Locating the Structural High from 2D Seismic Data

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5-6-10

The goal of this project was to interpolate a surface that represented the depth to a surface that was picked on a 2D seismic survey. From this interpolated surface it is possible to locate the structural high, which is a key step in the hydrocarbon exploration process.

DATA

The data to complete this project came from a lab for GEO 330K, Energy Exploration. The lab consisted of a basemap that showed the 386 shot points used to create the 2D survey (Figure 1), and 9 seismic lines (Figure 2).

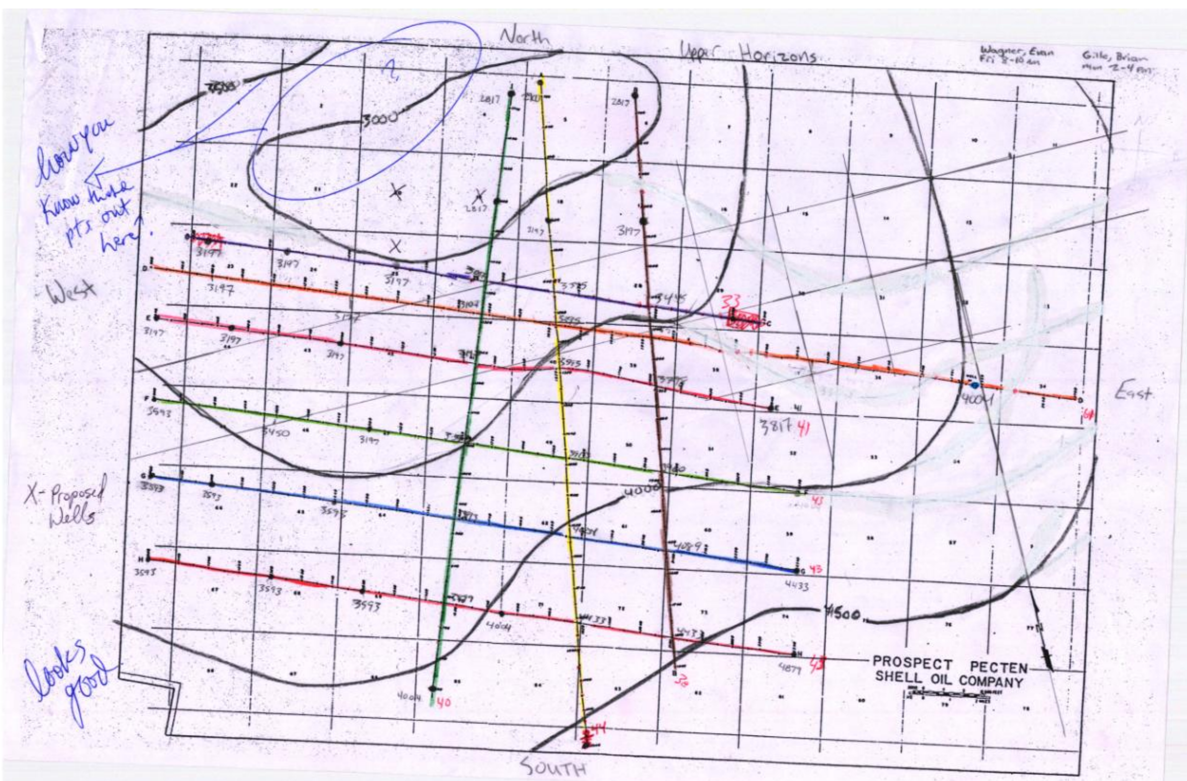


Figure 1. Basemap showing shot points.

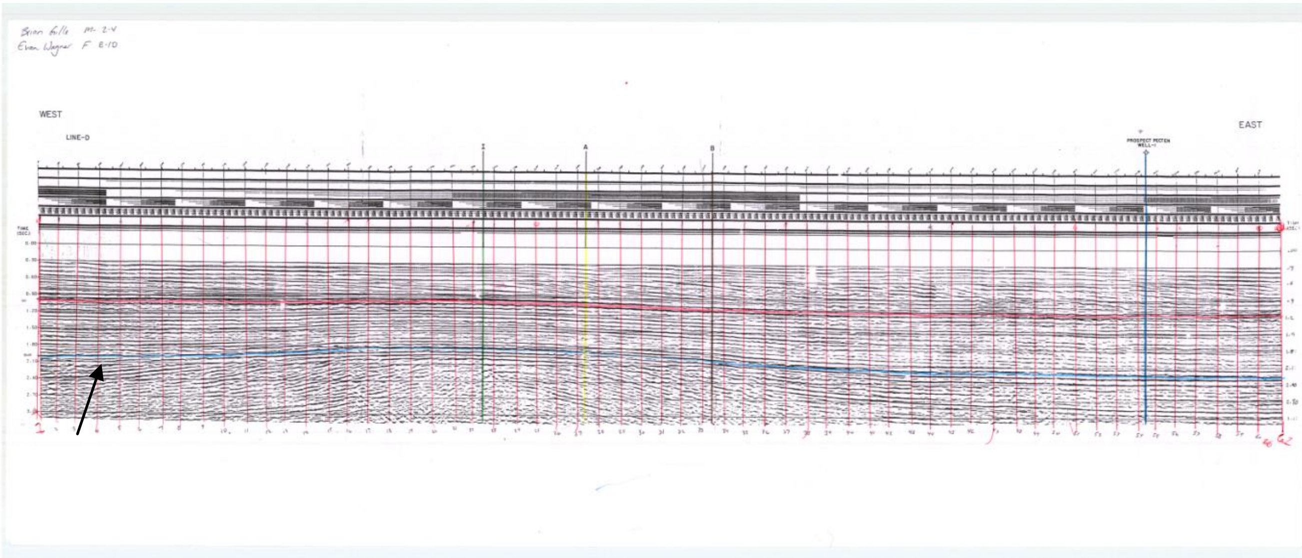


Figure 2. Seismic line D. One of nine seismic lines included in the survey. The red vertical lines correspond to the shot points shown on the basemap in Figure 1. The arrow indicates the 2 second surface mapped for this project.

The first step in preparing the data for ArcMap was to map the same surface on all nine seismic lines by hand. For this project I chose to pick a surface on at a depth of 2 seconds. Depth is measured in 2 way travel time. The surface I used for this project is shown on Figure 2. After the surface was mapped across all nine lines I measured the time to that horizon for each shot point.

PROCEDURE

Steps to locate the structural high from seismic data:

A. Define a coordinate system
B. Georeference the basemap
C. Digitize shot points
D. Interpolate the entire surface from the shot point depth data

A. Define a coordinate system

The basemap and seismic data was provided by Shell Oil Company. Unfortunately, Shell did not provide the exact location of this data. This lack of information is not significant for this project because the structural high of the region will remain the same no matter where the region is. Because of this I decided to put the base map in the middle of UTM Zone 14N (Figure 3).

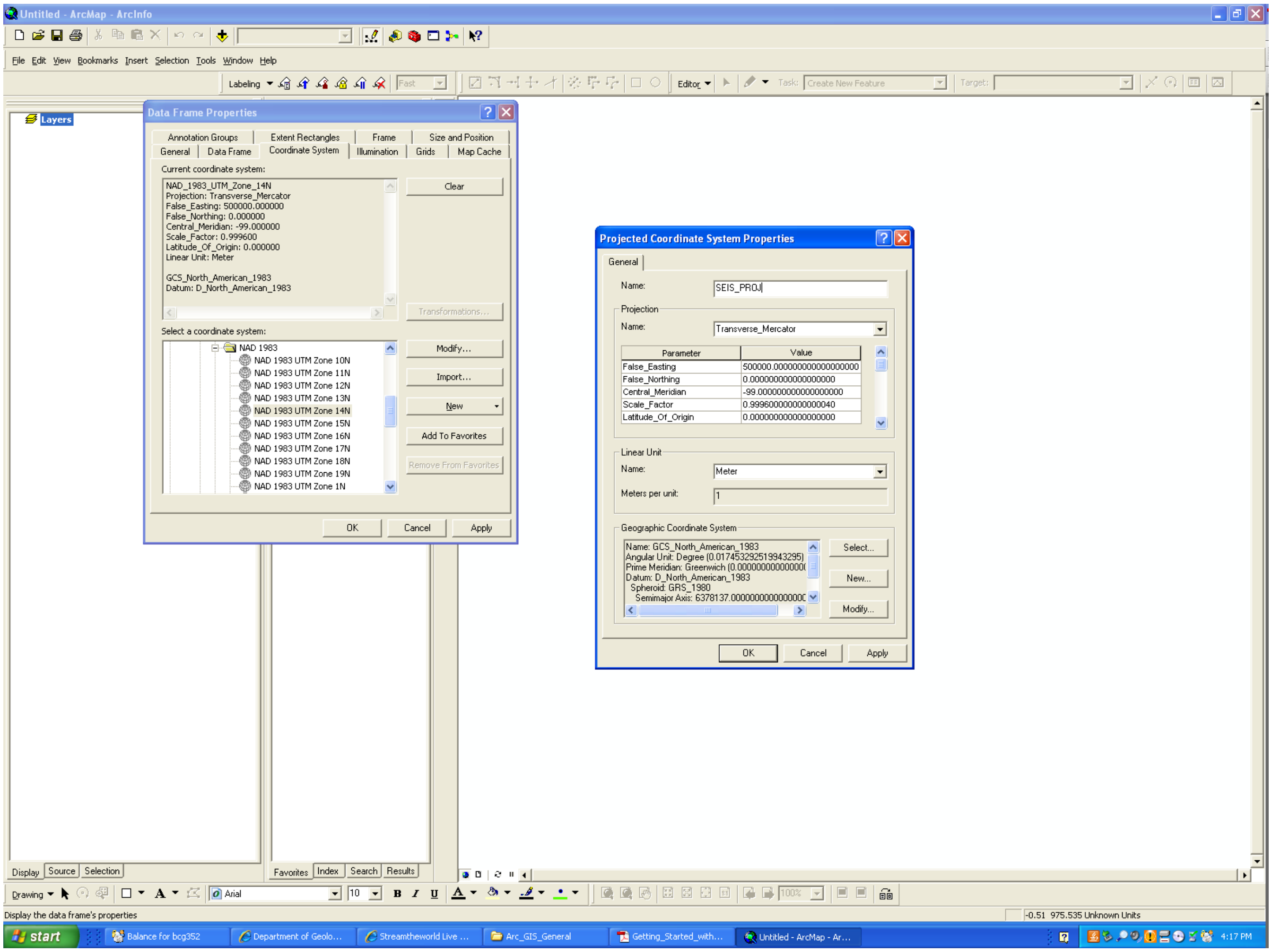


Figure 3. Defining the coordinate system of a new map project in ArcGIS as NAD_1983_UTM_Zone_14N

B. Georeference the basemap

The next step was to put the basemap into the coordinate system by georeferencing it. In order to have some points on the map to define for georeferencing I drew a 3 mile by 3 mile grid on the basemap (highlighted on Figure 4 and visible on Figure 5), that was parallel to North – South longitude lines and parallel to East – West latitude lines. This grid was based off of the scale and North arrow on the basemap .

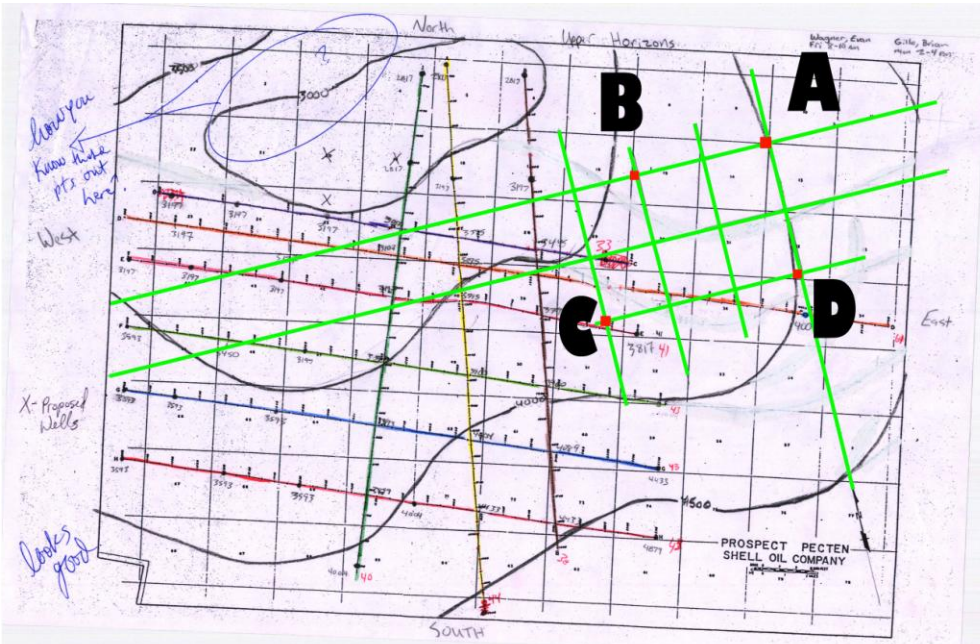


Figure 4. Basemap showing grid and points used for georeferencing. A is defined as 0,0. B is 6 miles dew East of A, and is at -3288.644, 0. C is at -4828.032, -3288.644. D is at 0, -3288.644. Georeferencing to these points resulted in a RMS value of 15.9.

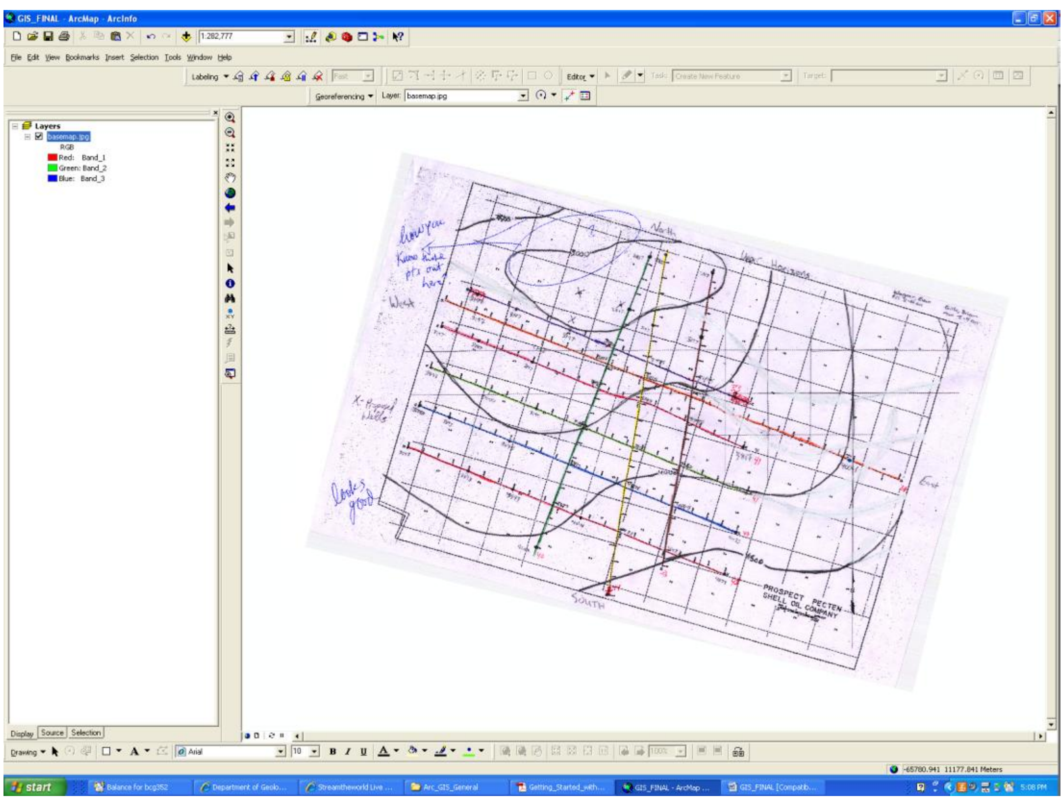


Figure 5. Basemap georeferenced in ArcGIS.

To georefrence the map I started by referencing point A (Figure 4) to 0,0. From there I was able to determine the locations of points B, C, and D, because of the 3 mile by 3 mile grid I had drawn. With these four points I was able to reference the map with an RMS value of 15.9, which I condsider acceptable for this project. Now I had the basemap put in a coordinate system and to scale.

C. Digitize shot points

Before digitizing the shot points I had to create a Personal Geodatabase that held a single Feature Dataset to hold 9 Feature Classes. I was able to do this in ArcCatolog (Figure 6). The nine feature classes, 1 for each seismic line, were point features.

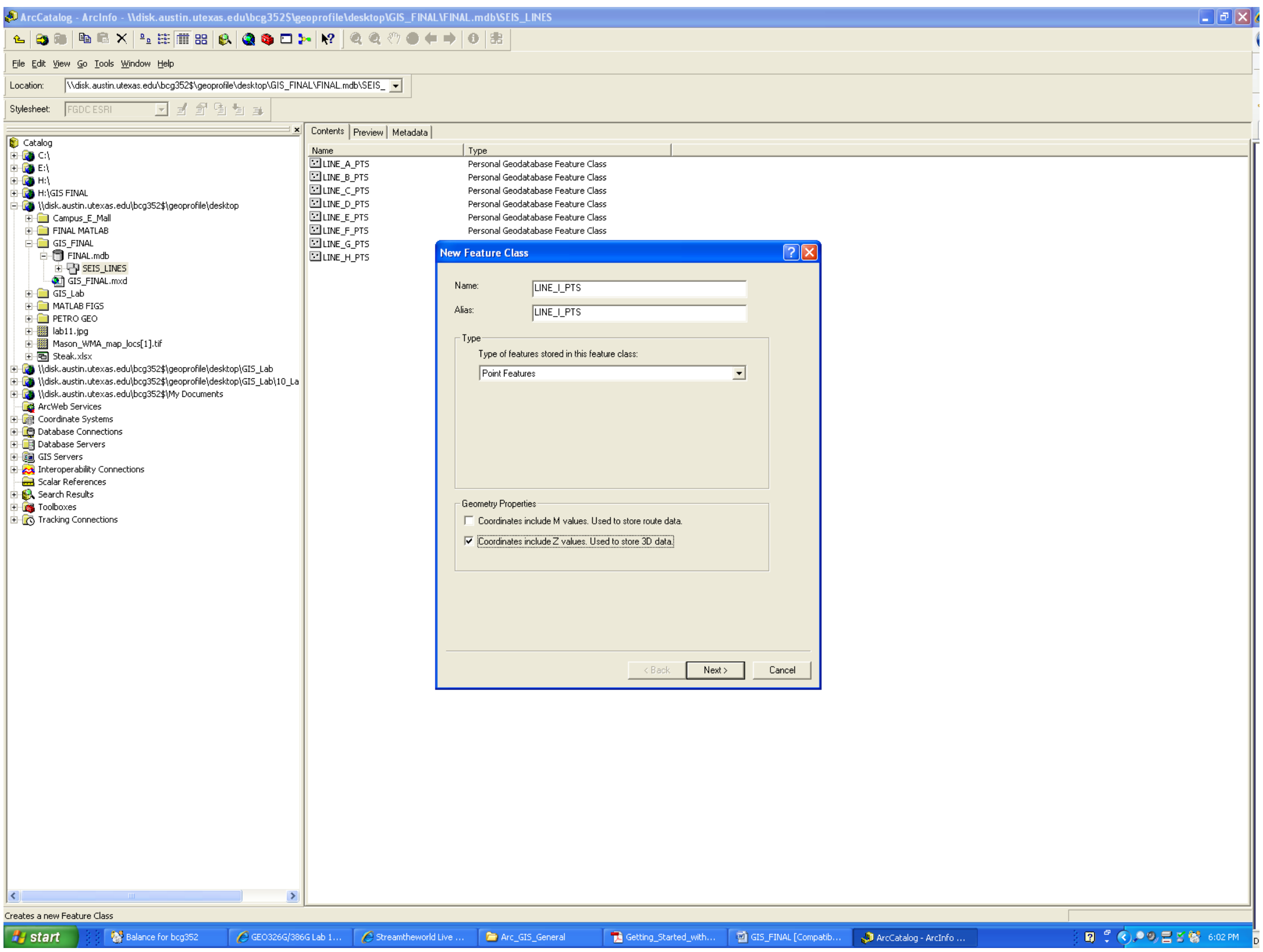


Figure 6. Creating feature classes for digitizing shot points in ArcCatalog.

With these nine feature classes loaded into my map project in ArcGIS I was able to digitize each shot point by using the Editor Toolbar to Create New Feature in ArcGIS (Figure 7).

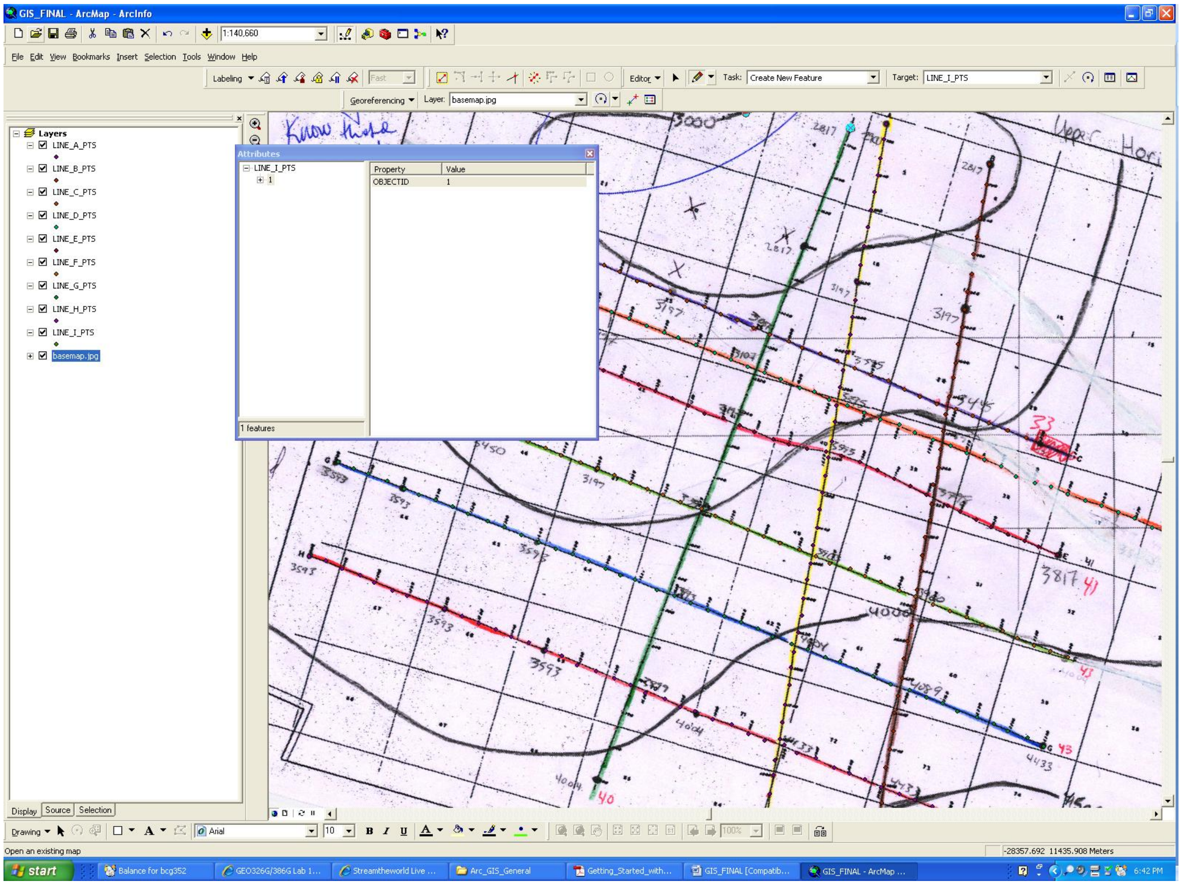


Figure 7. Digitizing the shot points in ArcGIS.

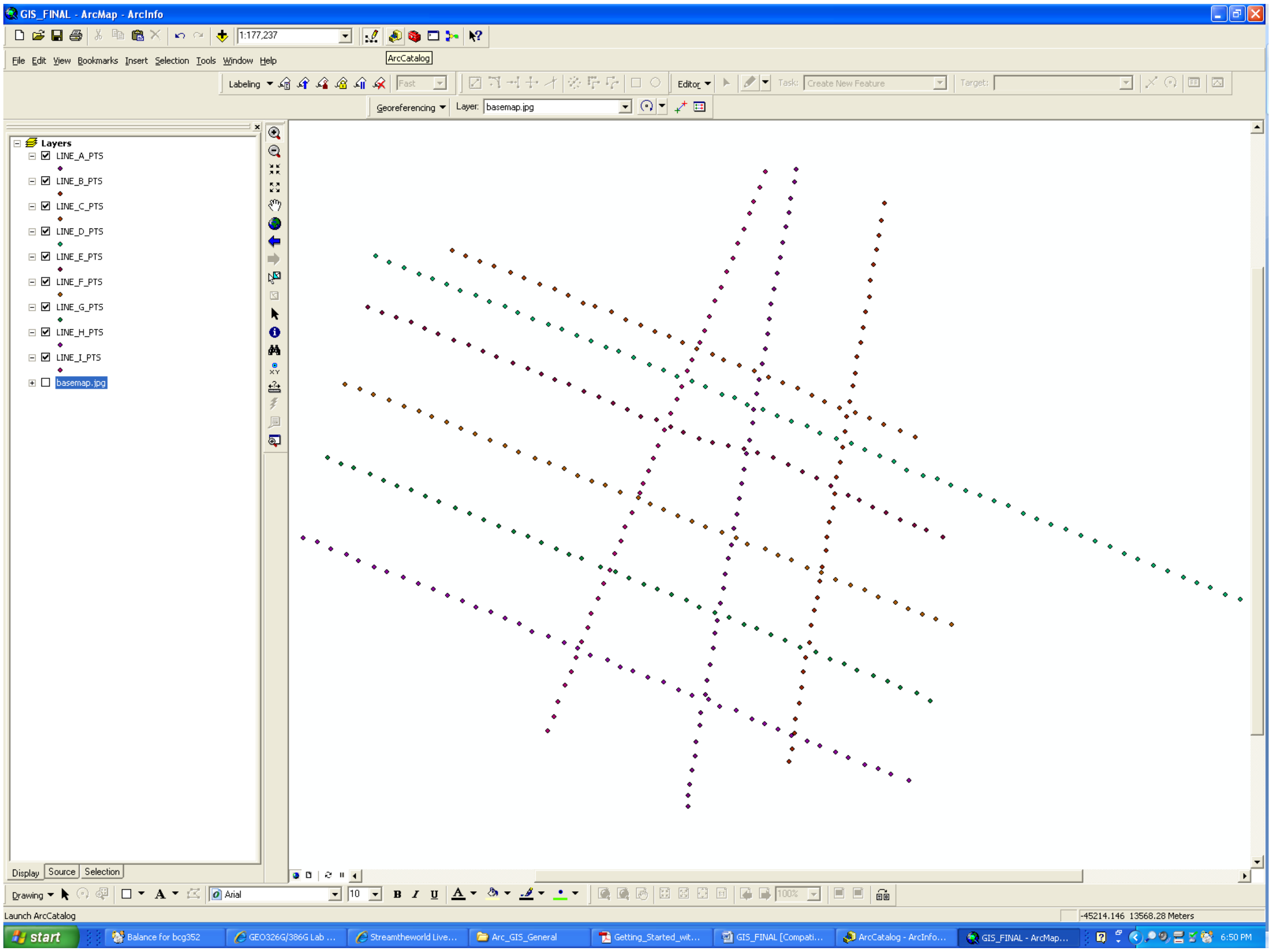


Figure 8. All shot points digitized.

After all of the shot points were digitized (Figure 8) I was able to add a Z field to the attributes table for each of the feature classes. In that Z field I input the depth to the surface that I measured off of the seismic lines. Once I had all the points digitized and the Z values filled, I merged all of the feature classes into one layer (Figure 9).

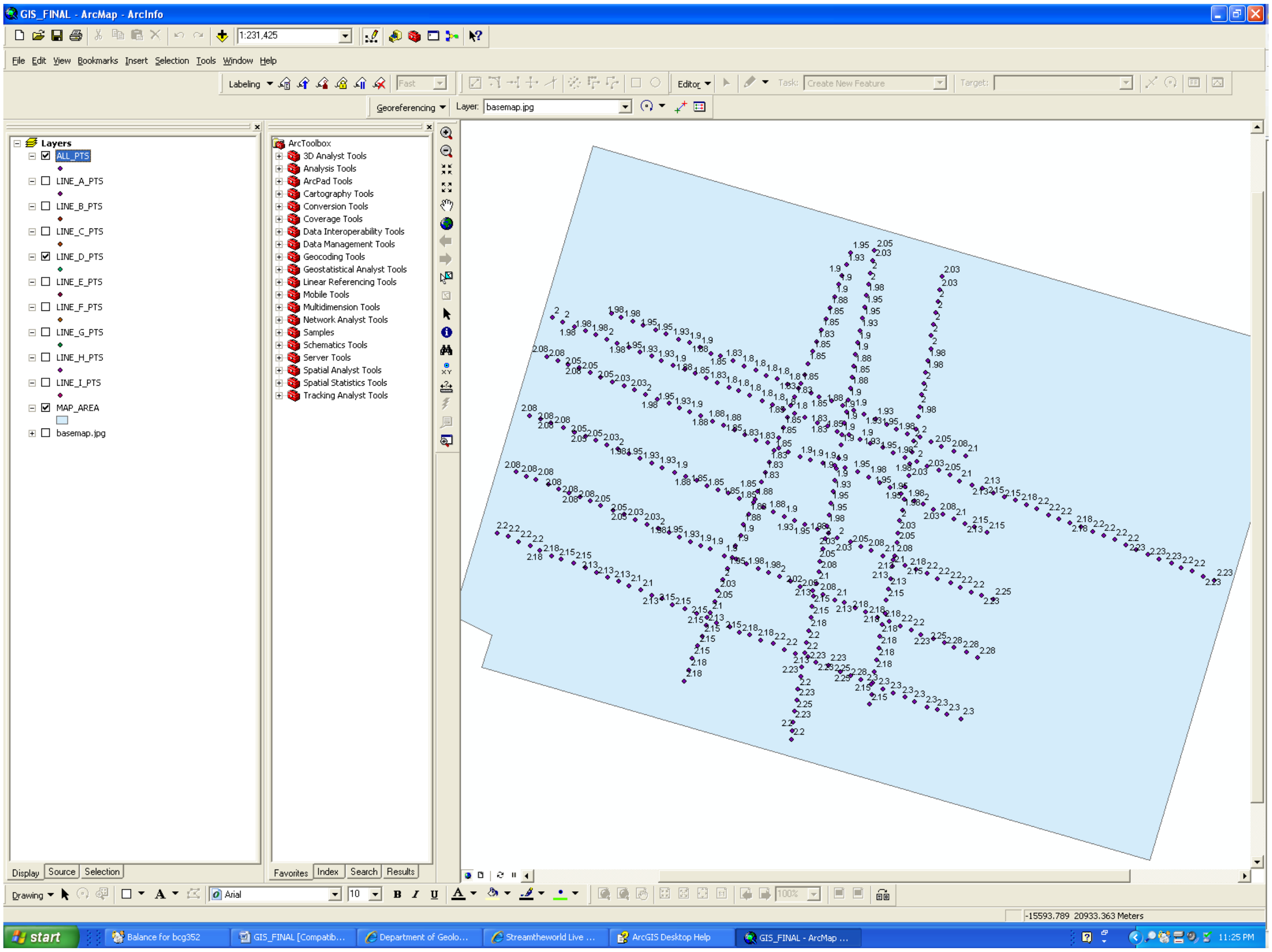
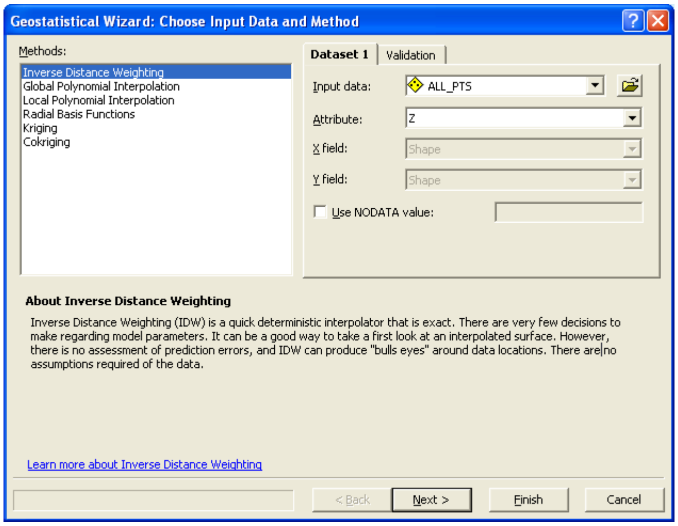
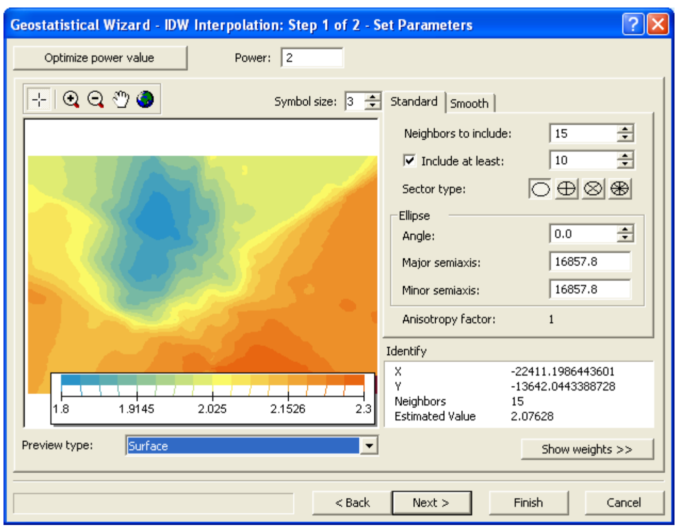


Figure 9. All points digitized and merged into one layer with their Z values defined.

D. Interpolate the entire surface from shot point depth data

Once I had all of depths input as Z values I could use the Geostatistical Wizard in the Geostatistical Analyst tool to interpolate the entire surface. The Geostatistical Wizard allows you to choose the method for interpolating a surface. I chose to use three of these methods, and compare the different surfaces to see which one was best for this data set.


Geostatistical Wizard: Choose Input Data and Method
Methods:
Inverse Distance Weighting
Global Polynomial Interpolation
Local Polynomial Interpolation
Radial Basis Functions
Kriging
Cokriging
Dataset 1
Validation
Input data:
ALL_PTS
Attribute:
Z
X field:
Shape
Y field:
Shape
Use NODATA value:
About Inverse Distance Weighting
Inverse Distance Weighting (IDW) is a quick deterministic interpolator that is exact. There are very few decisions to make regarding model parameters. It can be a good way to take a first look at an interpolated surface. However, there is no assessment of prediction errors, and IDW can produce "bulls eyes" around data locations. There are no assumptions required of the data.
Learn more about Inverse Distance Weighting
< Back
Next >
Finish
Cancel


Geostatistical Wizard - IDW Interpolation: Step 1 of 2 - Set Parameters
Optimize power value
Power: 2
Symbol size: 3
Standard
Smooth
Neighbors to include: 15
Include at least: 10
Sector type:
Ellipse
Angle: 0.0
Major semiaxis: 16857.8
Minor semiaxis: 16857.8
Anisotropy factor: 1
Identify
X -22411.1986443601
Y -13642.0443388728
Neighbors 15
Estimated Value 2.07628
1.8
1.9145
2.025
2.1526
2.3
Preview type:
Surface
Show weights >>
< Back
Next >
Finish
Cancel

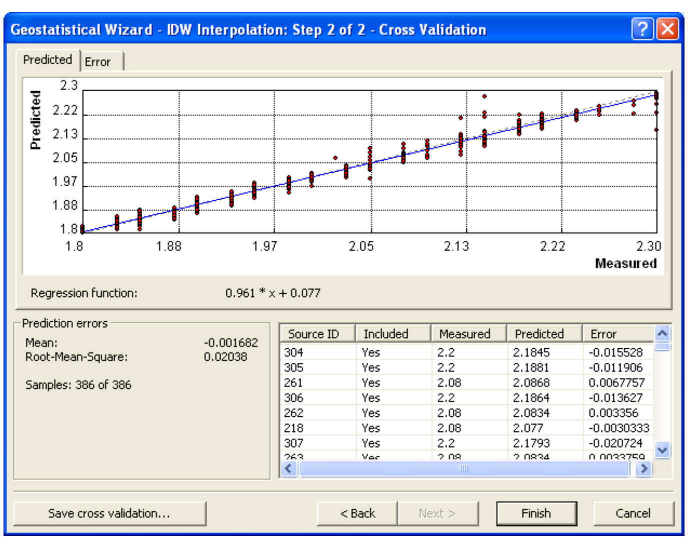

Geostatistical Wizard - IDW Interpolation: Step 2 of 2 - Cross Validation
Predicted
Error
Predicted
2.3
2.22
2.13
2.05
1.97
1.88
1.8
1.8
1.88
1.97
2.05
2.13
2.22
2.30
Measured
Regression function: 0.961 * x + 0.077
Prediction errors
Mean: -0.001682
Root-Mean-Square: 0.02038
Samples: 386 of 386
Source ID | Included | Measured | Predicted | Error
304 | Yes | 2.2 | 2.1845 | -0.015528
305 | Yes | 2.2 | 2.1881 | -0.011906
261 | Yes | 2.08 | 2.0868 | 0.0067757
306 | Yes | 2.2 | 2.1864 | -0.013627
262 | Yes | 2.08 | 2.0834 | 0.003356
218 | Yes | 2.08 | 2.077 | -0.0030333
307 | Yes | 2.2 | 2.1793 | -0.020724
Save cross validation...
< Back
Next >
Finish
Cancel

Figure 10. Using the Geostastical Wizard to interpolate the surface using Inverse Distance Weighting

RESULTS

The following maps display the surface interpolated from the same data using 3 different methods. The symbology has been adjusted to show the contours of the

surface.

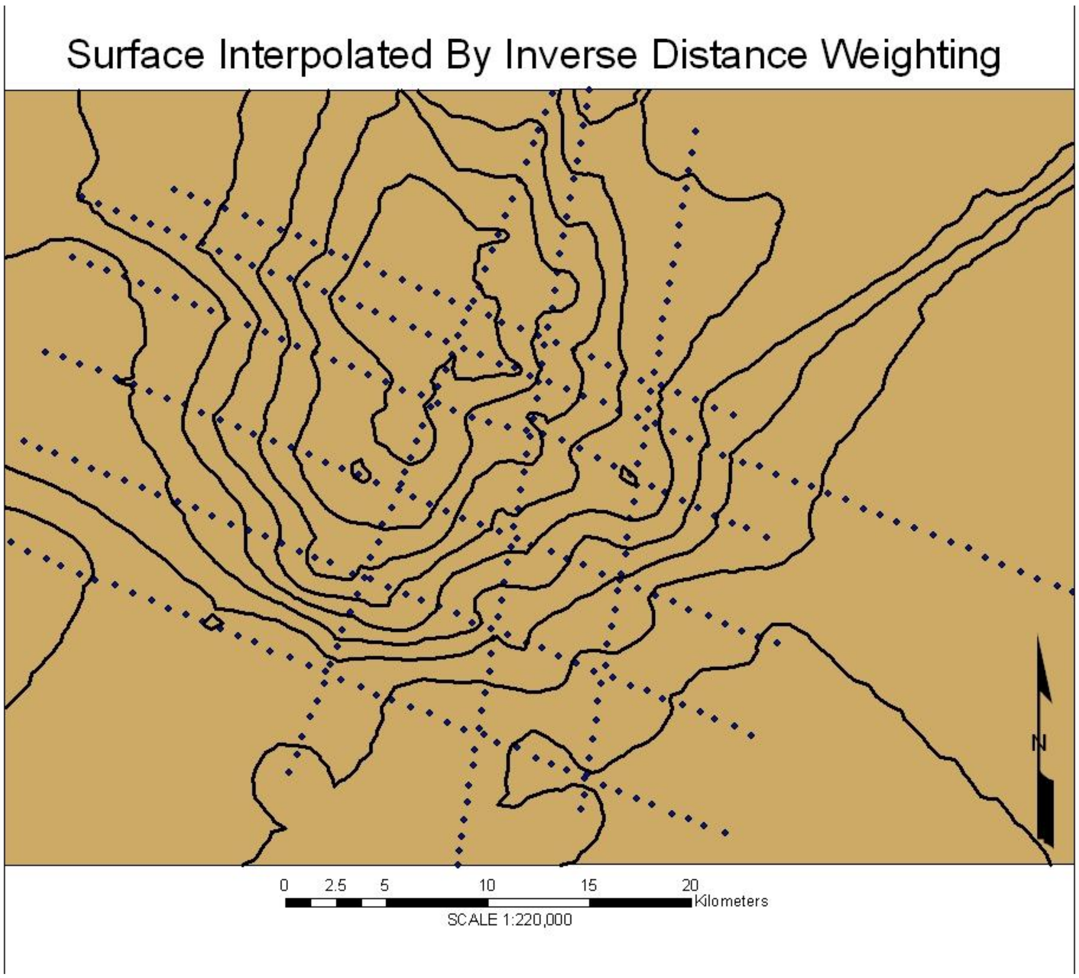


Figure 11. Surface interpolated by Inverse Distance Weighting.

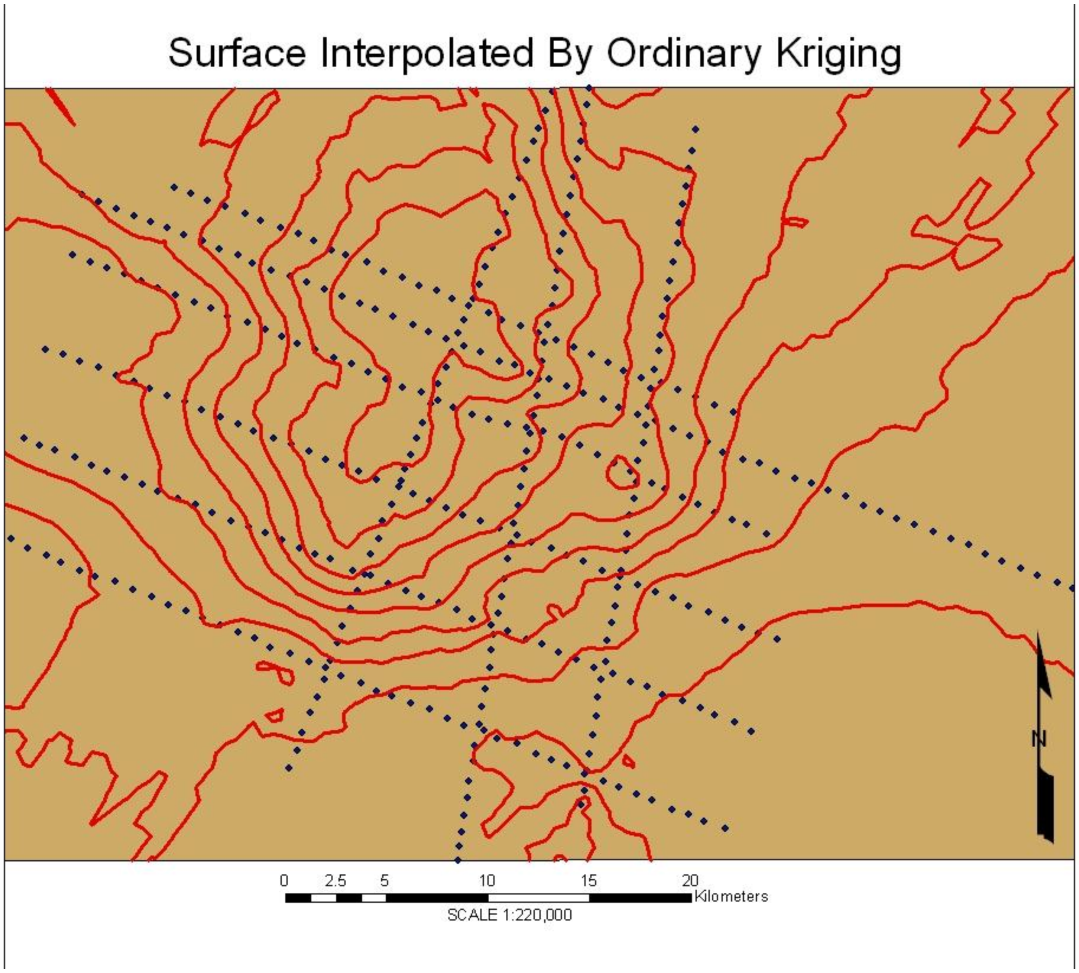


Figure 12. Surface interpolated by Ordinary Kriging

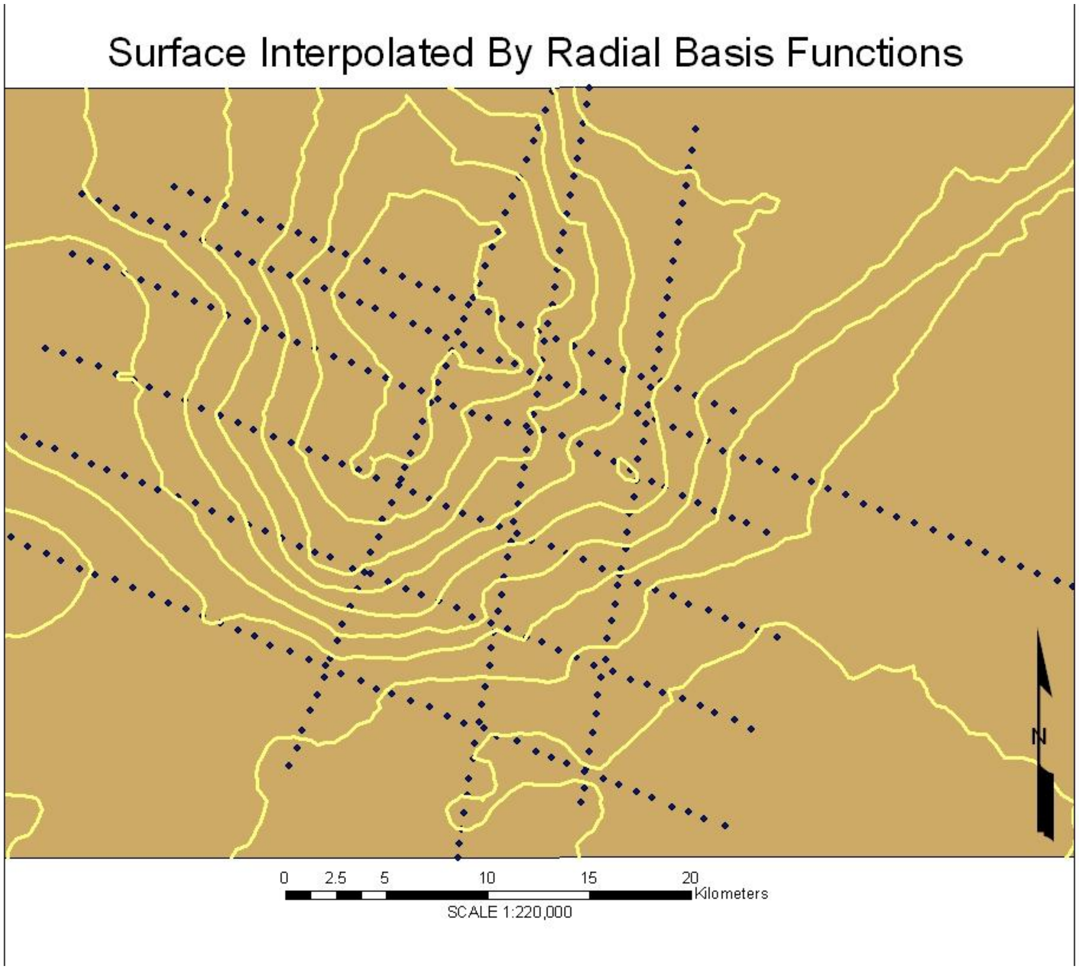


Figure 13. Surface interpolated by Radial Basis Functions.

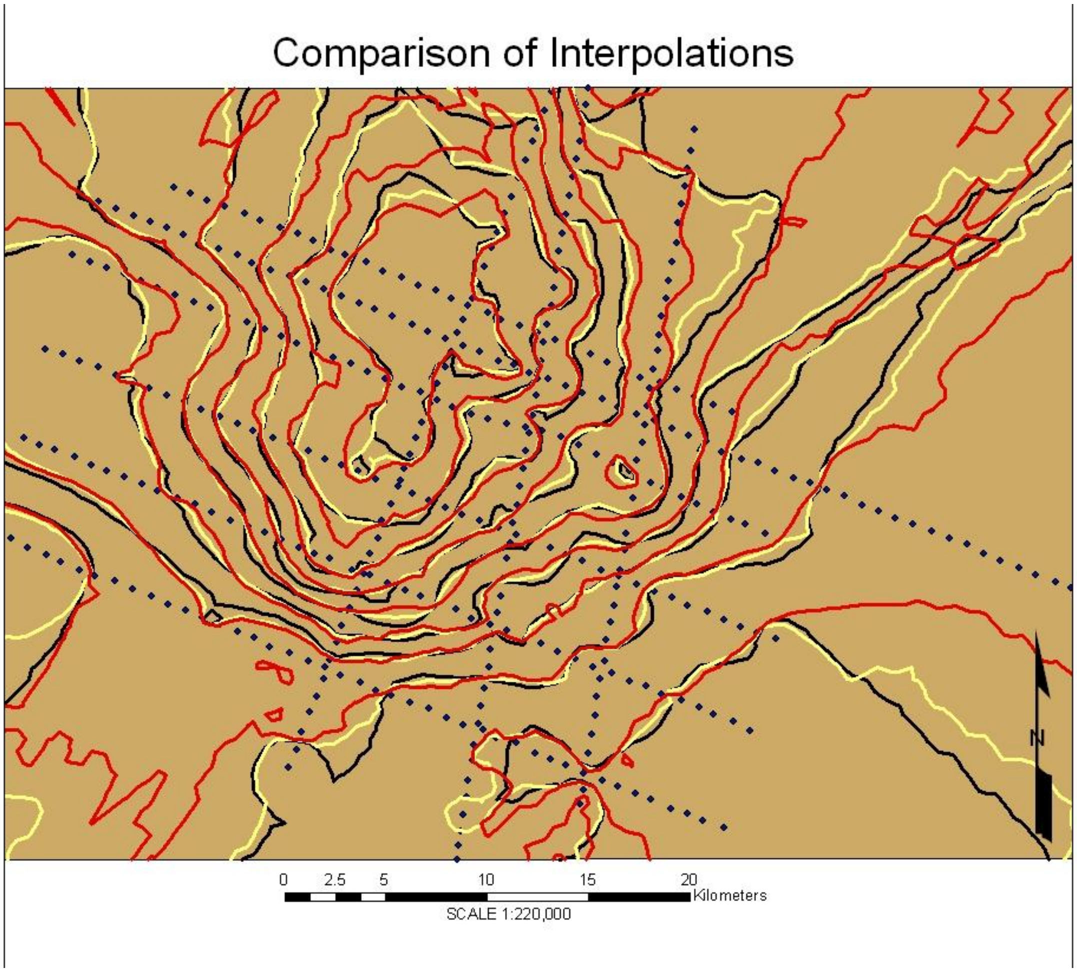


Figure 14. A comparison of the surfaces interpolated by inverse distance weighting (black), ordinary kriging (red), and radial basis functions (yellow).

DISCUSSION

As can be seen from figures 11, 12, and 13 the structural high of the region is just northwest of the center of the map. These figures show the contours of the surfaces that were interpolated. Displaying the contours as opposed to the entire surface makes it easier to compare the different interpolated surface. There are some differences in the interpolated surfaces towards that are fairly significant towards the corners of the map. These differences can be explained by the different processes used to interpolate the surfaces, and by the fact that these region contain very few data points and are therefore open to interpretation. The process used to create these maps could be applied to a number of different situations, such as mapping the water table from well data.

As far as locating the structural high of the regions, all of the surfaces are in agreement. If this surface was a sand horizon overlain by a good sealing shale, this map would be invaluable in determining the shape and structure of a hydrocarbon reservoir.