

Real-time Mapping of Laser Rangefinder to Photograph in ArcMap

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Overview

- LaserSketch is an ArcMap/ArcScene extension which provides real-time mapping (or offline mapping) of point measurements by a laser or total station on a vertically oriented structure to their proper location on a photograph of the structure.
- Requirements:
 - One time distortion characterization of the camera
 - Laser with XYZ encoder or total station
 - For real-time plotting: Bluetooth, USB, or serial link between laser/total station and laptop computer running ArcMap and LaserSketch
 - For offline plotting: computer running ArcMap and LaserSketch
 - Identify a minimum of four tiepoints between the photograph and the XYZ coordinates from the laser/total station. Tiepoints are graphic markers placed on the photograph in ArcMap.

Examples of Laser Systems

Laser Rangefinder



Total Station

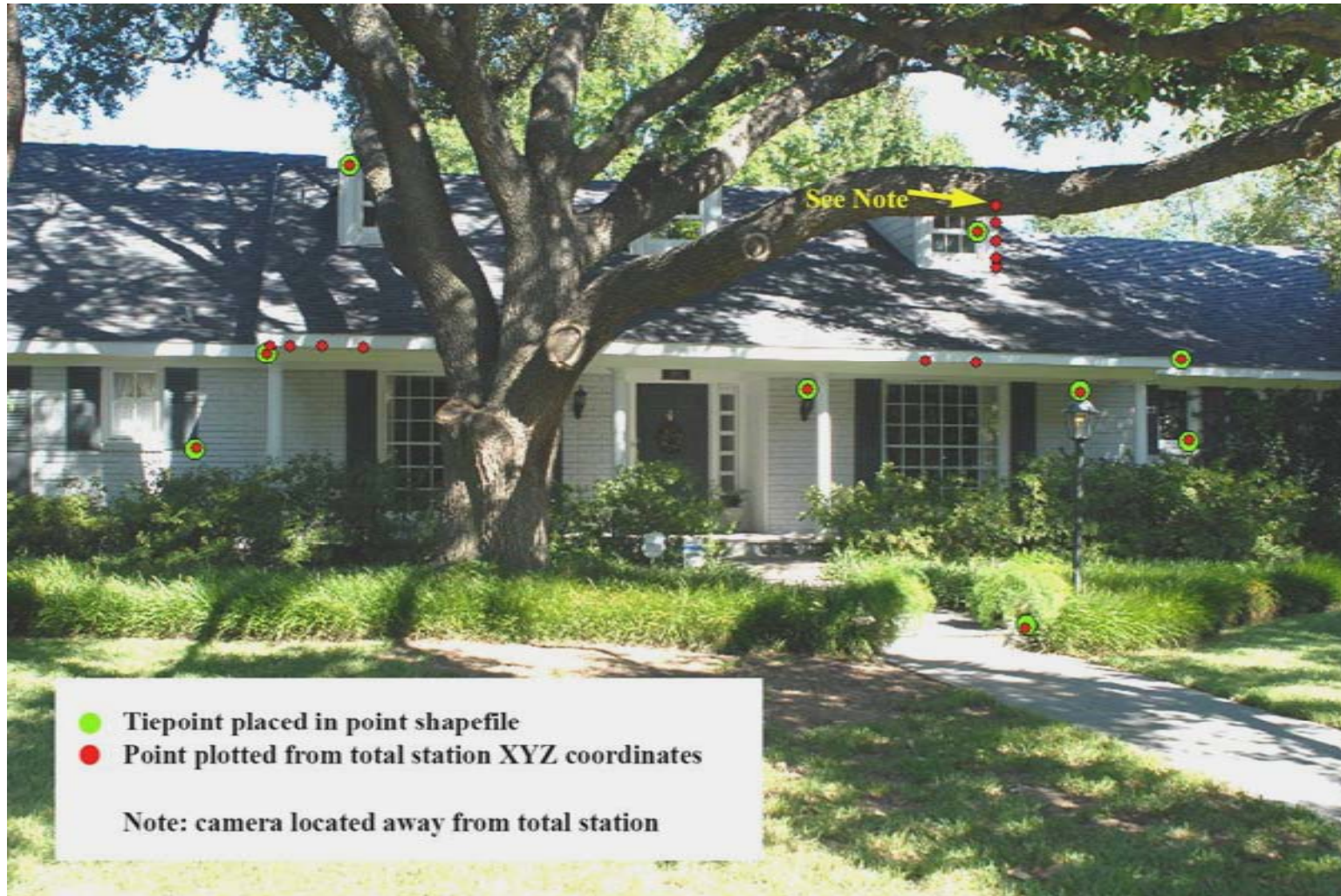


Examples of Application

1. Matching of laser points to photograph in real-time
2. Construction of hallway from laser rangefinder
(Points to polygons and polyline shapefiles)
3. Mapping and analyzing natural (geologic) features

Matching of laser points to
photograph in real-time

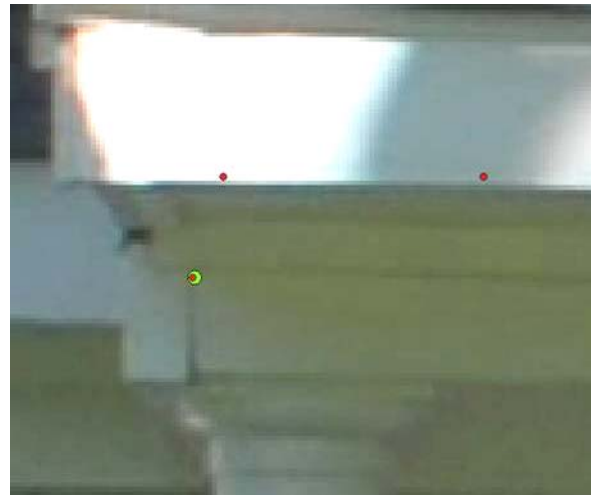
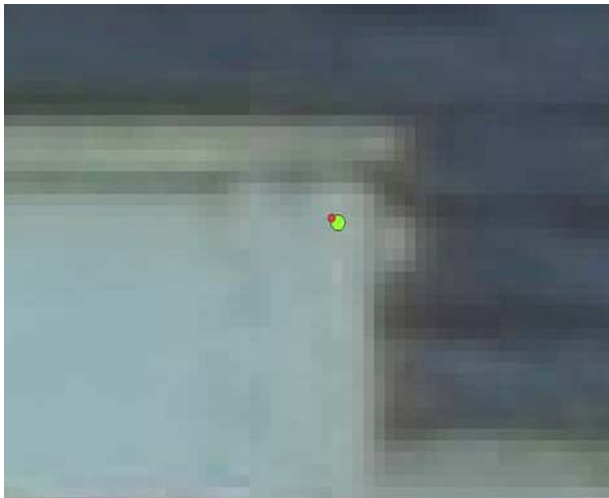
Dimensions of Residential Structure



CloseUp of Tiepoints



Tiepoint placement to measured points are within 1.5 pixels of each other.



Subsequent points plotted on photo are within a couple of pixels of true location on the structure.

Process Flow

- One time distortion characterization of camera and lenses. Each camera/lens combination must have a separate set of distortion parameters
- Take photograph of target
- Load photograph in ArcMap/ArcScene
- Identify a tiepoint in ArcMap/ArcScene with graphic marker and shoot XYZ location with laser/total station
- Repeat until at least four points have been selected
- Calculate 3D => 2D transformation parameters, repeat process if residuals are unsatisfactory
- All subsequent XYZ points which are shot will be plotted on the photograph in real-time. Points can be named and attributed at time of capture

Transformation Parameters

- Six transformation parameters are needed to map the 3D coordinates to the 2D coordinates of the photograph. Three rotation parameters (Ω , Φ , K) and three translation parameters (ΔX , ΔY , ΔZ) are used.
- A least squares method for solving for the transformation parameters is used requiring four tiepoints.
- Rotation parameters are used to construct the rotation matrix

Transformation Equation

$$X_p = \frac{m_{11} * (X_s + \Delta X) + m_{12} * (Y_s + \Delta Y) + m_{13} * (Z_s + \Delta Z)}{m_{31} * (X_s + \Delta X) + m_{32} * (Y_s + \Delta Y) + m_{33} * (Z_s + \Delta Z)}$$
$$Y_p = \frac{m_{21} * (X_s + \Delta X) + m_{22} * (Y_s + \Delta Y) + m_{23} * (Z_s + \Delta Z)}{m_{31} * (X_s + \Delta X) + m_{32} * (Y_s + \Delta Y) + m_{33} * (Z_s + \Delta Z)}$$

X_p, Y_p are coordinates on the photograph

X_s, Y_s, Z_s are 3D coordinates on the structure

Rotation Matrix

$$\begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

Results of Transformation Calculation

Focal Length = 24.99 solution: 1.54801706 3.56885707 -0.00938988 -0.108 -0.658 -0.106

Transformation created by Lasersketch

Date: 5/13/2009 Time: 10:30:11 AM execution time = 0 min 8 sec

		Tiepoint Data				
point	weight	U	V	X	Y	Z
C01	1	-7.13252	+1.61971	+10.6764	-11.7421	+1.4466
C02	1	-5.66417	+4.99690	+11.4119	-14.1733	+4.1375
C04	1	+5.62192	+3.77949	+4.3675	-19.8008	+3.6180
C05	1	+9.44444	+0.03516	+1.5477	-21.1500	+0.5614
C06	1	+9.32573	+1.50950	+1.4349	-18.3332	+1.5561

Residual analysis for each tiepoint

point	residual(mm)			residual(pixels)		
	X	Y	vector	X	Y	vector
C01	+0.0003	+0.0017	0.0017	+0.04	+0.27	0.27
C02	+0.0007	-0.0031	0.0032	+0.12	-0.50	0.51
C04	-0.0025	+0.0059	0.0064	-0.41	+0.94	1.03
C05	-0.0005	-0.0030	0.0030	-0.07	-0.48	0.49
C06	+0.0015	-0.0015	0.0021	+0.24	-0.24	0.34

Number of unique solutions = 6			Total number of solutions = 62			rms	camera-scanner	
omega	phi	kappa	dx	dy	dz	residual(mm)	distance(m)	
+1.54798052	+3.56882448	-0.00940651	-0.105	-0.665	-0.105	0.0037	0.681	**
-1.59361213	-0.42723182	+3.13218614	-0.105	-0.665	-0.105	0.0037	0.681	
-1.73236019	-0.44284027	-0.05549126	-15.333	+33.438	-3.220	1.0794	36.927	
+4.55082512	-0.44284027	-0.05549126	-15.333	+33.438	-3.220	1.0794	36.927	
+1.40923247	+3.58443292	+3.08610139	-15.333	+33.438	-3.220	1.0794	36.927	
+1.40923247	+3.58443292	-3.19708392	-15.333	+33.438	-3.220	1.0794	36.927	

Construction of hallway from laser rangefinder

Points to polygons and polyline shapefiles

GeoConverter

Capabilities:

- Export XYZ for each point to ASCII file.
- Import any XYZ ASCII file
- Create 2D or 3D point, polyline, polygon or multipatch shapefile
- Input feature name for each feature

The screenshot shows the 'XYZ Conversion Tool' window. It features three columns for X, Y, and Z coordinates, each with a list of 20 values and a scroll bar. To the right of these columns are buttons for 'Clear Tables', 'Import xyz', 'Save Log File', 'Create Points', 'Create Line', 'Create Polygon', 'Close', and 'Hide'. Below the coordinate columns is a 'Feature Name' text field. At the bottom left are 'Select Point File' and 'Select Layer' buttons. The 'Select Layer' dropdown menu is open, showing a list of layer names including 'AntiSynClineFullUTM_plgn_Databas'. To the right of the dropdown are radio buttons for '2D' and '3D' output formats.

X Coordinate	Y Coordinate	Z Coordinate
670648.1687382	3805475.297233	378.3445545870
670648.1416883	3805475.443267	378.5460208110
670648.2283197	3805475.584962	378.8516800385
670648.3093575	3805475.785899	379.1126037478
670648.3191956	3805476.012051	379.3613411110
670648.3243324	3805476.226513	379.5122874290
670648.3618389	3805476.475401	379.5502995991
670648.3996074	3805476.791279	379.5523503018
670648.5145337	3805477.034591	379.5507569433
670648.5533983	3805477.272051	379.4520725674
670648.5886477	3805477.560307	379.3242565833
670648.7030630	3805477.799191	379.3860084745
670648.7350769	3805477.995308	379.4369506166
670648.8361749	3805478.292171	379.4863336523
670649.0151074	3805478.546584	379.4648987298
670649.1590290	3805478.792524	379.3165484016
670649.3408753	3805479.062584	379.2525719494
670649.2799368	3805479.427265	379.0772535241
670649.3094137	3805479.981590	380.2350447636
670649.2615052	3805479.342523	380.8085327579
670649.4255028	3805478.509514	381.3930693842

Model construction from laser points of manmade structure

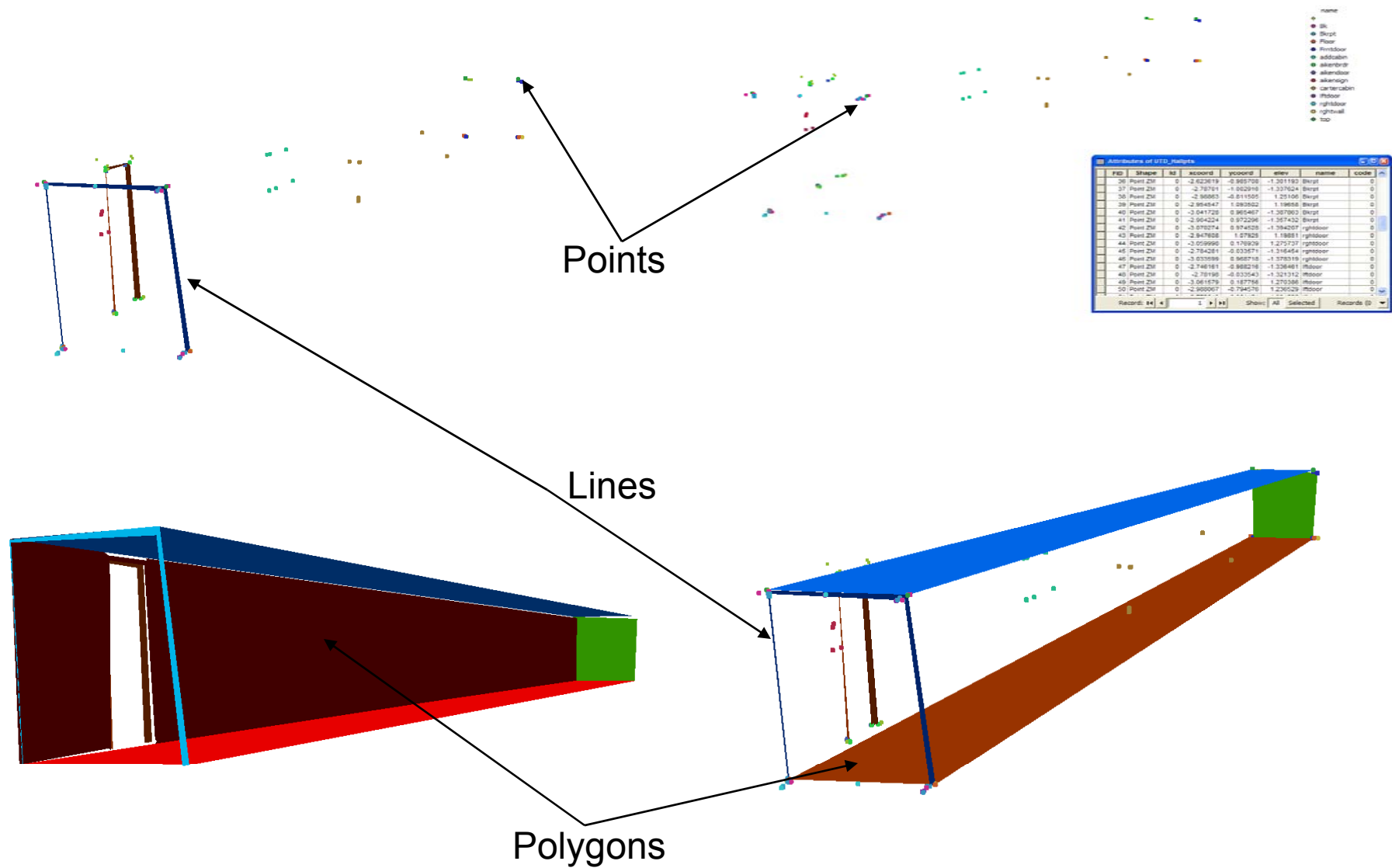
Shoot key features:

1. Walls
2. Corners
3. Door frames
4. Floor
5. Ceilings



Convert points to polylines
and polygons

Founders building corridor, UTD

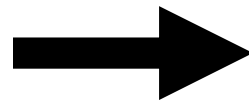


Mapping and analyzing natural
(geologic) features

Model construction from laser points of natural features

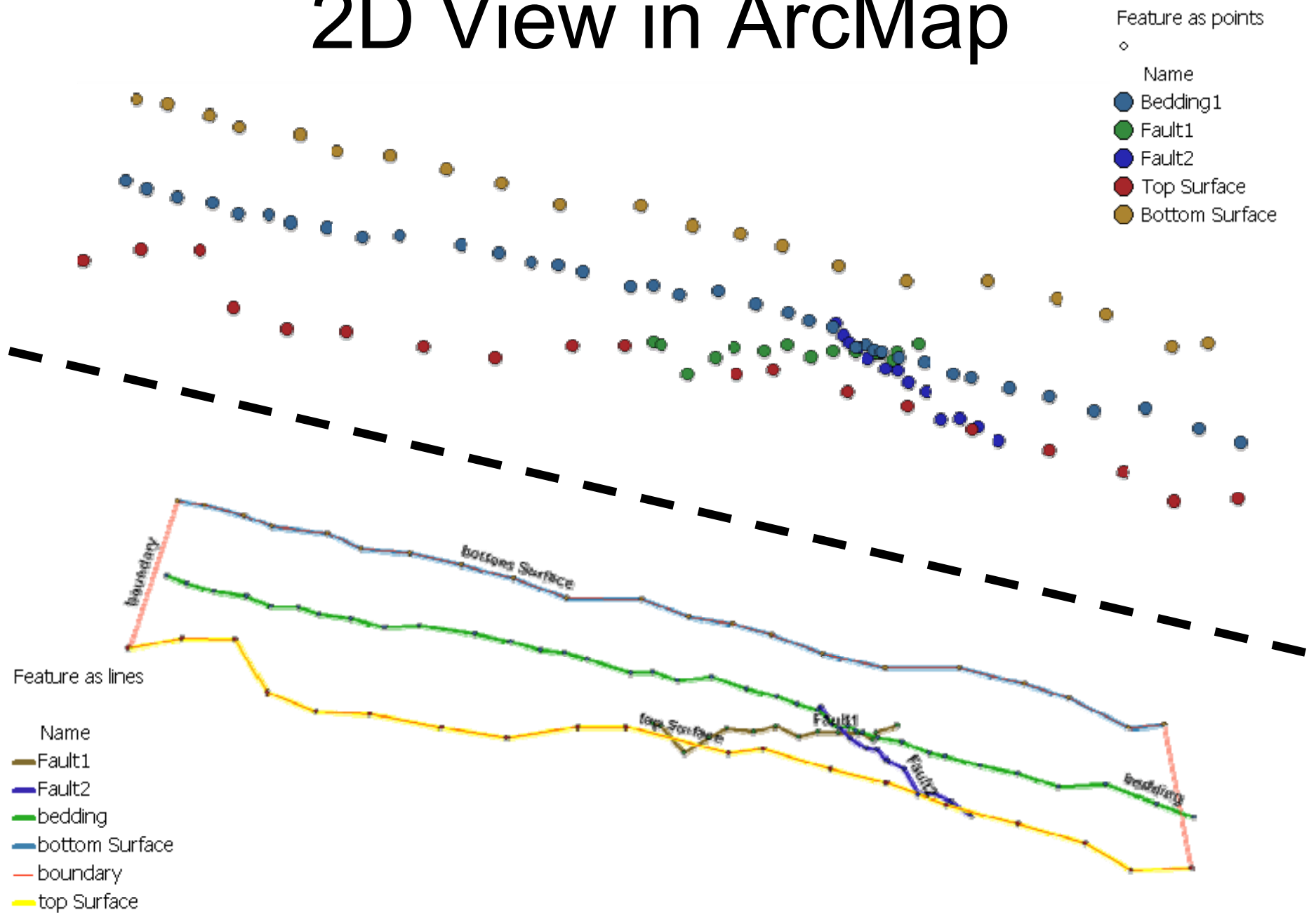
Shoot key features:

1. Faults
2. Bedding
3. Top surface
4. Bottom Surface

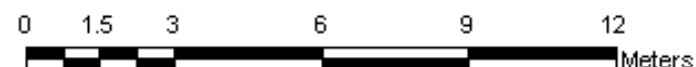
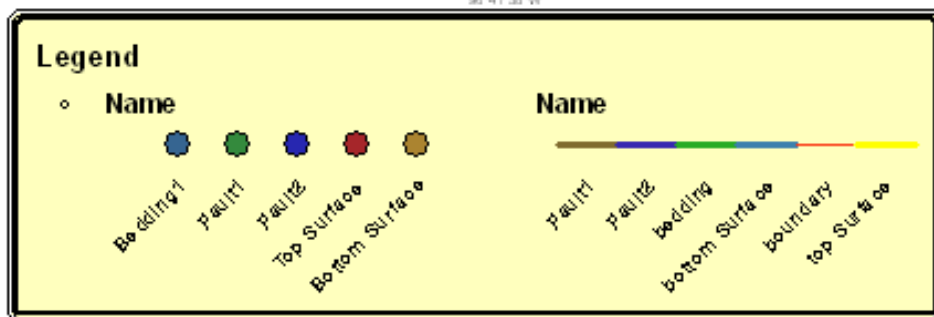
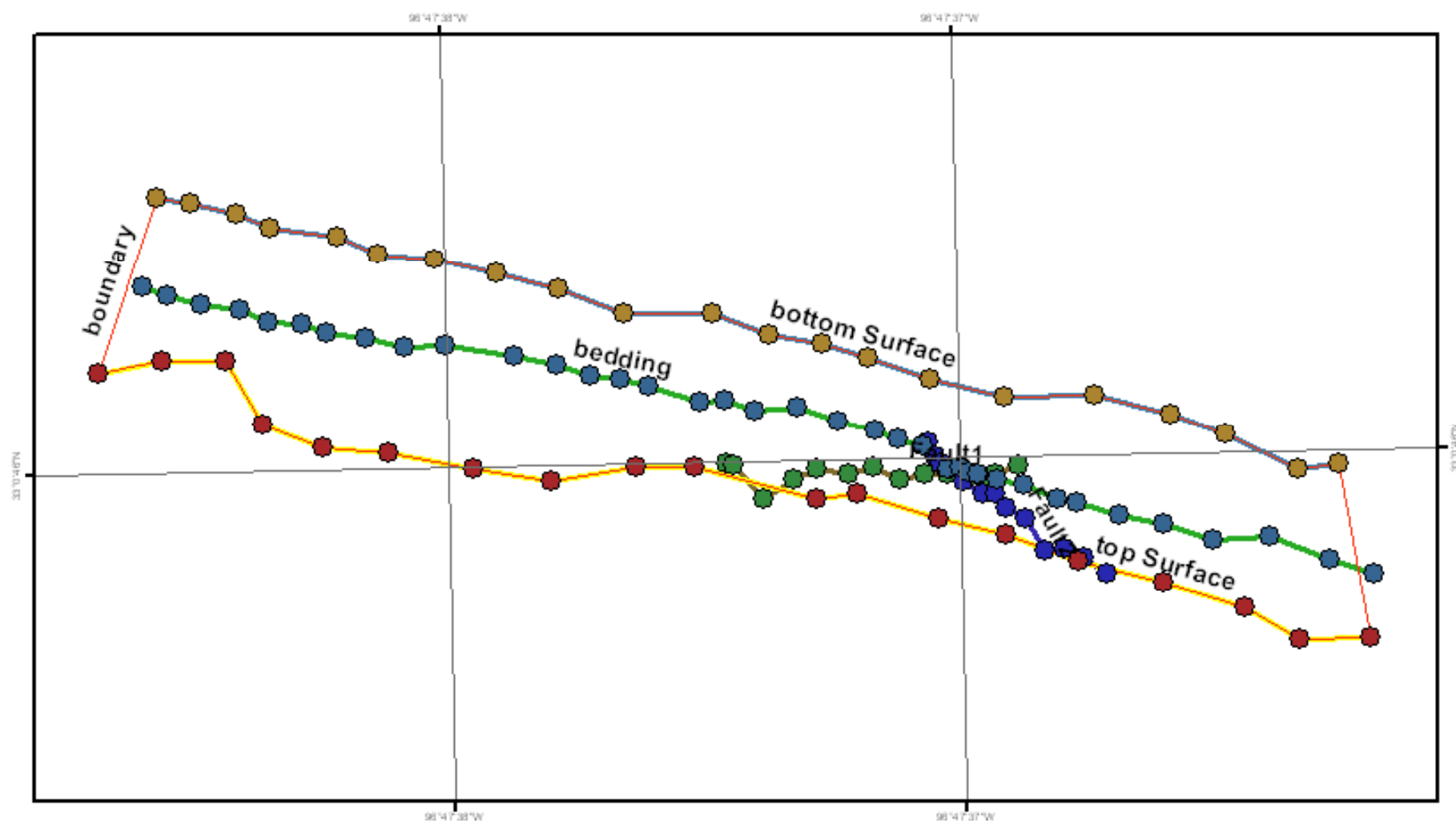


Convert points to polylines
and polygons

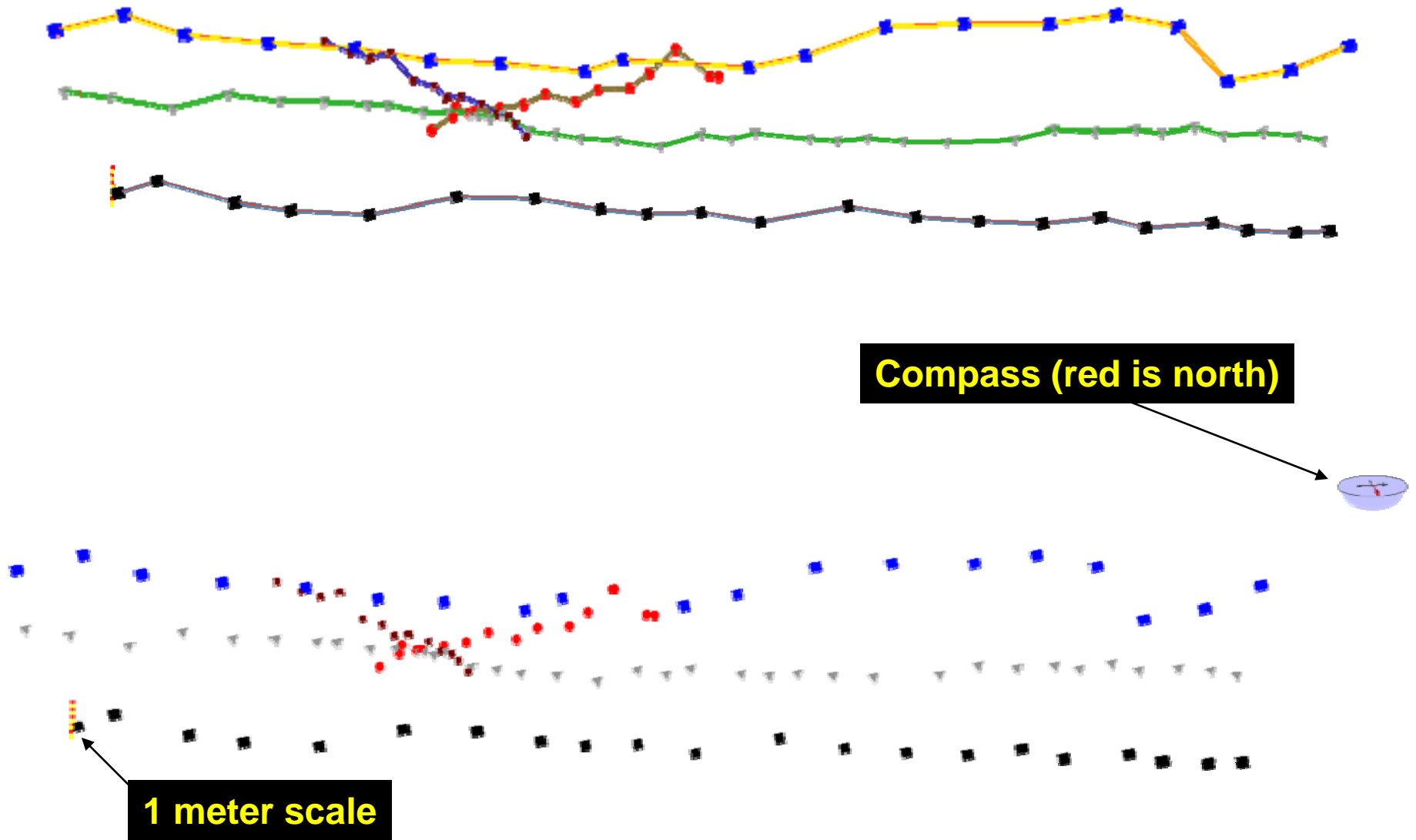
2D View in ArcMap



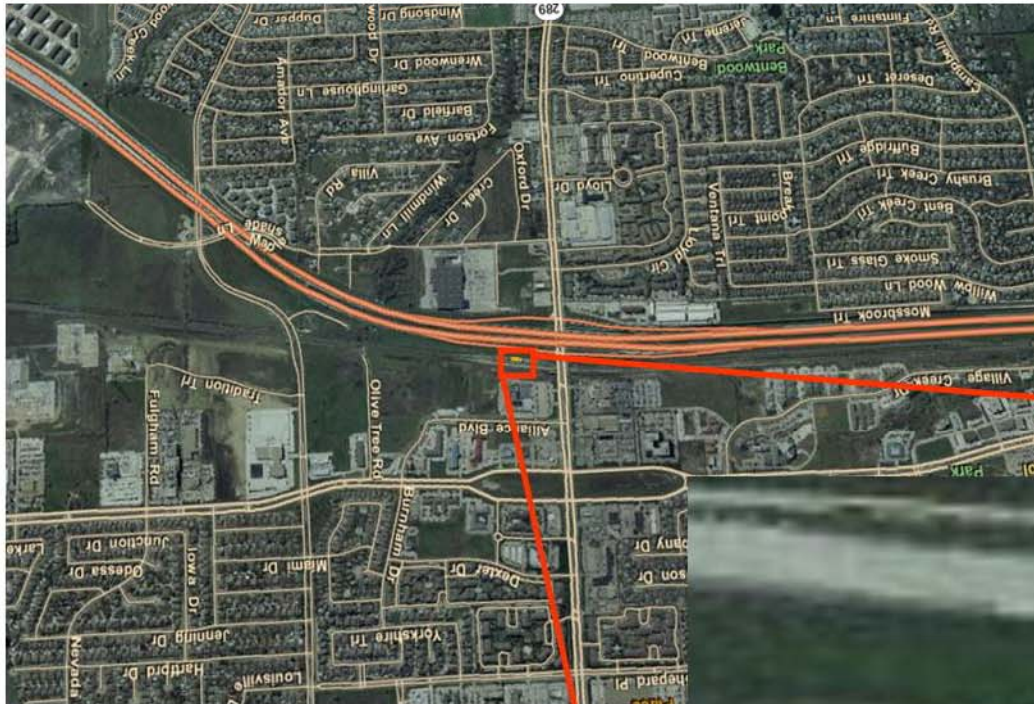
Rail Road Cut, Plano, Texas



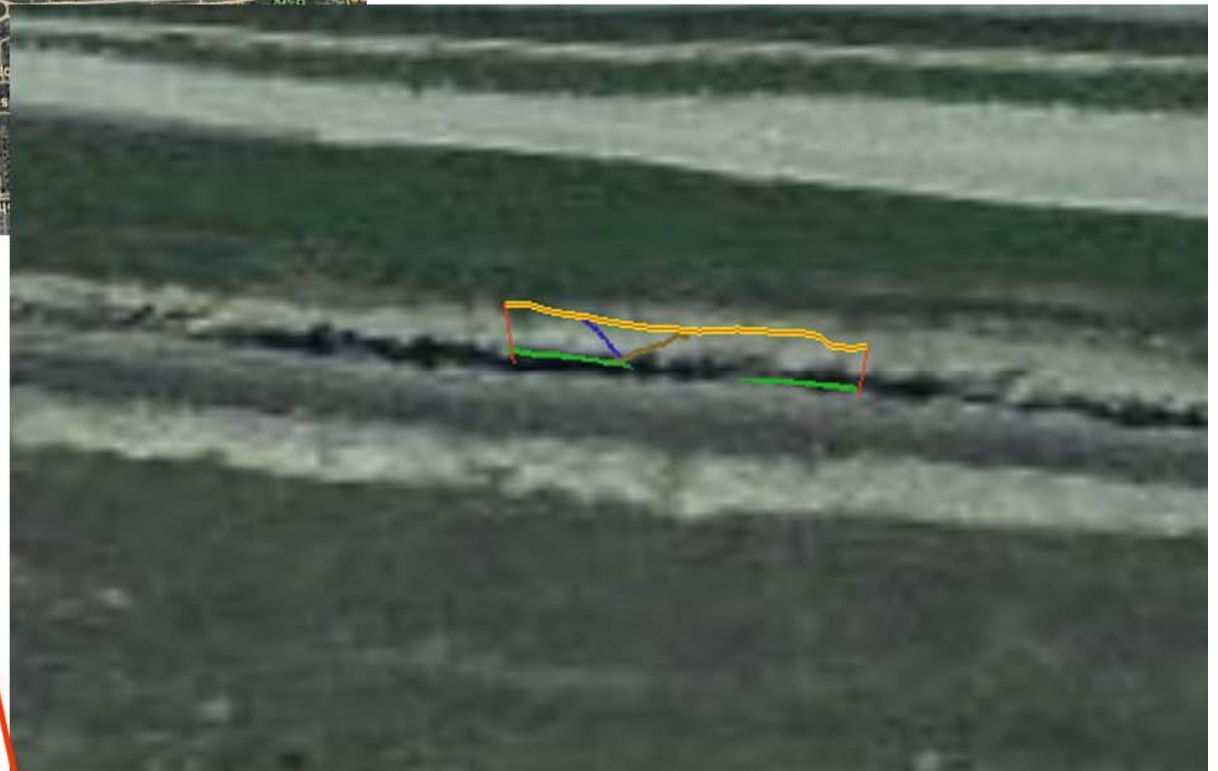
3D View in ArcScene



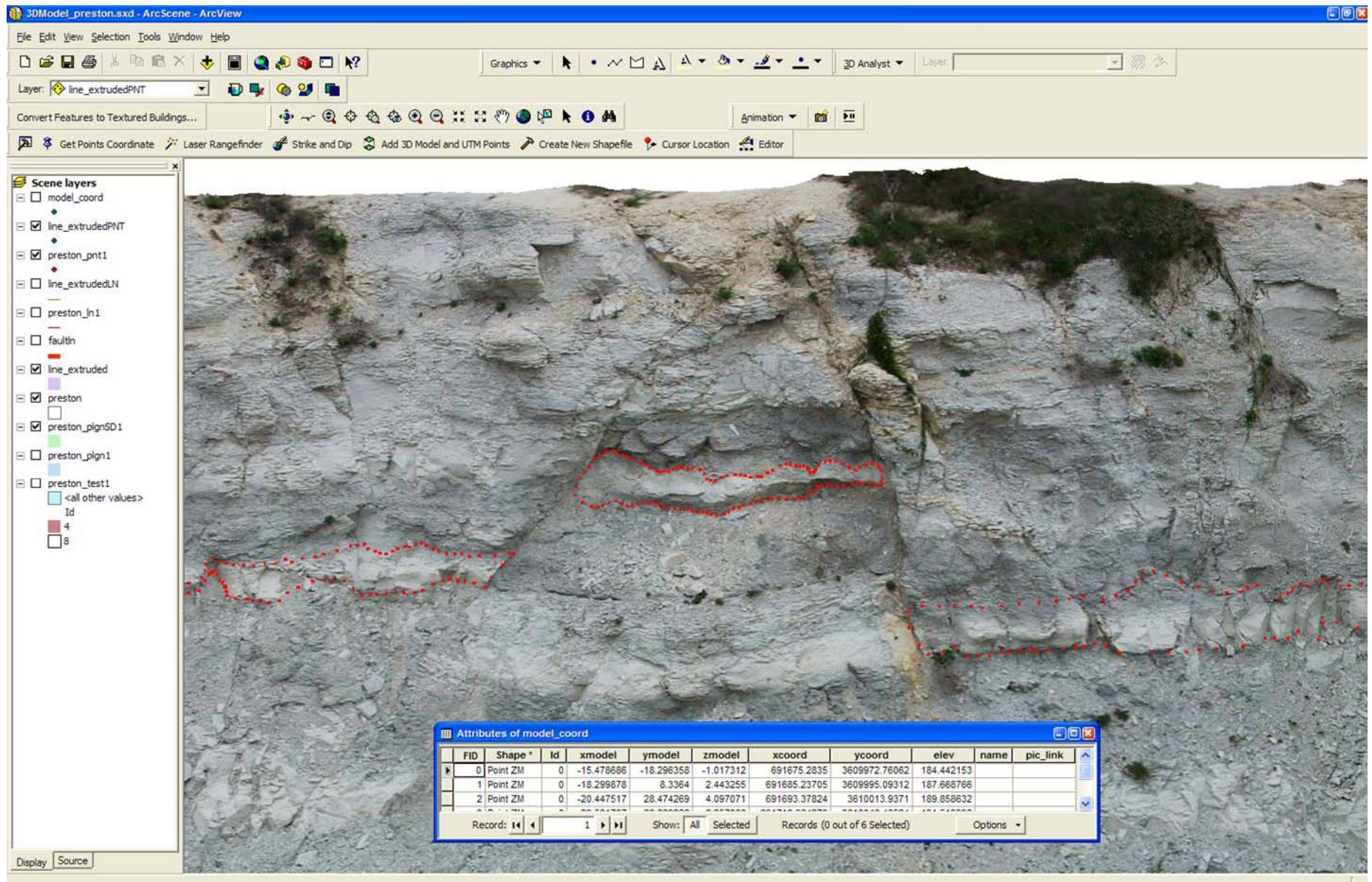
3D View in ArcGlobe



Location of the study area
Preston railroad cut, Plano, Texas



Comparison of laser points to 3D photorealistic model



Extracting Bedding in a Dangerous Environment (active railway)

