Stockpile Volume Calculation
White Paper by Atterbury Consultants, Inc.

In recent times, calculating stockpile volumes has been difficult and expensive. This white paper explains an easy, yet consistently accurate method for measuring stockpiles and calculating volumes. A variety of stockpiles including wood chips, hog fuel, sand, rock, dirt, or anything else can be measured with only one person. In fact, depending on the shape of the piles, it takes approximately 1-2 hours for a novice user to measure a 100,000 yd^3 stockpile. Our experience has shown that one person can measure an entire chip yard in one day, depending on the number of piles and their location.

Jason Martin, an Atterbury Consultants, Inc. forester, and the TruPulse 360 Package

Software and Equipment:
- LTI TruPulse 360B laser rangefinder (or Alternate Equipment)
- LTI MapSmart volume calculation software for Pocket PC
- TDS Recon handheld computer (rugged, lightweight, waterproof, easy to carry)
- Range pole, bi-pod, and mounts

Alternate Equipment:
LTI Impulse or TruPulse 200 laser rangefinder with MapStar Angle Encoder

Accuracy:
0.05 to 7% of actual volume (dependent on equipment used and site characteristics)

Units: Cubic Yards, Cubic Meters, Tons with a user specified cubic volume to weight conversion factor

Calculate volume of rock piles, chip piles, slag piles, etc.:
There are multiple options for measuring stockpiles. One involves Laser Technology's TruPulse 360, a laser rangefinder with built-in compass, another includes LTI's Angle Encoder in combination with an Impulse or TruPulse 200; each system has its place in meeting the needs of the end user. A pocket PC, tripod, and the MapSmart software accompany both options. With this equipment, Atterbury Consultants, Inc. employees are able to locate points with a single shot that instantly combines azimuth, distance, and inclination, as well as an assigned note (e.g. base, pile, traverse, or wall). The program will use the notes to build the pile.

Procedures:
1.) Walk around the pile, temporarily marking instrument points with reflective cones that will afford full coverage of the surface (see diagrams on Page 3).
2.) Choose a starting point, set up and configure the equipment.
3.) Aim and shoot the base or "toe" points of the pile. Then shoot the surface or "pile" points and the wall or "projected base" points (when pile is supported by a wall or barrier).
4.) After collecting your last data point on the pile, aim and shoot to the next instrument location (traverse) and then occupy that point. (Backsight necessary with Angle Encoder.)
5.) Continue shooting the pile from each new location until the entire surface has been measured.
6.) Volume information is instantly available on the Pocket PC. Export your field data to your PC as a DXF file, a text file list of data point measurements, a BMP file of the contours, and other formats.

Performing Calculations:
When working with a file, you may perform several calculations: Distance, Area, Closure, and Volume. The available calculations depend upon which data collection method is associated with the file. The table to the right lists the different types of calculations and the available data collection methods.

		Radial with Angle Radial with Azimuth	Range Triangulation	Baseline Offset
Distance	Point to Point	✓	✓	✓
	Point to Line	✓	✓	✓
Area	Area of Traverse	✓	N/A	N/A
	Area of Side Shots	✓	N/A	N/A
	Area of non-CP Points	N/A	✓	N/A
	Area of All Points	✓	✓	✓
	Area of Feature	✓	✓	✓
Closure	Closed Traverse	✓	N/A	N/A
	Open Traverse	✓	N/A	N/A
Volume		✓	✓	✓

✓ = option is available in this data collection method.
N/A = option is not available in this data collection method.

Features:
• The MapSmart Software runs on a Pocket PC. (e.g. TDS Recon with Windows Mobile 5.0 or 6.0)
• Choose from four mapping methods.
• Create or upload a custom list of descriptions from your PC to quickly identify common measurement points.
• Verify serial data communication between the laser and the Pocket PC.
• Receive wireless measurement data from LTI measurement tools using a Bluetooth® connection.
• Perform Distance, Area, Closure, and Volume calculations.
• Print using a Bluetooth® enabled inkjet printer.
• Download MapSmart files from the data collector to a PC for import into a CAD-based drawing program.

Creating Reports & Transferring Data:
Any time that you have a file open, MapSmart can generate reports that may be sent to a printer or stored in the Pocket PC's memory.

• Printed Report • Text Report • Spreadsheet Report • CAD File • Raw Data • Bitmap Image

Equipment Descriptions:
TruPulse 360 System
The package combination that includes LTI's TruPulse 360 is the easiest to use, set-up, and maintain. The TruPulse 360 is very easy to carry and operates in rain, snow, and minor fog. The 7X magnification allows users to see small anomalies from a distance and really focus in on the point being measured. The TruPulse 360 has the proprietary, TruVector Compass Technology™ that provides the best possible compass accuracy regardless of the laser's inclination and protects the compass from interference from power lines. The drawback to the TruPulse 360 is the compass inaccuracies due to local magnetic attractions. However, the TruPulse 360 continually monitors the integrity of the compass calibration and alerts the user if a re-calibration in required. It is very easy to recalibrate (**see video on our website**). Recalibrating with the local attraction increases the reliability and repeatability of the horizontal angle. The TruPulse 360 laser's measurement range is from 0 to 3,280 ft (1,000 m) with repeatable accuracy and without a reflective target: Distance accuracy: ±1 ft (±30 cm); Inclination: ±0.25 degrees; Azimuth: ±1 degree.

Local attractions are caused by objects of iron, steel, nickel and other ferrous materials. The effect of a local attraction depends upon the proximity to the compass and the mass and strength of the local attraction. Small metallic objects carried by the operator may affect the compass reading. In some work situations, the strength of the interference could prevent the compass from providing a useful azimuth. Usually the potential for local attraction can be determined by visually inspecting the site or from local knowledge of any buried utilities.

Angle Encoder System
Atterbury Consultants, Inc. uses a combination of a laser rangefinder (inclination and distance) and a MapStar Angle Encoder (azimuth) to avoid local magnetic attraction interference. The angle encoder can be referenced to any point and calculate a turned horizontal angle. The modular design allows the user to pivot the laser 90 degrees up or down while maintaining the rotary encoder level for the greatest possible accuracy. When tripod-mounted, you can obtain measurements accurate to 0.05 degrees. For increased versatility, the system's data output format is compatible with other software, meaning it can be used for many different applications beyond stockpile measurements. Other key features include audible and visual indicators that assist in the aiming and leveling process.

One potential draw back is the increased amount of time required to measure a stockpile due to user back-sighting to the last control point. However, the angle encoder can be set-up where other instruments cannot, which may save the user time. Starting multiple files from one position eliminates the need to climb on each individual pile. Angle Accuracy: Staff Mounted: 0.1 deg. Tripod Mounted: 0.05 deg. Angle Resolution: 0.01 deg.

TruPulse™ 200
A low-cost workhorse for professional measurement, the TruPulse 200 reflectorless laser rangefinder incorporates an integrated tilt sensor for height measurements, through-the-lens targeting, in-scope data display and advanced targeting modes to easily provide accurate distance and height data for Forestry, Telecom, T&D and GIS professionals.

The TruPulse™ 200 was created with your field needs in mind. It weighs a mere 8 ounces and integrates with existing LTI mapping products, giving you a highly flexible, extremely usable tool for your field measurement needs. Its large, crystal-clear optics with an in-scope data display and through-the-lens targeting help eliminate parallax issues. An adjustable eye diopter makes using the TruPulse 200 comfortable even when wearing glasses. The integrated tilt sensor provides accurate height measurements, even from the steepest angles, and the unit offers a choice between Closest, Farthest, Continuous or Filter modes for improved target acquisition. Best of all, the TruPulse 200 delivers more than just one measurement at a time; it calculates horizontal, vertical AND slope distance with a single press of the fire button. This unit can adapt to varying conditions and save you untold time in the field. Both the standard serial port and Bluetooth® wireless option allow for easy transfer of your data once it has been collected. The only thing not engineered into this unit is a big price tag.

Impulse Laser 200
The Impulse 200 is a light-weight, low cost laser for a full range of accurate measuring. The Impulse puts the power and speed of a laser rangefinder and optional tilt sensor into the palm of your hand. Simply aim and push a button. The Impulse acquires horizontal or slope distance in less than a second, all without prisms or reflective targets.

Known Issues:
One known issue for laser rangefinders is fog. Fog can disrupt the laser's ability to get an accurate reading. Fortunately, the TruPulse lasers have the ability to run in a "farthest" mode which enables use with a light fog. In "farthest" mode, if the unit gets a return from a light fog and from a target further away, it will report the farthest distance. Press and hold down the fire button for 1 to 1.5 seconds when you take a reading allows the TruPulse to take several shots, giving you more opportunity to reach your target through the fog. Certain Impulse lasers can be set up to deal with fog. In very heavy fog, the instrument is largely unusable for distances. Interestingly enough, the laser rangefinders do not have any problem working in a heavy rain. Even in fog, the electronic compass would still be operational.

Comparison:
Atterbury Consultants, Inc. did a comparison test on the accuracies of the measurement systems we use (Pages 5 and 6). The results, although not consider to be exactly scientific, small changes in the piles surface, point location, and equipment location also had effects on the results, give a good look at the differences between the two systems as well as results between multiple measurements (pile measured twice with both systems). Results include the volume calculated by MapSmart, the number of points taken, the difference between the first and last point with the same physical location, the difference between the average of the all four measurements taken, and the difference between the two measurements taken with the individual measurement system.

Additional Information:
More examples of volume calculations, images, and data files produced by MapSmart are on pages 7 and 8. The associated .dxf file from MapSmart was loaded in ArcMap to create a point diagram, a contour picture, and a 3D image. Also included is a photograph of the actual pile we measured.

Conclusion:
Volume calculation of stockpile volumes can be completed easily and safely. Atterbury Consultants, Inc. is now providing a service for measuring stockpile volumes, as well as selling the equipment, and providing training so that you can do it yourself. Please visit our website for more information.

Advantages of having Atterbury Consultants, Inc. do the measurement include:
1. Fast turnaround for the volume information
2. Financial savings, greatly reduced price over aerial flyovers
3. Increased accuracy over volume estimates
4. Provide third party accountability
5. All work can be done with one person
6. Each measurement is recorded and can be easily provided in a report
7. Reports also include a contour map and 3-D image of each pile measured

Basic traverse and shot display around stockpile:
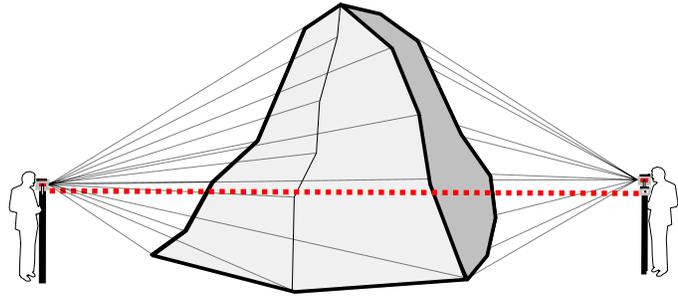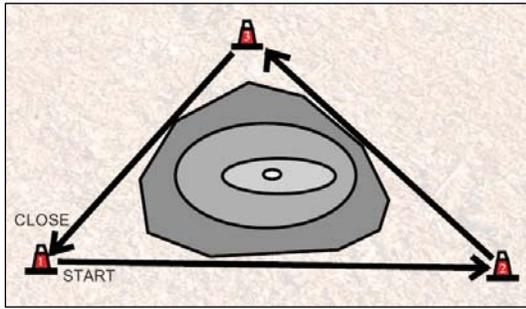
Screen shot from MapSmart showing the volume setup, calculated volume and traverse closure:
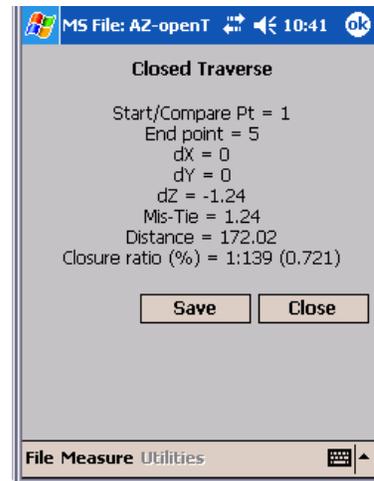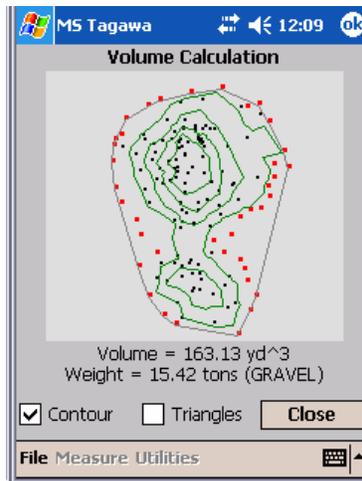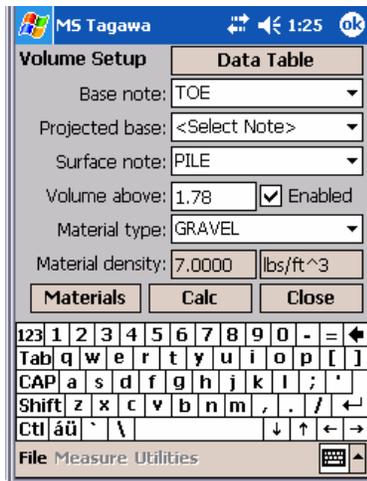
**Overview of the Four Measurement Methods:**

| Method	Requirements	Compatible Hardware
Radial with Azimuth	Proper care and procedure when using a compass in the vicinity of magnetic objects such as cars, utilities, buildings, etc.	MapStar Compass Module Impulse 200 TruPulse 200 / 200B
Radial with Angle	Higher accuracy and/or need to work in the vicinity of metal or magnetic objects.	MapStar Angle Encoder Impulse 200 TruPulse 200 / 200B
Range Triangulation	Able to occupy (stand over) every feature to be mapped. Only have access to a laser, no MapStar module.	Impulse 200 TruPulse 200 / 200B
Baseline Offset	Able to walk a straight line from one end of the site to the other. Only have access to a laser, no MapStar module.	Impulse 200 TruPulse 200 / 200B

Comparison of Results- ACI compared the two measurement systems
*Contour picture created in MapSmart, tin created in ArcMap

TruPulse 360 test 1
-Volume: 1,343 YD^3
-Points: 218
-First/Last point difference: 14ft, 222deg
-% Difference of Average: – 5%
-% Difference of TruPulse tests – 3%
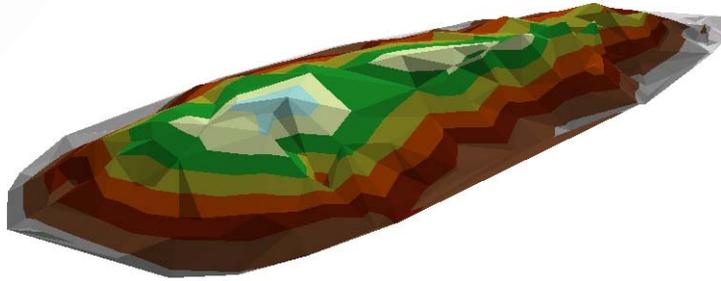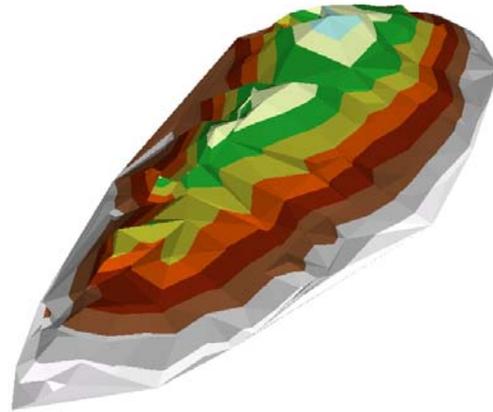
TruPulse 360 test 2
-Volume: 1,426 YD^3
-Points: 289
-First/Last point difference: 8.5 ft, 248 deg
-% Difference of Average – 12%
-% Difference of TruPulse tests – 3%
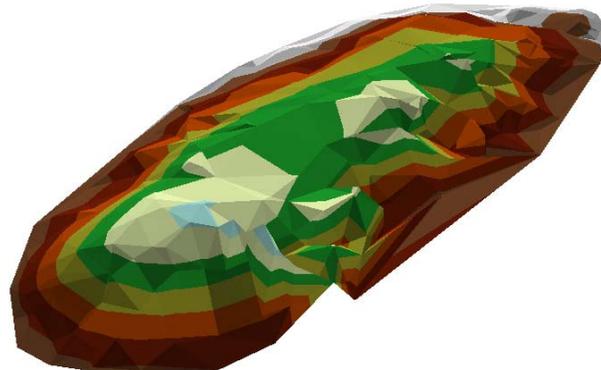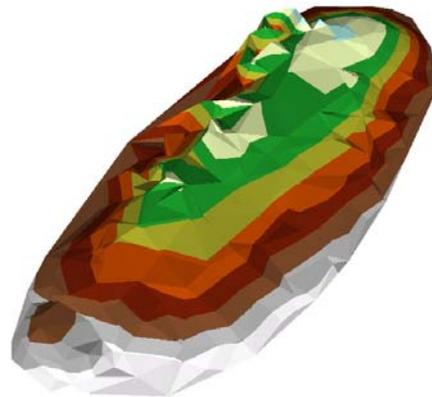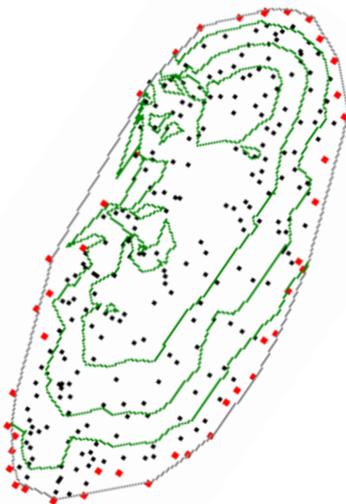
Impulse test #3
-Volume: 1,198 YD^3
-Points: 241
-First/Last point difference: .31ft, 74deg
 -% Difference of Average – 6%
-% Difference of Impulse tests – 2%
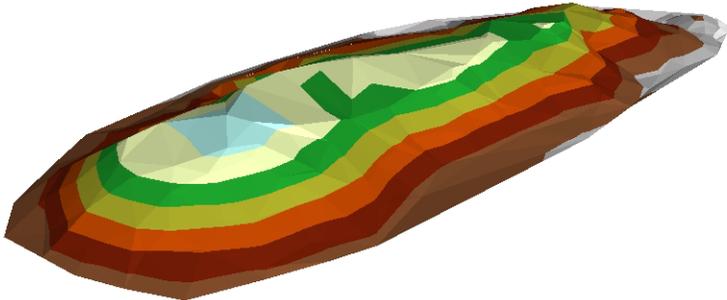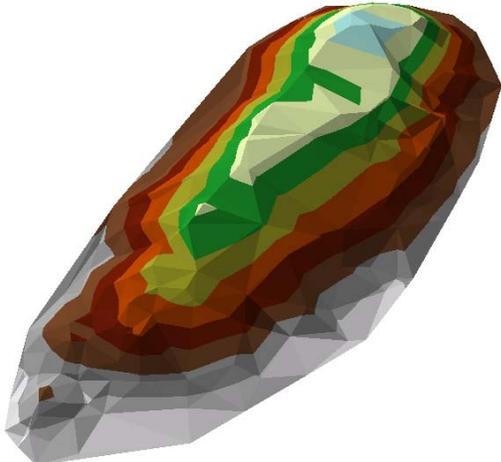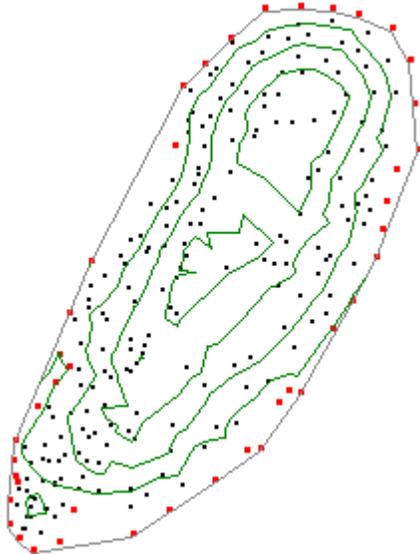
Impulse test #4
-Volume: 1,147 YD^3
-Points: 320
-First/Last point difference: 2.04 ft, 321 deg
-Percentage Difference of Average: – 10%
-% Difference of Impulse tests – 2%
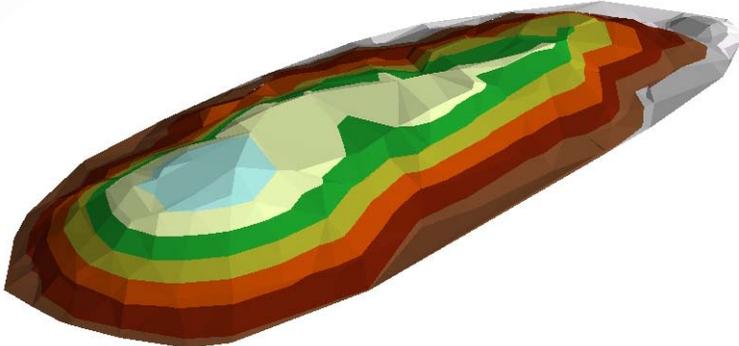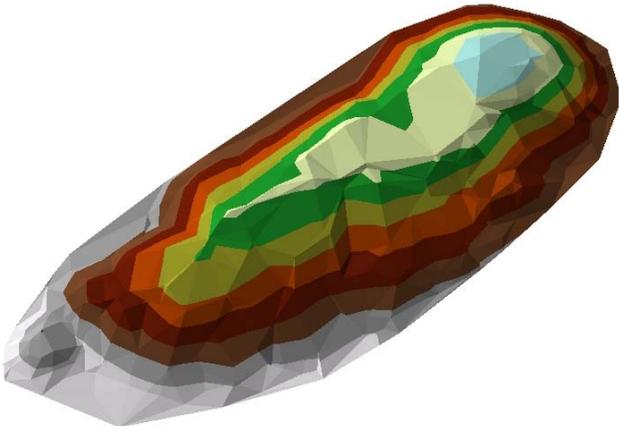
MapSmart pictures and Cad file Conversions - two examples of .bmp files produced by MapSmart and the associated .dxf file loaded in ArcMap to create a point and contour picture
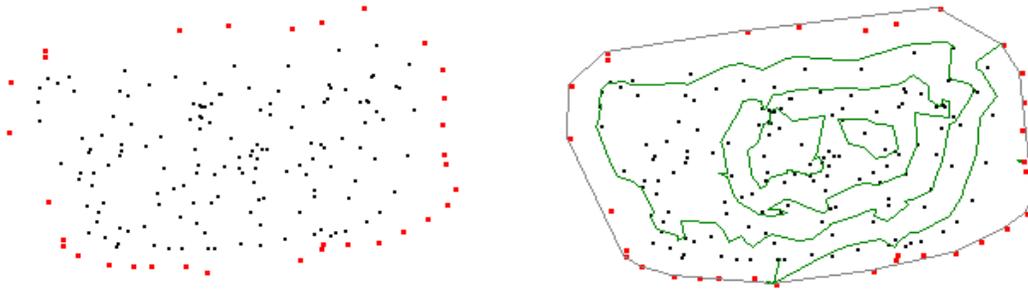

MapSmart Point and Contour pictures, 184 Points, 936.34 Cubic Yards

ArcMap Point and Contour created from MapSmart .dxf file, 184 Points
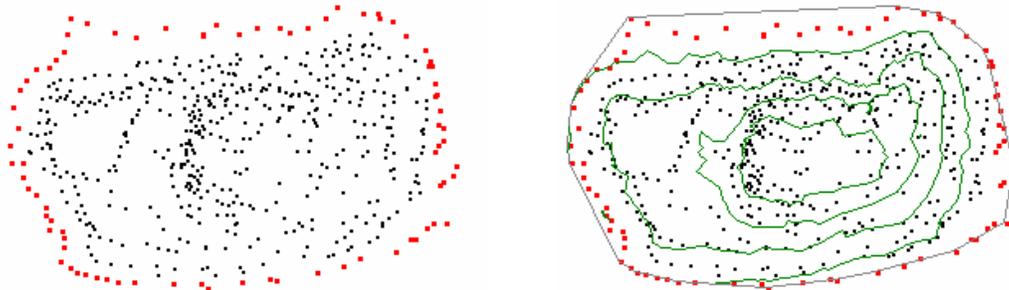

MapSmart Point and Contour pictures, 552 Points, 1092 Cubic Yards
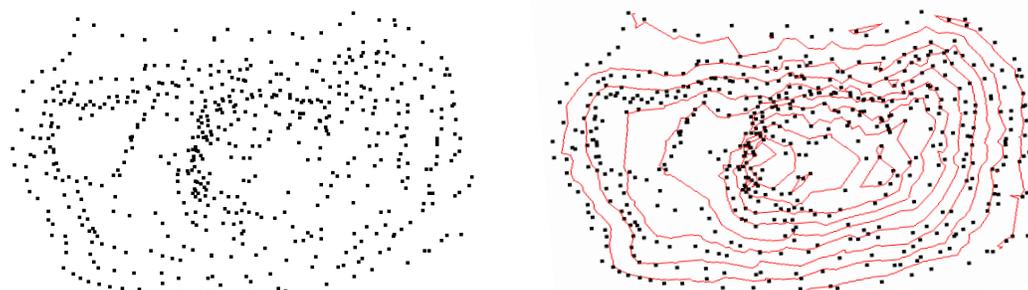
ArcMap Point and Contour created from MapSmart .dxf file, 552 points

Cad file Conversions Continued - the associated .dxf file loaded in ArcMap to create a 3D image and a photograph of the actual pile measured.
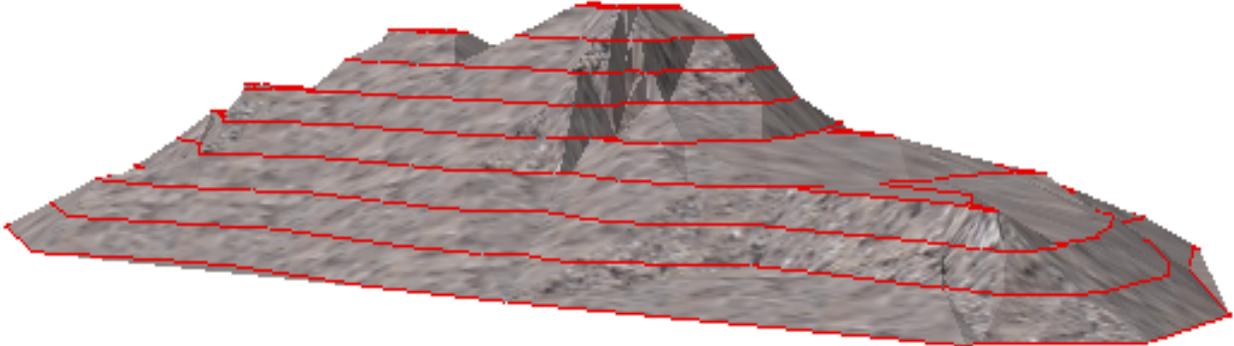
3D image created in ArcMap, 184 Points
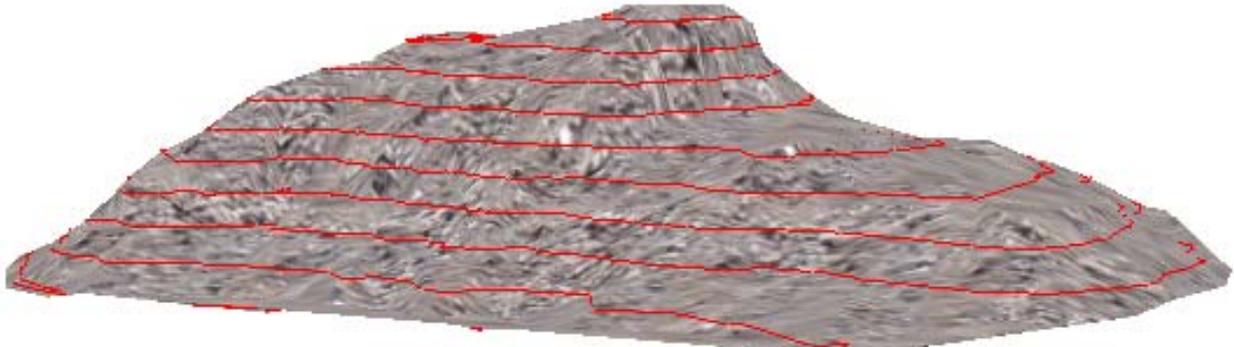
3D image created in ArcMap, 552 Points

Photograph of Pile

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System Components:

LTI Laser:	<u>Impulse</u>: Any of Laser Technology's Impulse 200 laser models may be used to collect measurement data.
	<u>TruPulse</u>: Either of Laser Technology's TruPulse 200 laser models may be used to collect measurement data.
MapStar Module	<u>MapStar Angle Encoder</u>: Calculates the turned horizontal angle between a reference point and a target object. It can be referenced to any desired point and is not affected by local magnetic interference.
Pocket PC:	<u>Minimum System Requirements</u>: Microsoft® Pocket PC 2003 version 4.20 (or Microsoft® Windows Mobile Pocket PC 2003 2nd Edition).
MapSmart:	The MapSmart program runs on the Pocket PC and collects data downloaded from the LTI laser and/or MapStar Module. The software ships on a CD.
Office PC:	<u>System Requirements</u>: Windows® 98/ME/2000/XP. Microsoft® ActiveSync® is used to transfer data between the Pocket PC and your Office PC. The Pocket PC connects to your Office PC using a cable that is provided with the Pocket PC. Transferring the data to your Office PC allows you to print reports, archive data, and import data into almost any CAD-based drawing program.