Applications of High Resolution Stereo Satellite Imagery for Permitting, Inspection, and Monitoring of Surface Coal Mines in the Western Region

JACIE 2003 Meeting

Reston VA

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Why use remote sensing?

Map and monitor large areas

Obtain a top down view

Create a permanent record

Extract new information

To do our job better

US Office of Surface Mining

- Created by public law in 1977 to enforce regulations related to surface coal mining
- Special regulation needed because impacts to land,water, and people can be great
- Comprehensive set of regulations
- Some regulations are well suited to verification and monitoring with remote sensing

Permitting and Inspection

- Permitting occurs before and during the operation of a surface coal mine
- Baseline Pre-Mine condition is documented
- Comprehensive quarterly inspections to inspect mining and reclamation activity
- Almost all activities have a spatial component that lend themselves to GIS, GPS and RS technology

Evaluation of Remote Sensing Data Sources

- Early on, OSM realized that remote sensing could be a valuable tool
- Technology was not mature
- Prices were too high
- Resolution was not adequate
- Computer and software technology were not adequate
- ca. 1998 things began to change

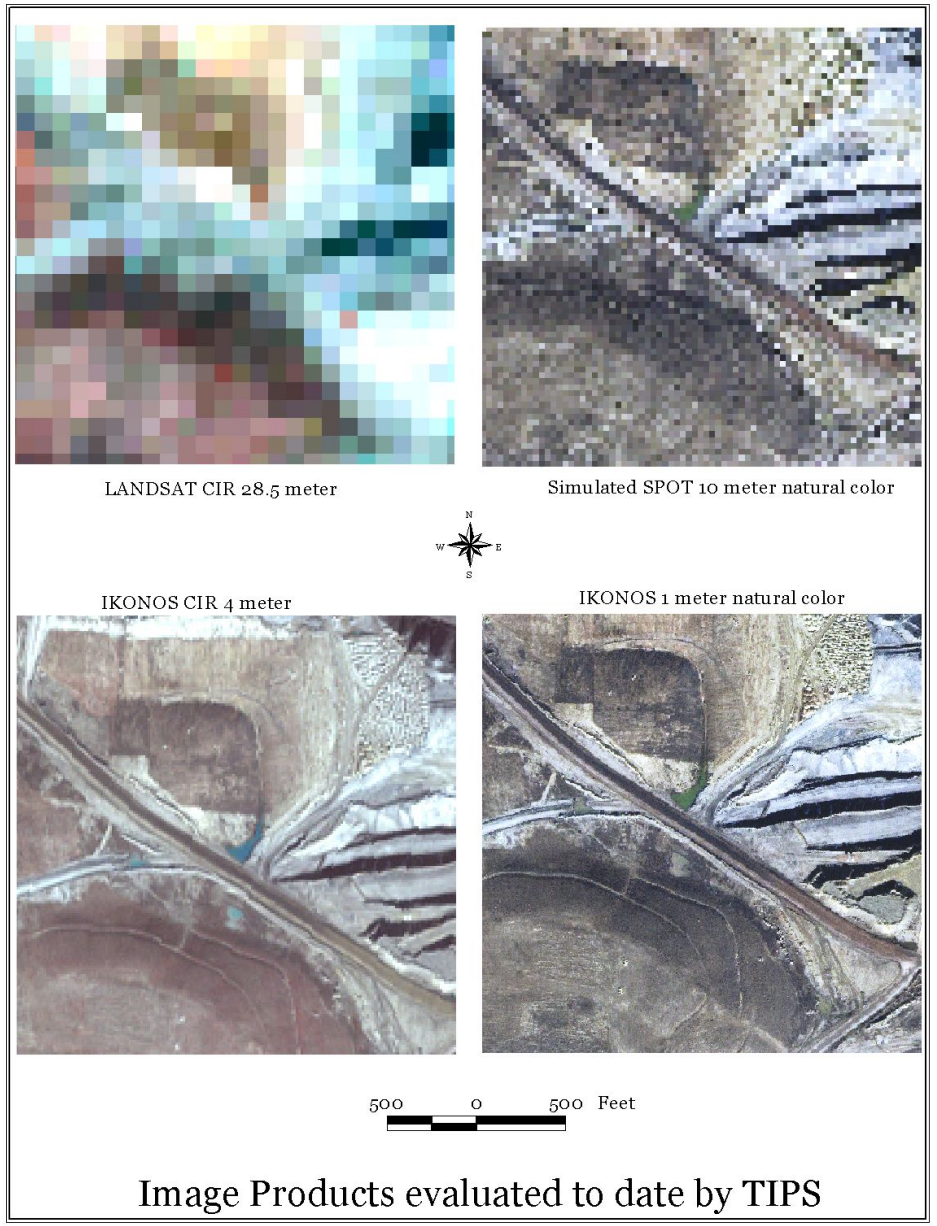


Image Products evaluated to date by TIPS

Evaluation of Remote Sensing Data Sources

- Aerial photography
  - detailed volumetric and topographic analysis
  - in house softcopy production
- USGS DOQQ
  - used for low priority/non-RA sites
- LIDAR
  - detailed topography with short turn around time
- Low to Medium Resolution Satellite
  - vegetation and regional mapping
- High Resolution Satellite
  - quarterly monitoring

High Resolution Satellite Imagery

- Utilize Stereo Ikonos, Monoscopic Ikonos, and Quickbird imagery
  - Cost effective: about $54 per km^2 for stereo product
  - Seamless, color balanced mosaics
  - Easy to order and procure
  - Good geo-referencing potential
  - Excellent dynamic range
  - Consistent radiometric performance

- The world is not perfect
  - clouds/fog/aerosols
  - sun angle in winter in steep terrain
  - coal is very black

High Resolution Satellite Imagery

•It is very accurate when ground control panels and high accuracy GPS are utilized. For sub-meter accuracy, stereo data is generally required.

• Photogrammetric processing methods, especially bundle adjustments can be utilized resulting in perfect mosaic

• DEM extraction using autocorrelation methods yields good results

•Stereo feature collection is very accurate: breaklines and elevations

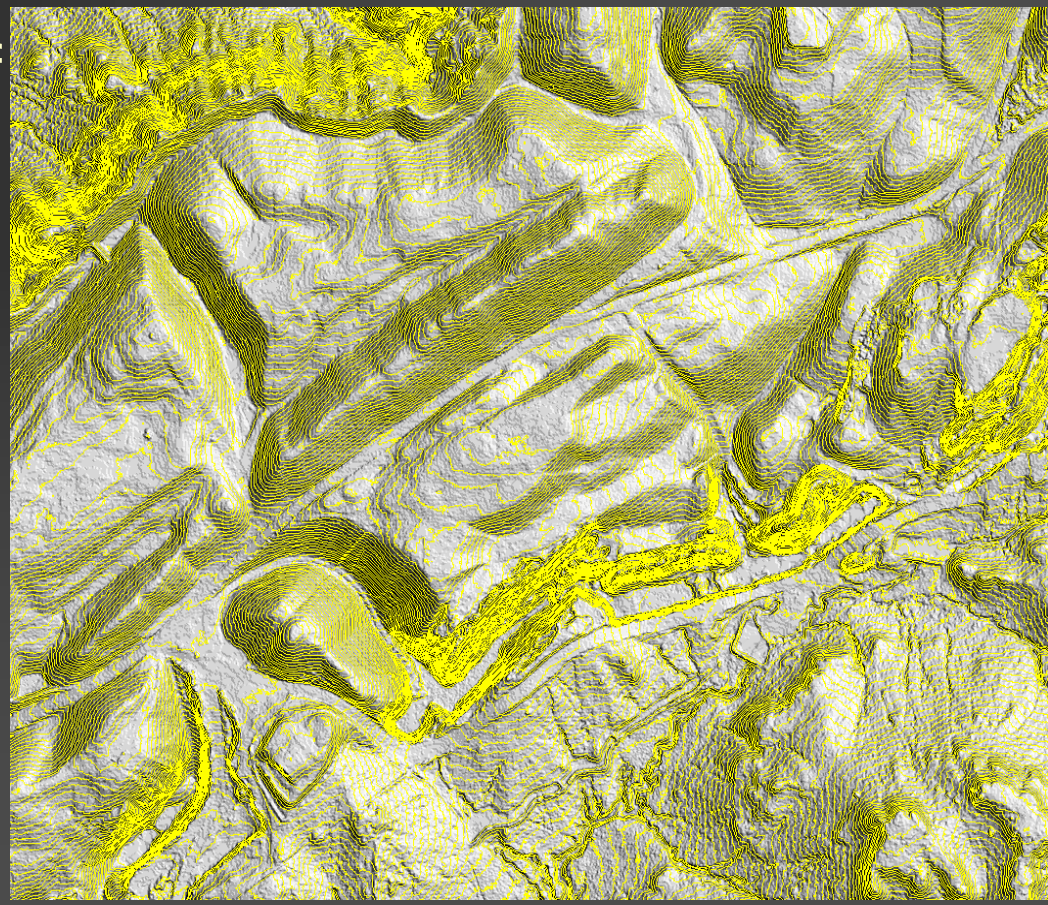
• The active mine site changes frequently, therefore a new DEM must be created for proper orthorectification

Aerial Photography

- Investigating the use of 1:2400 to 1:24000 aerial photography
- Color IR, Natural Color, and B&W
- Utilizing Airborne GPS to reduce the amount of ground control
- Using professional and in house scanning
- 2-5 foot contours and 0.5-1 foot orthophotos

LIDAR Data

- Captures snapshot of topography
- 2 foot contours, 6” precision
- Also captures B&W aerial photos in stereo
- About $500.00 km^2



New Technology on the Horizon

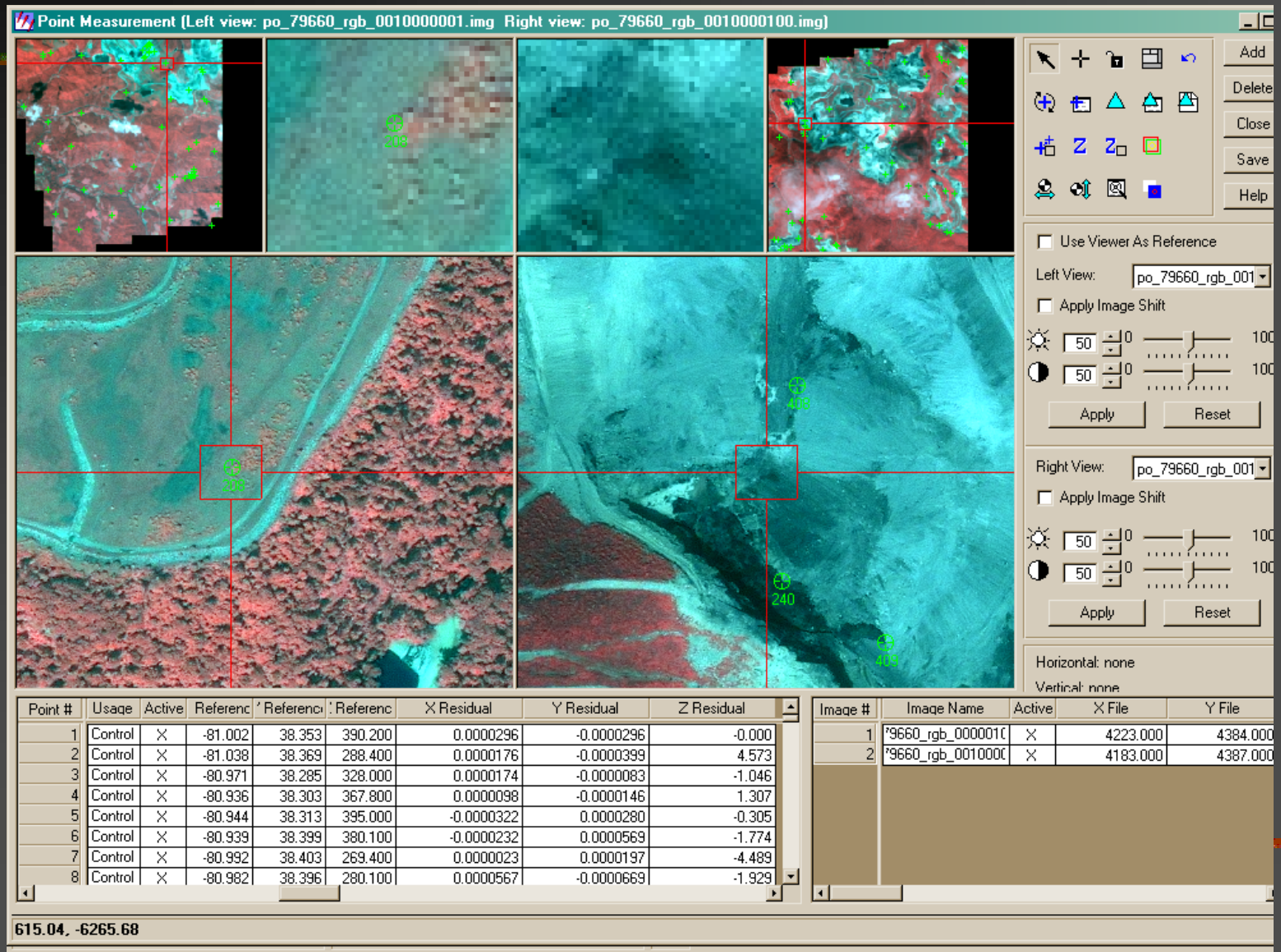
- SPOT 5: 2.5m resolution, 60kmx60km
- 0.5m satellites by 2004
- Increased competition in the high resolution market will drive prices down
- Hyperspectral and RADAR technology by 2005 on a commercial basis
- Digital Metric Airborne Cameras

Using Imagery for Regulatory Enforcement

- Requires high degree of accuracy to be useful
- Timely delivery of imagery
- On the ground inspectors use this as a tool to supplement their field visits
- Most valuable when integrated with other data and tools

High Accuracy GPS Surveying

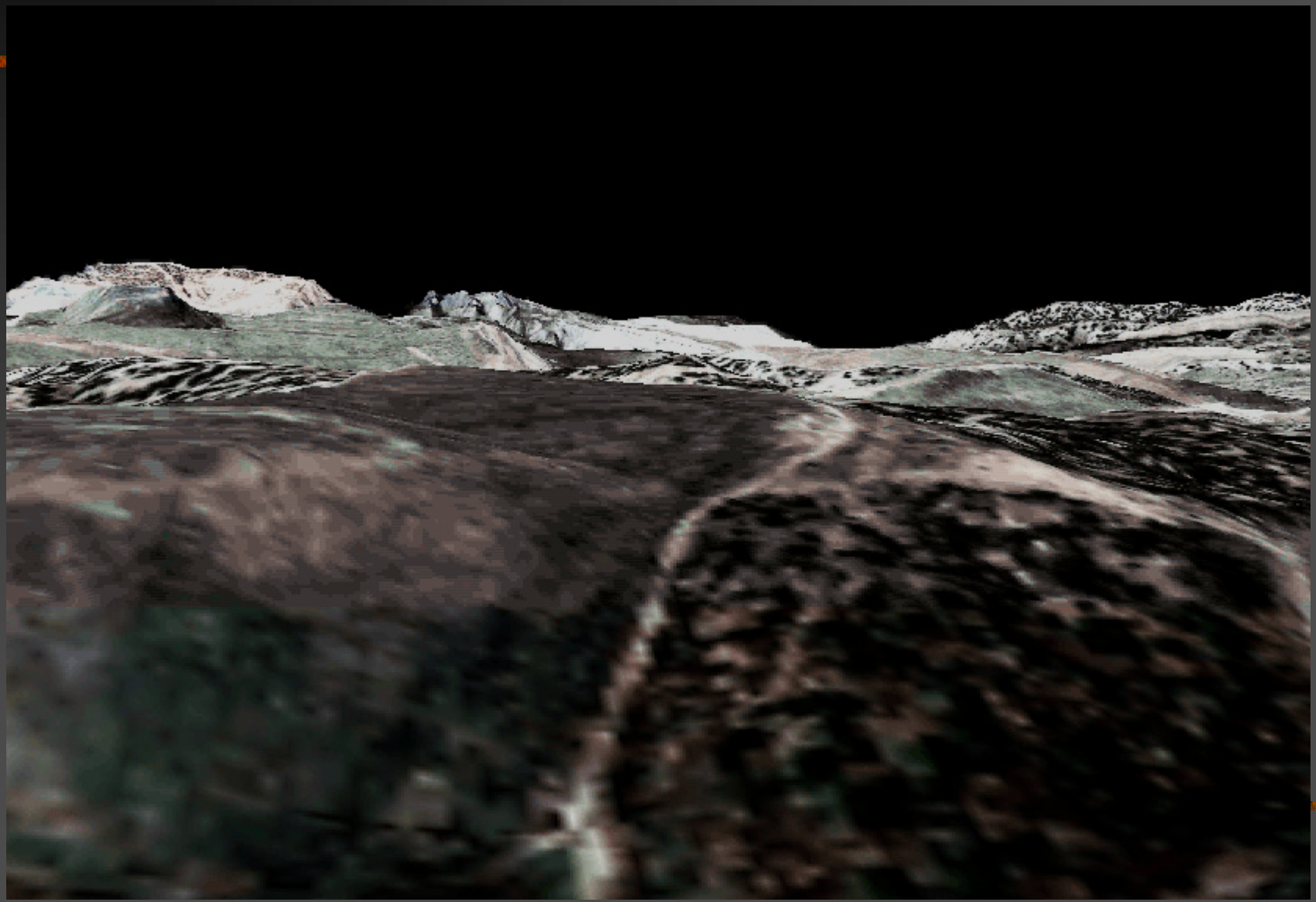
Sophisticated Software is required for processing: ERDAS Imagine 8.6



Western Region Imagery Uses

- Permitting
- Quarterly Acquisitions for change analysis and creating a permanent record
- Inspectors use before, during and after inspections
- R&D in vegetation cover mapping
- Topographic Mapping and Volumetrics

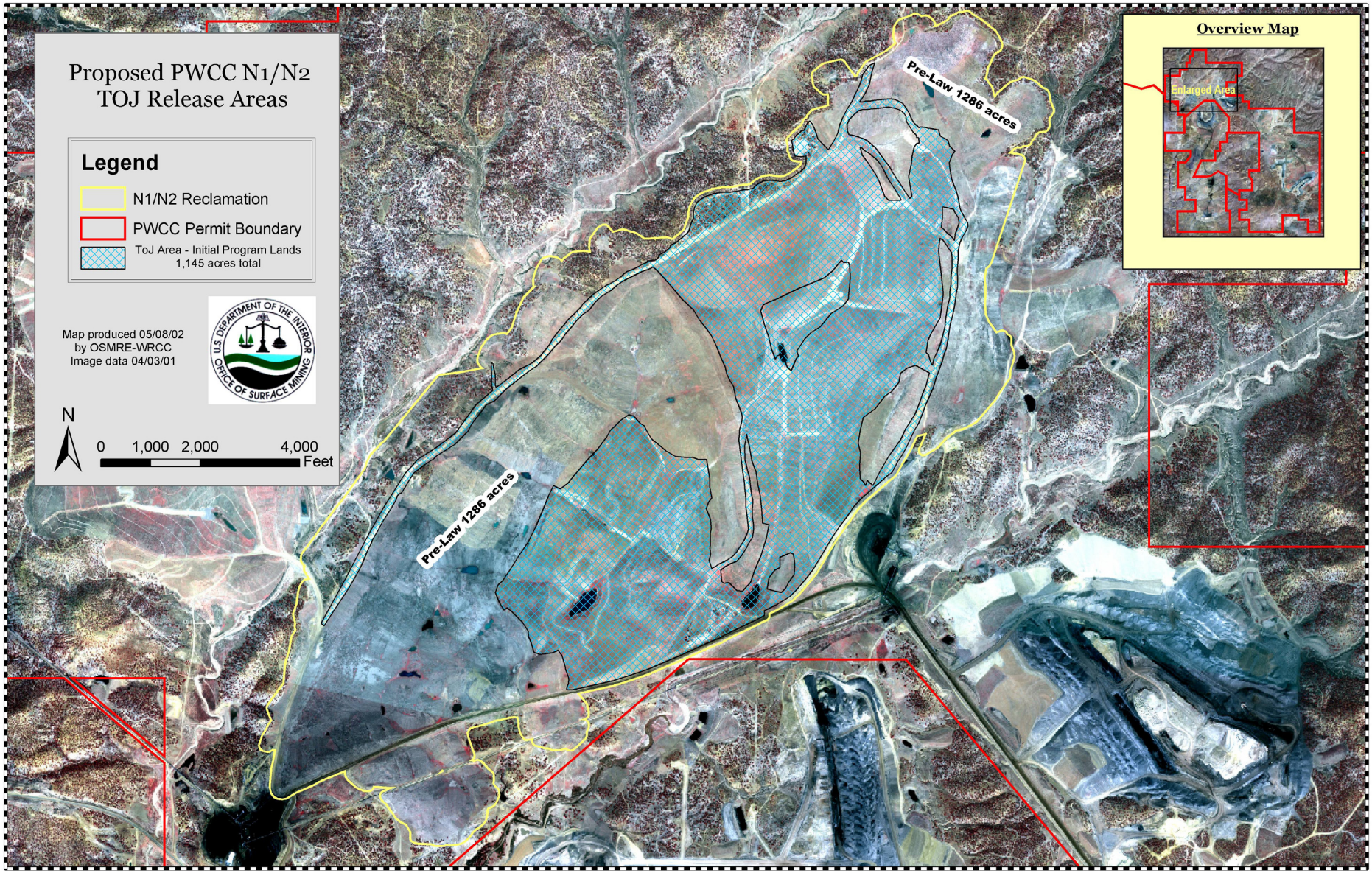
Site Visualization: 0.8m IKONOS and 2m DEM

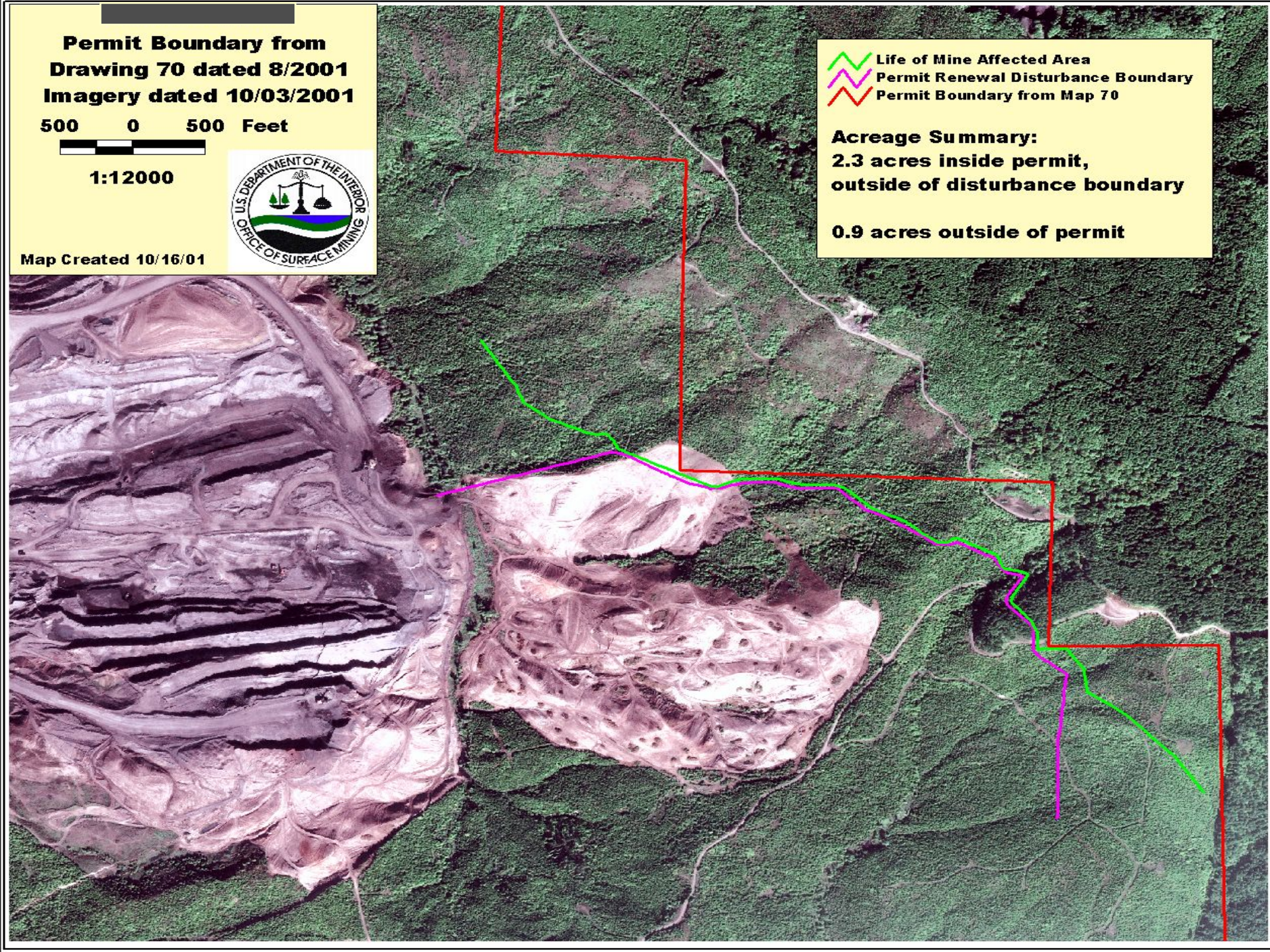


Permitting and Imagery

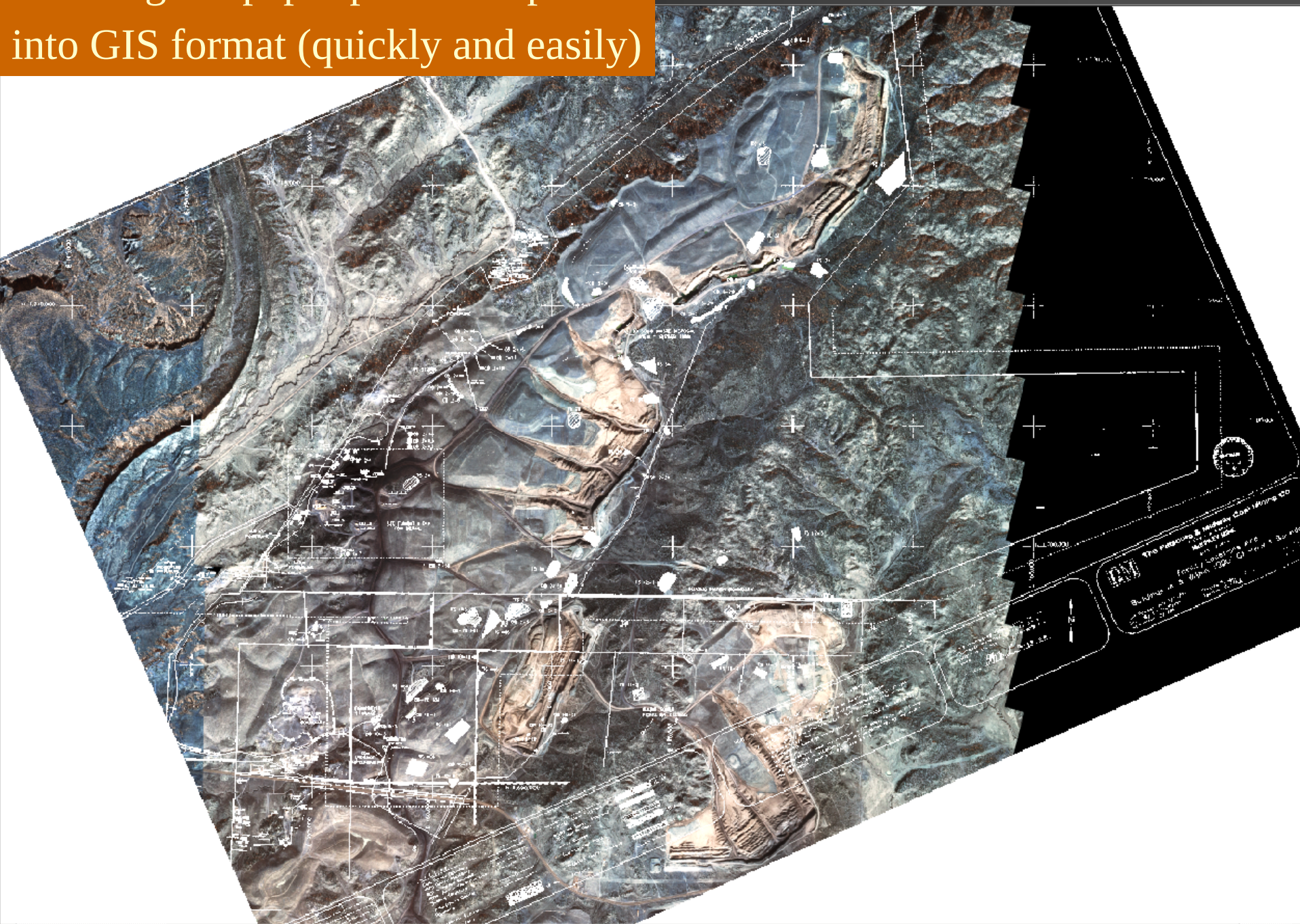
- Overlay with paper permit maps and engineering diagrams
- Topographic measurements to verify slope and approved elevations
- Used for basic cartography in reports

Permitting


Proposed PWCC N1/N2
TOJ Release Areas
Legend
N1/N2 Reclamation
PWCC Permit Boundary
ToJ Area - Initial Program Lands
1,145 acres total
Map produced 05/08/02
by OSMRE-WRCC
Image data 04/03/01
U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF SURFACE MINING
N
0 1,000 2,000 4,000
Feet
Pre-Law 1286 acres
Pre-Law 1286 acres
Overview Map
Enlarged Area

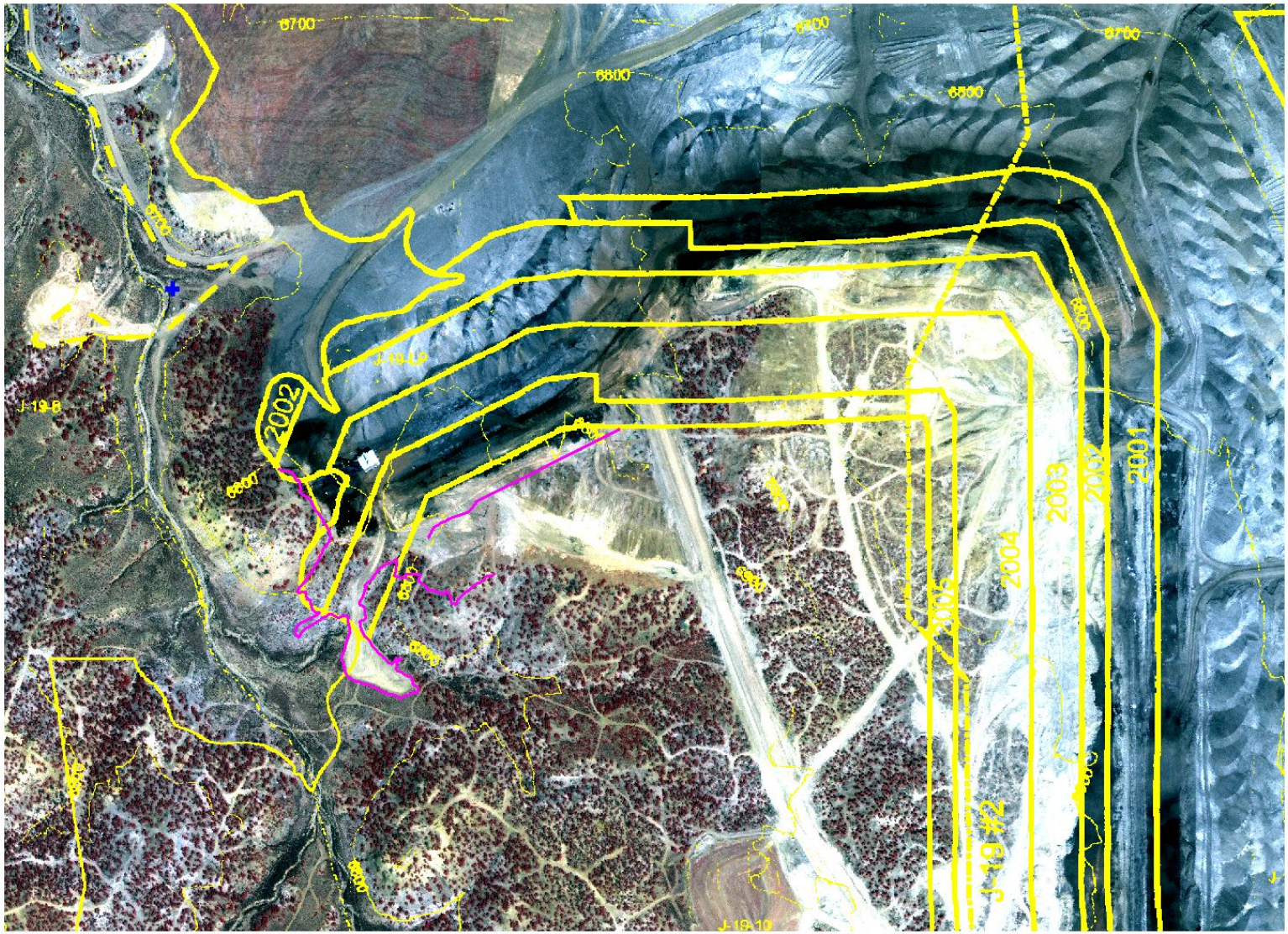

Permit Boundary from
Drawing 70 dated 8/2001
Imagery dated 10/03/2001
500 0 500 Feet
1:12000
Map Created 10/16/01
U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF SURFACE MINING
Life of Mine Affected Area
Permit Renewal Disturbance Boundary
Permit Boundary from Map 70
Acreage Summary:
2.3 acres inside permit,
outside of disturbance boundary
0.9 acres outside of permit

Integrate paper permit maps into GIS format (quickly and easily)



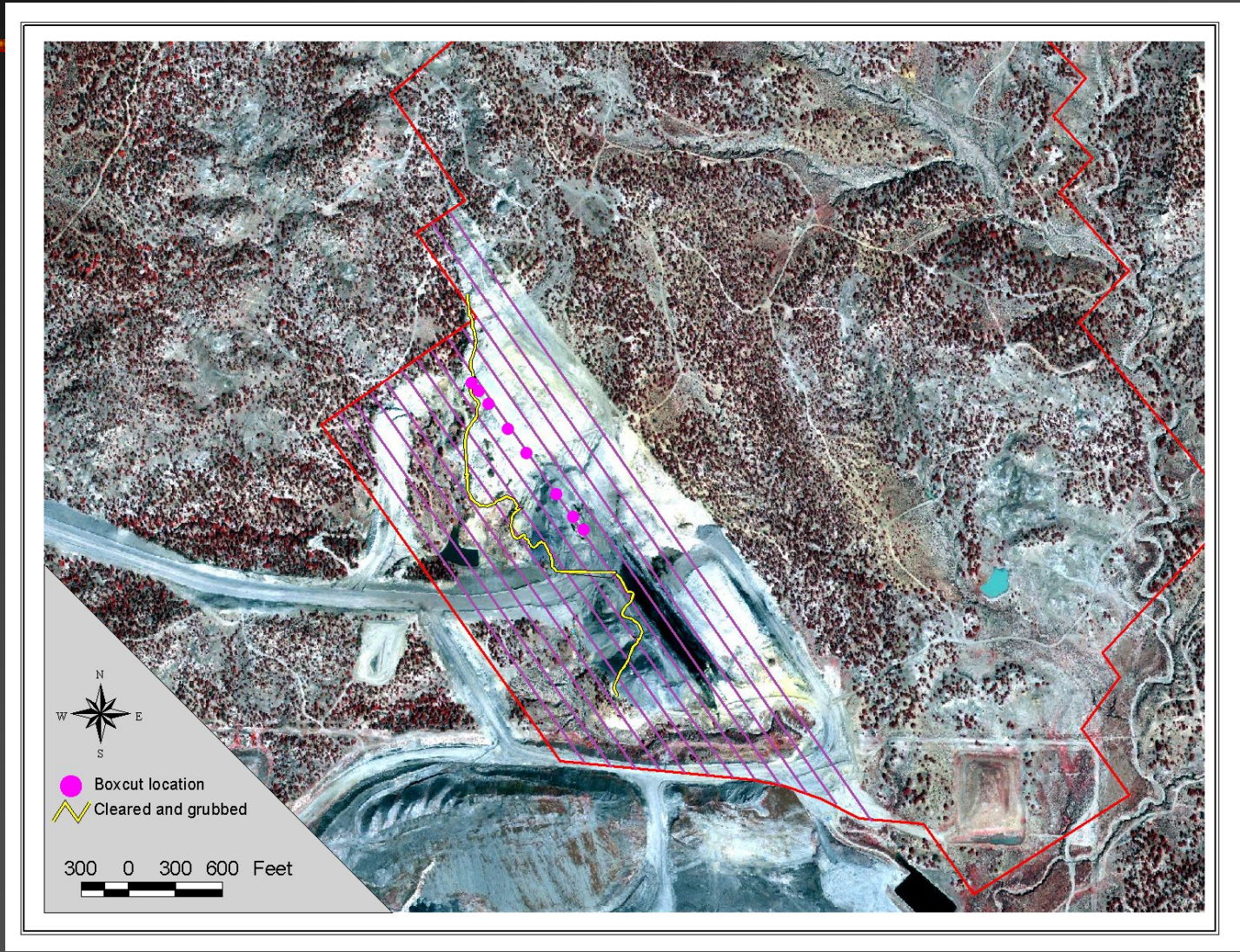
CB 2-13
CB 2-12
SP 1N
SP 3N
SP 2N
SP 4N
SAMPLING BUILDING
CRUSHER & HOPPER
TIPPLE SHOP
TS 24
CABIN HOUSE
ELECTRICAL SUBSTATION
COAL LOADOUT
BELT TAKE-UP
SAMPLE PREP BUILDING
FOREMAN'S OFFICE
DIESEL FUEL
DIESEL FUEL LOAD/UNLOAD
WATER TANK
TRAINING TRAILER
DELIVERY STATION
NORTH OFFICE
TANK STORAGE AREA
2C OIL DOCK
SECURITY BUILDING
NORTH OIL DOCK
WASH PAD
SP 5N
SECURITY BUILDING
BUCKET SHOP
PARTS STORAGE
SEE EXHIBIT 4.3-1 FOR DETAIL
CABLE YARD
SHED TRAILER
CB 1-7
NTUA POWERLINE
CB 2-20

Integration with Inspector GPS Data and Permit Maps



J-19 Area with 85210 map

Maps are used as supporting documentation in Inspector Reports and NOV's



GIS and imagery can help inspectors work more efficiently

TABLE 5.1-1
MINING/RECLAMATION ENVELOPE DISTANCES

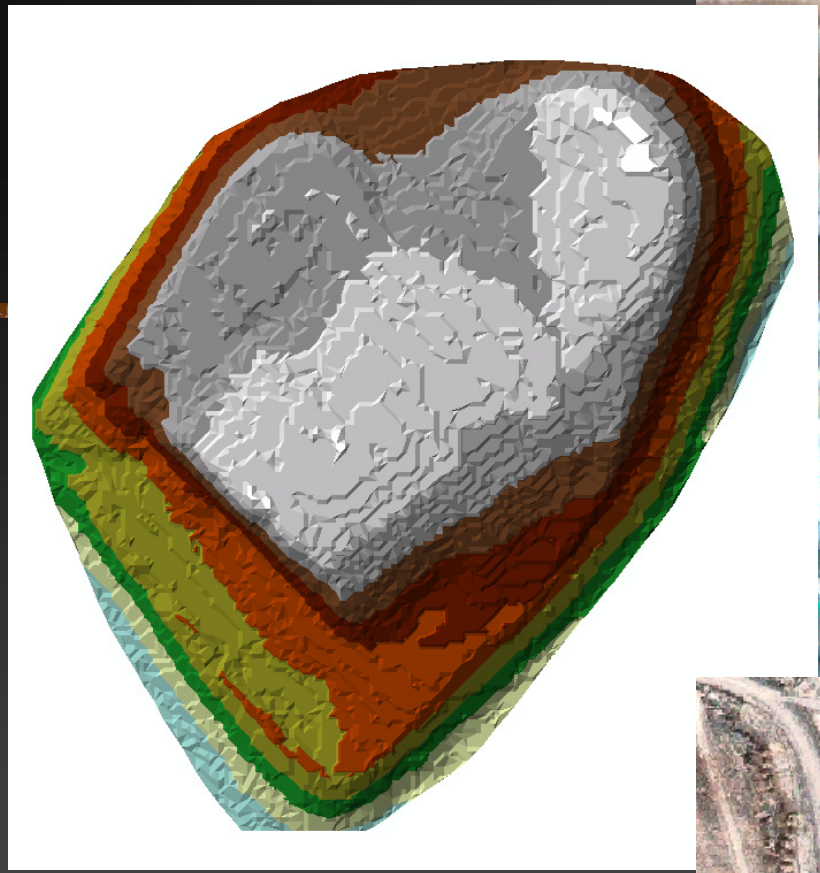
MINING AREA*	1996			1997			1998			1999			2000 & Beyond		
	A-B	B-C	C-D	A-B	B-C	C-D	A-B	B-C	C-D	A-B	B-C	C-D	A-B	B-C	C-D
Area 2 - prestrip	800	1400	800	800	1300	800	800	1200	800	800	1100	800	800	1000	800
Area 2 - no prestrip	600	1500	1100	600	1400	1000	600	1200	900	600	1000	800	600	800	800
Area 3 - no prestrip	600	1400	800	600	1300	800	600	1200	800	600	1100	800	600	800	800
Area 3 - Idled	600	1400	800	600	1300	600	600	1200	200	600	1100	200	600	800	200
Area 3A Plug***															
Area 6 - prestrip	800	1400	800	800	1300	800	800	1200	800	800	1100	800	800	1000	800
Area 6 - no prestrip	600	1300	800	600	1200	800	600	1100	800	600	1000	800	600	800	800
Area 10 - prestrip	800	1000	800	800	1000	800	800	1000	800	800	1000	800	800	1000	800
Area 10 - no prestrip	600	800	800	600	800	800	600	800	800	600	800	800	600	800	800
Area 12 - no prestrip	600	1200	800	600	1200	800	600	1000	800	600	800	800	600	800	800

* FOR AREA LOCATIONS AND MAPSHEET INDEX, REFER TO EXHIBIT 1.4-2 IN VOLUME I.

*** Buffer reserved for 3A Plug - see Exhibit 5.1-1, Sheet 2, for area to be held open to accommodate mining. See Section 5.1.2 for specific details.

For pits that are planned to be idled for more than six months, the C-D distance will be closed to 400 feet (unless a shorter distance is noted above) within 180 days of last exposed coal removal. Four-hundred feet allows for the mitigation and topsoiling of whole grids plus a 70-foot buffer for future grading. The 180 days is required to allow time for grid sampling, pre-stripping/distribution of mitigation material, topsoiling and seeding.

Envelope Distance Monitoring



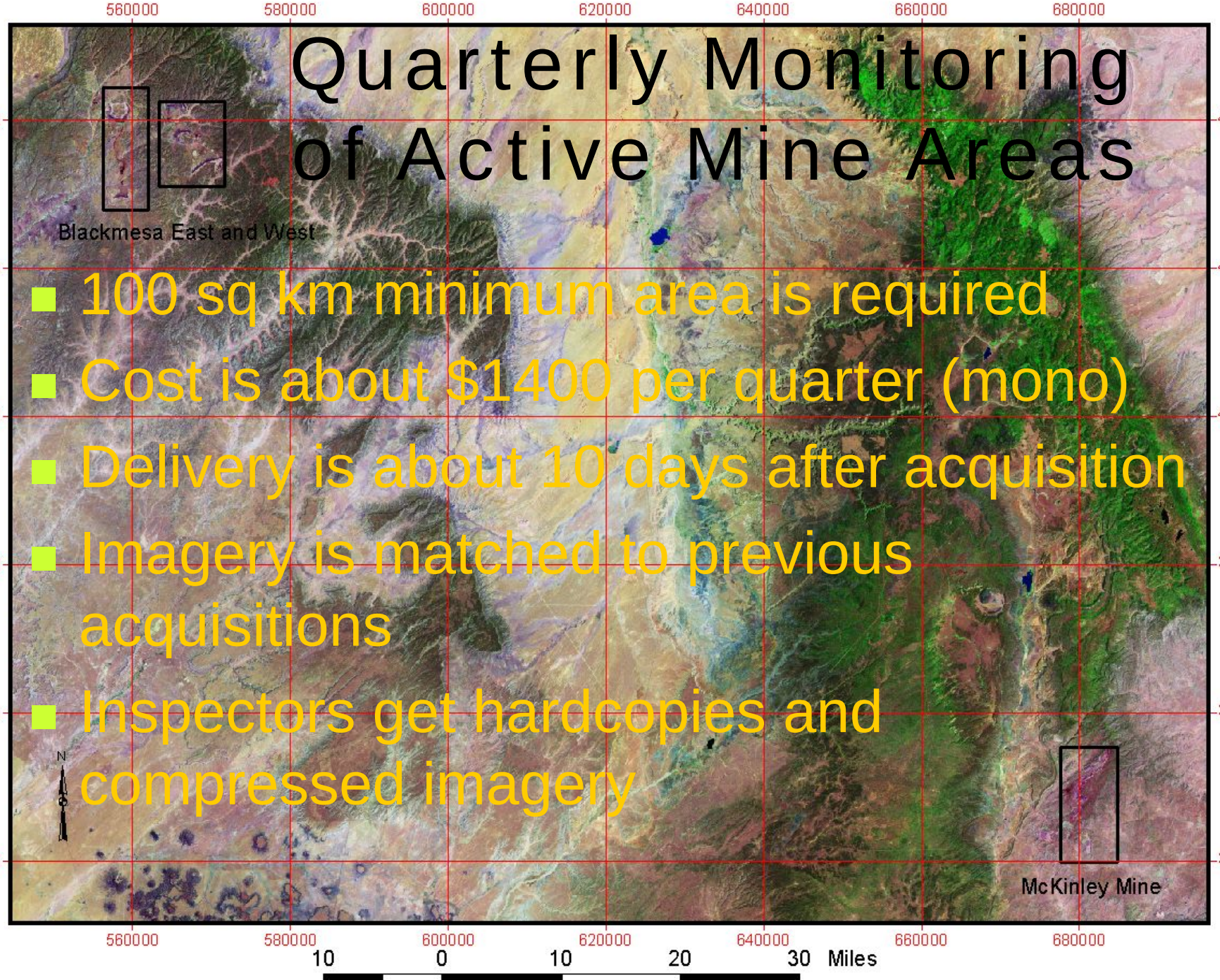
Volumetric Calculations
Area: 460,800 ft^2
Volume: 356,000 cubic yards

Comparison of volumetric measurements using IKONOS and 2000 Annual Report

Stockpile #	IKONOS	2000 Annual Report	diff in %	area ft^2	
25	122	191	-36.13	366724	
32	356	315	13.02	565913	
63	77	176	-56.25	260205	
103	380	389	-2.31	465533	
104	74	126	-41.27	332044	
122	24	40	-40.00	92480	
Total Cubic Yards	1032	1237	-16.57	47.81678	Acres

Cubic yards in 000’s

Quarterly Monitoring of Active Mine Areas



- 100 sq km minimum area is required
- Cost is about $1400 per quarter (mono)
- Delivery is about 10 days after acquisition
- Imagery is matched to previous acquisitions
- Inspectors get hardcopies and compressed imagery

Vegetation Monitoring

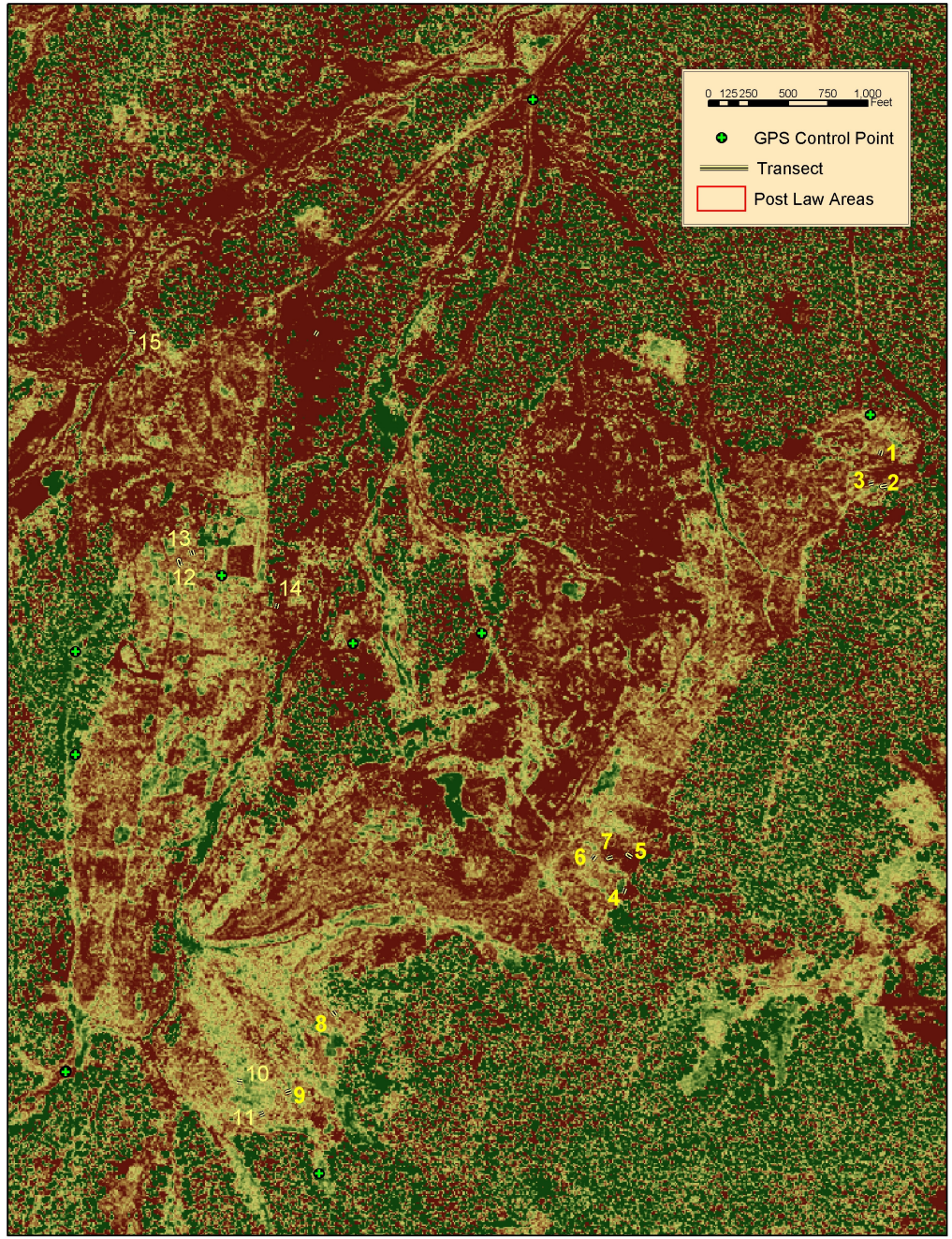
- Want to be able to identify bare spots in reclaimed areas
- Want to be able to determine percent cover
- Will not be able to determine species mixes with satellite data
- Goal is to speed up bond release process

Finding Bare Spots in Bond Release Areas

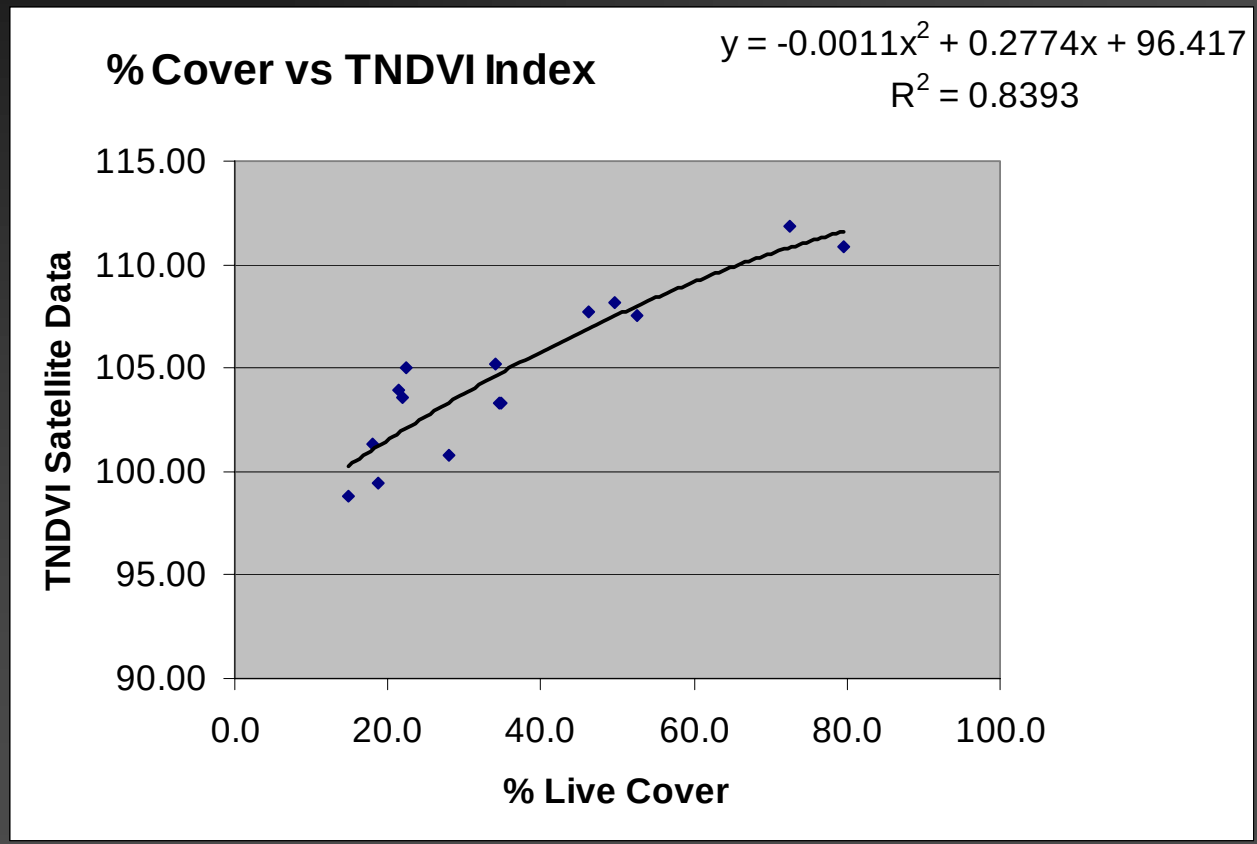
What did we find?

click to start movie clip

Quickbird MS MSAVI



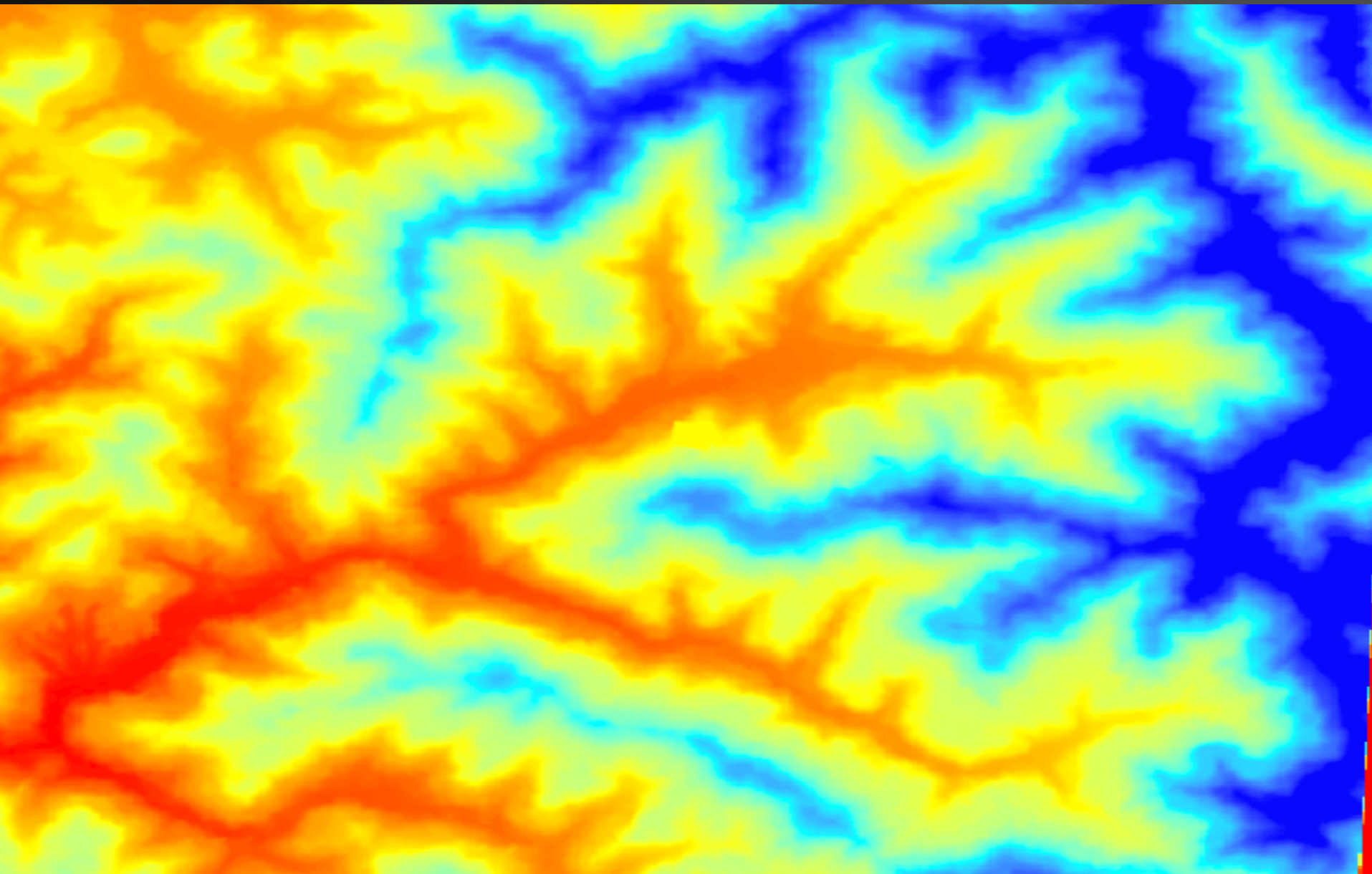
Regression Analysis: Quickbird MS data and Field Transects (% Live Cover)

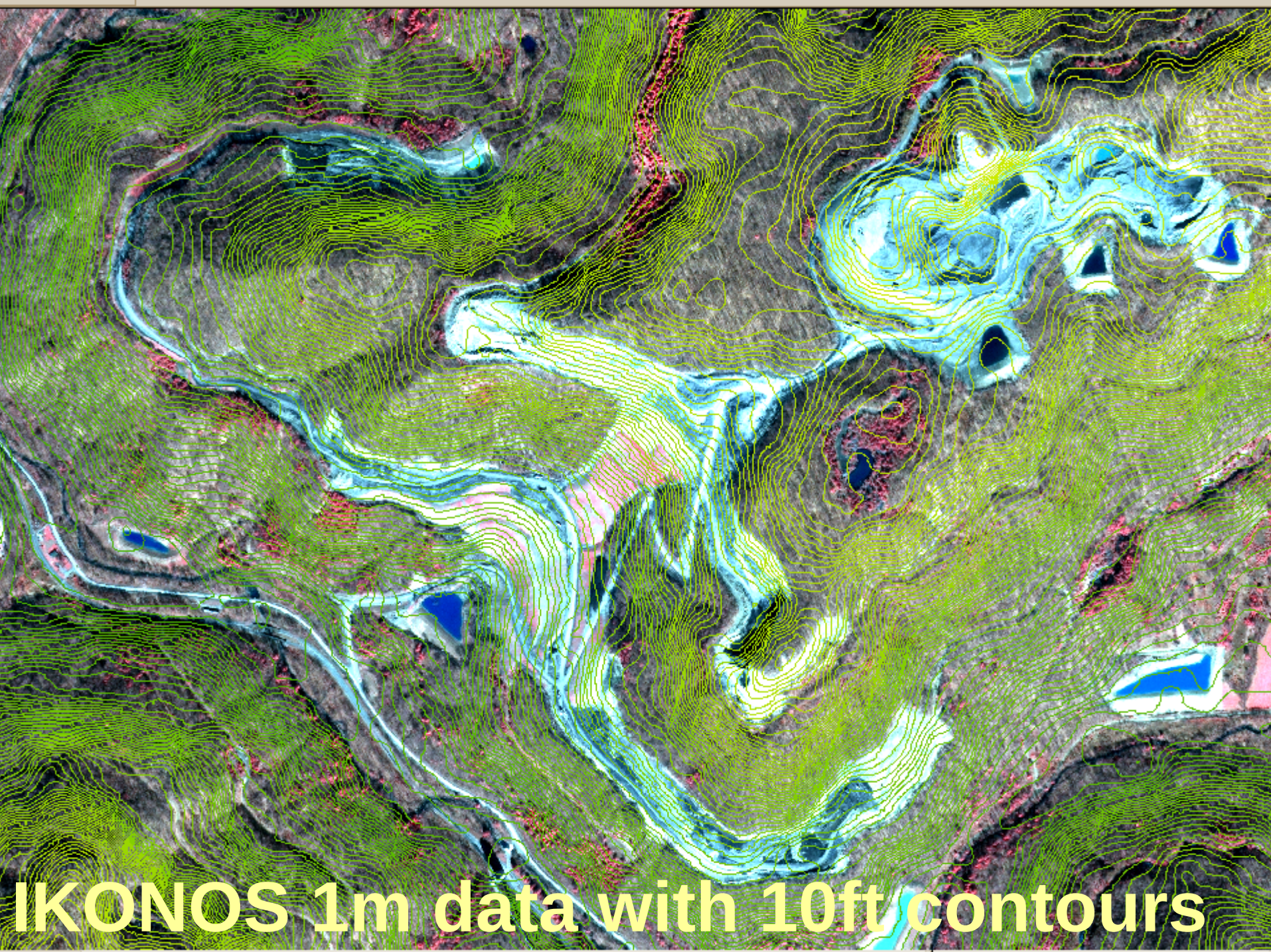


Topography for Volumetric and Hydrologic Analysis

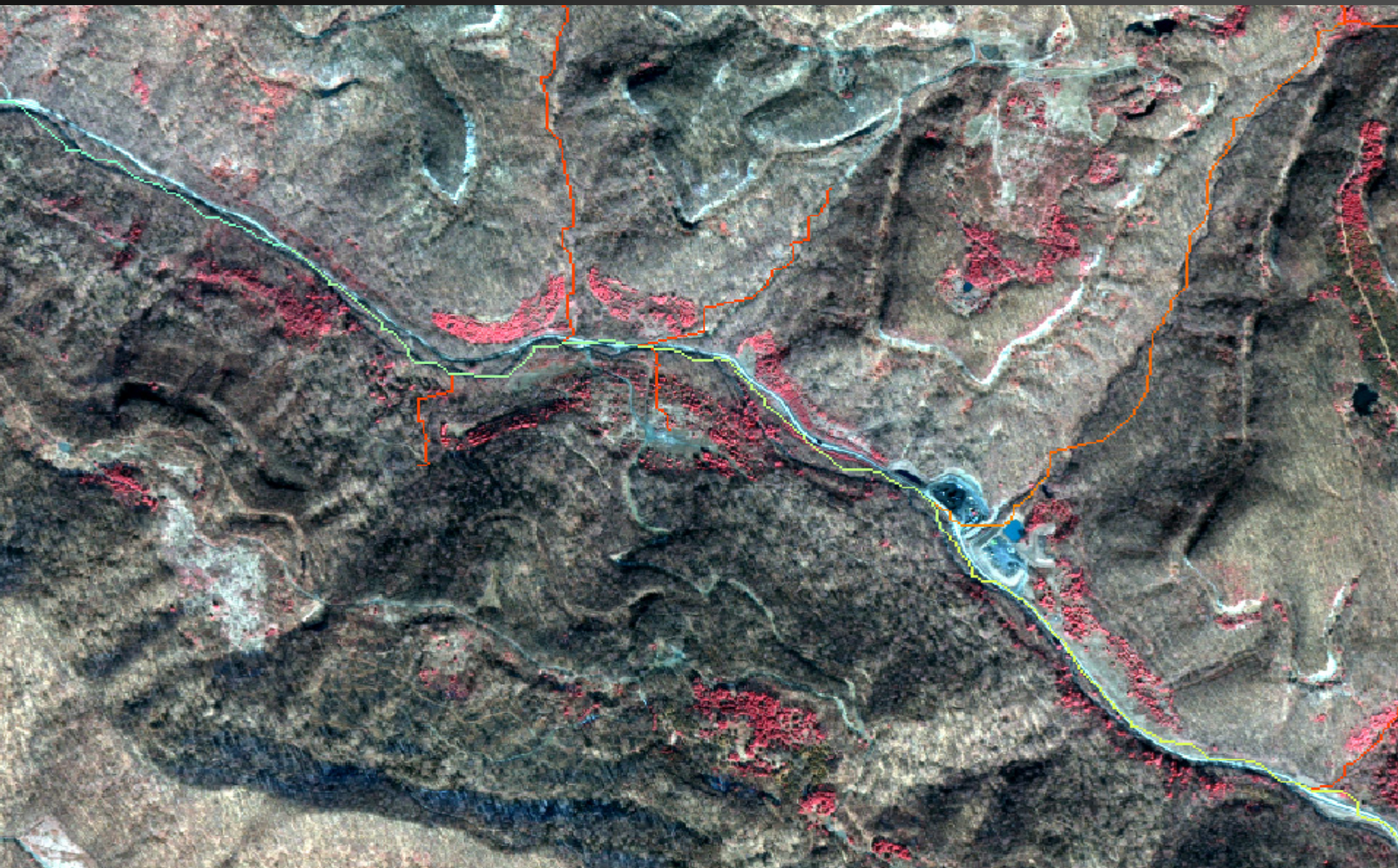
- Stereo pairs of aerial and satellite imagery are used to generate topographic contours of the mine site
- Cost effective method that allows OSM mine teams to analyze bond amounts and pit closure plans
- ArcGIS 3-D analyst and EarthVision are used to do volumetric analysis
- Topography is also used for surface water hydrologic studies

IKONOS DEM- 5m posting




IKONOS 1m data with 10ft contours

Flow Accumulation Grid



Impoundment Failure Analysis

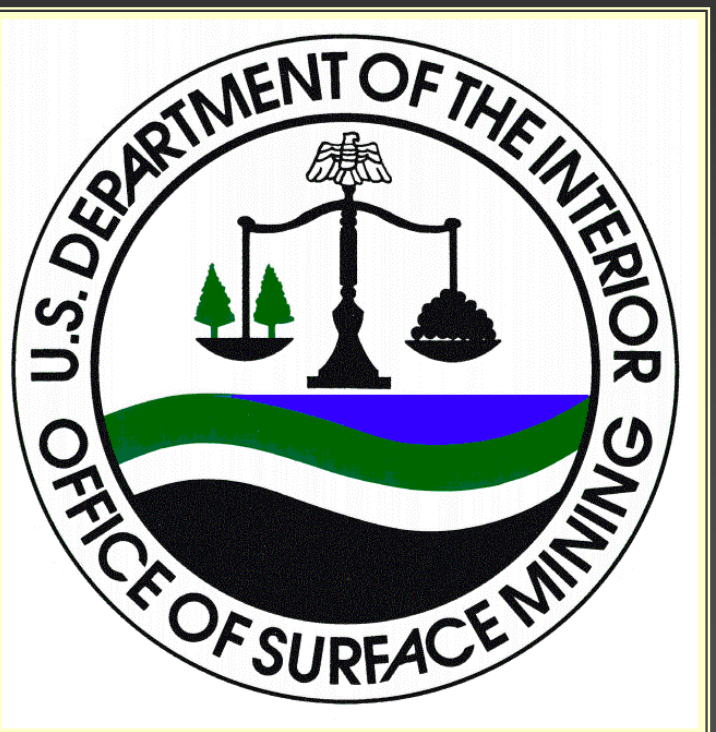
Conclusions

- **High Resolution Satellite Imagery is a good tool for monitoring surface coal mining**
  - **Data licensing restricts distribution**
  - **Derived topographic information is not suitable for engineering grade volumetric analysis**
  - **Future vendor policies and better satellites may allow satellite imagery to replace aerial photos**

Conclusions

- Remote Sensing is an Operational Tool in the Western Region
- Inspectors are the biggest adopters of the technology
  - Mobile Computing, GIS, and GPS are all used by Inspection Staff
  - Remote Sensing is a great complement to these technologies

For More Information:



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