Recent Developments in Close Range Photogrammetry (CRP) for Mining and Reclamation

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Preface

- This talk is a follow-on to my paper in this Conference's Proceedings. For that paper, the photos used for CRP were collected randomly and only to document a large project. Regardless, results were impressive.
- For this talk, the photos were taken with CRP in mind. Lacking experience and climbing the "learning curve" resulted in LOTS of photos - mostly worthless – but results continue to impress.
- I am NOT an expert in CRP and look forward to collaborating with true experts like Matthews (2009) to refine techniques to make CRP practical for mining and reclamation, especially SMCRA workers.
- This prototyping work is an effort sponsored by the OSM TIPS program under the TIPS Remote Sensing initiative.
- Use of trademarks and brand names are to identify the tools used and do not imply endorsement by OSM; they are included as examples of current technology.

Introduction

- The mining/reclamation community depends on accurate mapping for almost all activities. Traditional ground surveys are totally adequate for small, uncomplicated jobs but at some point, the size and/or complexity of a project makes it more economical to have a site “flown” (mapped using photogrammetry.)
- Aerial photography is best known; it is mature, accurate, and trusted, but expensive. Newer forms like photography/LiDAR hybrids and pure LiDAR provide more detail but are often more expensive.
- Because of cost, most projects are only “flown” at the start and less often when completed. Changes during the project may be surveyed but in many cases aren’t worth it – negative cost/benefit, too dangerous, or inaccessible.
- AML complaint investigators can face similar issues. For example, monitoring a nuisance landslip to decide whether it is a true emergency.
- Close Range Photogrammetry (CRP) offers much potential for measuring features that can’t or aren’t being measured otherwise.

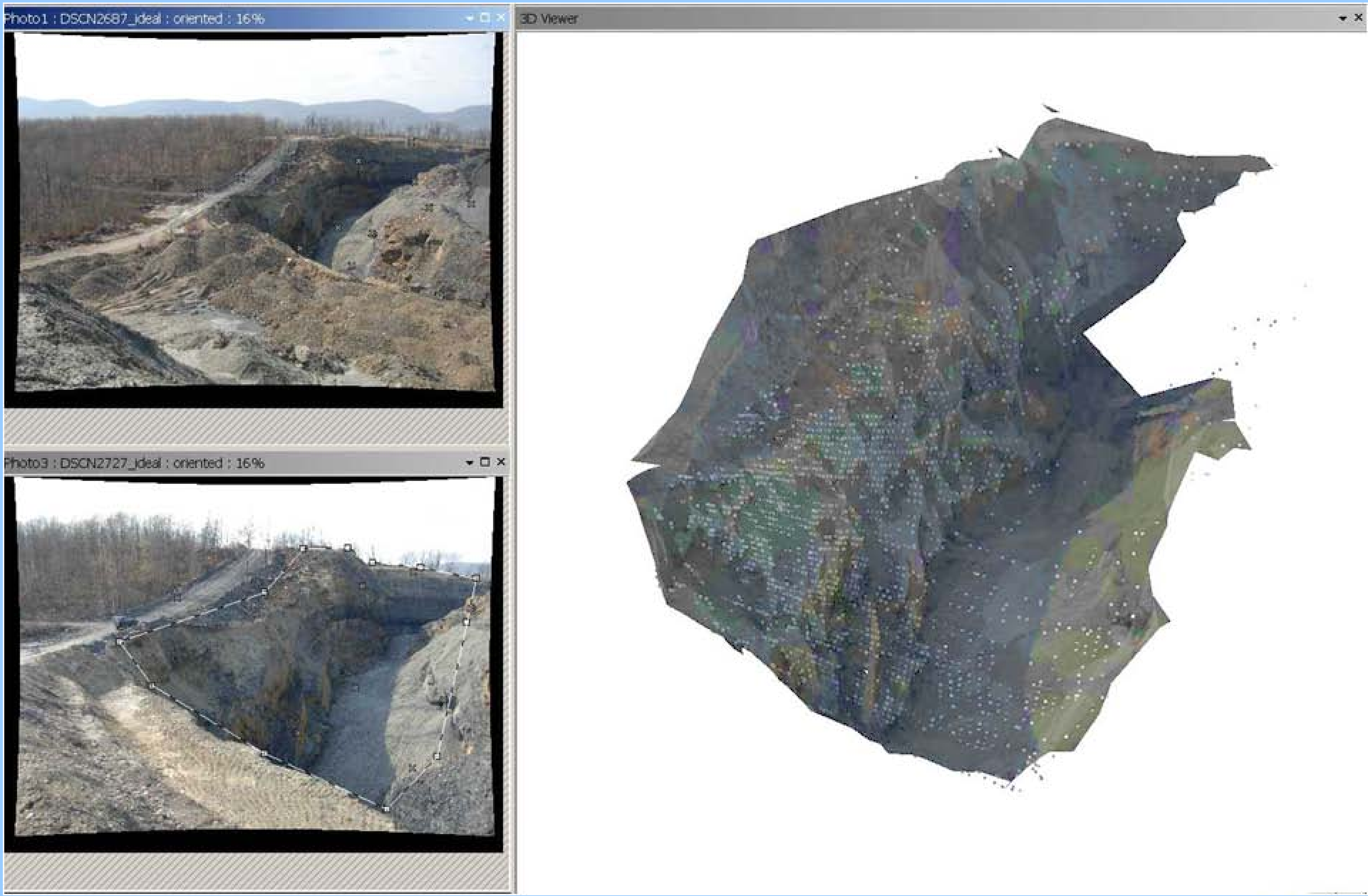
CRP

- Using non-metric photography to accurately measure objects at distances less than 1,000 feet.
- Types (my interpretation):
  - Perspective (regular geometric objects)
  - Stereo (random, irregular objects)
- Perspective is well suited for and widely used in accident investigations and architectural studies; it doesn't work well on mine sites.
- Stereo is potentially ideal for mines but for a number of reasons, few practical solutions have ever been readily available. One of these, PhotoModeler Scanner, was selected to test CRP for mining and reclamation applications.
- Because hand-held, "consumer grade" digital cameras are part of most field workers equipment, photos from these non-metric cameras are used exclusively in this study.
- An overview of the CRP process and techniques is presented in the Paper.

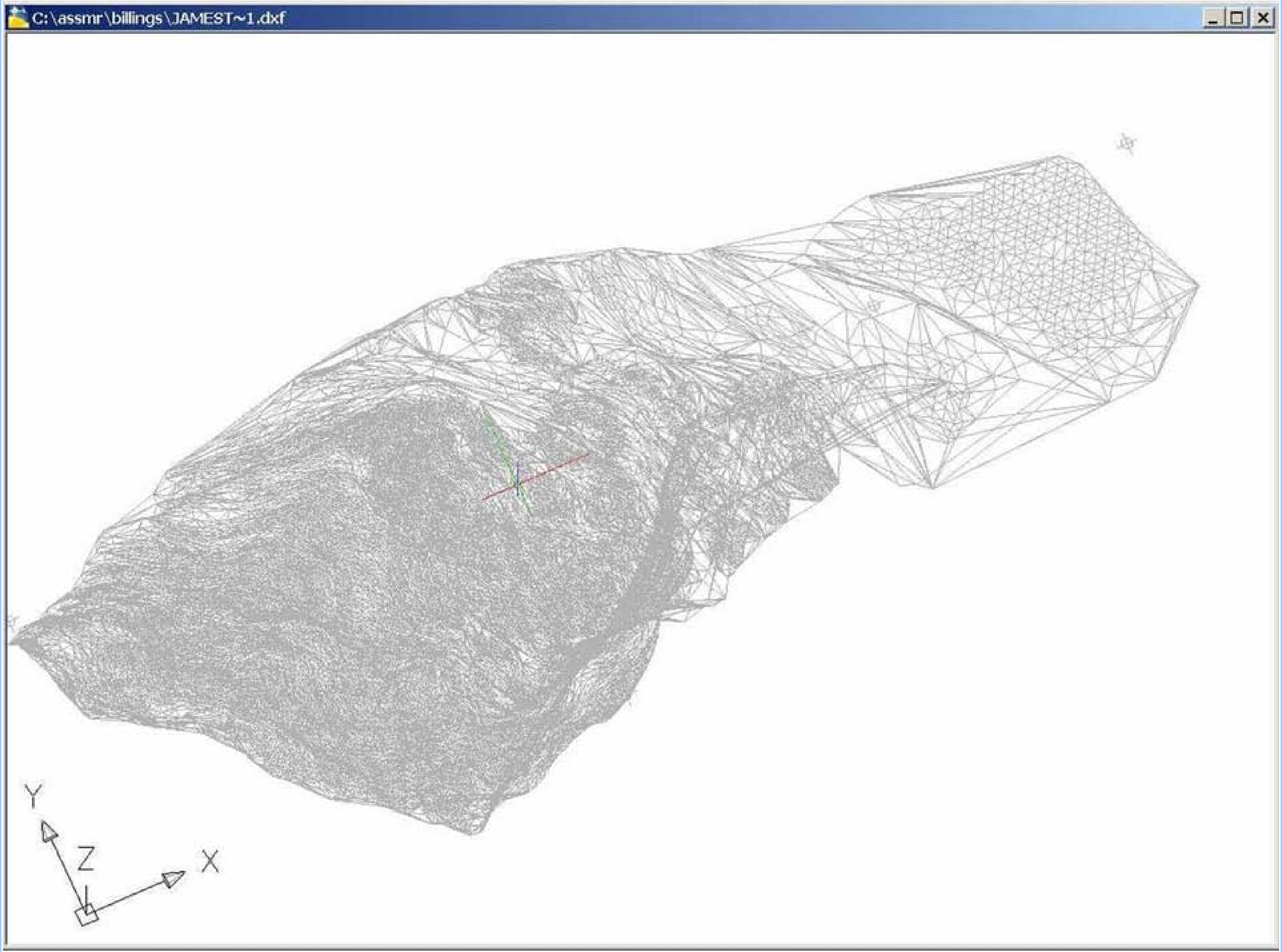
First Tests

- Several thousand pictures of the Dolph Fire Project were taken on the ground and from a small plane.
- The site was flown before and after construction and detailed topography and surface features were generated and supplied as digital drawings.
- On ground surveys were done to keep to design and locate new boreholes.
- An detailed unreferenced stereo mesh model of the trench was created from random photos.
- The digital topography and surveys provided enough ground control to generate referenced stereo models using random photos from a small plane.

Unreferenced Trench Model



Trench Model – 3D Mesh in CAD

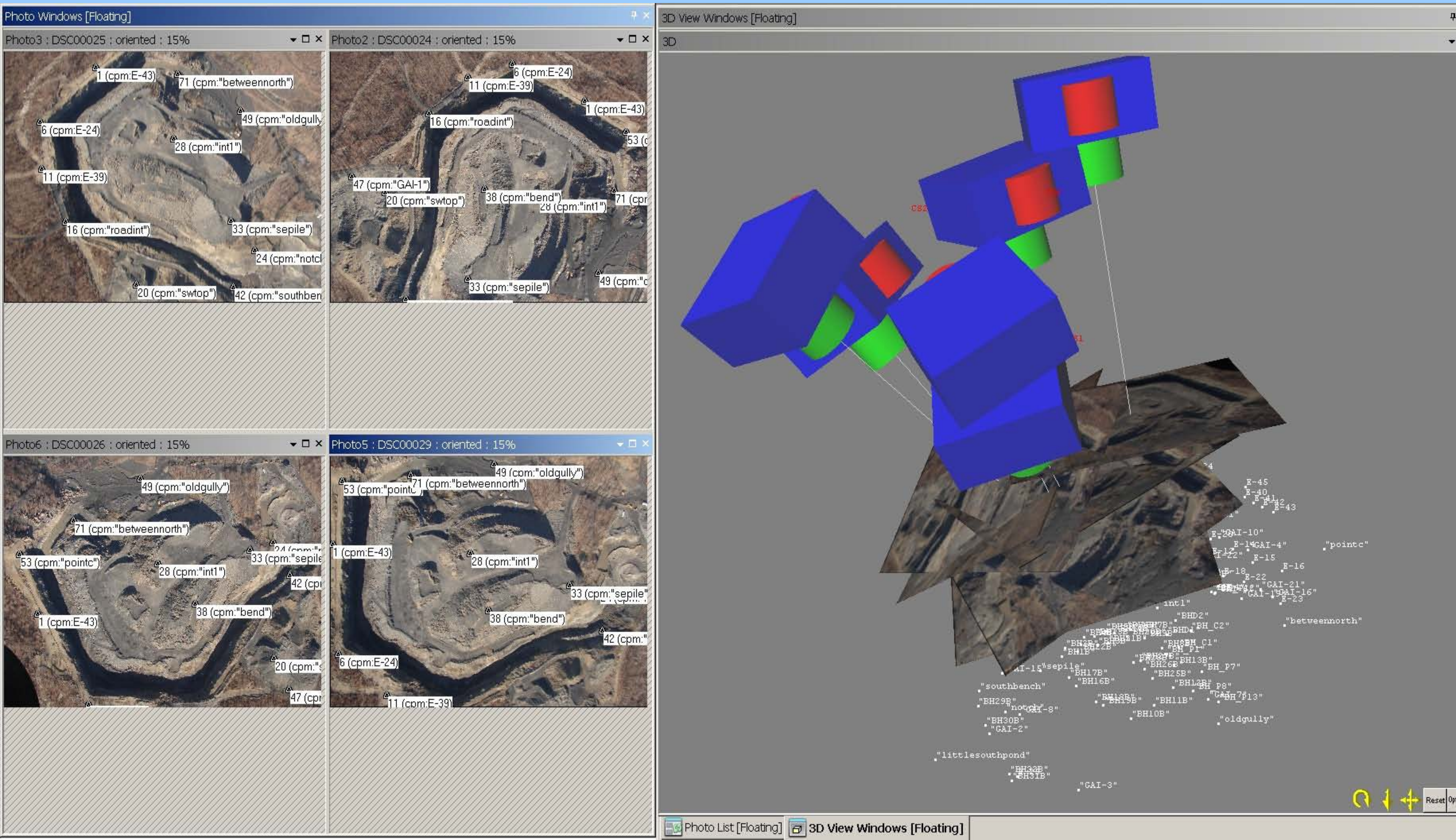


Trench Model Analysis

- The photos were taken with a camera that was later calibrated to remove lens and other distortions.
- The stereo coverage was not optimum yet the mesh was truly proportioned in XYZ.
- After scaling, rotation, and repositioning in CAD, the mesh matched closely to the aerial topography.

Small Plane Photo– March (left) Aerial Survey Photo – April (right)

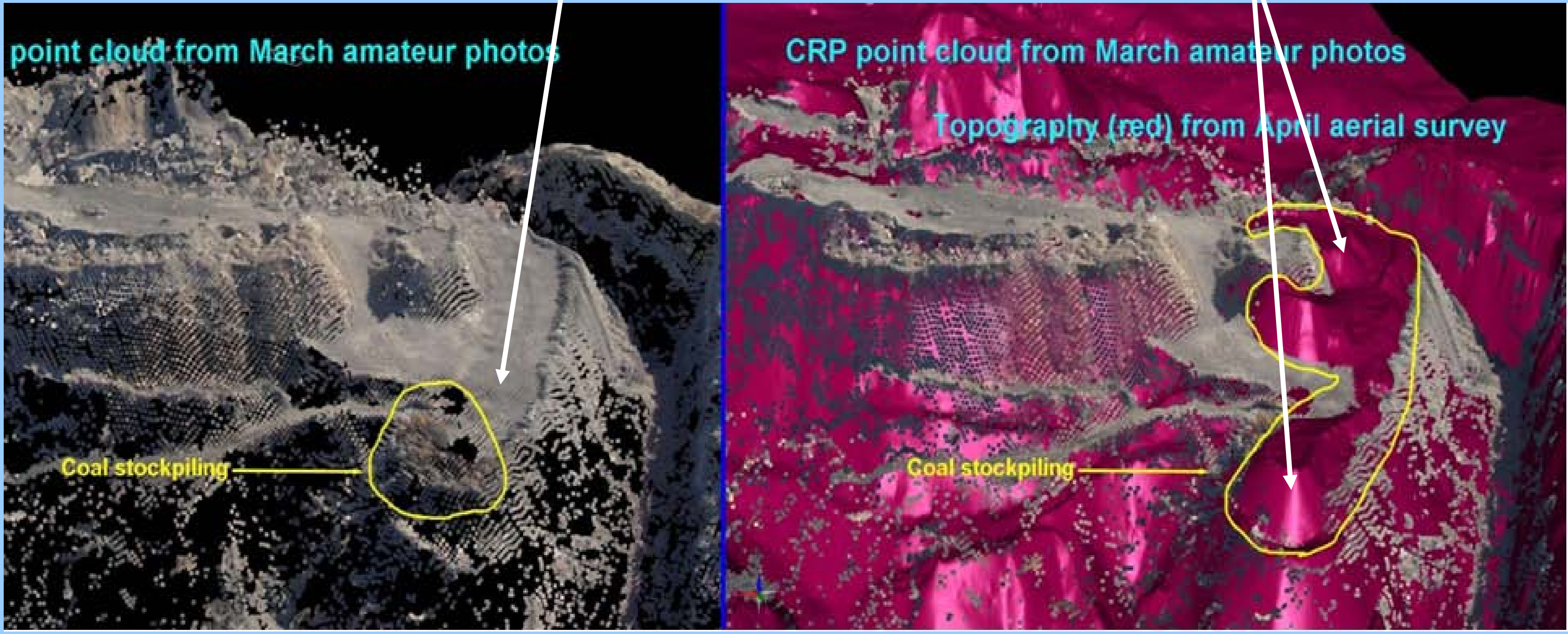
Small Plane Photos, Ground Control Points, Calculated Camera Positions



Referenced Stereo Model from Small Plane Photos (left); Overlain with Aerial Survey (right)

Stockpiling Pad

Stockpiles



Stereo Model Analysis

- The photos were taken with an unknown camera.
- Only ground control points were used to correct distortions and scale/reference stereo model.
- The stereo model is only accurate and stable near the model center (the stockpile pad); away from the center, the model is worthless.
- At center, model XYZ positions are within inches of the aerial survey.
- Stockpile volume estimates agree well with on-the-ground measurements.

First Tests Findings

- Random photographs from calibrated and uncalibrated cameras can yield realistic and accurate models.
- Additional testing with more technique and control is worthwhile.
- The Kentucky program has a helicopter with belly-mounted non-metric camera; but past attempts at photogrammetry have all failed. They believe this is a solution and are “gearing up” to test.

Second Tests

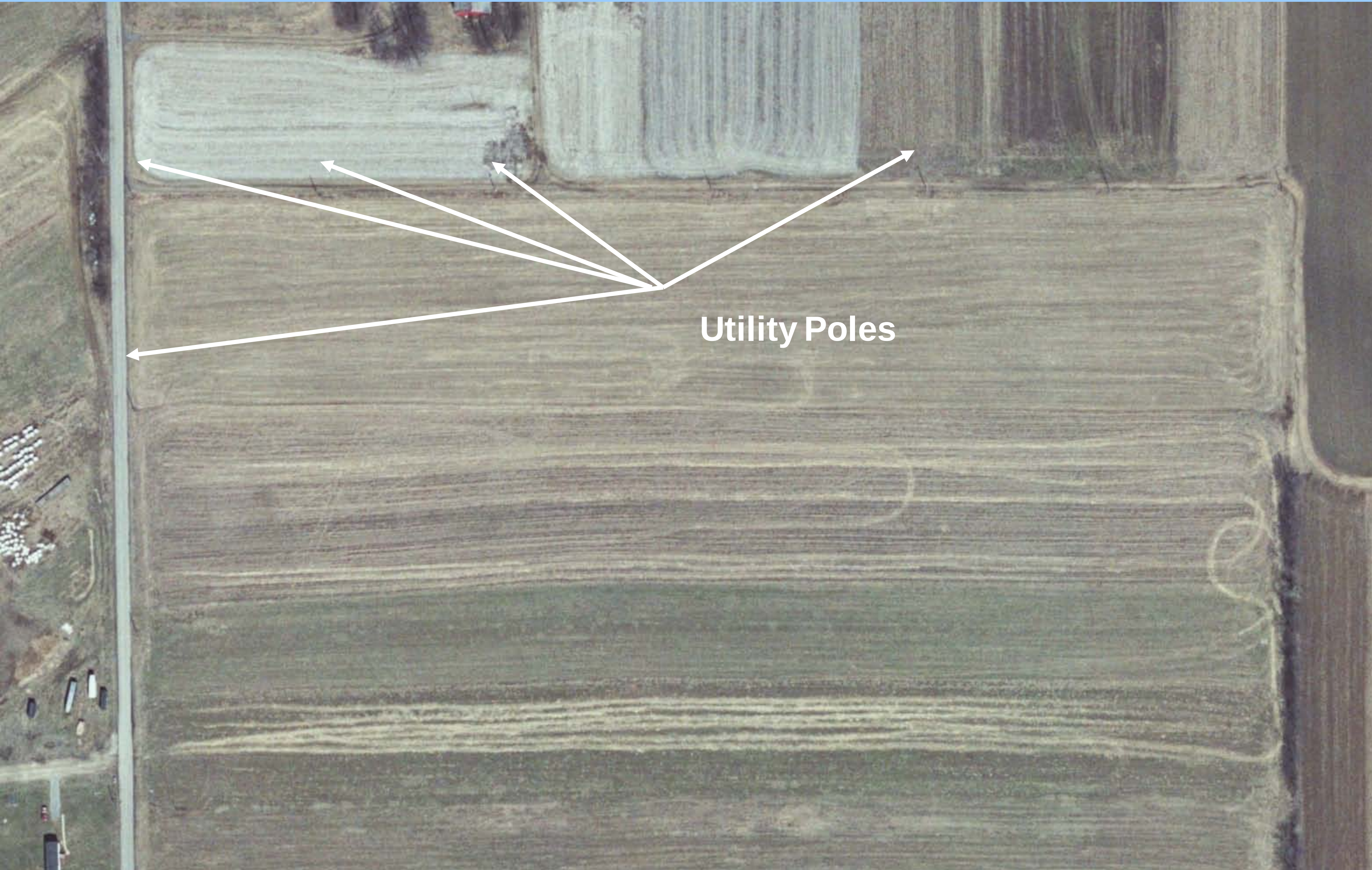
- Experiment on picture-taking techniques under controlled, realistic conditions:
  - Ideally, a mine site, but a natural rock face or construction project would suffice.
  - No shadows in mid day and good lighting.
  - Ground control.
- Create surface model to compare against surroundings, or better, against undisturbed ground.

Site

- In 2006, LiDAR and digital color imagery was collected for Western Pennsylvania. The imagery and DEMs and sometimes the raw data are publicly available.
- Ground control is therefore likely for any test site within the covered area.
- Best case would be a disturbance after 2006 with undisturbed features visible on the 2006 aerials AND that could be included in test photos.
- *I found one!*

Sand and Gravel Pit, May 17, 2009

Digital Imagery, Spring 2006
No Mine



Virtual Earth Imagery, Spring 2008
Disturbed Area ~ 200’ by 500’

Sand and Gravel Pit, May 17, 2009

Disturbed Area ~ 400’ by 1000’

- Extraction and segregation, topsoil stockpiling.
- Many features visible on 2006 digital imagery unchanged.
- Strong light, sun near nadir.
- Pit walls steep, near vertical.

Technique

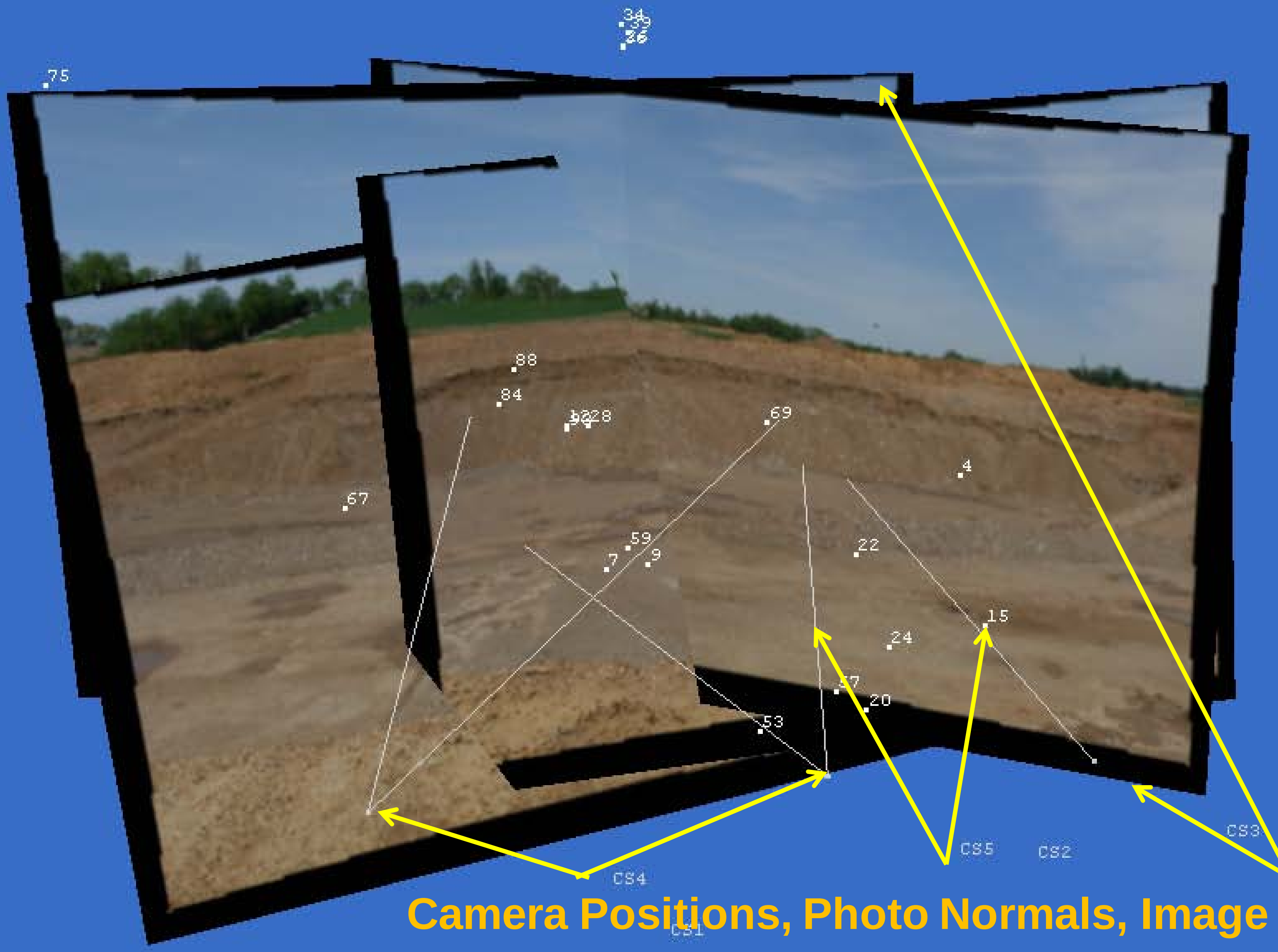
(Old habits are hard to break!)

- Tended to take panorama photos instead of stereo photos.
- Average photo only had about 40% pit, rest was background (landscape and sky).
- Perpendicular to surface, parallel image axes and good overlaps were rare.
- However, enough photos were taken to compensate for mistakes.

High Quality Photo Pairs with Points for Orientation and Ground Control

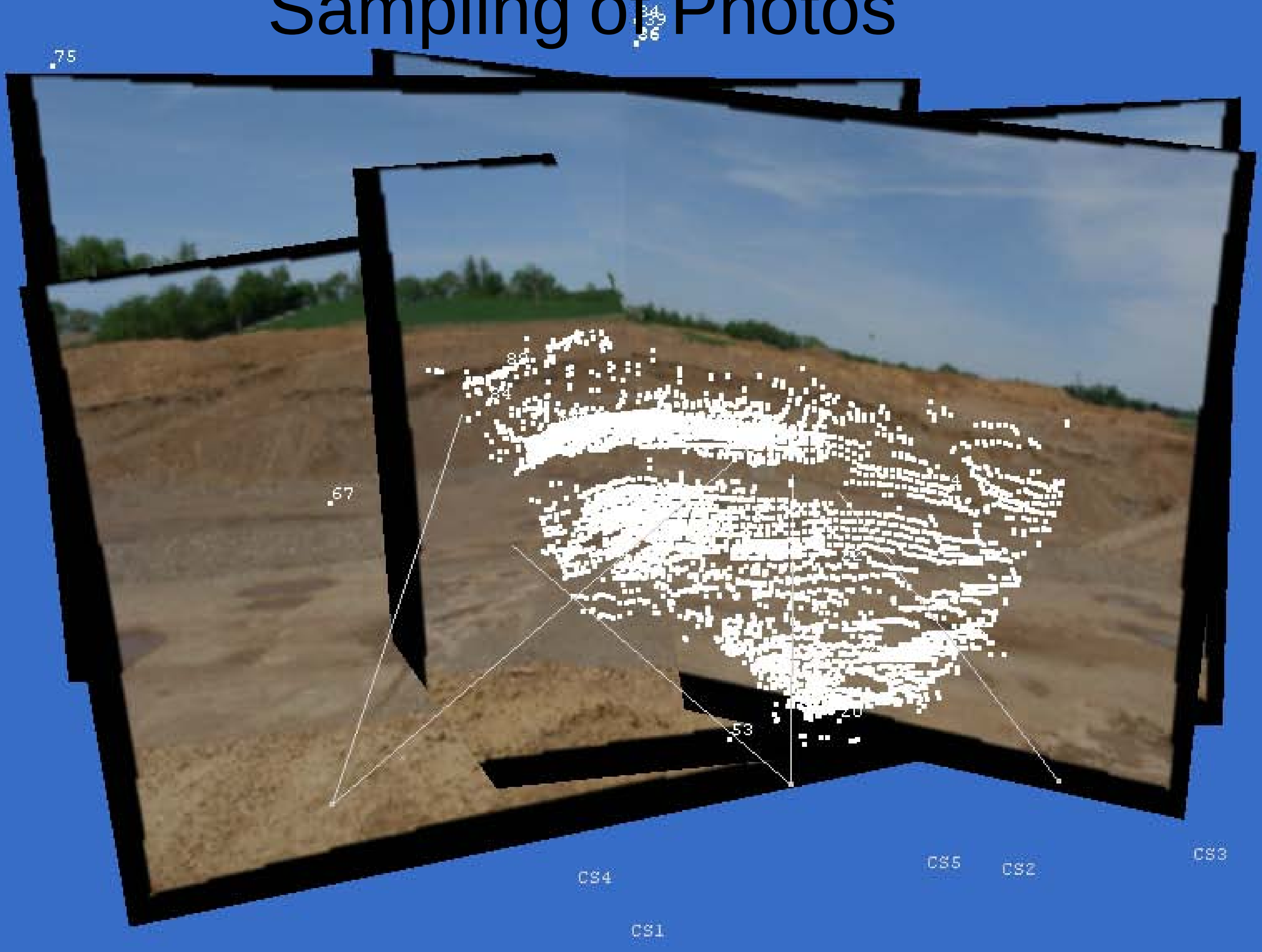
Points and lines in the far distance are X,Y,Z ground control picked from features visible on the 2006 imagery and these photos.

Oriented Photos in 3D



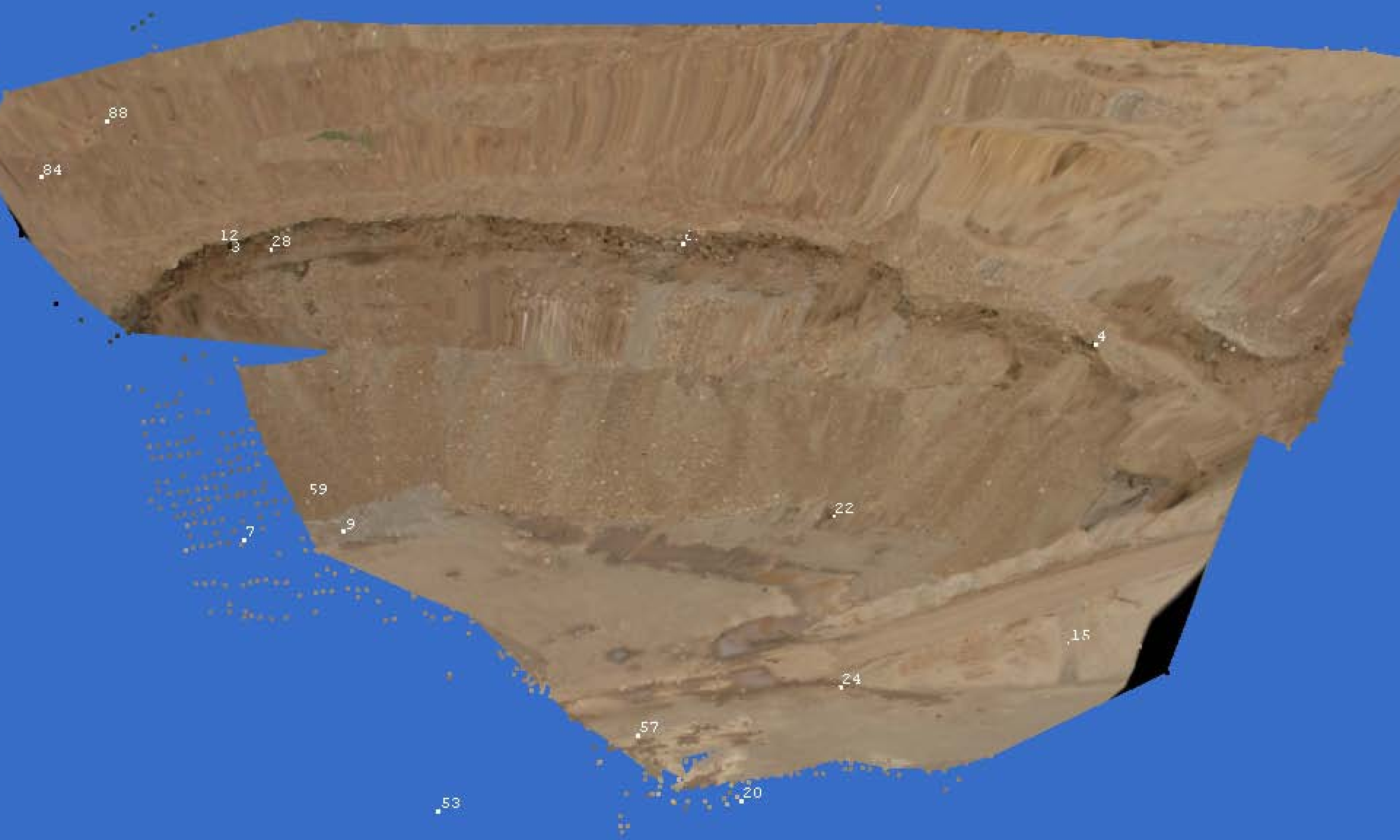
Camera Positions, Photo Normals, Image Planes

Point Cloud Extracted by Sub-pixel Sampling of Photos



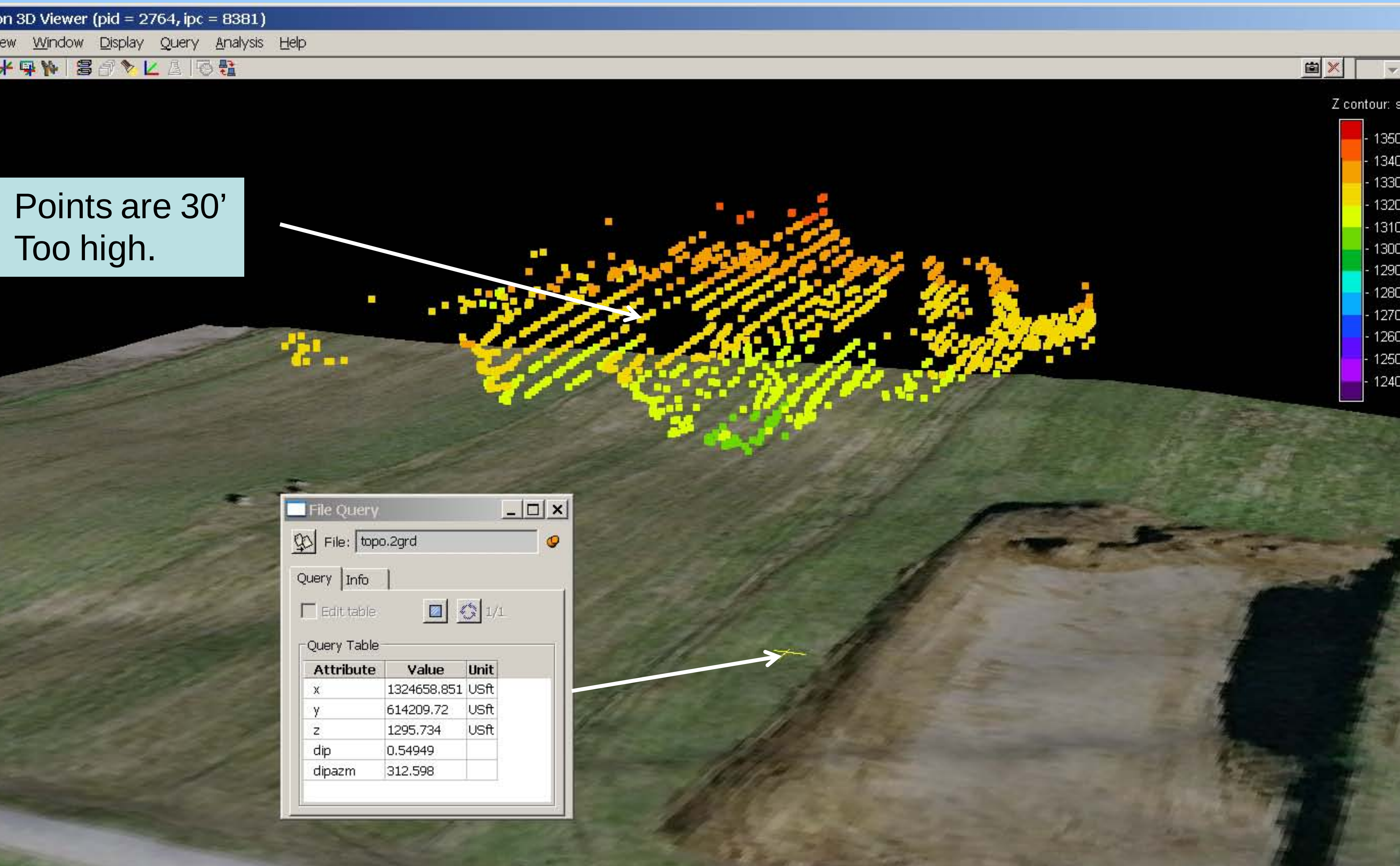
Point Cloud “Painted” in Image Colors

Point Cloud "Painted" in Image Colors



Point Cloud with 2008 Image on Topo - Something's Wrong!

Points are 30' Too high.



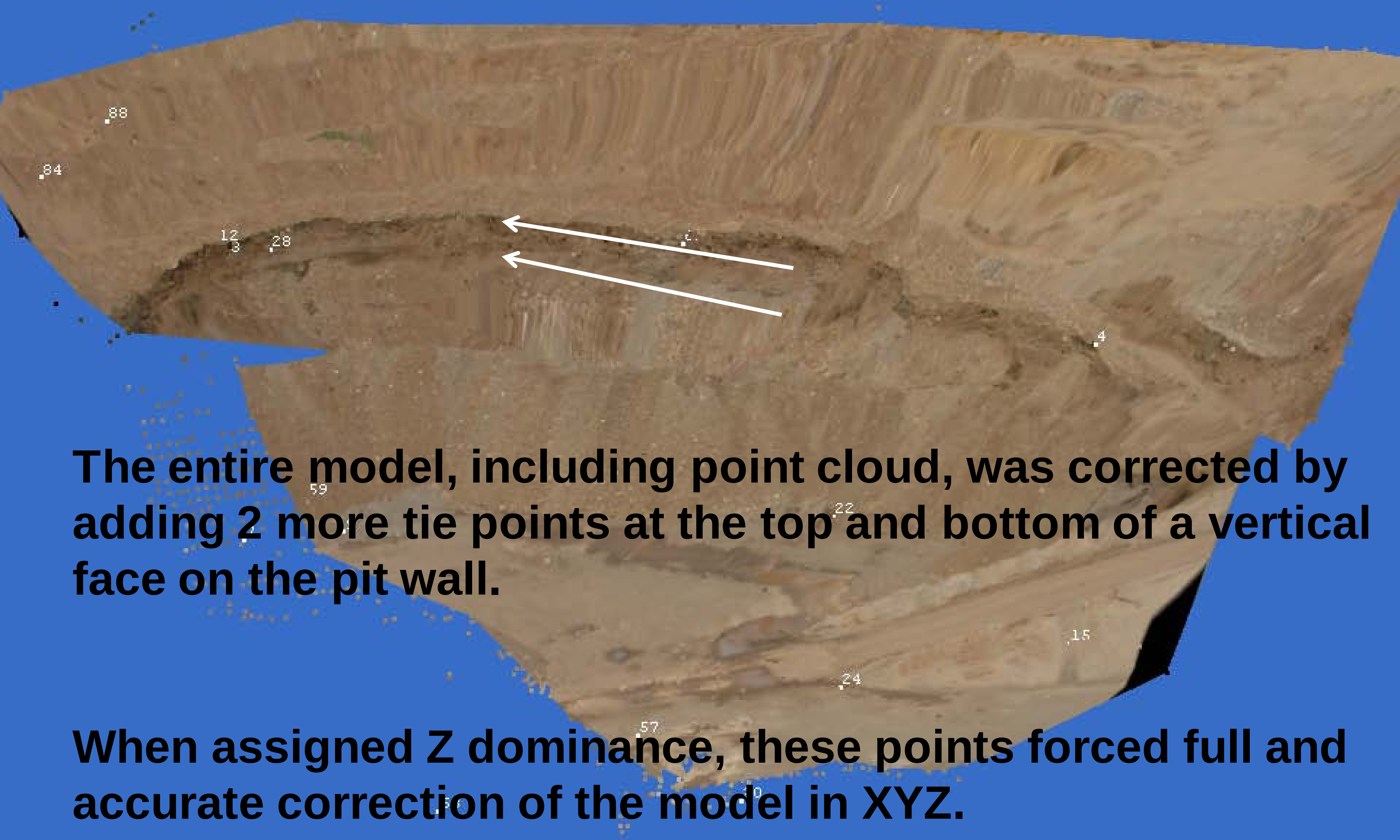
Other Problems

- Although, the XY coordinates appear accurate:
- The Z values are 20 to 50 feet too high.
- The point cloud is tilted in 2 directions with a northwestward resultant.

Diagnosis

- The control points used were well-spaced in the XY plane but not in Z.
- The Z points were at the edge of model space and disproportionally impacted the low-angle geometry causing rotation upward.
- A line of known length was not level and caused westward tilt.

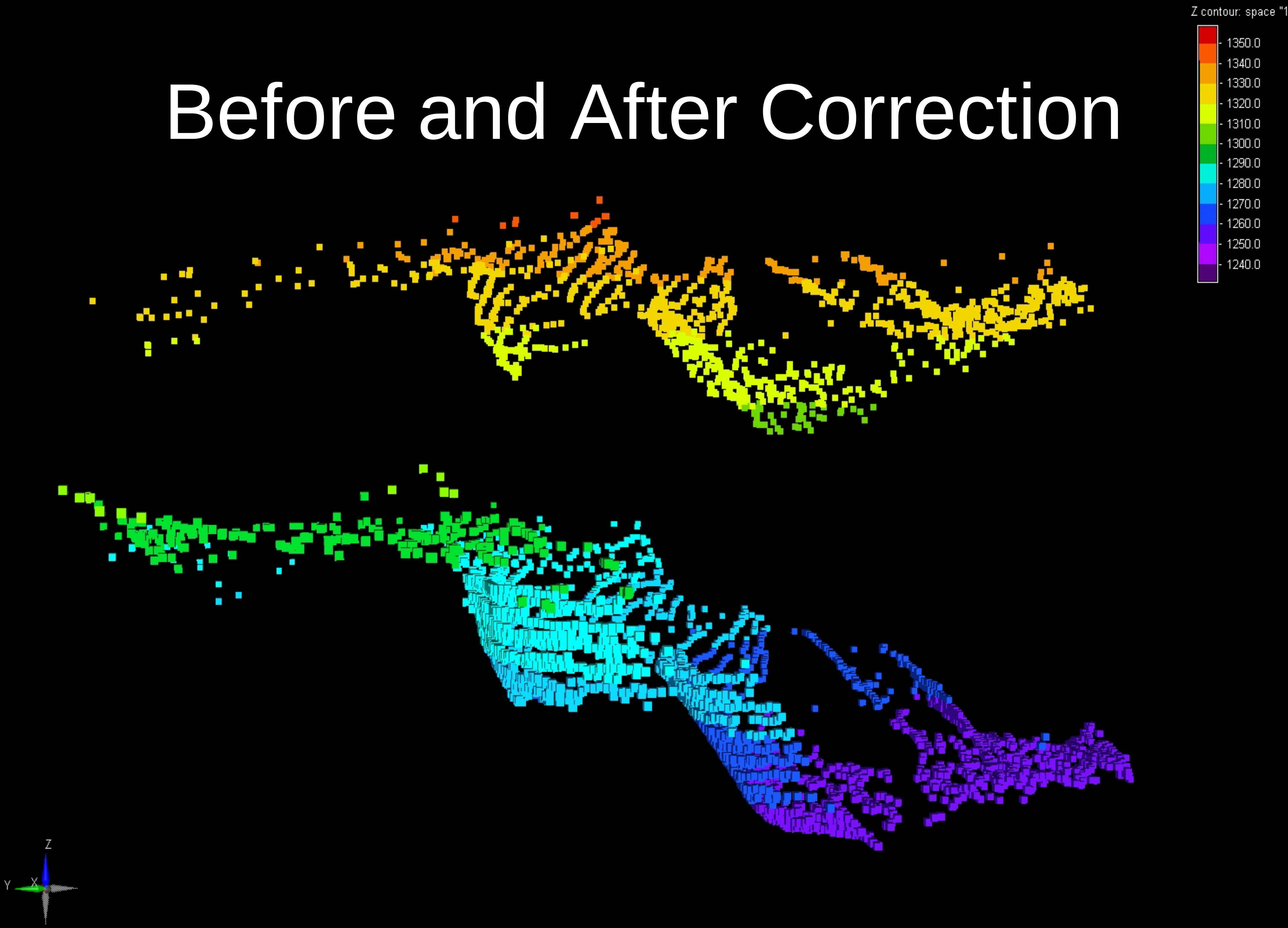
Correction was Trivial



The entire model, including point cloud, was corrected by adding 2 more tie points at the top and bottom of a vertical face on the pit wall.

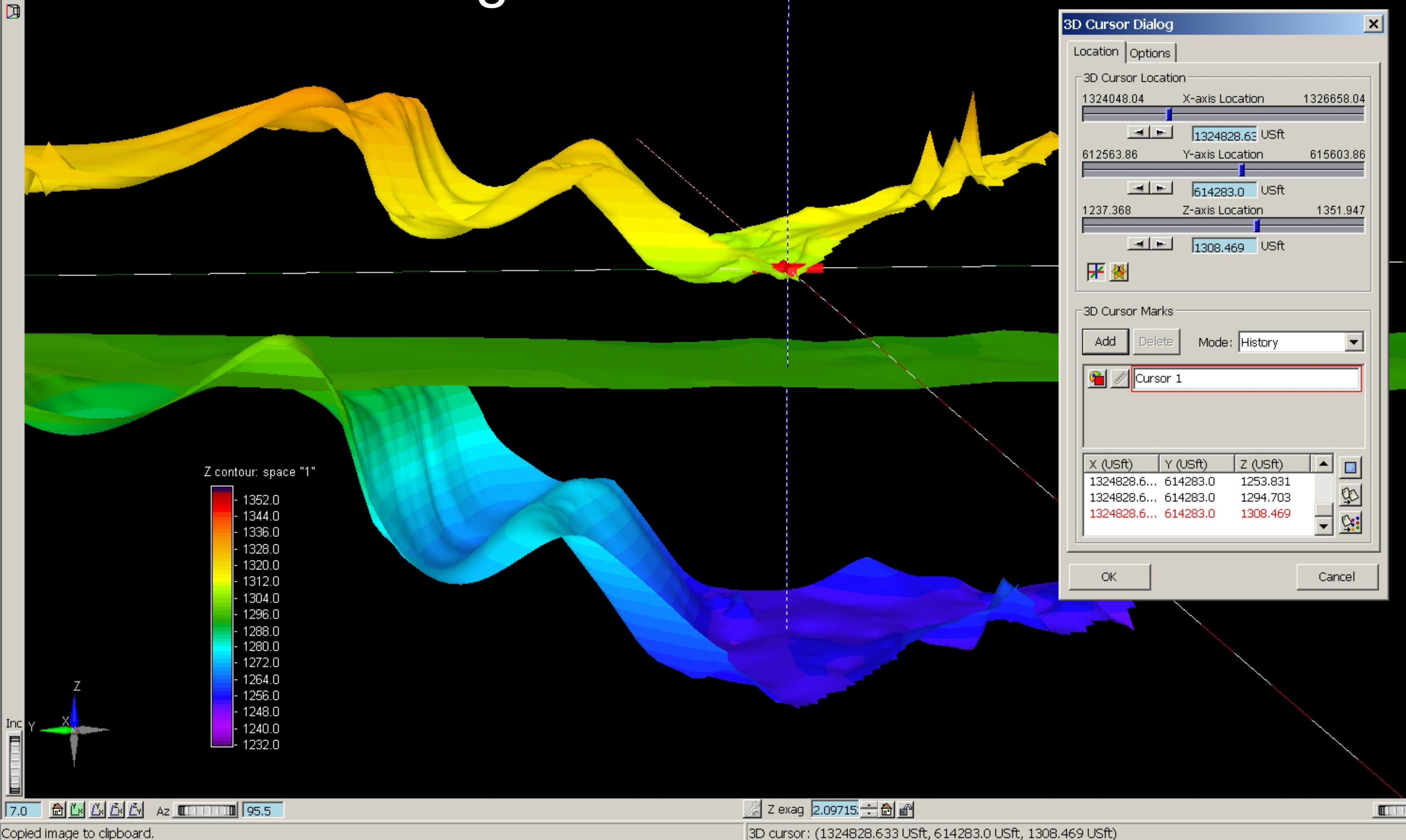
When assigned Z dominance, these points forced full and accurate correction of the model in XYZ.

Before and After Correction



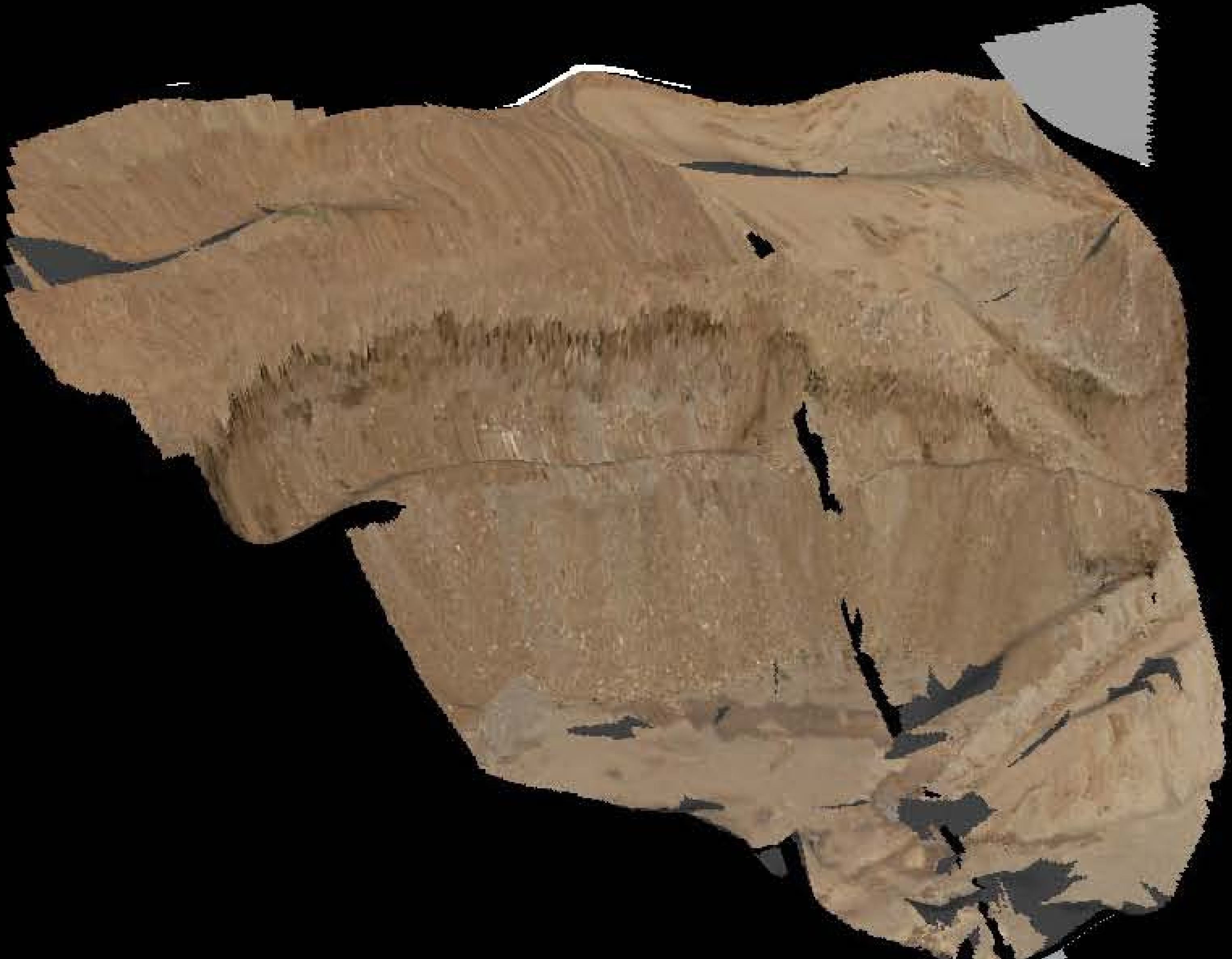
Before and After Correction

Original Ground Shown



Putting the Pieces Together

- 2006 topography
- 2008 image showing start of pit
- 2009 partial pit model



Second Test Findings

- Close Range Photogrammetry with consumer-grade and better cameras is capable of very accurate surface modeling.
- Careful planning and guidelines for photography are crucial.
- Technique is everything.

Next Steps

- Kentucky Regulatory and AML will be conducting new user testing on landslip monitoring, attempting aerial photogrammetry with the State helicopter, and working on adding rangefinder and GPS components in highwall/pit situations.
- In August, we plan to begin discussions with the REAL experts in the Bureau of Land Management.

(Parting Shot)

CRP Techniques Perfected!

(BLM gets “on top” of things)

References

- Burtch, Robert. 2008(?). Short History of Photogrammetry. http://www.ferris.edu/htmls/academics/course.offerings/burtchr/sure340.html
- Doneus, Michael. 1996(?) Introduction to Photogrammetry. http://www.univie.ac.at/Luftbildarchiv/wgv/intro.htm
- Fritsch, Dieter. 2005. The Photogrammetric Week Series – A Centennial Success Story**.** http://www.ifp.uni-stuttgart.de/publications/phowo05/phowo05.en.htm
- Matthews, Neffra A. 2009 (in preparation). Resource Documentation, Preservation, and Interpretation: Aerial and Close-Range Photogrammetric Technology in the Bureau of Land Management. Bureau of Land Management Technical Note 428, Bureau of Land Management National Operations Center, Denver, Colorado 80225.

Discussion