STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

INVESTIGATION OF AIRBORNE LASER SWATH MAPPING

FINAL REPORT

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Prepared by:

Dr. Shih-Lung Shaw
Jerry Everett
University of Tennessee

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16. Abstract
Under a contract with the Tennessee Department of Transportation (TDOT), the University of Tennessee at Knoxville (UTK) and the University of Florida (UF) formed a team to work on the "Investigation of Airborne Laser Swatch Mapping (ALSM)" project. UF flew over and collected ALSM data in a 5-mile study area near Decatur, TN for both leave-on and leave-off conditions. TDOT used the UF ALSM data to create contour lines and compared the ALSM contours with the contours created from the TDOT aerial survey data. It was noticed that the contour lines generated from the ALSM data were inconsistent with the contour maps created with the TDOT aerial survey data. The two sets of contours show different contour shapes as well as horizontal coordinate shifts. In order to investigate the possible causes of these differences between the two sets of contour lines, UTK was asked to conduct an evaluation of the ALSM data. This report presents the findings of this evaluation study.

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Introduction

The Tennessee Department of Transportation (TDOT) contracted with the University of Tennessee at Knoxville (UTK) to manage an "Investigation of Airborne Laser Swatch Mapping (ALSM)" project. A subcontract was issued to the University of Florida (UF) to fly over and collect data in a 5-mile study area near Decatur, Tenn. for both leave-on and leave-off conditions. The ALSM data collected by UF were forwarded to the TDOT on two CD-ROMs.

TDOT used the UF ALSM data to create contour lines and displayed the ALSM contours with the contours created from the TDOT aerial survey data. It was noticed that the contour lines generated from the ALSM data were inconsistent with the contour maps created from the aerial survey conducted by the TDOT. The two sets of contours appeared to show different contour shapes as well as horizontal coordinate shifts. In order to investigate the possible causes to these differences between the contour lines generated from the UF ALSM data and the contours created from the TDOT aerial survey data, the TDOT asked UTK to conduct an evaluation of the ALSM data. This report presents the findings of this evaluation study performed at UTK.

Data Description

TDOT provided UTK with three data CDs. Two of the CDs include UF ALSM data, which were flown on September 30, 2000 (i.e., leave-on condition) and on December 18, 2000 (i.e., leave-off condition), respectively. The third data CD contains the data sets created by the TDOT.

The UF ALSM data CDs

According to the information provided by Mr. Michael Sartori at UF (email communication of July 30, 2001), UF flew the airplane running Global Positioning System (GPS) during the survey, simultaneously with a ground-based receiver. The airplane trajectory was then differentially post-processed, yielding a precise 1 hertz position of the aircraft in the reference frame of the ground-based receiver. In addition to the GPS, the aircraft IMU was measuring the roll, pitch, and heading angles of the aircraft at 50 hertz during the survey. These angles, along with the laser-scanner mirror angles and the laser ranges were then combined to calculate vectors that yielded coordinates that are in the reference frame of the control station on the ground. The result is an ALSM dataset that is geo-registered from the start to the finish. The ALSM coordinate data are referenced to the GPS 36 with the ellipsoid heights based on the geoid model of GEOID96.

All coordinates in the ALSM data sets on both CDs are referenced to the horizontal data of NAD83, vertical data of NAVD88, coordinate system of State Plane Coordinates (SPC) Zone 4100 (Tennessee), and units in feet. All laser points were transformed from Universal Transverse Mercato (UTM) coordinates and ellipsoid heights using CORPSCON - (US Army COE) which employs the geoid model of GEOID96 (NOAA). The UF ALSM data represent points with (x,y,z) coordinates. Additional software is required to create contour lines from the ALSM data.

Both CDs consist of a Read_me.txt file and three file folders. These two CDs include the same types of files, except that one CD provides leave-on data (flown on September 30, 2000) and the other CD provides leave-off data (flown on December 18, 2000). Data files included in the three folders of the CDs are described below.

- "Unfiltered" file folder: This folder includes 14 coordinate files that correspond to the 14 tiles created for the study area. Each tile covers 5,000 feet x 5,000 feet. Filenames are based on the lower left corner (minimum coordinate vales) found in each tile with a format of XXXX_YYY (e.g., 2300_435.unf), where XXXX = first four significant digits of X (easting) coordinate in state plane (feet) and YYY = first three significant digits of Y (northing) coordinate in state plane (feet). Each file in this folder consists of four data fields, which are "X (easting)", "Y (northing)", "Elevation", and "Laser intensity". The files are stored in a space-delimited ASCII text format.

- "Filtered" file folder: This folder contains data for each of the 14 tiles that have been filtered to remove buildings and vegetation using automatic filtering algorithms. Files follow the same naming convention as the unfiltered files, except that a different file extension (e.g., 2300_435.fil) is used for the filtered data files. The Read_me.txt file indicates that the filtered files include three data fields – "X (easting)", "Y (northing)", and "Elevation". There are no intensity values since the filtering program does not carry these values along. However, while working with these filtered files, we found that some filtered files do include values for a fourth data field (e.g., the 2315_425.fil file flown on December 18, 2000). The files are stored in a space-delimited ASCII text format.

- "TIFF images" folder: The TIFF images show shaded relief maps of unfiltered and filtered ALSM data (see Figures 1 & 2). They are not GeoTIFF files (i.e., The image files are not geo-referenced.)

The TDOT data CD

The TDOT data CD contains a Readme.txt file, a text file of TDOT control points, and a set of Bentley's DGN files. According to the Readme.txt file, the coordinates included on this CD are based on the horizontal data of NAD83, vertical data of NAVD88, State Plane Coordinates Zone 4100 (Tennessee), and units in feet. Descriptions of these files are provided below.

- SR30CONTROL.TXT: This is a comma-delimited ASCII text file of twenty-seven (27) control points surveyed by the TDOT. Each record includes an ID field, two data fields for X (easting) and Y (northing) coordinates, and a fourth data field for elevation.

- TDOT.DGN: This file includes the contour lines generated from the TDOT aerial surveys, text annotations for contour labels, and polygons delineating the study area.
- ON2300-05.DGN, ON2300-10.DGN and ON2300-15.DGN: These are files of "leave-on" ALSM data that have been converted by TDOT into contour lines in DGN format. The three DGN files cover the beginning section, middle section, and the end section of the survey area (see Figure 3). These DGN files also include text annotations and polygons as the TDOT.DGN file does.
- OFF2300.DGN and OFF2315.DGN: These are files of "leave-off" ALSM data that have been converted by TDOT into contour lines in DGN format. The two DGN files cover the first half section and the second half section of the survey area (see Figure 4). These DGN files also include text annotations and polygons as the TDOT.DGN file does.

According to the information provided by the TDOT (email communication with Mr. Michael Chumney at TDOT), contour lines represented in these DGN files were created with the Cubic Convolution method available in the Intergraph's ISDC (Image Station DTM Collection) software.

Problem of Mis-matched Contour Lines

After converting the UF ALSM data into contour lines in DGN format, TDOT noticed that the contour lines generated from the UF ALSM data did not match with the contour lines created from the TDOT aerial survey data. Figures 5 & 6 illustrate the problem of mis-matched contour lines for "leave-on" data and "leave-off" data, respectively. Items below describe the files and their graphic symbols used in Figures 5 and 6.

1. SR30Control (TDOT control points, shown as points in "blue" color) with horizontal data of NAD83 and vertical data of NAVD88. In the example area presented in Figures 5 & 6, there is no TDOT control point.
2. TDOT.DGN Line (Contour lines produced from TDOT aerial surveys, shown as lines in "red" color) with horizontal data of NAD83 and vertical data of NAVD88.
3. TDOT.DGN Text (Annotations for the contour lines produced from TDOT aerial surveys, shown as texts in "red" color).
4. ON2300-10.DGN Line (Contour lines created by TDOT from the UF "leave-on" ALSM data, shown as lines in "green" color) with horizontal data of NAD83 and vertical data of NAVD88.
5. ON2300-10.DGN Text (Annotations for the contour lines created by TDOT from the UF "leave-on" ALSM data, shown as texts in "green" color).
6. OFF2300.DGN Line (Contour lines created by TDOT from the UF "leave-off" ALSM data, shown as lines in "light blue" color) with horizontal data of NAD83 and vertical data of NAVD88.
7. OFF2300.DGN Text (Annotations for the contour lines created by TDOT from the UF "leave-off" ALSM data, shown as texts in "light blue" color).

These two figures clearly indicate that there exist mis-matches between the contour lines created from the TDOT aerial survey data and those generated from the UF ALSM data in terms of contour line shapes and horizontal coordinates. Upon a request by the TDOT, UTK conducted an evaluation study to look into the possible causes to the mis-matched contour lines derived from the two different data sets.

Data Processing and Data Evaluation

To carry out the evaluation study, various data sets in different formats must first be brought into a unified software environment for comparisons. UTK chose the ArcView 3.2 and the ArcInfo 8.1 (ESRI, Redlands, CA) as the GIS software platform for this evaluation study because of the software availability. All DGN files provided by the TDOT were directly loaded into the ESRI GIS environment without any modification to the source data. ESRI shapefiles were then created from the DGN file by preserving the original coordinate values and the same data. The SR30CONTROL text file was directly loaded into a dBase table in ArcView software. The coordinates in the dBase table then were used to create a GIS map layer of the twenty-seven TDOT control points.

The first evaluation step conducted by UTK was to find out how well the TDOT control points matched with the contour lines created from the TDOT aerial survey data. Among the 27 control points, seven of them fall outside the contour lines generated from the TDOT aerial survey data and therefore are excluded from this evaluation. Of the remaining twenty control points, fourteen fall within the correct 1-ft contour interval and six are off by one 1-ft contour interval (i.e., off by less than 2 feet). Figures 7, 8 and 9 show three examples of these control points. The results of this evaluation step suggest that the TDOT control points match well with the contour lines created from the TDOT aerial surveys.

On the other hand, comparisons of the contour lines generated from the UF ALSM data by the TDOT and the contour lines derived from the TDOT aerial survey data also confirmed the problem of mis-matched contour lines as reported by the TDOT (see Figures 5 & 6). The next evaluation task therefore focused on what might have caused the problem of the mis-matched contour lines as shown by the DGN files on the TDOT CD. In order to carry out this evaluation task with the original ALSM data provided by UF, we re-generated the contour lines from the ALSM data files provided on the UF CDs using the ESRI GIS software. The steps of this evaluation task are described below.

Prepare the UF ALSM Data and Load the Data into GIS

The ALSM data sets provided on the UF CDs are in space-delimited ASCII text format. These files were first changed to comma-delimited format and then were loaded into the ArcView software as dBase tables. We chose the filtered ALSM data flown on December 18, 2000 (i.e., leave-off condition) to conduct this evaluation since the filtered data collected under the leave-off condition were likely to include elevation data that are more consistent with the TDOT survey data. We applied the same procedure to the ALSM data as the procedures we used to create the TDOT control points GIS map layer from the SR30CONTROL.TXT file. This step ensures that both the UF ALSM data and the TDOT data are loaded into the GIS environment with the same procedures. The resulting dBase tables populated with the ALSM data were used to create fourteen (14) GIS map layers that represent the locations of over 3.2 million filtered ALSM data points, with each GIS map layer corresponding to one tile of the study area. These fourteen GIS map layers follow the same naming convention as the files stored on the UF CD. They are named as F2300-435, F2300-440, F2305-430, F2305-435, F2305-440, F2310-425, F2310-430, F2310-435, F2315-425, F2315-430, F2320-425, F2320-430, F2325-425, and F2325-430. Figure 10 shows a test area of which the TDOT contours (TDOT.DGN) is displayed with the ALSM contours (OFF2315.DGN) that were provided on the TDOT CD. Mismatches between the TDOT contours and the ALSM contours are evident in this figure. Figure 11 adds the ALSM point map layer (F2325-430) to the display of TDOT contours and ALSM contours shown in Figure 10.

Generation of Contour Lines

The filtered ALSM GIS map layers represent the (x,y,z) coordinates at locations where the LIDAR data points were collected. In order to generate contour lines from these data points, we must apply an interpolation method to the data. There are many interpolation methods available for this purpose. Due to the different assumptions and mathematic models used in these interpolation methods, they could generate different contour lines from the same data set. In this evaluation, we included three interpolation methods for the purpose of investigating if particular interpolation methods applied to the ALSM point data would generate contour lines that are comparable to the contours lines provided on the TDOT CD.

The three interpolation methods included in the evaluation are the inverse distance weighted (IDW) method, the ordinary kriging method, and the universal kriging method. Each of the three interpolation methods was applied to the ALSM data such that an interpolated surface and the contour lines based on the interpolated surface were generated. The test results indicate that the inverse distance weighted method and the ordinary kriging (KO) method both generate comparable contour lines to the ALSM contours (i.e., OFF2315.DGN) provided on the TDOT CD (see Figures 12 and 13). In other words, it does not appear that the interpolation method used to generate the contours is the major cause to the horizontal coordinate shift problem as illustrated in Figures 10 and 14.

Evaluation of the Horizontal Coordinate Shift Problem

To further assess the horizontal coordinate shift problem, it is necessary to identify pairs of matching points between the TDOT contours and the ALSM data. Since the TDOT control points are not included in the ALSM data sets, there is no easy method of finding the matching pairs between the TDOT data and the ALSM data. To work around this problem, we selected one test point in the TDOT contours map and estimated its matching location on the ALSM contour map. This allowed us to derive estimates of the x-coordinate shift and the y-coordinate shift between the two data sets. The estimated coordinate shifts are (X + 154.76 ft) and (Y + 31.17 ft) for the selected test point in order to move the ALSM coordinates to match with the corresponding point on the TDOT contours. It should be noted that this estimation method is not suitable for a quantitative analysis due to its lack of a precise and systematic way of identifying the matching points between the two map layers. However, it is sufficient for a qualitative evaluation of the horizontal coordinate shift problem.

Using the estimates of x-shift and y-shift based on the selected test point, we first adjusted the (x,y) coordinates of all filtered ALSM data points in the test area and then re-interpolated and re-generated the contours from the adjusted ALSM coordinates. Figures 15 and 16 indicate that the ALSM contours derived from the adjusted horizontal coordinates have similar shapes and locations as the contour lines created from the TDOT aerial survey data. This is other evidence that the horizontal coordinate shift problem is likely to be caused by reasons other than the different interpolation methods used by TDOT and by UF. We also noticed that the horizontal coordinate shits did not appear to be uniform across the test area. For example, the contour lines on the left-hand half of Figure 16 show better matches (offsets are generally less than 10 ft) than the contour lines on the right-hand half of the Figure (offsets are generally in the 10-50 ft range).

Further Evaluation of Selected Test Points

Findings from the evaluation steps above raised an important question – what might have been the major cause to the horizontal coordinate shift problem between the contours derived from the TDOT aerial survey data and the contours created from the ALSM data? The evaluation results presented so far can help us eliminate some of the possible causes to the problem. For example, the horizontal data and the vertical data used by the TDOT and the UF are consistent and do not appear to be the cause to the horizontal coordinate shift problem. In addition, the different interpolation methods applied to the data sets could generate different contour shapes, but they do not appear to be the major source of the horizontal coordinate shift problem. In order to further examine the problem, both UF and UTK performed coordinate transformations of a set of test points selected from the U.S. Geological Survey's (USGS) 7.5 minute quad sheet and then computed basic statistics to compare the differences of the transformed coordinate values. This section reports the findings from this evaluation task (Note: Information regarding the test performed at UF was provided by Mr. Michael Sartori at UF.)

In order to check the accuracy of the ALSM coordinates, the UF team scaled the longitudes and latitudes of six road intersections in the town of Decatur, Tenn.. from the USGS 7.5 minute quad sheet. The coordinates in (longitude, latitude) of these six test points are listed in Table 1. The locations of these test points are shown with the TDOT control points in Figure 17.

Table 1: Test points selected in the town of Decatur, Tenn. with coordinates in (longitude, latitude).

Test Point ID	Longitude	Latitude
1	W 84 47 29.88	N 35 30 43.73
2	W 84 47 29.51	N 35 30 52.50
3	W 84 47 22.53	N 35 30 43.53
4	W 84 47 18.83	N 35 30 46.25
5	W 84 47 18.16	N 35 30 57.88
6	W 84 47 43.11	N 35 30 35.62

These coordinates in (longitude, latitude) were converted into State Plane Coordinates (SPC) Zone 4100 (Tennessee) with the NAD83 data using the CORPOSCON software at UF. Table 2 shows the coordinates converted into SPC in NAD83.

Table 2: Test points selected in the town of Decatur, Tenn. with coordinates converted into State Plane Coordinates Zone 4100 (Tennessee) and NAD83 data.

Test Point ID	X coordinate	Y coordinate
1	2328132	431342
2	2328152	432229
3	2328740	431329
4	2329042	431608
5	2329083	432784
6	2327048	430508

The UF team also gridded the ALSM coordinates (in SURFER, Golden Software) using the laser intensities, in order to create a black and white image of the ALSM survey. With the geo-registered image, the UF team then picked the coordinates of the same six intersections as identified on the USGS 7.5 minute quad sheet. Table 3 provides the coordinates in State Plane Coordinates Zone 4100 and in NAD83 data of the six intersections as digitized from the ALSM.

Table 3: Coordinates of the same six test points derived from the ALSM image that are in State Plane Coordinate Zone 4100 (Tennessee) and NAD83 data.

Test Point ID	X coordinate	Y coordinate
1	2328178	431366
2	2328163	432229
3	2328746	431347
4	2329042	431614
5	2329060	432805
6	2327065	430511

A comparison of the two sets of coordinates derived from the USGS quad sheet and the ALSM image indicates that the coordinate differences range from -23 to +46 feet (see

Table 4). For the easting coordinates, the average difference is 9.5 ft and the standard deviation is 22.58. For the northing coordinates, the average difference is 12 ft and the standard deviation is 10.22. These statistics suggest that the ALSM horizontal coordinates deviate from the coordinates derived from the USGS 7.5 minute quad sheet with a smaller range than those shown between the ALSM contours and the TDOT contours included on the TDOT CD (see Figure 10).

Table 4: Difference in coordinate values between the ALSM data and the USGS 7.5 minute quad (i.e., ALSM – USGS) in State Plane Coordinates Zone 4100 (Tennessee) and NAD83 data.

Test Point ID	Difference in X (Easting)	Difference in Y (Northing)
1	+46	+24
2	+11	0
3	+6	+18
4	0	+6
5	-23	+21
6	+17	+3
Average Difference	9.5 (Ave. Diff. = 17.17 if all differences are treated as absolute deviations - i.e., as positive numbers.)	12.0
Standard Deviation	22.58 (Std. Dev. = 16.26 if all differences are treated as absolute deviations - i.e., as positive numbers.)	10.22

In order to assess the coordinate transformations of the six test points performed at UF, UTK also used the same six pairs of coordinates in (longitude, latitude) and transformed them into the State Plane Coordinates Zone 4100 (Tennessee) with the NAD83 data using the ArcInfo 8.1 GIS software (ESRI, Redlands, CA). Table 5 lists the SPC coordinate values derived from the ArcInfo 8.1. Table 6 shows the differences of coordinate values reported by UF and those converted by UTK. This test clearly shows that different software packages (i.e., the CORPSCON used by UF and the ArcInfo 8.1 used by UTK) result in consistent horizontal coordinate shifts (i.e., 16 ft in easting and 26 ft in northing). However, the horizontal coordinate shifts again are smaller than those shown in Figure 10.

Table 5: Test points selected in the town of Decatur, Tenn. with coordinates converted by the UTK team into State Plane Coordinate Zone 4100 (Tennessee) and NAD83 data.

Test Point ID	X coordinate	Y coordinate
1	2328116	431316
2	2328136	432203
3	2328724	431303
4	2329026	431582
5	2329067	432758
6	2327032	430482

Table 6: Difference in coordinate values between the USGS data converted by UF and the same test points converted by UTK (i.e., Table 5 – Table 2) in State Plane Coordinates Zone 4100 (Tennessee) and NAD83 data.

Test Point ID	Difference in X (Easting)	Difference in Y (Northing)
1	-16	-26
2	-16	-26
3	-16	-26
4	-16	-26
5	-16	-26
6	-16	-26
Average Difference	-16	-26
Standard Deviation	0	0

Summary

The main purpose of this evaluation study is to identify the possible causes to the problem of mis-matched contour lines derived from the TDOT aerial survey data and the contours created from the UF ALSM data. UF flew over the study area to collect ALSM coordinate data using GPS36 and a local project control point. The local control point was used during the ALSM data collection as the base station and the reference frame of the entire survey for both the leave-on and the leave-off conditions. The LIDAR technology used in the surveys is capable of collecting very accurate coordinate data. However, the data collection process did not include the TDOT ground control points in the ALSM data sets. A direct quantitative comparison of the ALSM data with the TDOT data therefore is not feasible for this data evaluation study. This data evaluation study used a series of indirect evaluation methods to examine the possible causes to the problem of mis-matched contour lines that are derived from the TDOT aerial survey data and those generated from the ALSM data. This section presents a summary of the findings of these evaluations.

Both TDOT and UF reported that the State Plane Coordinates Zone 4100 (Tennessee) with the NAD83 horizontal data and the NAVD88 vertical data were used in their data sets. On the other hand, the two agencies used different software packages and methods to transform the survey data into SPC and to interpolate the contour lines. Based on the evaluations performed at UTK, a summary of the findings is provided below.

- Contour lines interpolated from the TDOT aerial survey data match well with the locations of the TDOT control points. Among the 27 TDOT control points, seven of them fall outside the area covered by the contour lines generated from the TDOT aerial survey data and therefore are excluded from this evaluation. Of the remaining twenty control points, fourteen fall within the correct 1-ft contour interval and six are off by one 1-ft contour interval (i.e., off by less than 2 feet).
- Contour lines interpolated from the ALSM data by TDOT appear to have different contour line shapes from the TDOT contours and relatively large horizontal coordinate shifts (e.g., about 150 ft in the easting and 30 ft in the northing as shown in a test area).
- Different interpolation methods could generate different contour shapes as shown in this study. With the evaluations performed in the study, we have demonstrated that the inconsistent contour shape problem can be minimized through the selection of an appropriate interpolation method (e.g., the IDW method and the ordinary kriging method reported in this study). In addition, interpolation of contour lines is directly related to the density of survey data points. With the very high density of ALSM data points (over 3.2 million of survey data points for the study area), it is expected that the contour shapes created from the ALSM data are likely to be somewhat different from the contour shapes created from the TDOT aerial survey data.
- The automatic filtering algorithm applied to the ALSM data is imperfect for the heavy vegetation areas, and biases under dense canopy could be several feet. The photogrammetric methods also experience a similar problem of deriving the elevation data under dense canopy when the ground cannot be seen in the stereoscopic images. These limitations associated with various technologies could have introduced differences in elevation data for the two data sets. These differences tend to vary across the study area due to the varying vegetation covers. Therefore, some of the non-uniform patterns of horizontal coordinate shifts associated with the contour lines could be caused by the technological limitations of deriving the elevation data at different locations across the study area.
- Based on the evaluation of the six test points selected from the USGS 7.5 minute quad sheet, their coordinates differ from the coordinates derived from the ALSM image in the range of –23 to +46 feet in the easting direction and in the range of 0 to +25 feet in the northing direction.
- Based on the evaluation of the same six test points selected from the USGS 7.5 minute quad sheet, it also shows that different software packages can create consistent horizontal coordinate shifts when we transform the data from one coordinate system to another coordinate system. A test performed on the six test

points indicates that the horizontal shifts between the coordinates estimated from the CORPSCON software and from the ArcInfo 8.1 software are –16 ft in the easting direction and -26 ft in the northing direction.

The LIDAR technology is capable of collecting very accurate location data. According to the evaluation findings, several factors could have contributed to the problem of mis-matched contour lines derived from the TDOT aerial surveys and the UF ALSM data. However, none of these factors alone is likely to cause the relatively large horizontal coordinate shifts between the two data sets. It appears that even the combined errors of the above factors might not have caused the relatively large horizontal coordinate shift problem as observed between the two data sets, especially along the easting direction that shows approximate 150 feet difference between the TDOT data and the ALSM data. This leads us to speculate that the problem is likely to be associated with the coordinates of the ground reference point(s) that were used to process and to derive the coordinates of the survey data points.

In an email communication with the UF, we learned that the raw ALSM data were transformed by UF into the SPC Zone 4100 with NAD83 and NAVD88 using the coordinates of a local reference point. If incorrect ground coordinates were used for the local reference point during the coordinate transformation process, it could cause horizontal coordinate shifts. Mr. Michael Sartori at UF points out that "it is possible that this local reference station has incorrect coordinates, and would thereby offset the entire ALSM dataset, relative to the areial photography." (Email communication of July 13, 2001) Unfortunately, the person who did the field work and the data processing is no longer with UF to verify if this is the cause to the horizontal coordinate shift problem. Mr. Sartori suggests that "The only way I could check that possibility would be to restore the archived GPS data, and reprocess the baseline between GPS36 and the local station, then check the kinematic processing to see if the correct reference coordinates were used." Another possible cause to the horizontal coordinate shift problem is that the coordinates of the ground reference points used in the TDOT aerial surveys are based on different parameters (e.g., a different geoid model, different false easting and/or false northing) from the coordinates of the local reference point used in the UF ALSM survey. Either case could have introduced horizontal coordinate shifts. These possibilities need to be investigated with the information available at UF and at TDOT, respectively.

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Figure 12: Comparison of the ALSM contours (i.e., OFF2315.DGN shown in green color) and the contours created from the ALSM point data using the inverse distance weighted (IDW) method (shown in brown color).
Figure 13: Comparison of the ALSM contours (i.e., OFF2315.DGN shown in green color) and the contours created from the ALSM point data using the ordinary kriging (KO) method (shown in orange color).
Figure 14: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the ALSM point data using the ordinary kriging (KO) method (shown in orange color).
Figure 15: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the shifted ALSM point data using the inverse distance weighted (IDW) method (shown in blue color).
Figure 16: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the shifted ALSM point data using the ordinary kriging (KO) method (shown in black color).
Figure 17: Locations of the six test points (shown in red color) and the TDOT control points (shown in blue color).

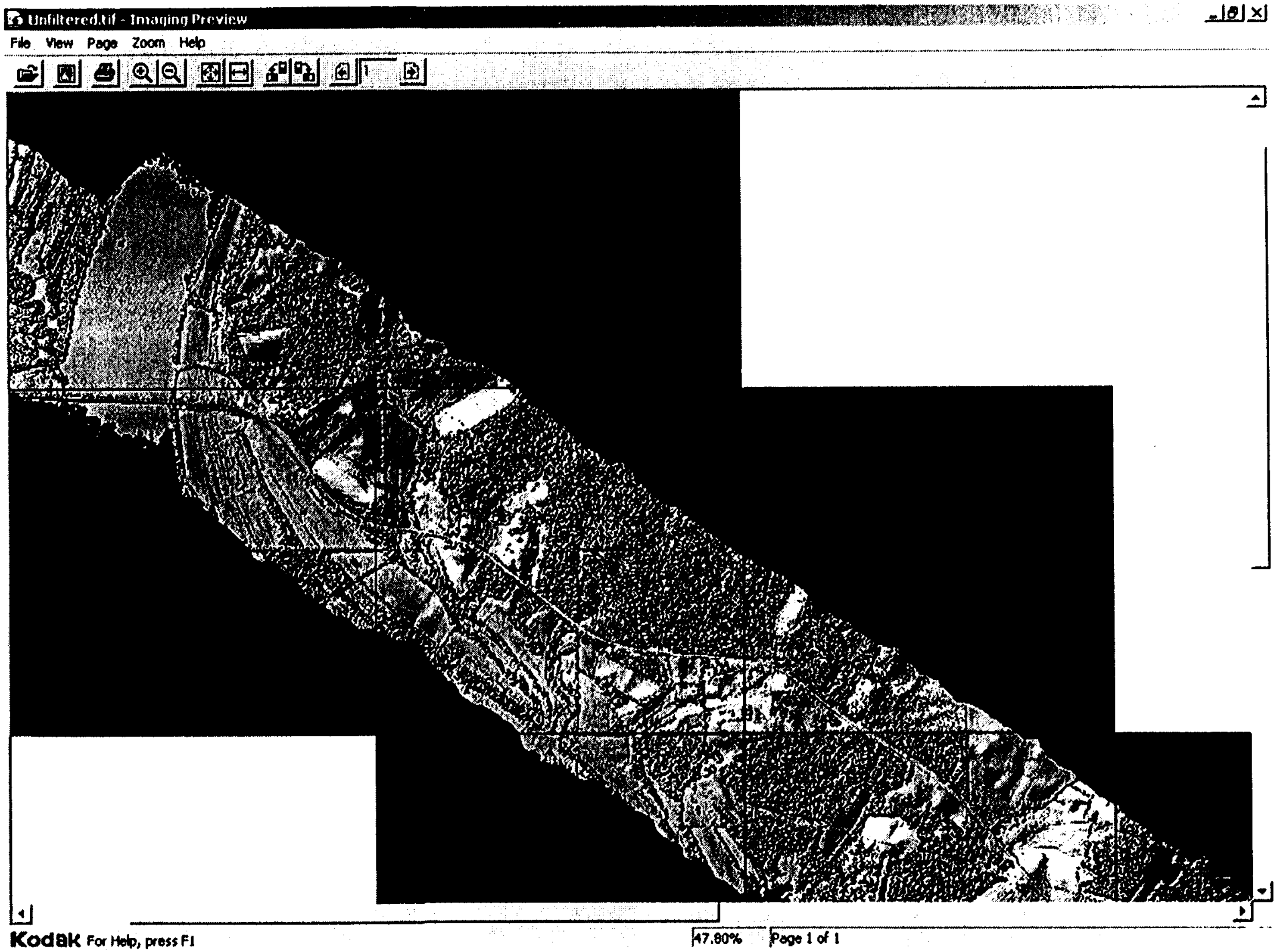

Figure 1: Unfiltered TIFF image of ALSM data flown on September 30, 2000. (Data source: UF CD)

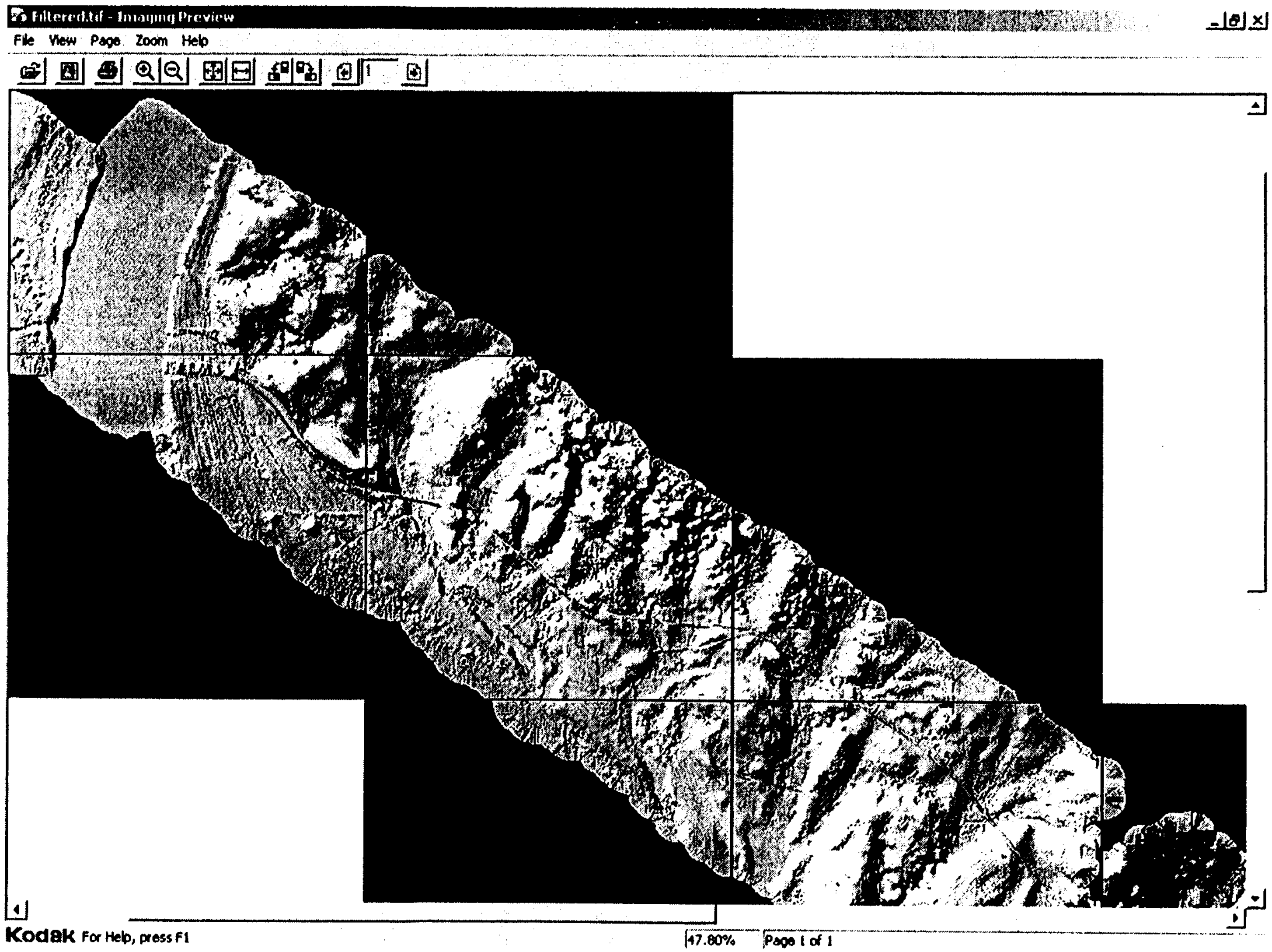

Figure 2: Filtered TIFF image of ALSM data flown on September 30, 2000. (Data Source: UF CD)

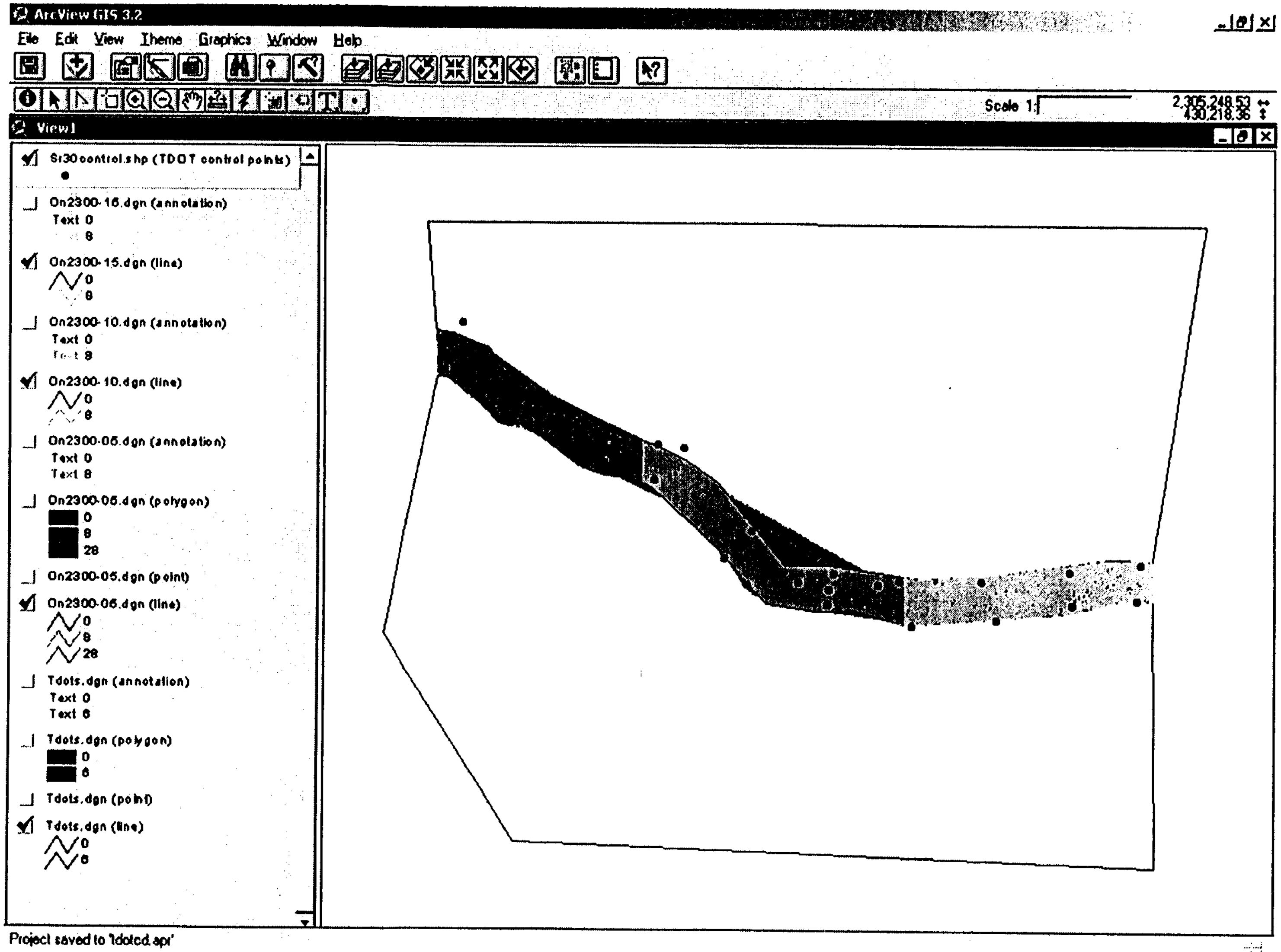

Figure 3: Display of "leave-on" files on the TDOT data CD. (Data source: TDOT CD)

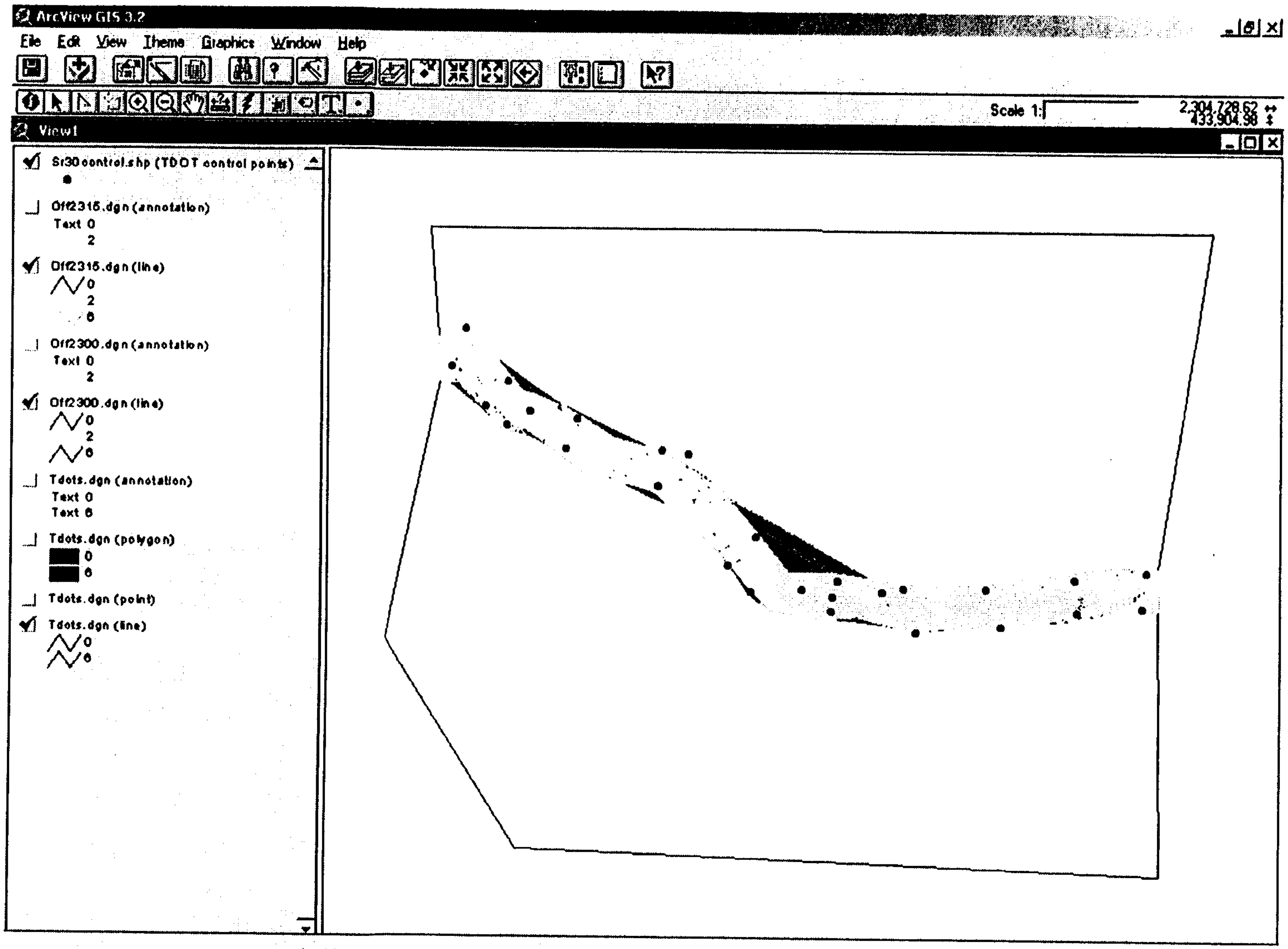

Figure 4: Display of "leave-off" files on the TDOT data CD. (Data source: TDOT CD)

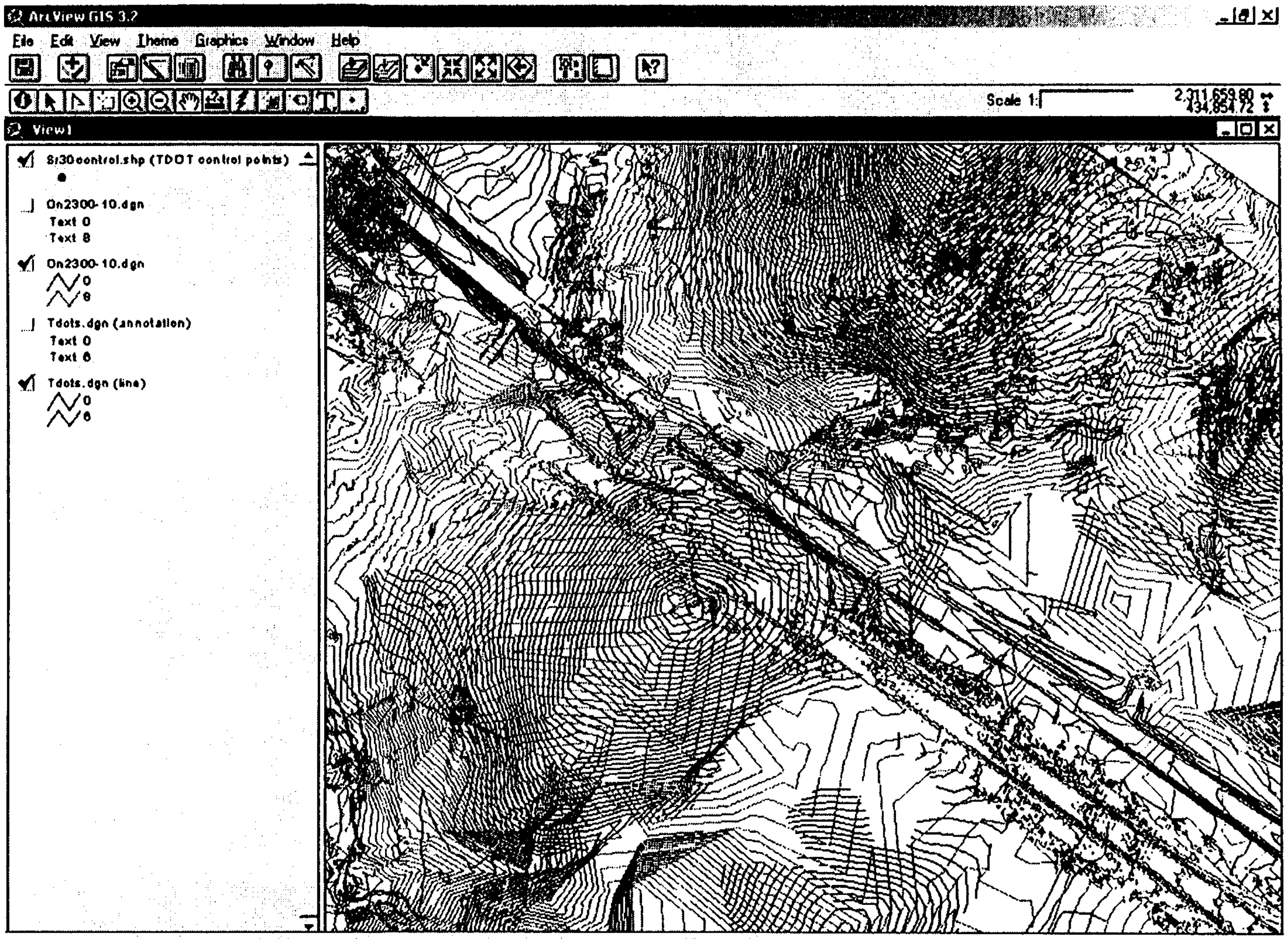

Figure 5: Example of mis-matched contour lines created from the TDOT aerial survey data and the UF ALSM "leave-on" data. (Data source: TDOT CD)

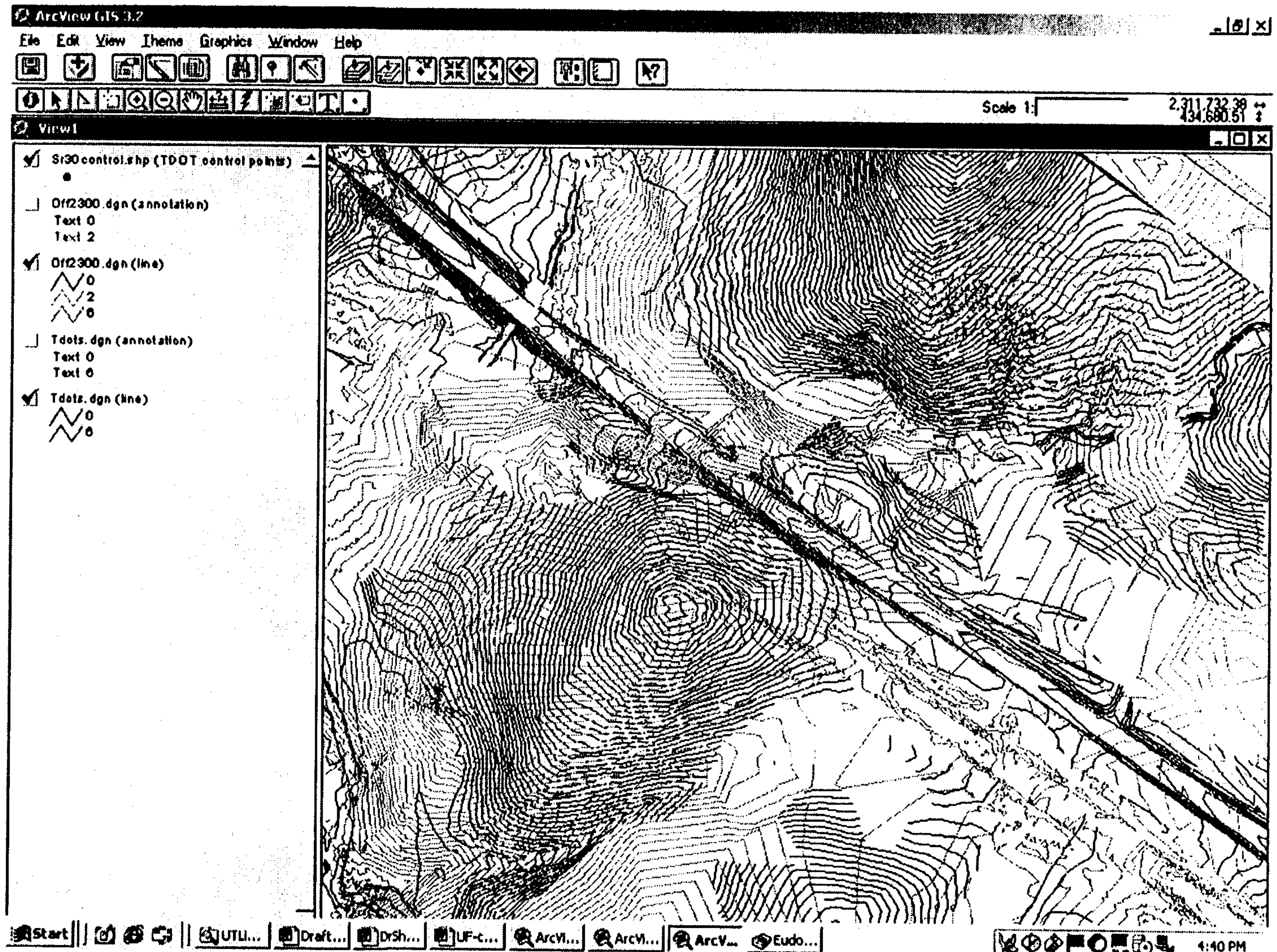

Figure 6: Example of mis-matched contour lines created from the TDOT aerial survey data and the UF ALSM "leave-off" data. (Data source: TDOT CD)

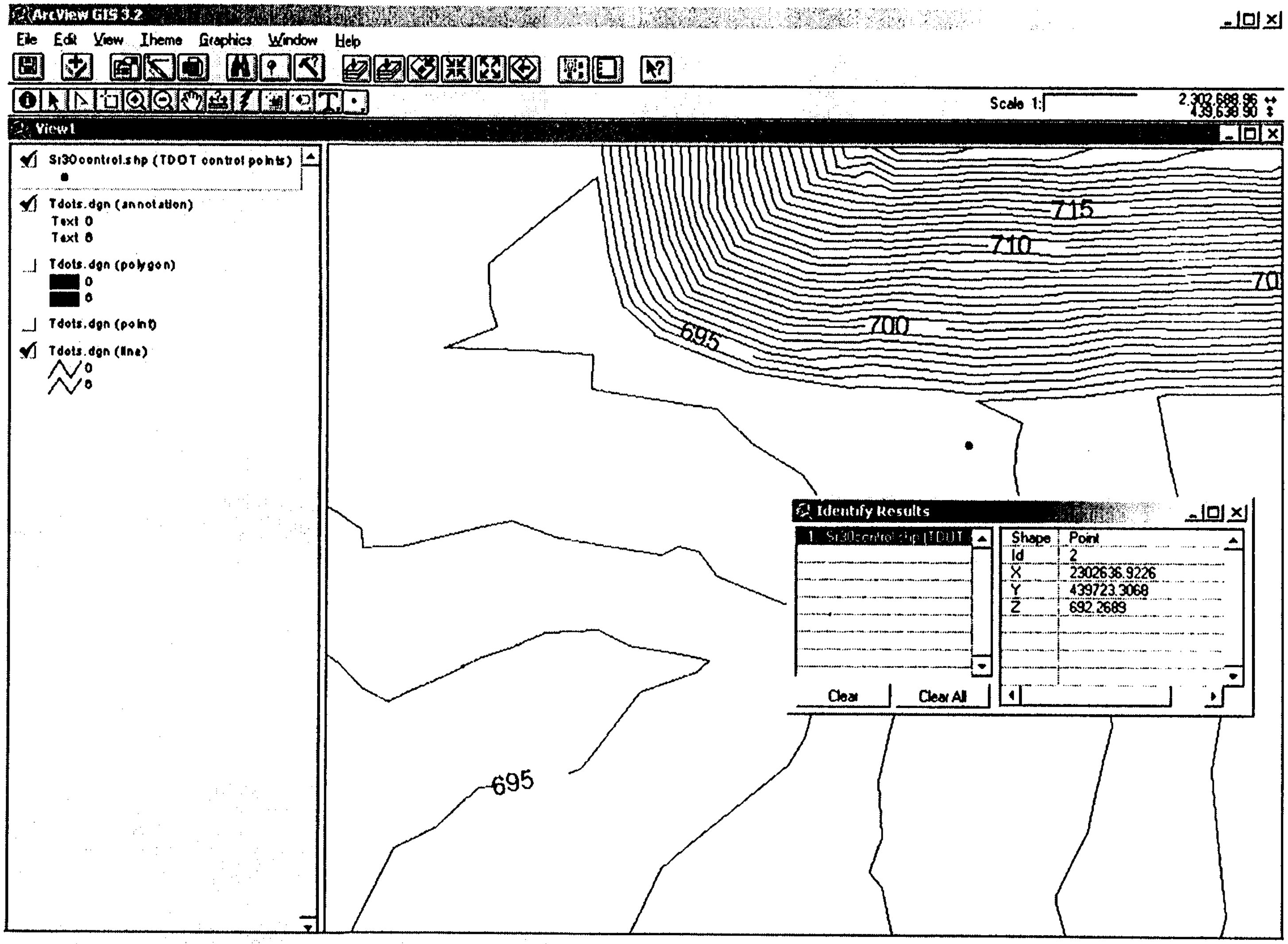

Figure 7: Evaluation of the TDOT control point (ID = 2) with the TDOT contour lines.

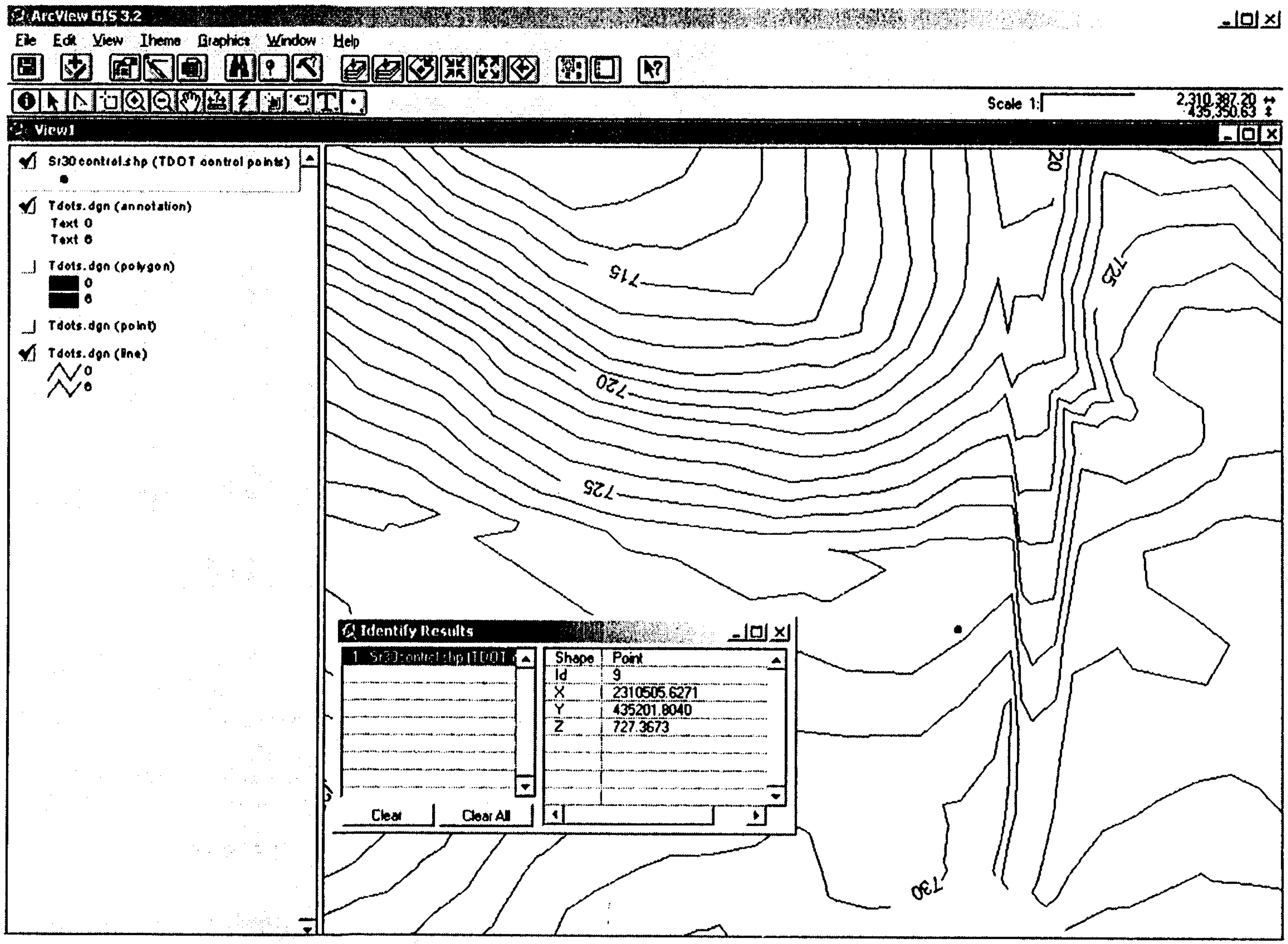

Figure 8: Evaluation of the TDOT control point (ID = 9) with the TDOT contour lines.

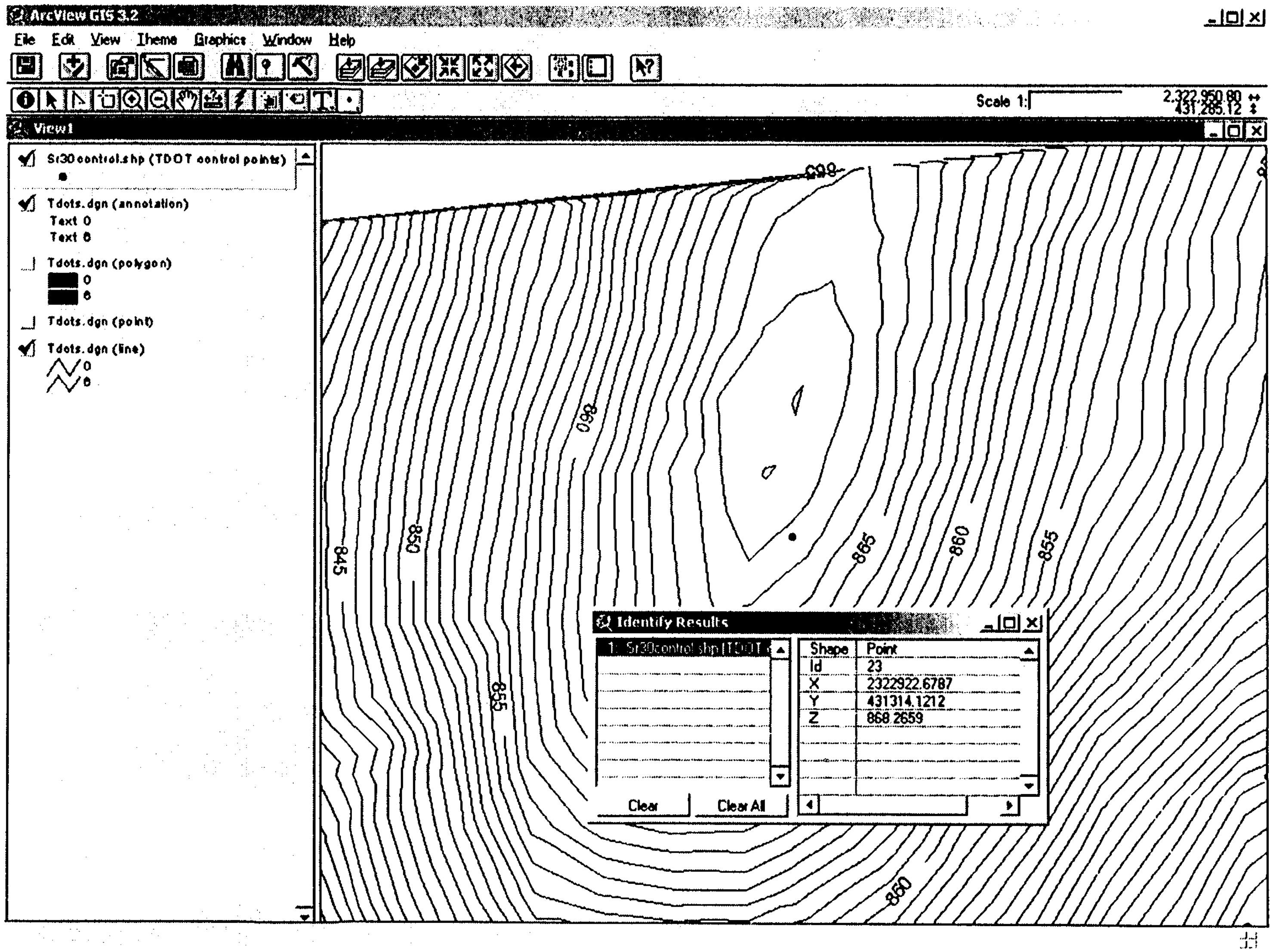

Figure 9: Evaluation of the TDOT control point (ID = 23) with the TDOT contour lines.

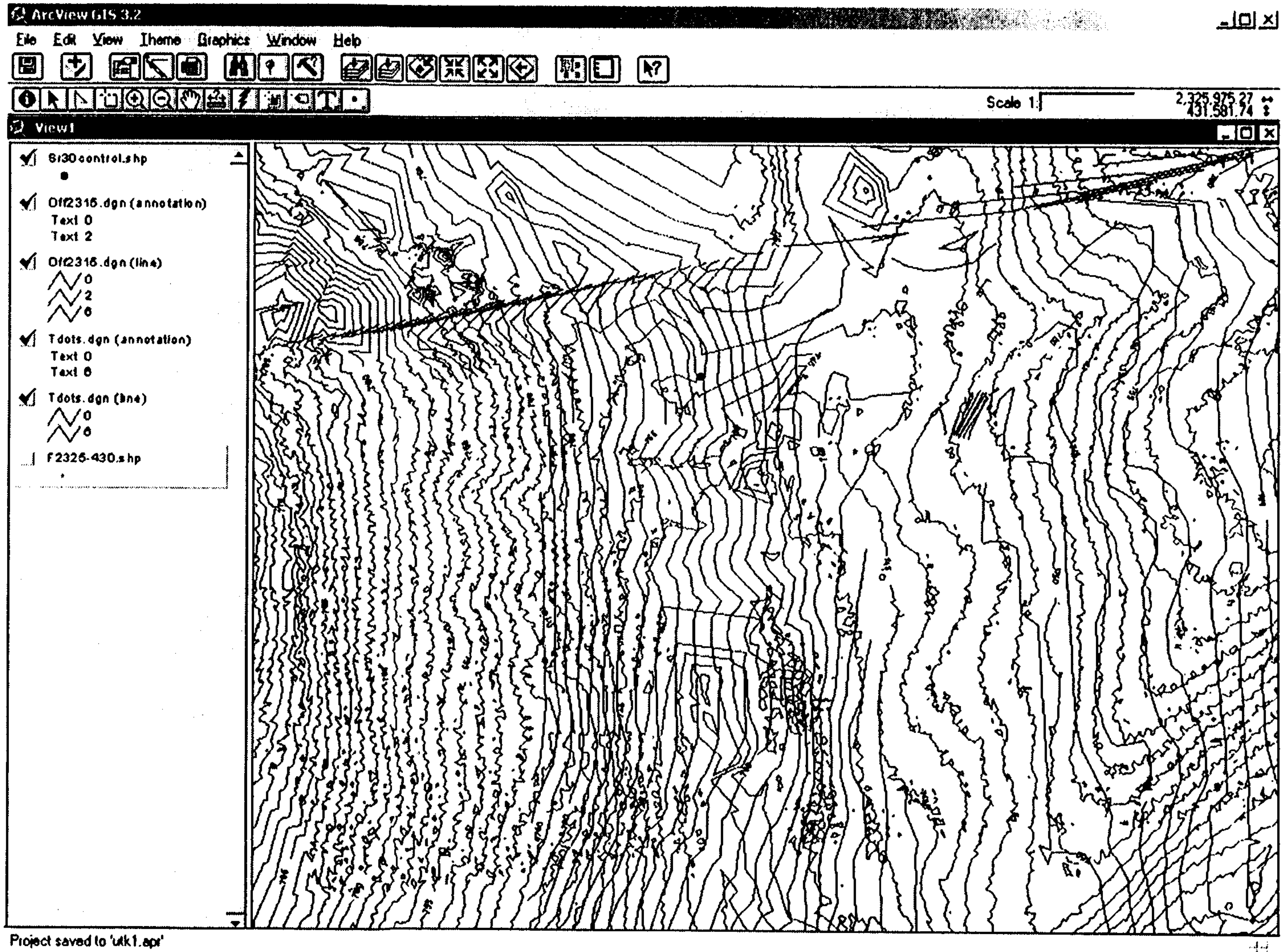

Figure 10: A test area with the TDOT contours (TDOT.DGN in red color) displayed with the ALSM contours (OFF2315.DGN in green color). (Data source: TDOT CD)

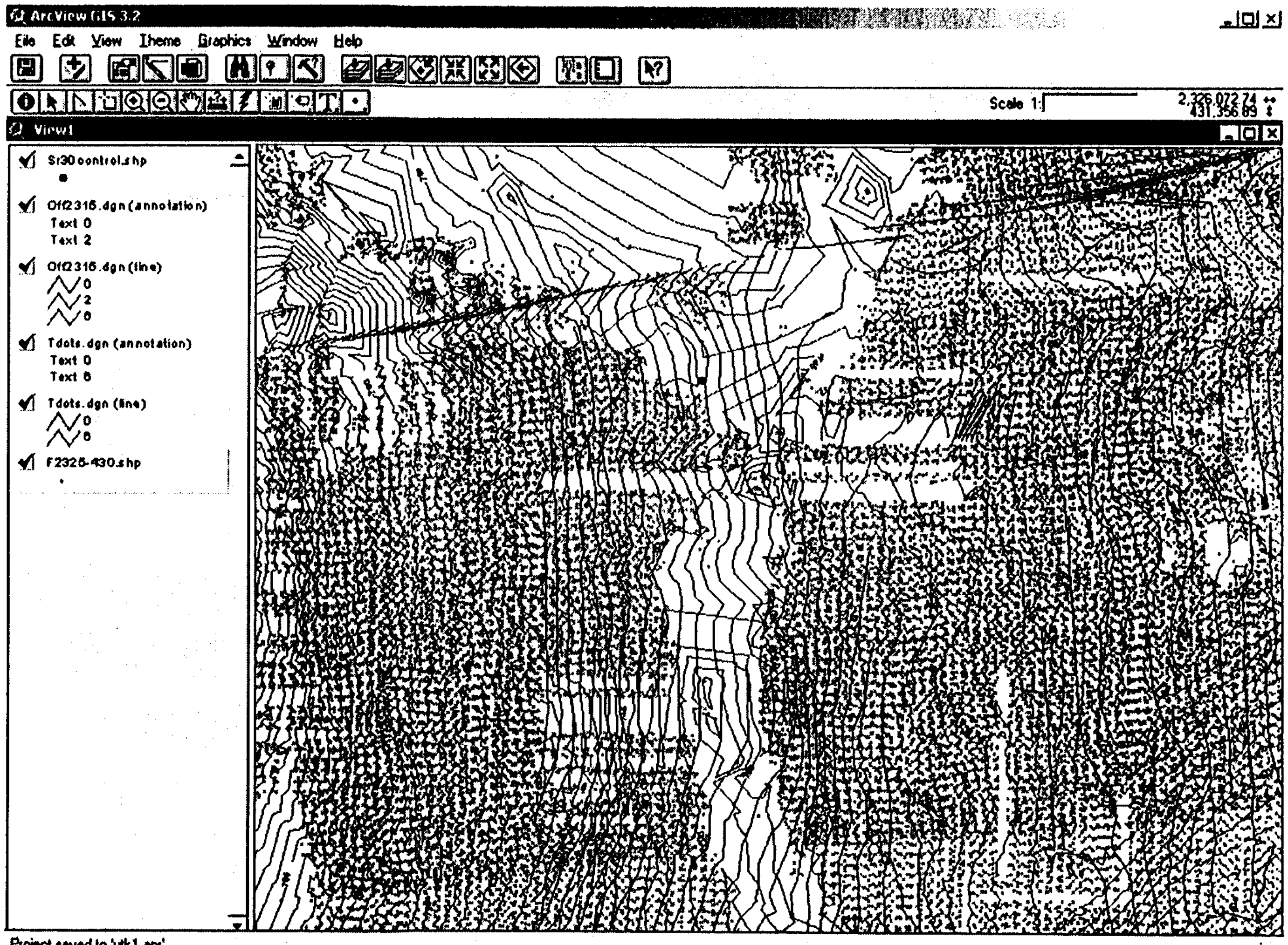

Figure 11: A test area with the TDOT contours (TDOT.DGN in red color) displayed with the ALSM contours (OFF2315.DGN in green color) from TDOT CD and the ALSM point layer (F2325-430.SHP in light blue color) created by UTK.

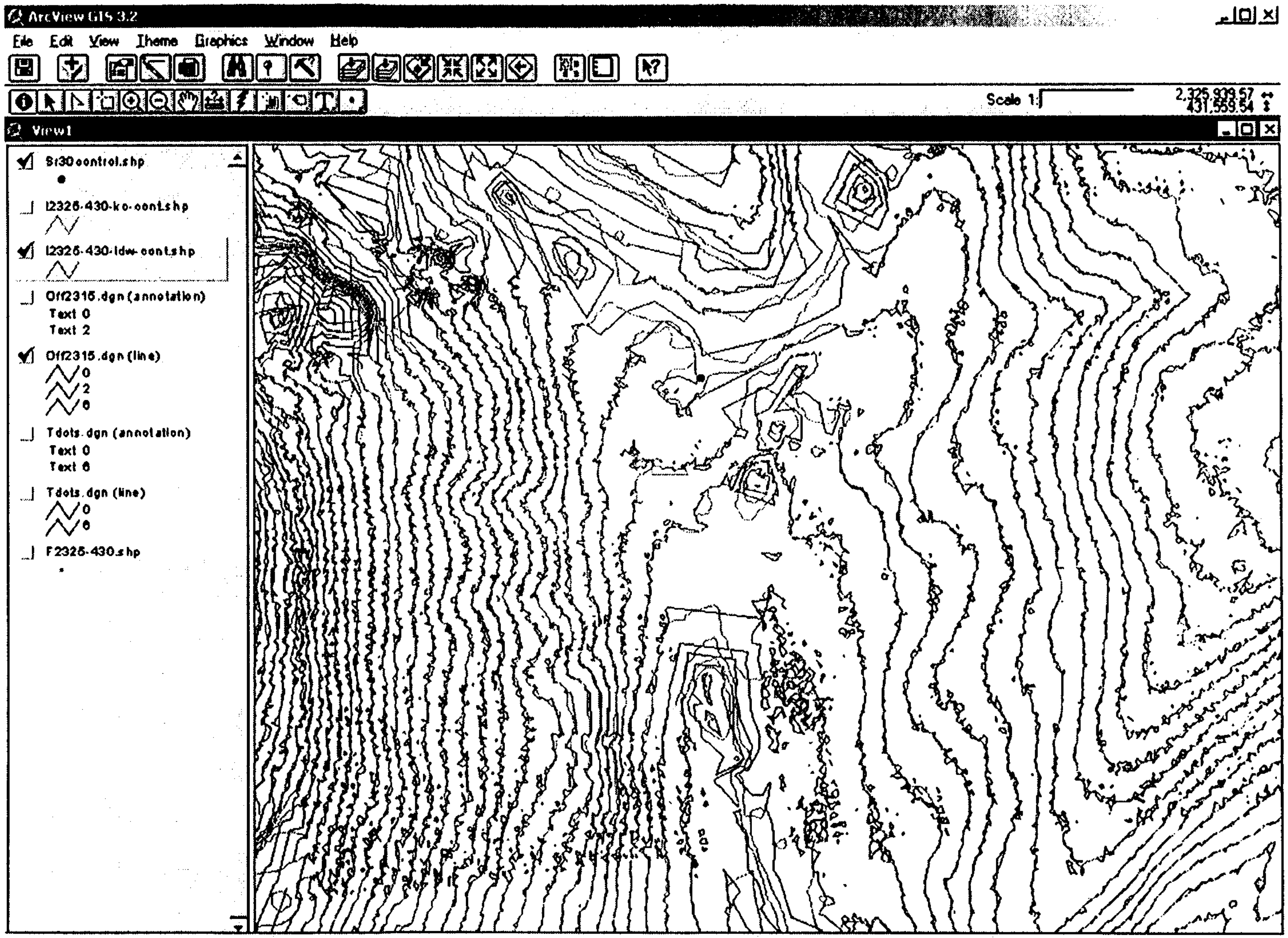

Figure 12: Comparison of the ALSM contours (i.e., OFF2315.DGN shown in green color) and the contours created from the ALSM point data using the inverse distance weighted (IDW) method (shown in brown color).

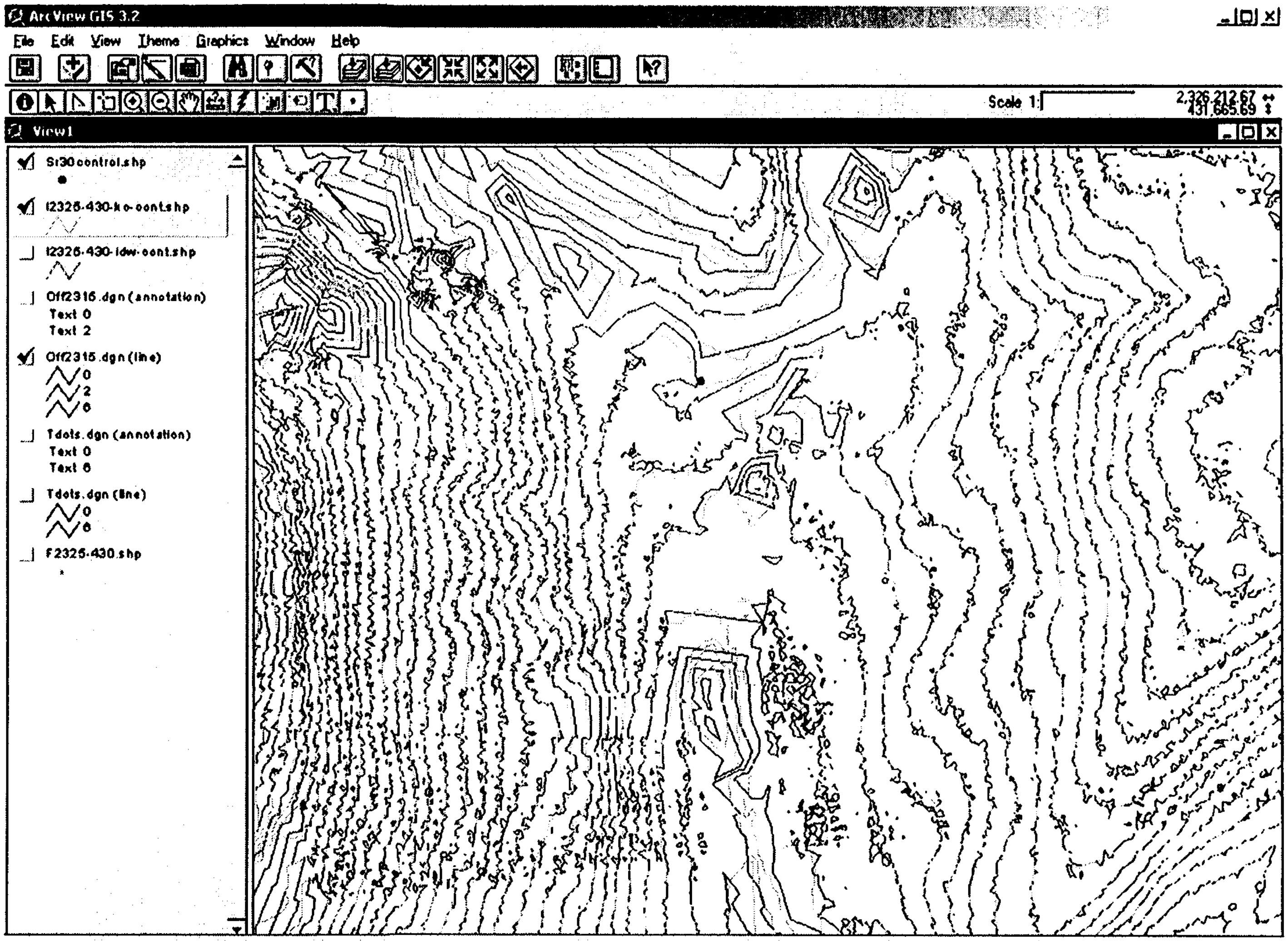

Figure 13: Comparison of the ALSM contours (i.e., OFF2315.DGN shown in green color) and the contours created from the ALSM point data using the ordinary kriging (KO) method (shown in orange color).

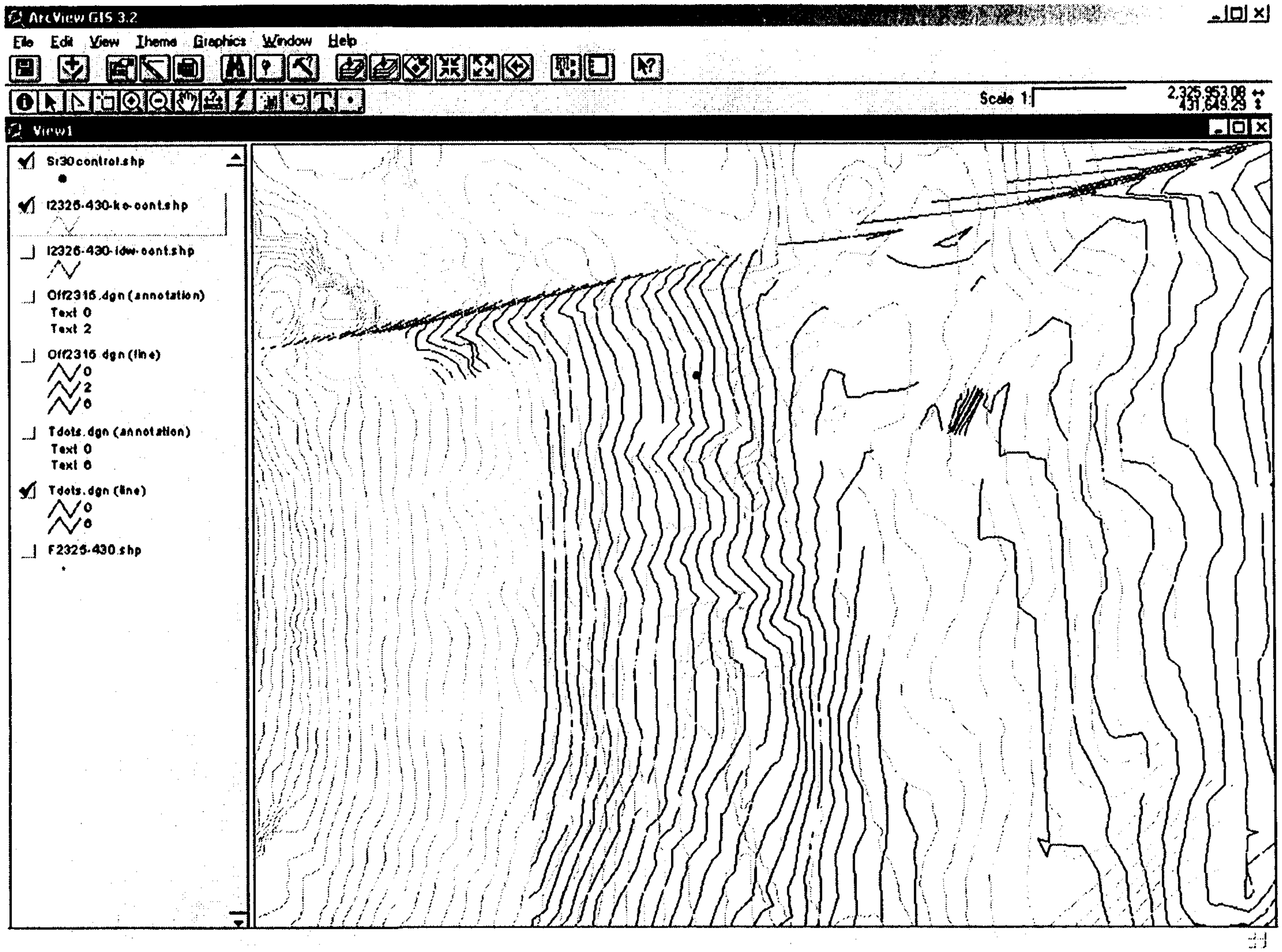

Figure 14: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the ALSM point data using the ordinary kriging (KO) method (shown in orange color).

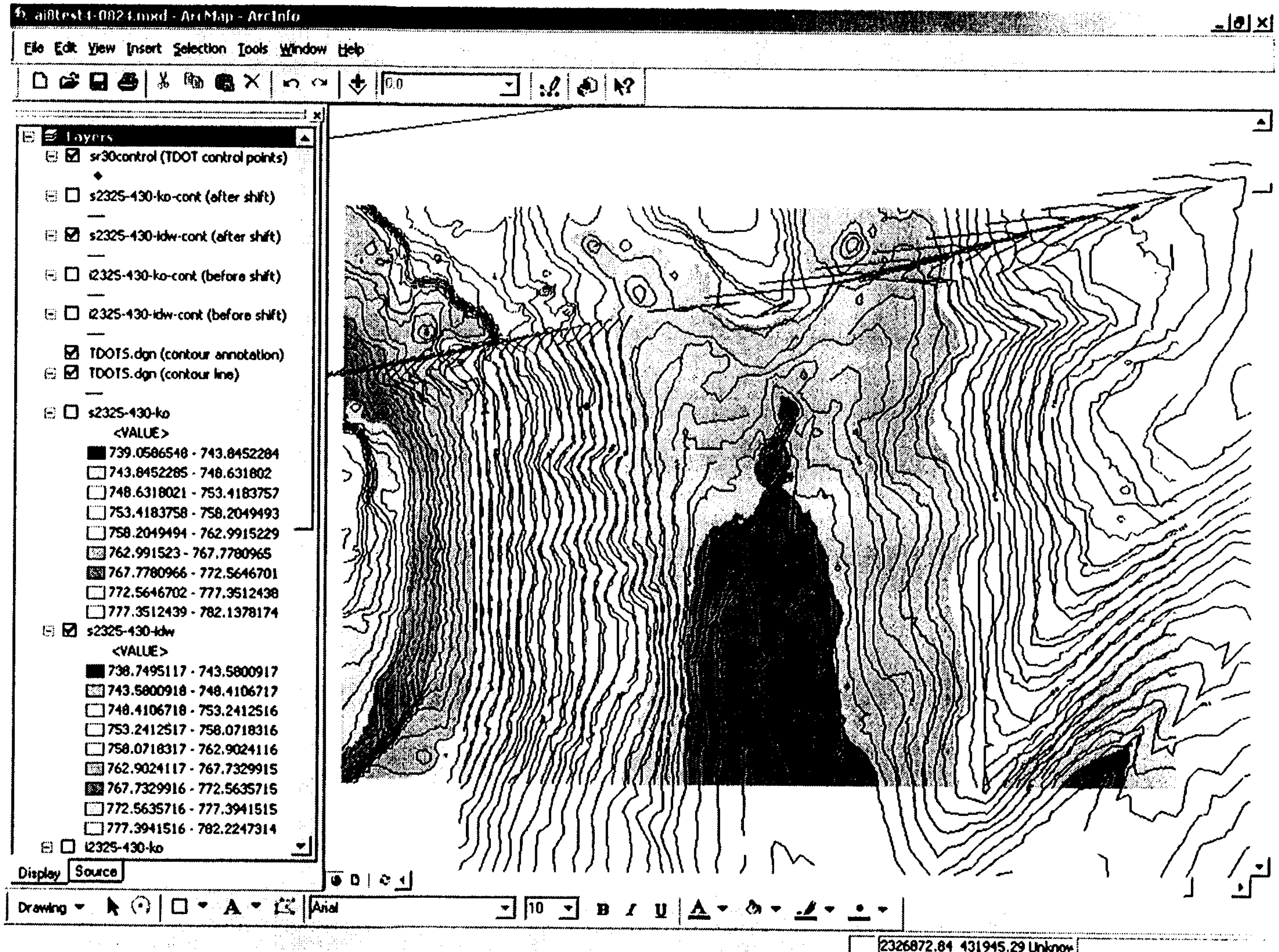

Figure 15: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the shifted ALSM point data using the inverse distance weighted (IDW) method (shown in blue color).

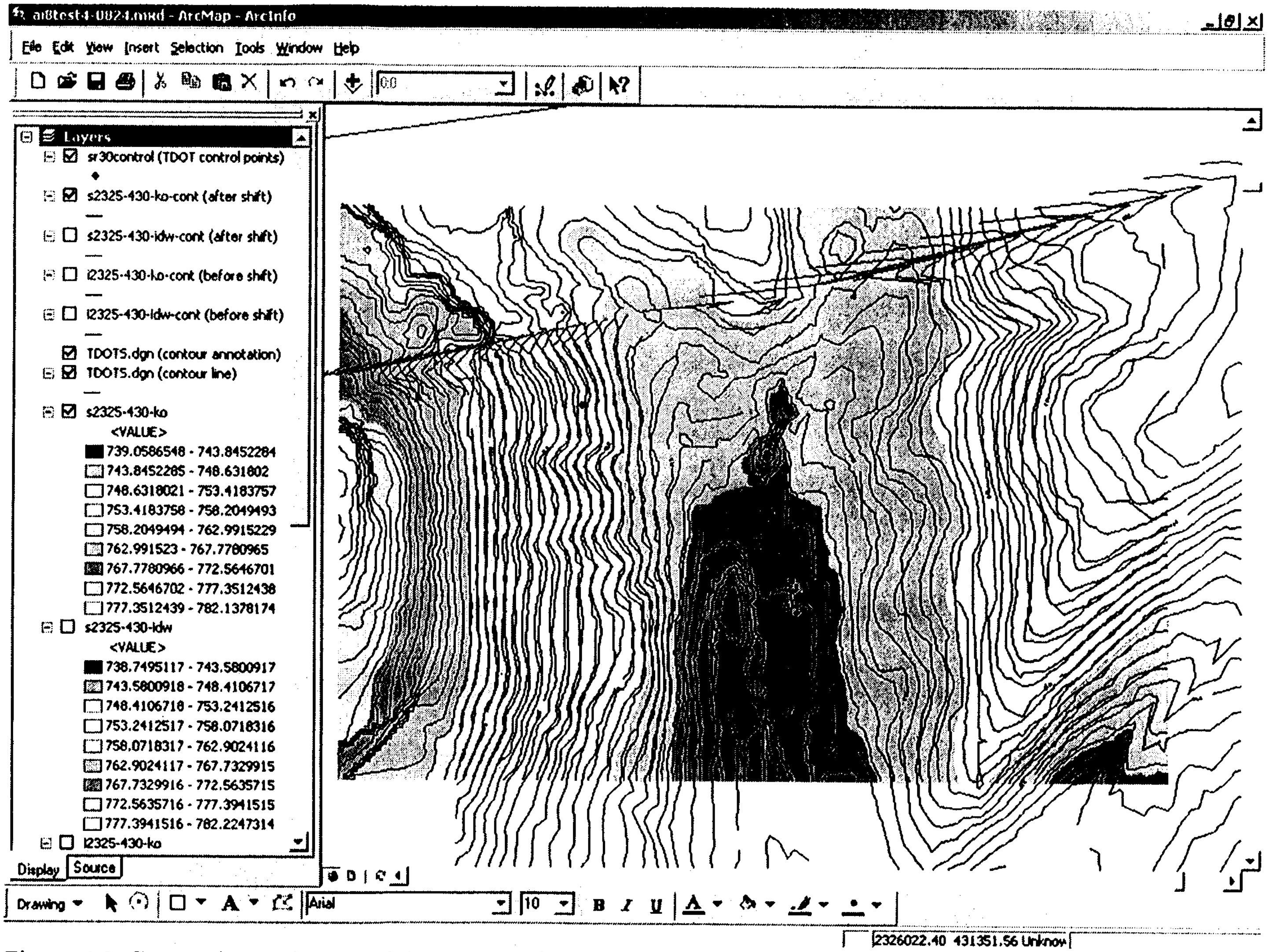

Figure 16: Comparison of the TDOT contours (i.e., TDOT.DGN shown in red color) and the contours created from the shifted ALSM point data using the ordinary kriging (KO) method (shown in black color).

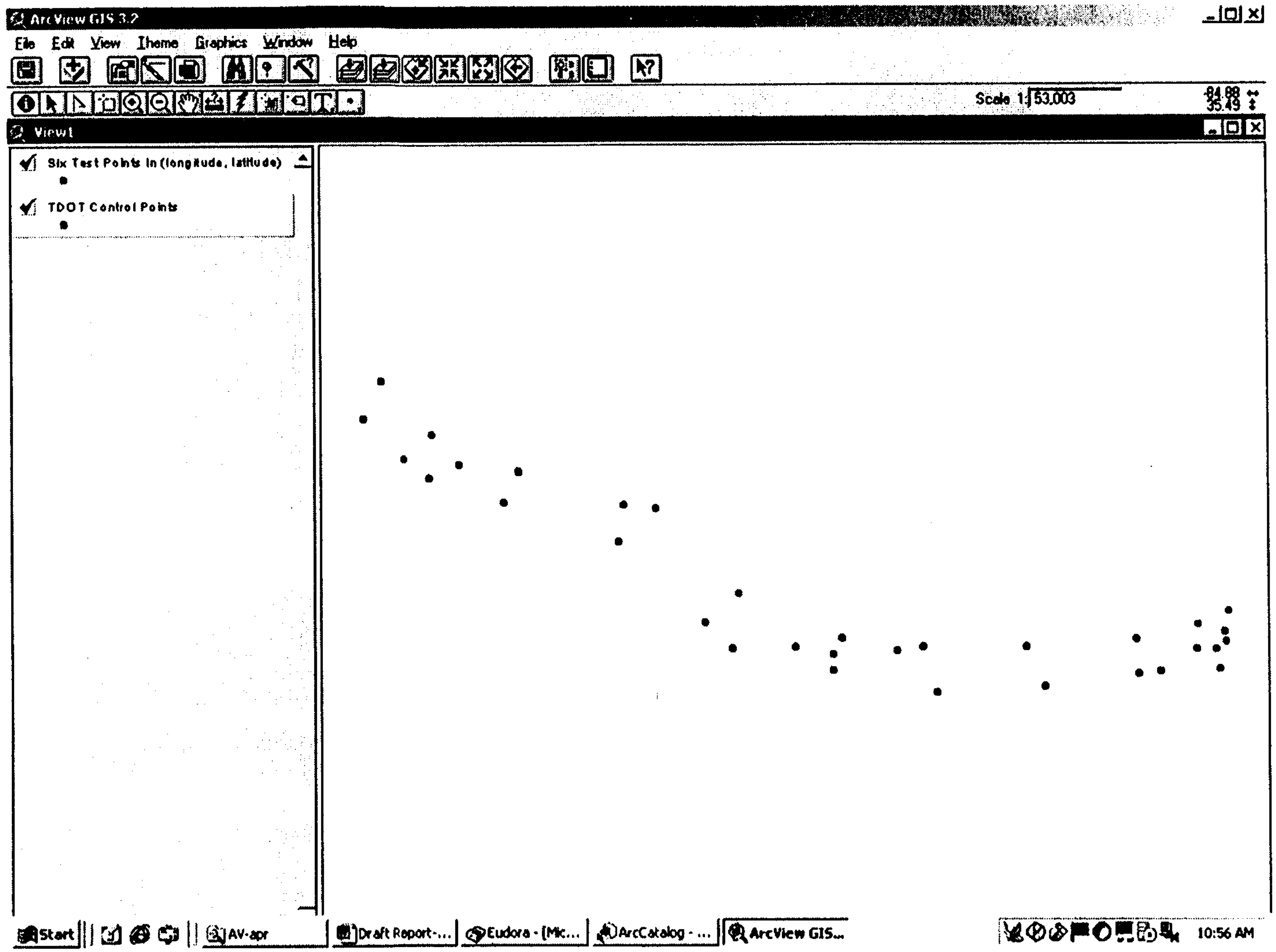

Figure 17: Locations of the six test points (shown in red color) and the TDOT control points (shown in blue color).