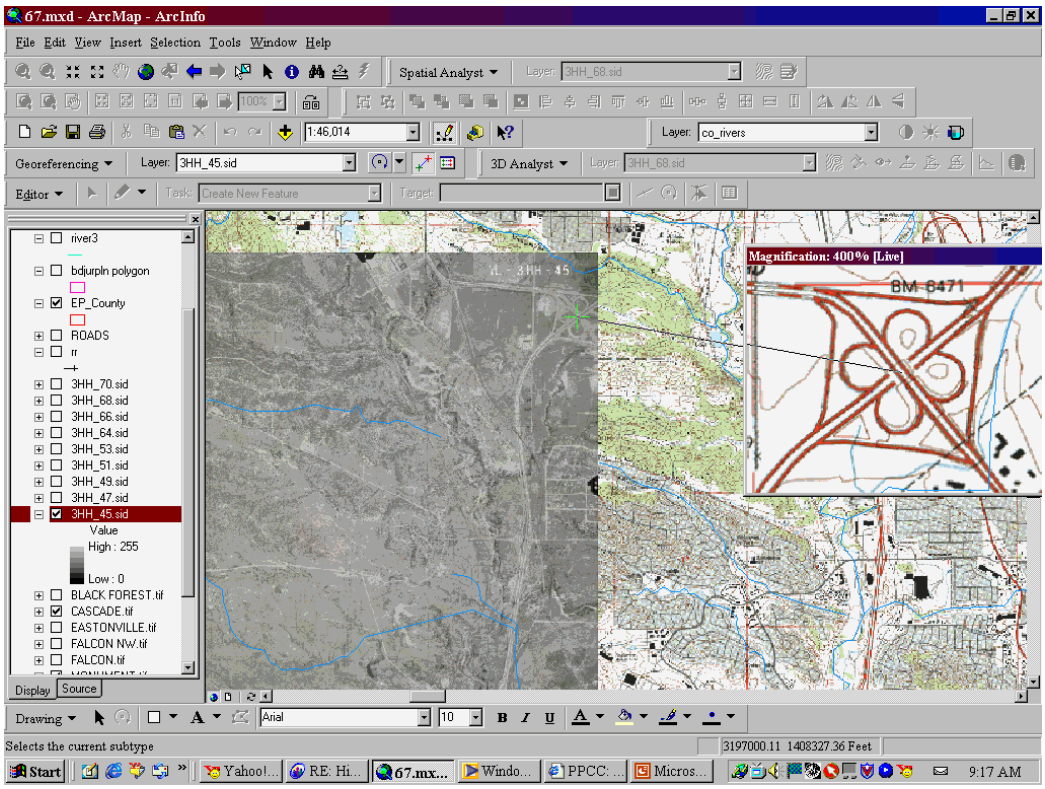


Figure 6: Using the magnification window to place control points to georeference imagery.

Once the image is in the appropriate location, control points are added to secure accurate placement.

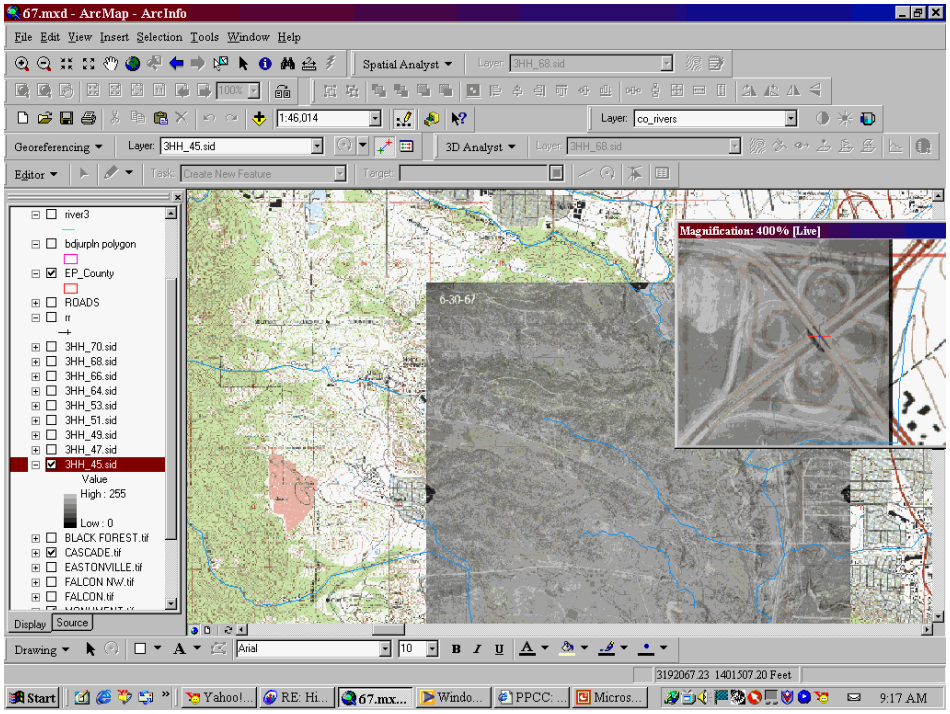


Figure 7: The control points have moved this image to the correct location.

The technician should get at least four control points evenly spread across the image to ensure that the pixels are stretched proportionately across the image.

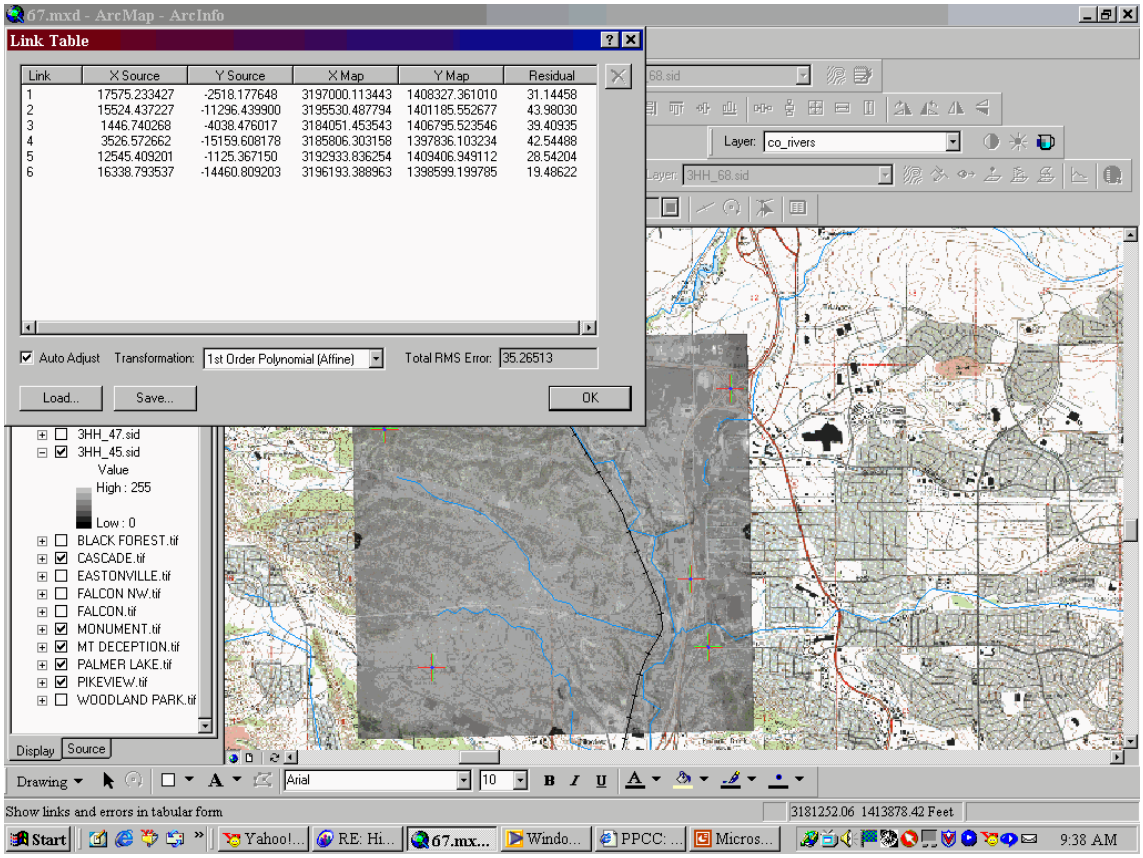


Figure 8: The link table with an adequate number of control points.

At this point the image is ready to update. The Update Georeferencing option will create a world file for the image. A world file is an ASCII file consisting of 6 lines. The Eastings and Northings of upper left corner of the image are noted as two separate lines in this file. The pixel size is noted as an X and Y length for two additional lines. The final two lines indicate the second and third parameters for X and Y rotation. A world file for a tiff image will have the same name as the tiff, however the extension is tfw. For a sid file the extension is sdw. It is important to keep the world file in the same directory with the same name as the image. We discovered that the Update Georeferencing option will not work with control points placed with second or third order polynomial affine. We found it necessary to get this level of accuracy when working with images on a steep slope.

These images were then tested in a variety of ESRI software packages and operating systems to ensure that the SID files would appear accurately registered regardless of ESRI software version and operating system at the Academy. The images appeared shifted when viewed in ArcView 3.2 and ArcMap 8.2. Technical support for ESRI was contacted to identify the problem. The georeferencing tool creates an .aux file to carry the rotation of the warped pixels. ArcView 3.2 cannot read an .aux file.

ESRI technicians informed us that this is a common problem. They recommended that we use the "rectify" tool after creating the SDW file. This process required additional virtual memory and RAM to be added to the GIS computers. The rectify process was time consuming and only worked occasionally. Another call to technical support brought us to the conclusion that this process works best with images in the native format processed locally on a computer with a great deal of RAM and virtual memory. We were able to take the sdw files and change the

extension to tfw. After copying the tiffs back into the directory with the tfw file the rectify process went smoothly. Files without an sdw file were converted to a tif format in ArcCatalog and rectified. Further testing confirmed that the rectification allowed the images to be viewed accurately by any ESRI software product.

Creating Raster Catalogs

Once the image files were all registered and rectified we found that the rectification process created white space around the warped tifs to keep the image square. This white space overlapped onto neighboring images causing the overall AOI to look choppy.

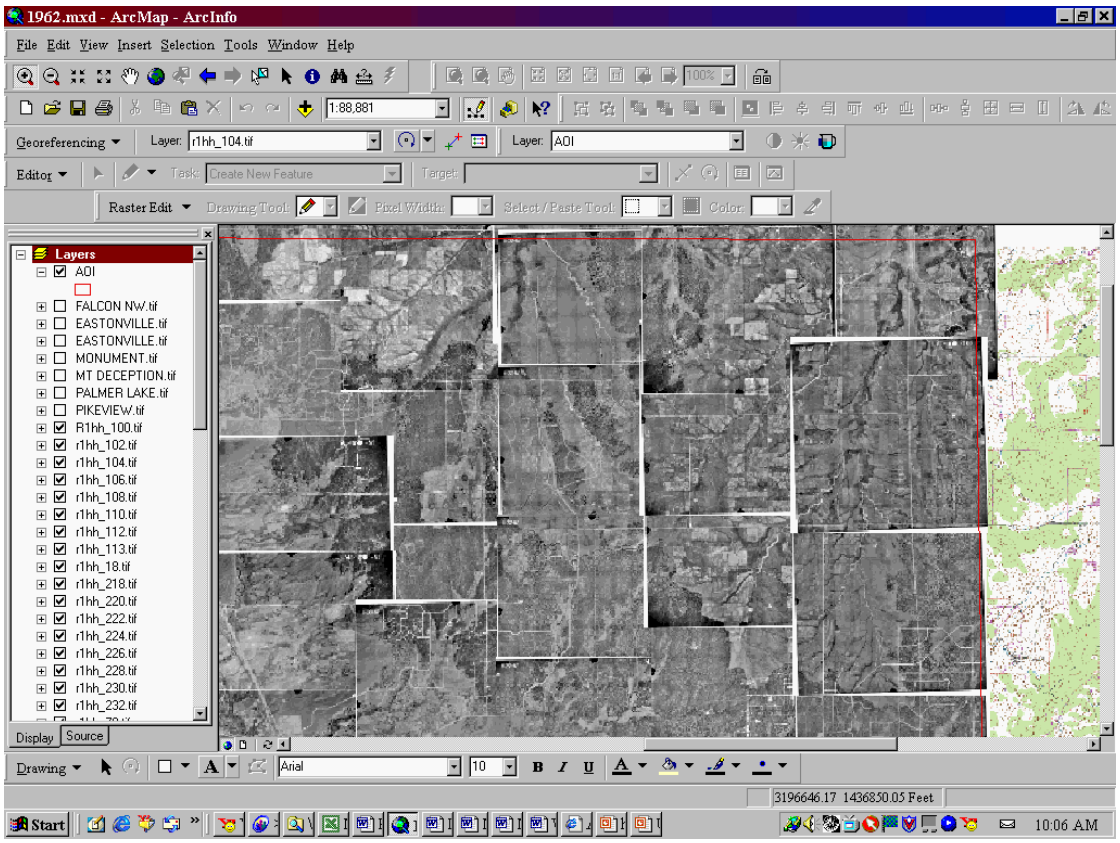


Figure 9: White space around rectified tiffs block out surrounding images.

We were able to adjust the symbology of the raster under the properties dialog window.

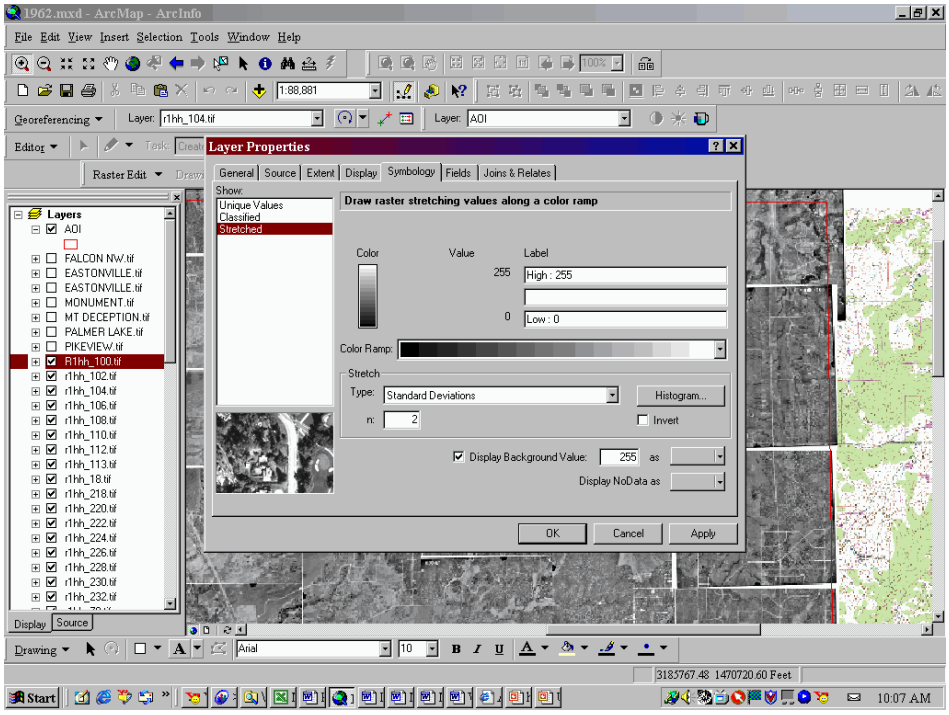


Figure 10: Setting the background value to 255 removes the white space.

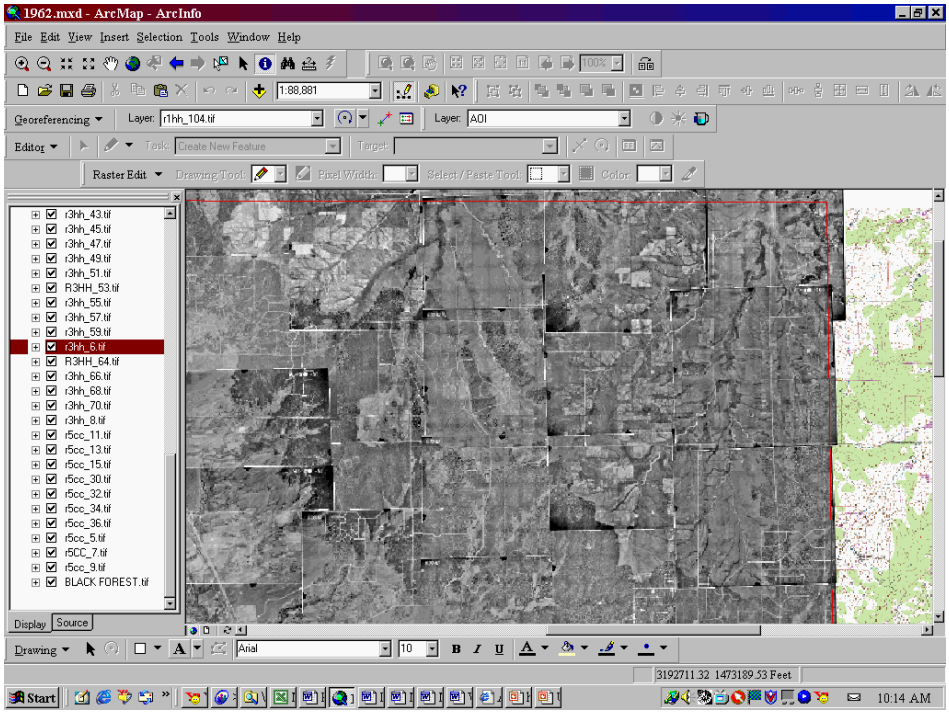


Figure 11: The results show much improvement.

At this point we were able to compress into a sid format and create raster catalogs. A raster catalog is a table that tracks the path of the image along with the X min, X max, Y min and Y max values. This table can be brought into an ArcMap project and will display the images in wireframe until the viewer zooms in at a specified level. This increases the display time for groups of large rasters.

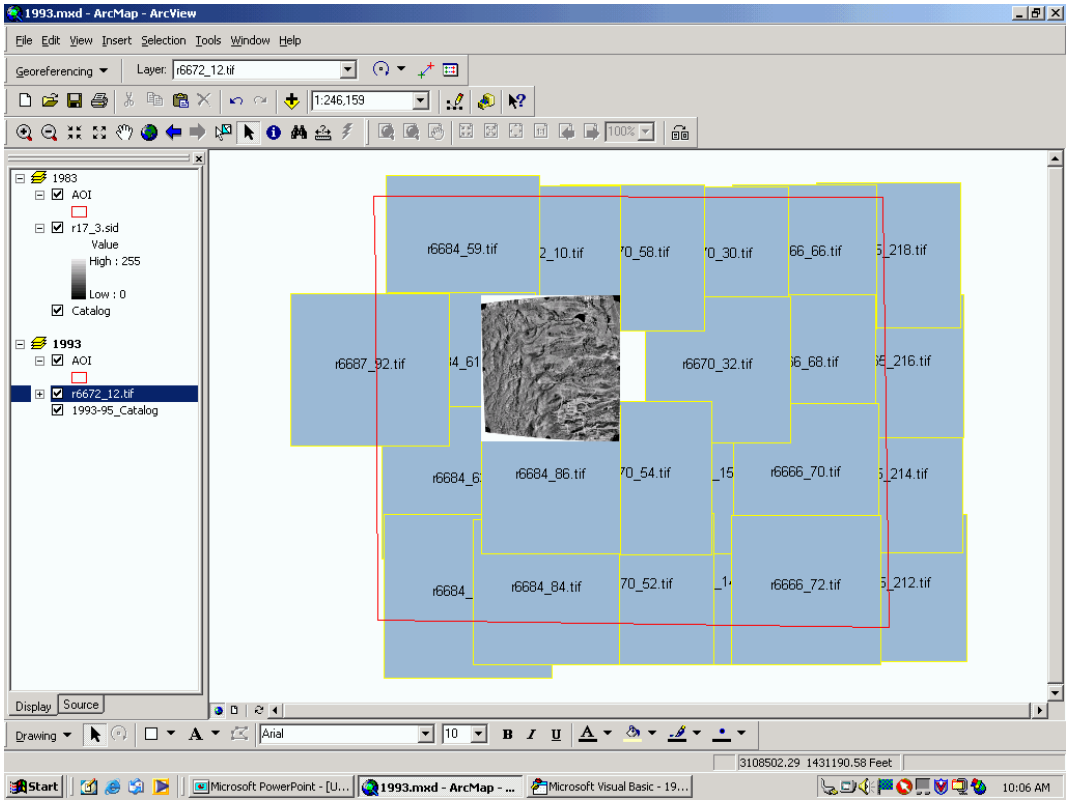


Figure 12: The imagery will display as a wireframe until less than nine images are visible.

Currently, there is no automated tool to create this table. However, there are code samples available to automate the process. These code samples can be downloaded from the http://arcobjectsonline.esri.com/ website.

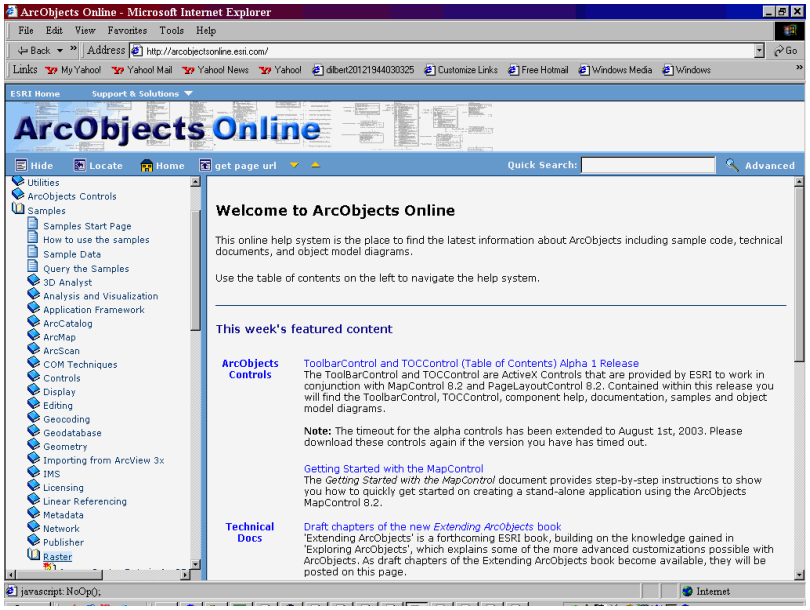


Figure 13: The navigation tree on the left of the web page is used to find code samples.

This code was used with the macro tools provided with ArcMap

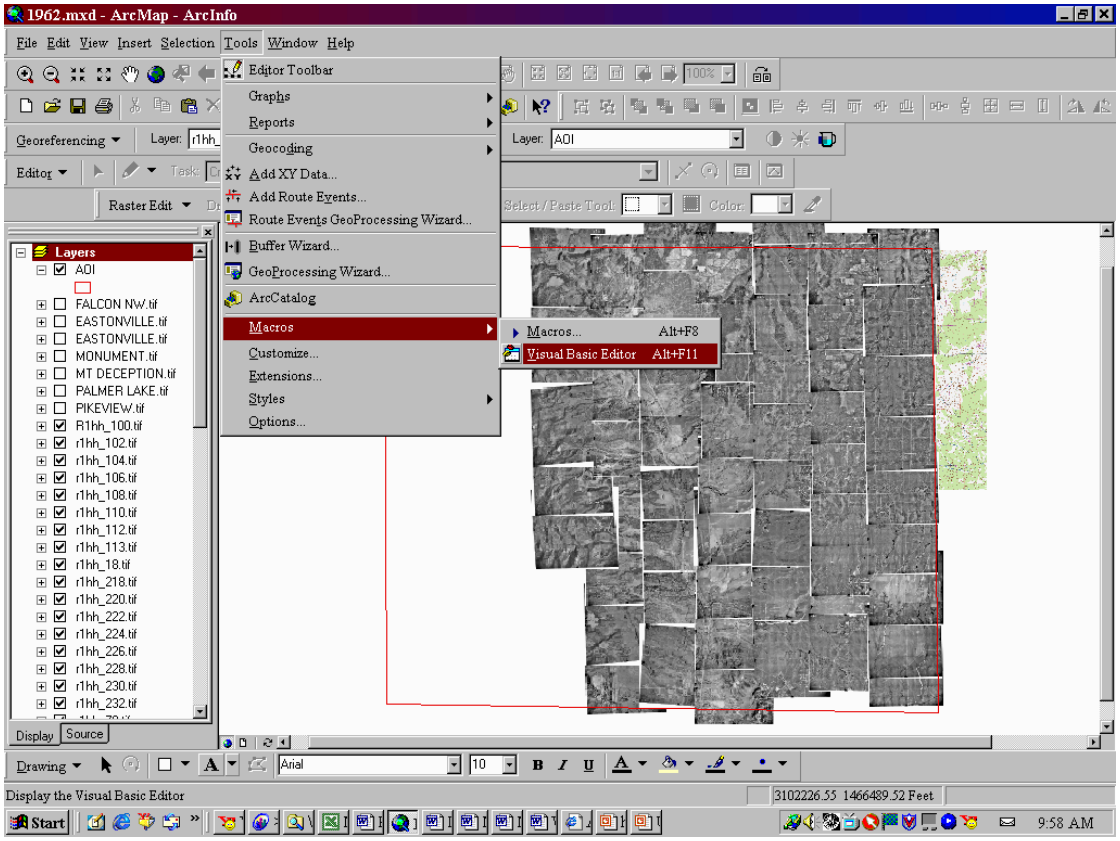


Figure 14: A visual basic editor is provided with ArcMap.

The results looked great. However. it was disappointing to see that the raster symbology lost the 255 value for background color. This means the white boxes were back. We discovered that symbology cannot be adjusted in a raster catalog. We went back to tech support and were directed to yet another code sample to resolve the problem.

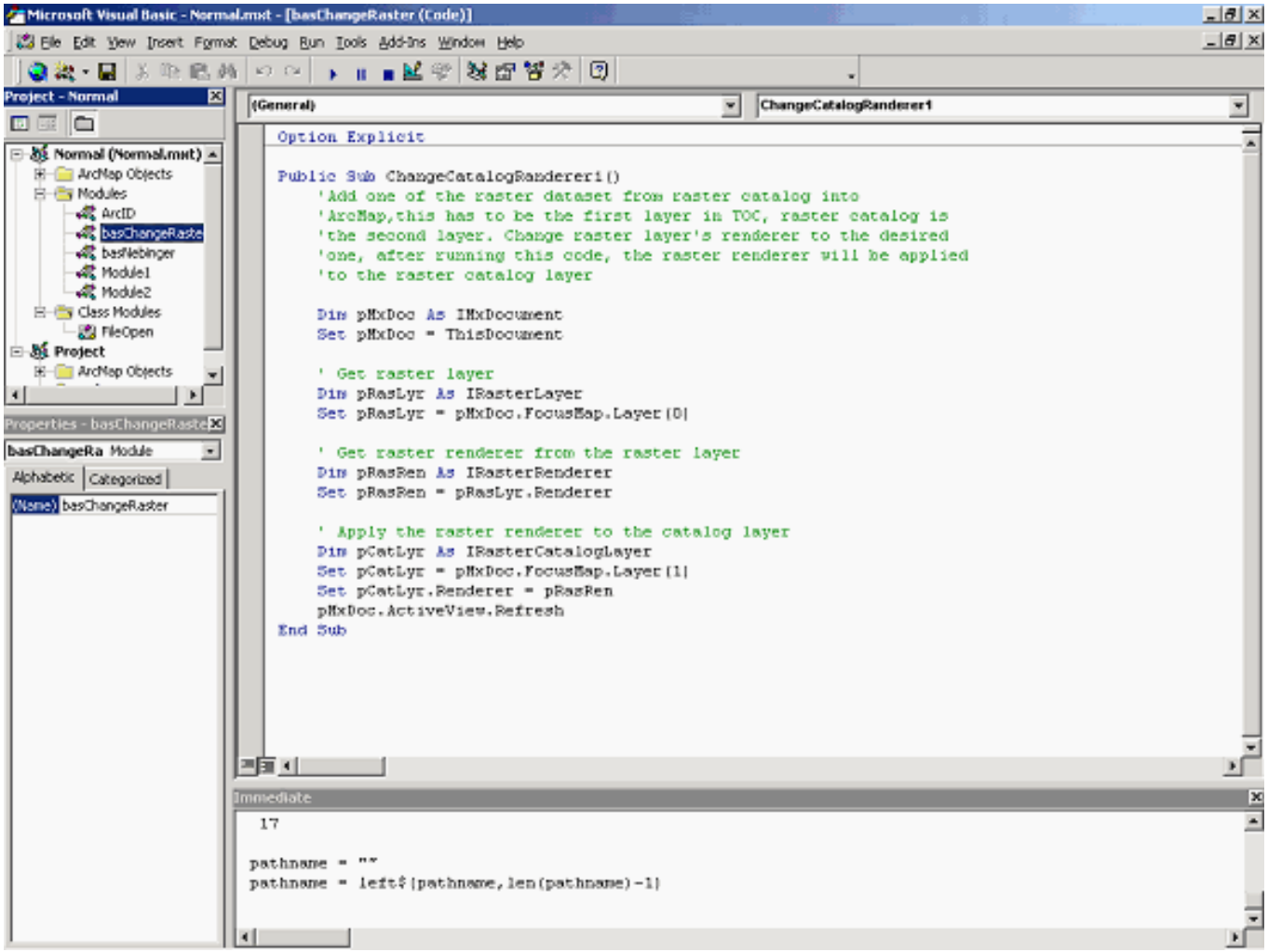


Figure 15: Pasting code samples into the visual basic editor.

Creating the Geodatabase

The next step in the process involved creating geodatabases to contain the digitized data. There are five unique data sets that we wanted to develop. These include water bodies, stream centerlines, vegetation boundaries, road centerlines and developed areas. We researched the Spatial Data Standards for Facilities Environment and Infrastructure (SDSFIE) to identify the feature classes relevant to these themes. We used the tools available from http://tsc.wes.army.mil/ to create a filter and build an SDSFIE compliant geodatabase for our features.

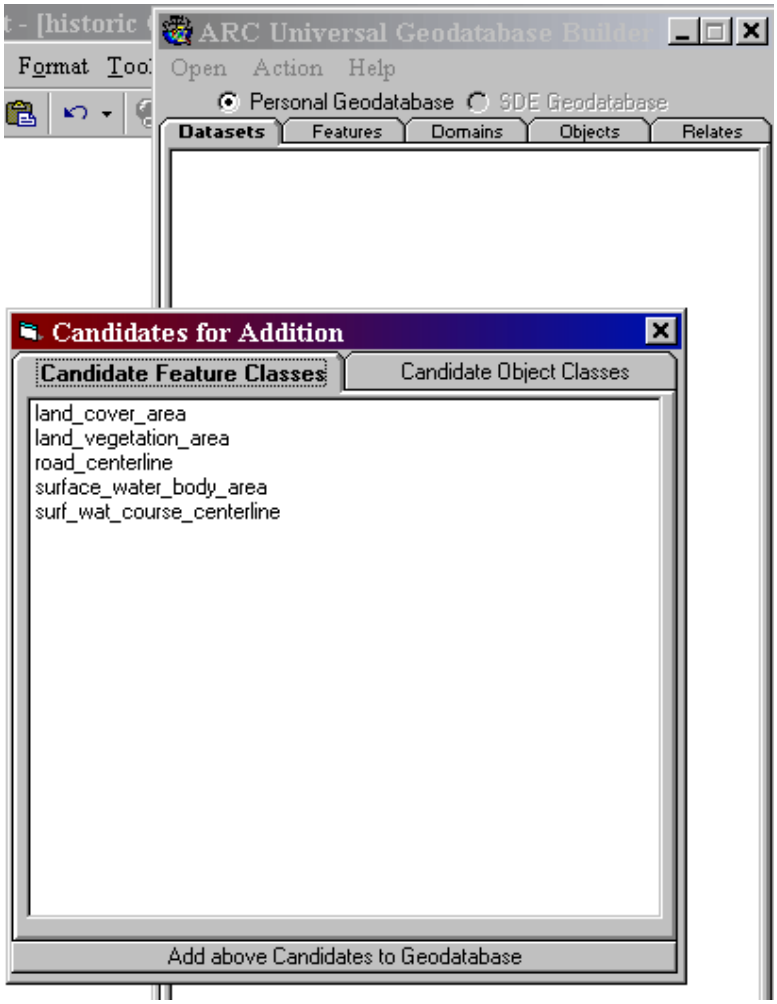


Figure 16: The SDSFIE Geodatabase builder uses filters to create candidates for feature classes.

Defining the spatial reference is the most difficult part of creating the SDSFIE geodatabase. These values should be set with consideration of all existing and potential data, as they cannot be changed in ArcGIS once defined. The spatial reference involves the coordinate system, precision and the extents of the geodatabase.

Precision defines the number of storage units in one map unit. The dataset precision is determined by dividing map units by storage units. If the data will be integrated with existing datasets, it is important to know the current precision so that the new data will not modify the accuracy of the existing data. Double precision in an ArcInfo coverage provides sub millimeter accuracy.

It is also critical to define the extents of the geodatabase accurately. This process involves identifying the largest theme in the geodatabase and using the values for the extents to calculate a center for the data.

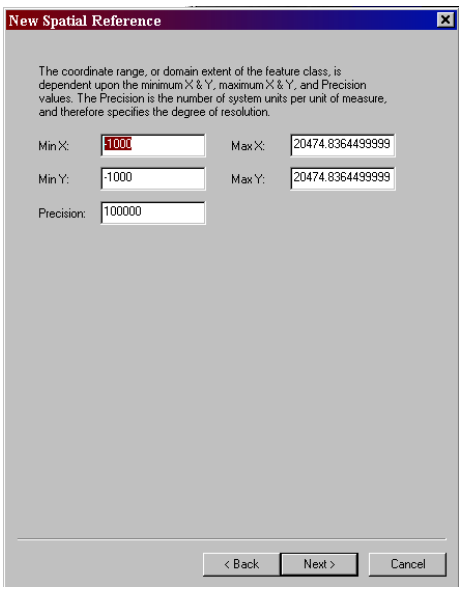
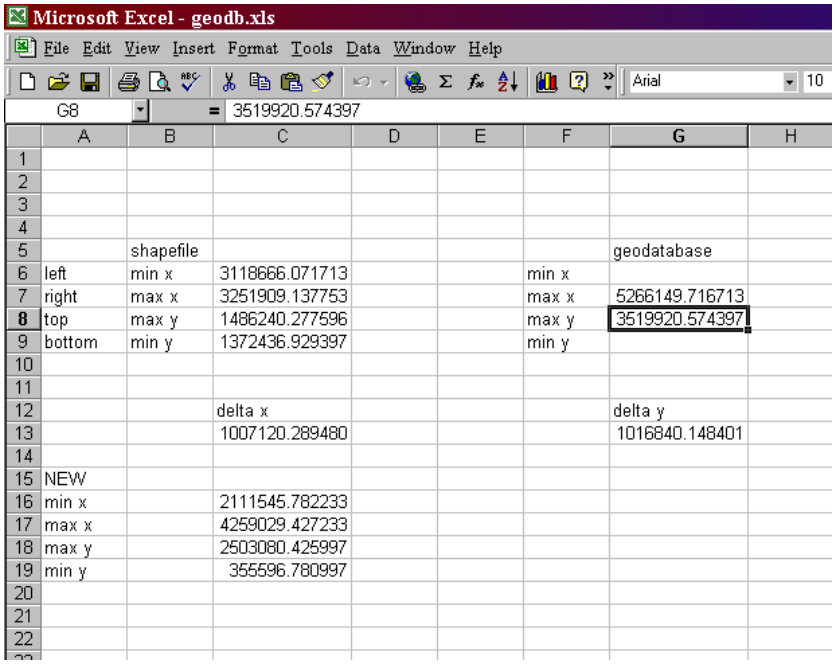


Figure 17: Min X and Min Y values have to be plugged in to the default settings.



Microsoft Excel - geodb.xls

File Edit View Insert Format Tools Data Window Help

G8 = 3519920.574397

	A	B	C	D	E	F	G	H
1								
2								
3								
4								
5		shapefile					geodatabase	
6	left	min x	3118666.071713			min x		
7	right	max x	3251909.137753			max x	5266149.716713	
8	top	max y	1486240.277596			max y	3519920.574397	
9	bottom	min y	1372436.929397			min y		
10								
11								
12			delta x				delta y	
13			1007120.289480				1016840.148401	
14								
15	NEW							
16	min x		2111545.782233					
17	max x		4259029.427233					
18	max y		2503080.425997					
19	min y		355596.780997					
20								
21								
22								

Figure 18: Max X and Max Y values will change and they need to be put into a spreadsheet to calculate a delta.

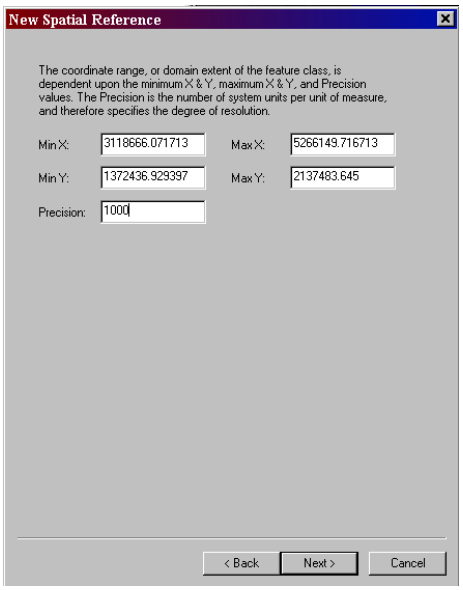


Figure 19: A mathematical formula is applied to the delta and the original numbers to create the spatial reference and center the extents.

This process is well documented in several white papers available from the SDSFIE website.

Digitizing Data

With the geodatabases built, we were ready to begin digitizing our data. This process involved adding the raster catalog, the USGS DRG quads and the geodatabase. We worked at a scale of 1:10,000 to be sure that we were consistent in our level of detail when digitizing. We soon discovered that while the raster catalog was a convenient way of delivering the imagery, it was more beneficial to us to work with individual images because we could change the order of the images at will. When there is overlap of imagery, one photo might show the detail more clearly. It has been helpful to be able to restack the layers to find the clearest picture.

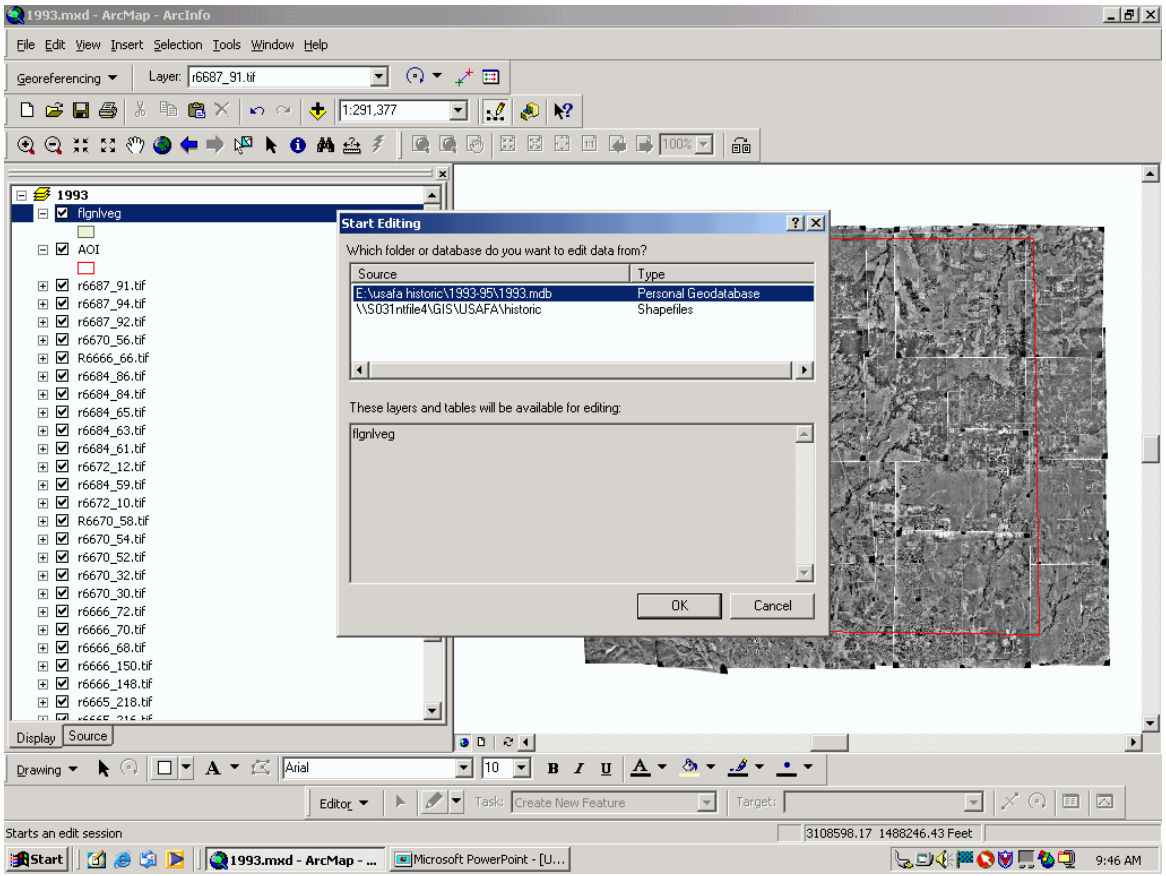


Figure 20: Adding the geodatabase to begin digitizing.

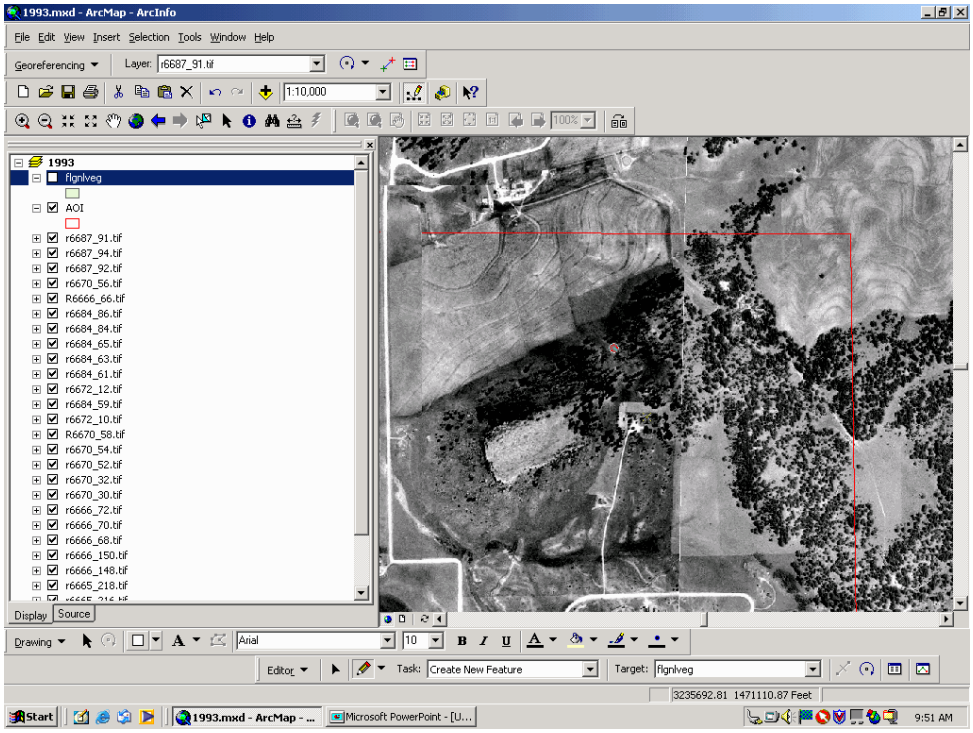


Figure 21: Zooming in to prepare to digitize vegetation.

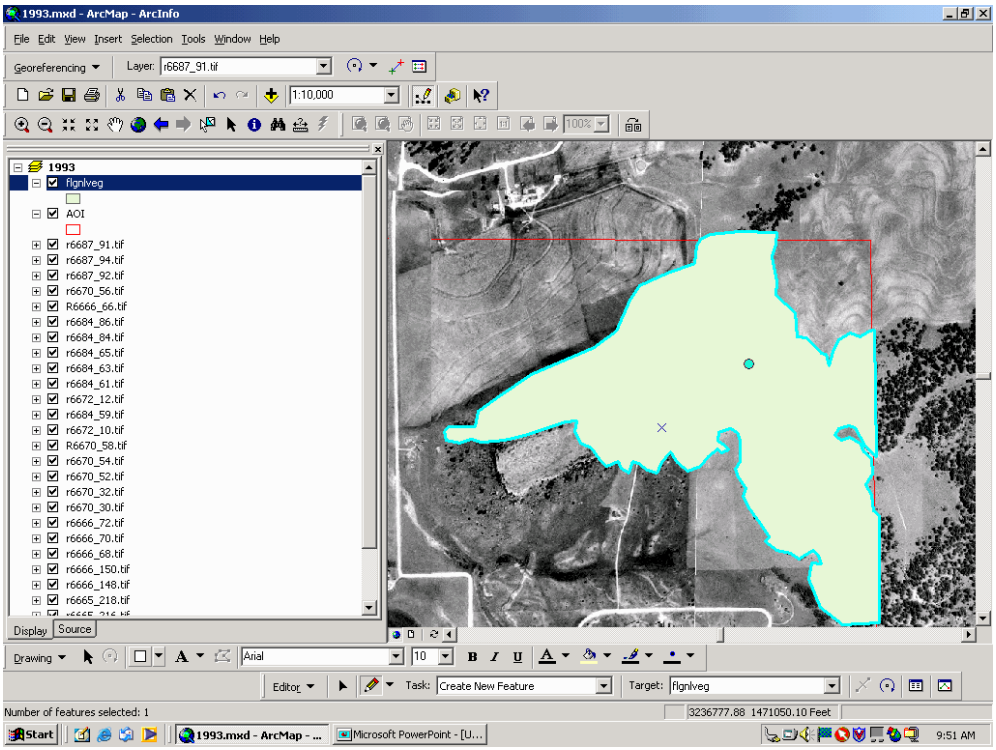


Figure 22: A digitized vegetation boundary at the corner of the AOI.

In Summary

This project has been extremely interesting and challenging. The Air Force Academy will be able to use this data to visualize the development of Colorado Springs over the last 50 years.

From decade to decade we can see the roads and developed areas increase while the vegetation decreases. It has been interesting to see the change in water bodies and watercourses relating to the additional roads and development. We have been able to quantify the changes to our community in terms of area and use this data to study trends in encroachment and natural resources.

Lessons Learned

1. Research historical data sources thoroughly to get the best vector and raster data to use for a foundation. The USDA is an excellent source for historic imagery.

2. Identify the Section, Township and Range of your area of interest to communicate the area for required imagery.

3. Ask the USDA to inform you of what imagery is available for your area and year of interest. Don't forget that they handle aerial photography taken for the Forest Service as well.

4. When ordering historic imagery be sure to quality control the requisition so that you get the photos you expect.

5. Remember to order photo indices along with the aerial photography to translate cryptic file names into actual locations.

6. Determine the resolution needed before ordering imagery. Understand that the file size of the tiffs will require more CDs and will therefore increase the cost of the order. If possible, ask for samples of the same image scanned at different micron levels to compare.

7. Work with tif files if at all possible. If size is a concern, compress to sid as a final step before creating the raster catalog.

8. Rectify imagery to write the rotation of the pixels into the header file of the image. End users of the imagery that are still working in ArcView 3.X and this software cannot read the .aux file that holds the rotation of the pixel.

9. When georeferencing be sure to activate the image to be moved and remove all control points until the image is as accurately placed as possible.

10. Use at least 4 control points placed in corners of the imagery for best results.

11. When rectifying images, work on a hard drive and not across a network. RAM and virtual memory are more important than processing speed in terms of system requirements.

12. Adjust the symbology of the rectified raster to display background at a value of 255 to eliminate the overlap of the white boxes.

13. Don’t be afraid to call ESRI technical support and use code samples to work with raster files.

14. The CADD/GIS Technology Center has excellent tools and white papers available from their website for the development of SDSFIE compliant geodatabases.

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