

# GIS and Spatial Analyst for Topsoil Regulatory Compliance

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2010 ESRI International User Conference  
July 11 – 16, 2010  
San Diego CA

Environmental impacts from coal mining prompted the U.S. Congress to enact **SMCRA**

-- The Surface Mining Control and Reclamation Act of 1977 --

Office of Surface Mining Reclamation and Enforcement (OSM)

SMCRA is:

Public Law 95-87

Federal laws and regulations

Standards for environmental protection

OSM Partners with States and Tribes to:

Assure lands affected by coal mine operations are returned to productive use under mandates of SMCRA

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SMCRA are federal laws and regulations defining the minimum requirements for the performance of specific activities during coal mining operations.

SMCRA sets standards for environmental protection that must be met to ensure that lands affected by coal mine operations are returned to productive use.

Sound science and proper application of technology are foundations for effectively implementing SMCRA

Use of geospatial technology can be a valuable tool towards the application of SMCRA



One common SMCRA activity concerns regulations addressing the removal, storage, and redistribution of topsoil



For example...

Regulatory Specialist visits mine site to monitor topsoil depth

Location and depth of topsoil samples collected using GPS

Coordinates and data converted into a point feature class

Using ESRI's Spatial Analyst extension the point feature can be interpolated to a raster surface

Implement statistical methods, classification schemes, and surface analysis functions

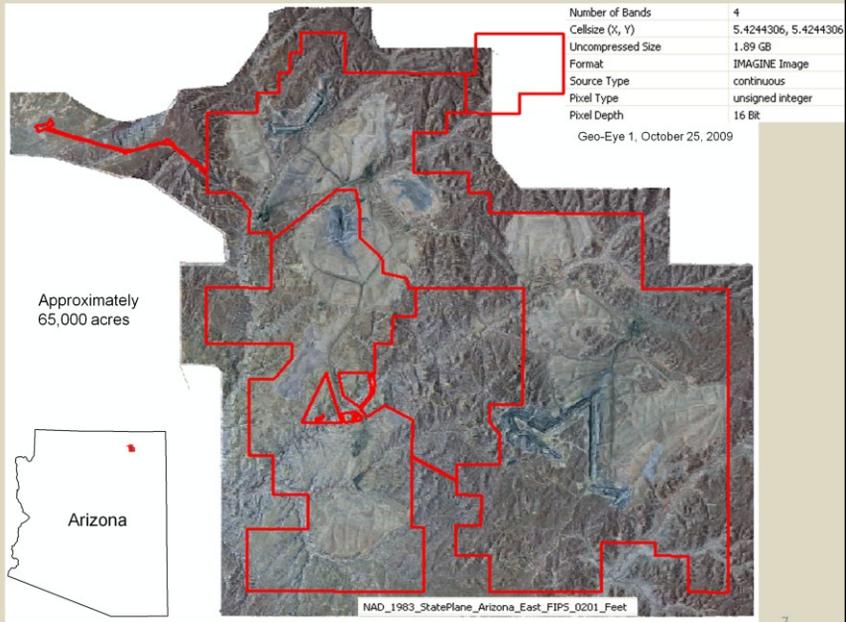
To derive models of topsoil depth distribution

5

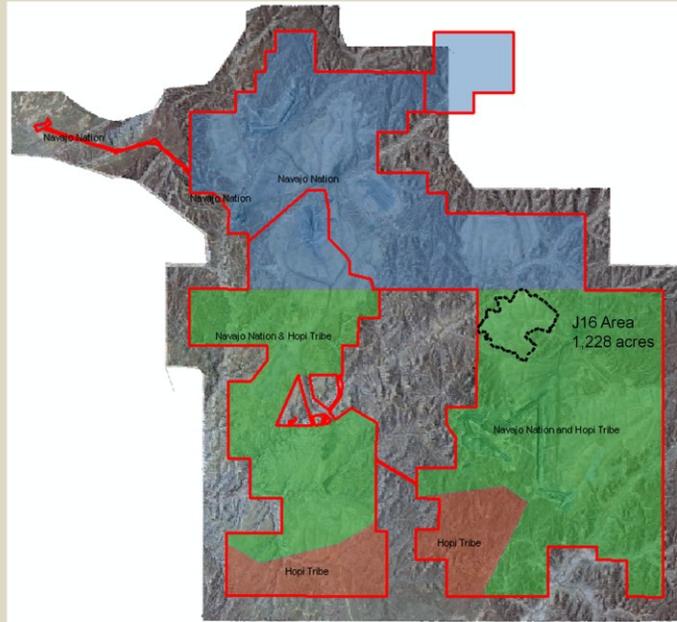
This presentation will describe modeling surface coal mine topsoil distribution using ESRI's Spatial Analyst extension

- Methodology for surface creation using interpolated points representing topsoil depth measurements
- Discuss classification schemes
- Value of cartography to aid in visual interpretation
- Statistical method to evaluate interpolation performance
- Illustrate a real-world example

# Blackmesa Complex Mine

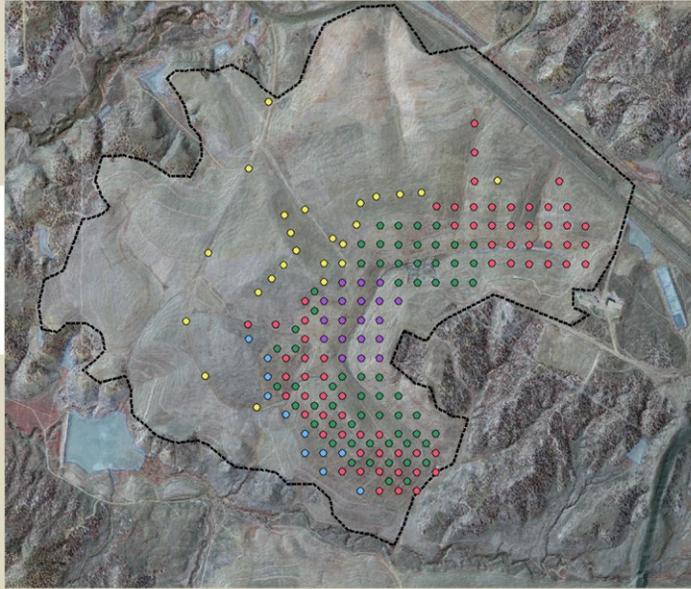


Area of Interest – J16

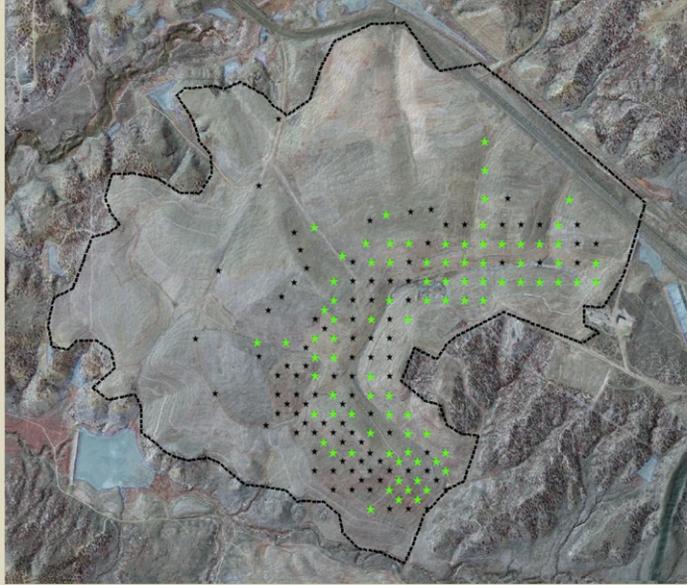


185 topsoil samples collected by PWCC  
Depth range 6 – 39 inches

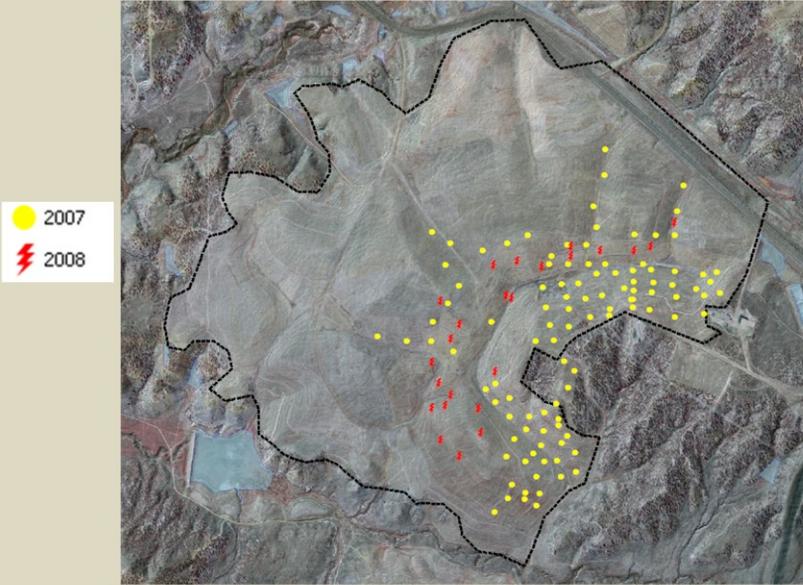
- 1994
- 1998
- 1999
- 2000
- 2001



86 of 185 PWCC collected samples report depth values



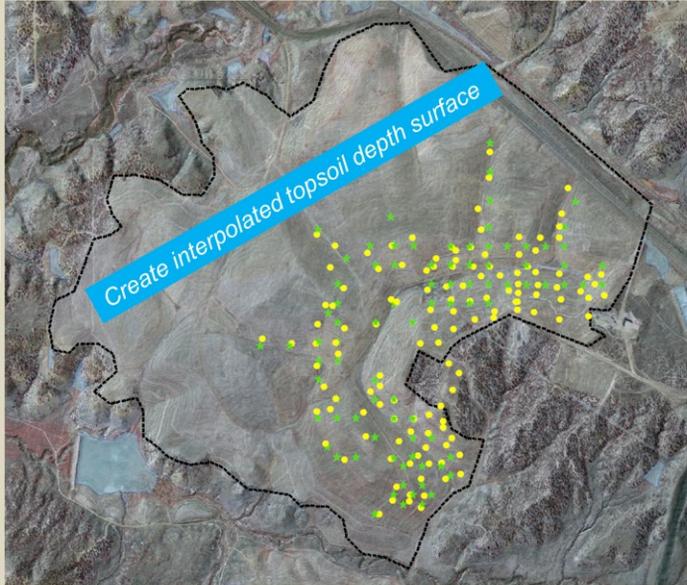
130 topsoil samples collected by OSM  
Depth range 6 – 38 inches



216 topsoil samples total  
Depth range 6 – 39 inches

CAVEAT  
Soil mechanics  
not considered

- 130 ● OSM
- 86 ★ PWCC



MERGE tables with unlike schema  
 Create new field in each table named Topsoil\_Depth, data type double  
 Use Field Calculator to transfer values

**Attributes of J16\_OSM\_Merge**

OBJECTID	Shape	type	date_gps	insp_id	jurisd	mine_name	nav_areas	brn_areas	kay_areas	mck_areas	rec_stat	location	comment	num_valu	GPS_Height	Topsoil_Depth
1	Point	Topsoil	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			16	6725.347	16
2	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			26	6660.503	26
3	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			15	6694.959	15
4	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			30	6741.145	30
5	Point	generic	6/10/2008	352	pp	other	null	null	16	null	vegetated			36	6700.736	36
6	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			30	6775.933	30
7	Point	generic	6/10/2008			other	null	null	null	null	vegetated			11	6744.479	11
8	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			13	6723.635	13
9	Point	generic	6/10/2008	352	pp	lavr	null	null	16	null	vegetated			30	6717.912	30
10	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			10	6746.799	10
11	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			36	6743.579	36
12	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			39	6737.989	39
13	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			11	6736.607	11
14	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			10	6719.263	10
15	Point	generic	6/11/2008	352	pp	lavr	null	null	16	null	vegetated			28	6717.854	28

**Attributes of overburden\_sample\_sites\_collected\_PWCC\_with\_TS\_depth**

OBJECTID	Shape	NAME	YEAR	MINE	SEASON	BondRet	fieldsoiddepth	mitigationABA	mitigationAll	mitigationrequired	Topsoil_Depth
80	Point	21R025	2001	J16	WINTER	On	13	12	12	+Null	13
81	Point	21R023	2001	J16	WINTER	On	19	12	12	+Null	19
82	Point	21R020	2001	J16	WINTER	On	21	24	24	+Null	21
83	Point	21R018	2001	J16	WINTER	On	16	48	48		32
84	Point	23R026	2001	J16	SPRING	On	19	12	12	+Null	19
85	Point	23R027	2001	J16	SPRING	On	25	12	12	+Null	25
86	Point	23R025	2001	J16	SPRING	On	21	48	48		27
45	Point	20R012	2000	J16	WINTER	On	10	12	26	+Null	10
46	Point	20R011	2000	J16	WINTER	On	10	24	48		14
47	Point	20R017	2000	J16	WINTER	On	14	12	12	+Null	14
48	Point	20R020	2000	J16	WINTER	On	14	12	12	+Null	14
49	Point	20R019	2000	J16	WINTER	On	21	36	48		15

Legend:  
 130 ● OSM  
 86 ★ PWCC

# Merge tables retaining date information and Topsoil\_Depth field

Now have table to create surface

- 130 ● OSM
- 86 ★ PWCC



**Merge**

Input Datasets

- \\smdennf02\gis\GISDEV\lanine\Topsoil\_2010\_UC\A\_Final\PM\_Topsoil.gdb\After\_...
- \\smdennf02\gis\GISDEV\lanine\Topsoil\_2010\_UC\A\_Final\PM\_Topsoil.gdb\After\_...

Output Dataset

\\smdennf02\gis\GISDEV\lanine\Topsoil\_2010\_UC\A\_Final\PM\_Topsoil.gdb\After\_Anal...

Field Map (optional)

- ☑ DATE\_GPS (Date)
- ☑ Topsoil\_Depth (Double)
- ☑ YEAR\_ (Short)

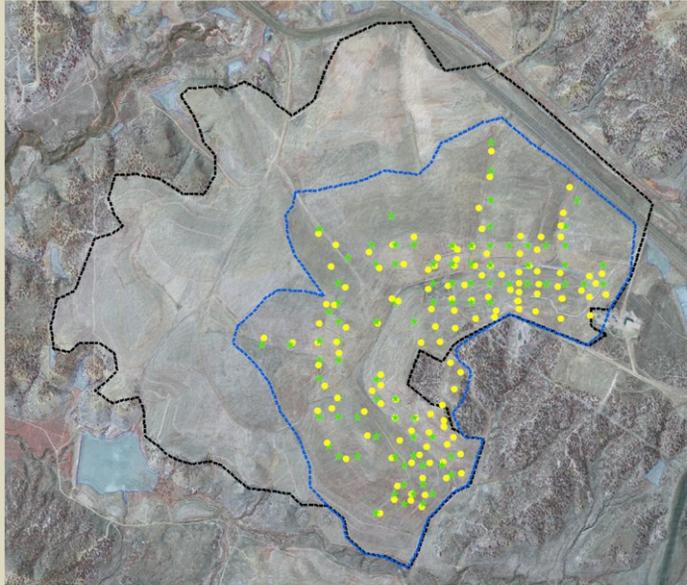
Cancel    Environments...    << Hide Help

**Attributes of J16\_OSM\_PWCC\_Merge**

OBJECTID *	Shape *	DATE_GPS	Topsoil_Depth	YEAR_
1	Point ZM	6/13/2007	12	<Null>
2	Point ZM	6/13/2007	14	<Null>
3	Point ZM	6/13/2007	6	<Null>
4	Point ZM	6/13/2007	31	<Null>
5	Point ZM	6/13/2007	26	<Null>
6	Point ZM	6/13/2007	26	<Null>
7	Point ZM	6/13/2007	12	<Null>
8	Point ZM	6/13/2007	23	<Null>
9	Point ZM	6/13/2007	17	<Null>
10	Point ZM	6/13/2007	31	<Null>
11	Point ZM	6/13/2007	28	<Null>
12	Point ZM	6/13/2007	28	<Null>
13	Point ZM	6/13/2007	26	<Null>
14	Point ZM	6/13/2007	20	<Null>
15	Point ZM	6/13/2007	12	<Null>

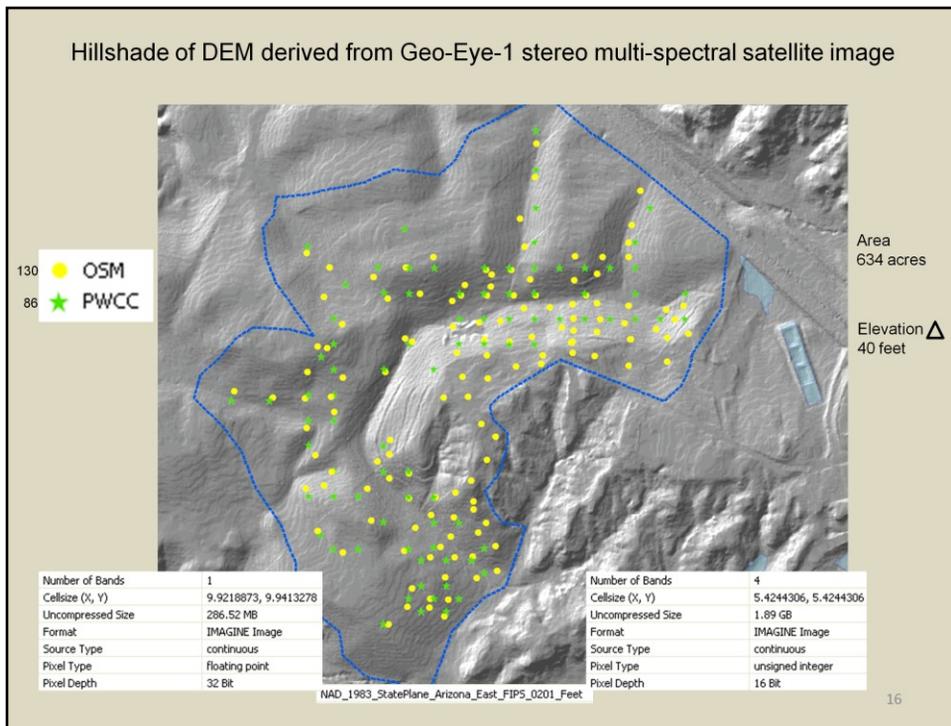
Record: 1 | Show: All Selected | Records (0 out of 216 Selected) | Options

Constrain AOI for interpolated surface to only Topsoil sample locations



15

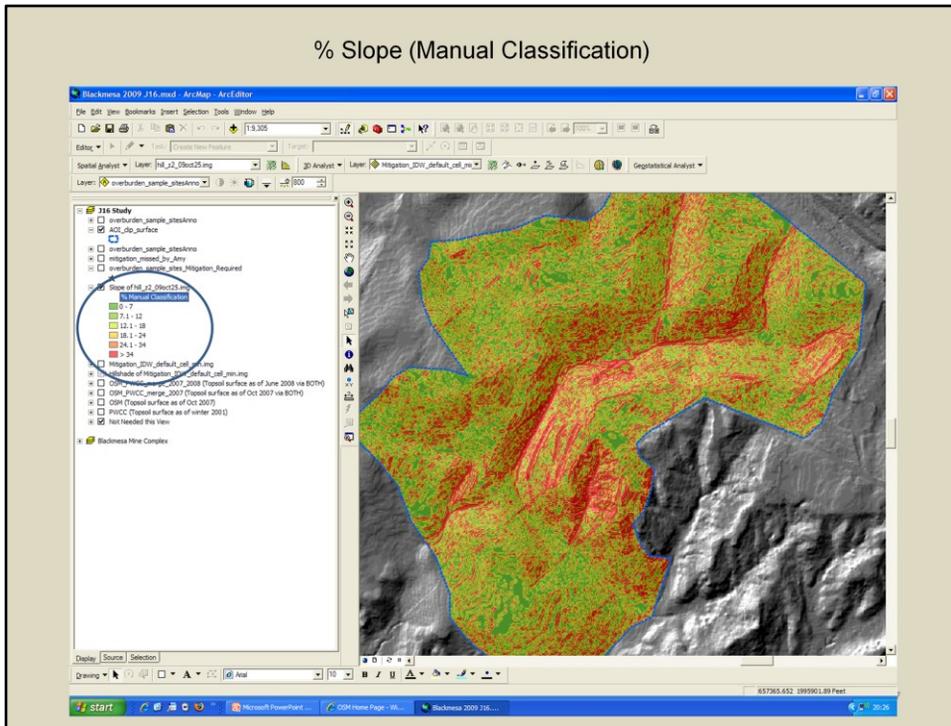
The interpolated surface will just “wang” extrapolate out to the edge of the black AOI if not constrained by the blue polygon mask. There’s no information out there so why plot it.



Diagonal distance SW to NE is 6600 ft. (about 1.25 miles, one and a quarter mile.)  
 Distance W to E is about the same.  
 Low contour 2040 ft., high contour 2080 ft. Area is 634 acres.

Distance W to E is about the same.

## % Slope (Manual Classification)





## Create interpolated surface

**Inverse Distance Weighted**

Input points: J16\_OSM\_PWCC\_merge\_2

Z value field: Topsoil\_Depth

Power: 2

Search radius type: Variable

Search Radius Settings

Number of points: 12

Maximum distance:

Use barrier polylines: OSM\_PWCC\_all\_c1

Output cell size: 37.5812989

Output raster: \\isdennf02\gis\GISDEV\Jani

OK Cancel

### Why IDW?

*Easy to conceptualize*

*Estimates values for locations as weighted average of nearby data points*

*Weight is inversely proportional to distance squared*

*therefore,*

- *More distant locations are less influential*
- *Estimated values never exceed range of data values*
- *Suited for samples independent of strong regional trends*

The only sure way to determine the best map is to empirically verify the results!

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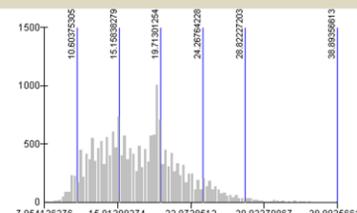
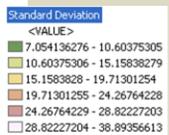
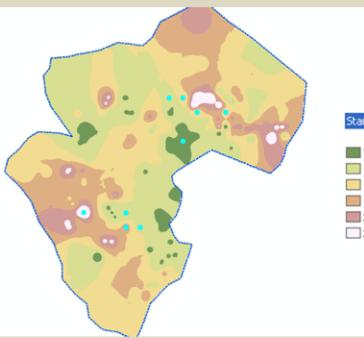
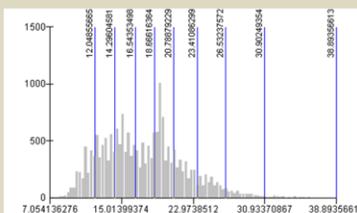
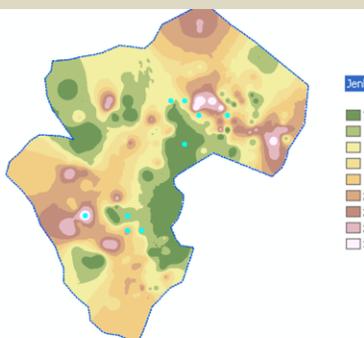
The IDW algorithm first uses the Pythagorean Theorem to calculate the Distance from a Grid Location to each of the data samples within the summary window. Then the distances are converted to weights that are inversely proportional to the distance ( $1/D^2$ ) effectively making more distant locations less influential. The sample values are multiplied by their corresponding computed weights and the “sum of the products” is divided by the “sum of the weights” to calculate a weighted average estimate. The estimate is assigned to the center cell location and the process is repeated for all map locations. The IDW procedure uses a fixed, geometric-based method to estimate map values at locations that were not sampled.

Classify the surface -- using which scheme?

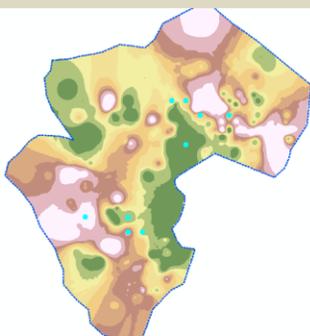
<b>Natural Breaks (Jenk's)</b>	Finds inherent groupings and patterns	Data unevenly distributed and gaps between groups of values
<b>Standard Deviation</b>	Each class defined by its distance from mean of all	Data evenly distributed and emphasize difference between features
<b>Quantile</b>	Each class has equal number of features in it	
<b>Equal Interval</b>	Each class has equal range of values	Data evenly distributed and emphasize relative difference between features
<b>Manual</b>		

Place features with similar values into the same class  
Make the difference in values between classes as great as possible

## Default Classification Schemes



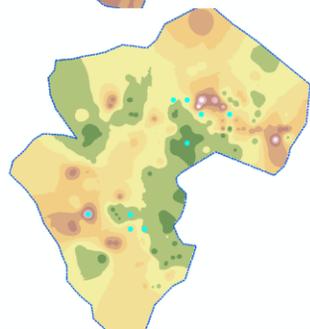
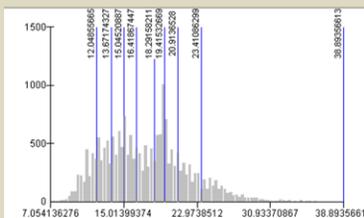
## Default Classification Schemes



**Quantile**

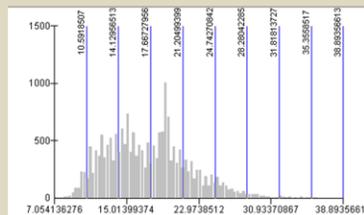
<VALUE>

7.054136276 - 12.04855665
12.04855666 - 13.67174327
13.67174328 - 15.04520887
15.04520888 - 16.41867447
16.41867448 - 18.29158211
18.29158212 - 19.41532669
19.4153267 - 20.9136528
20.91365281 - 23.41086299
23.410863 - 38.89356613



**Equal Interval**

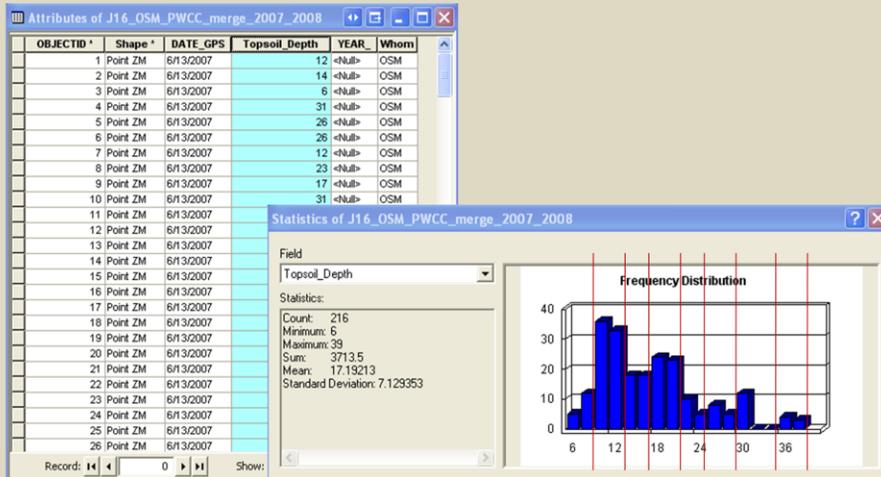
7.054136276 - 10.5918507
10.59185071 - 14.12956513
14.12956514 - 17.66727956
17.66727957 - 21.20499399
21.204994 - 24.74270842
24.74270843 - 28.28042285
28.28042286 - 31.81813727
31.81813728 - 35.3558517
35.35585171 - 38.89356613



Software default  
for this dataset

Try manual

## Manual Classification Scheme



Range [6 – 39]

Manual classification

8 classes

Break values at 10,14,18, 22, 26, 28, 36, 39

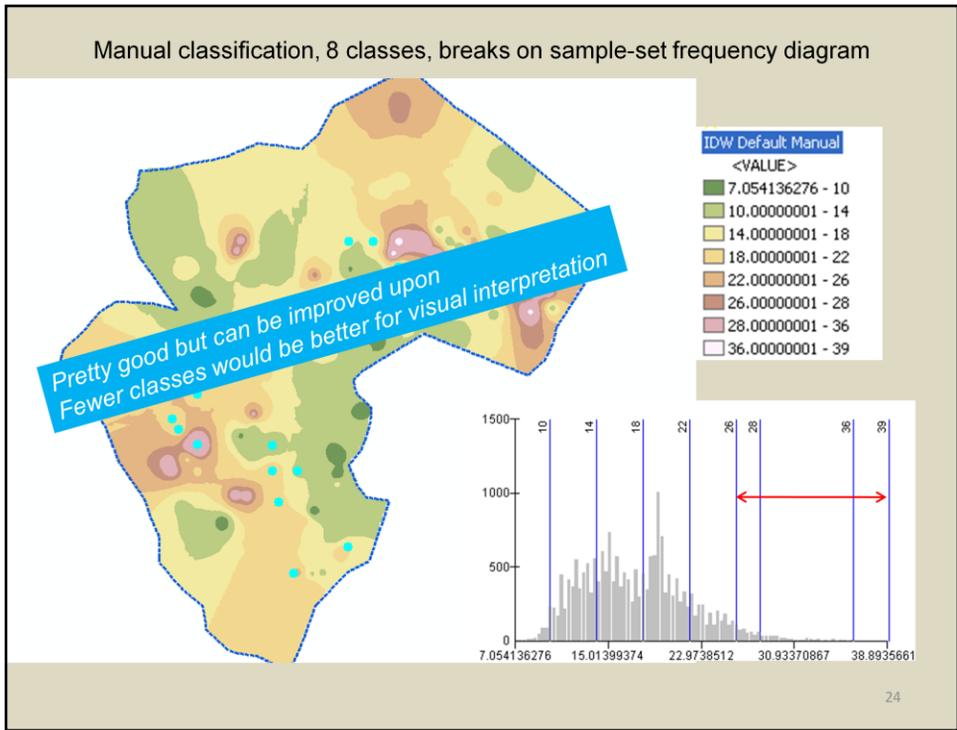
Mode = 12, with close second of 10  
(22 samples have depth of 12 inches)  
(21 samples have depth of 10 inches)

31 unique depth values

23

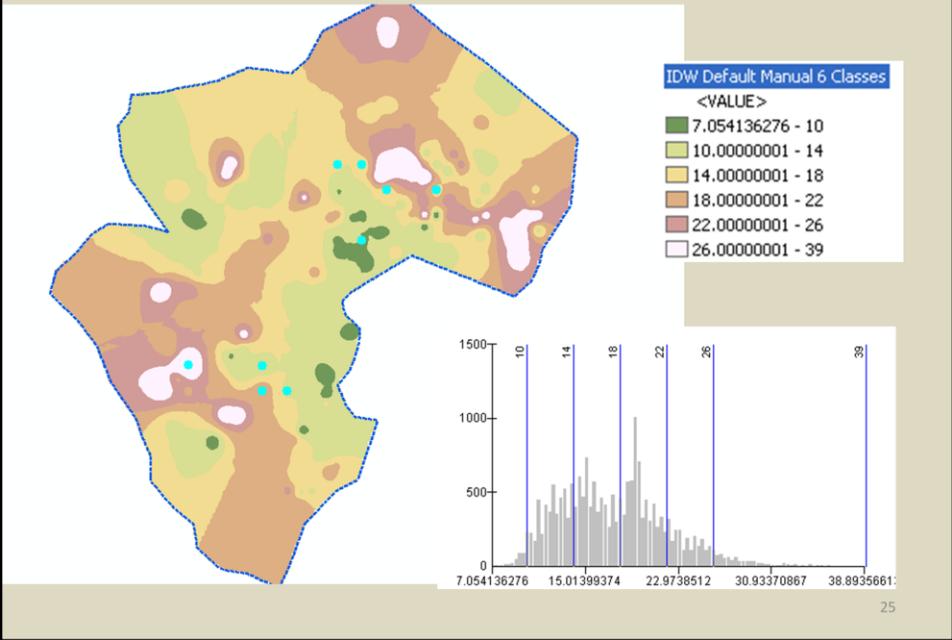
Mode = 12, with close second of 10  
(22 samples have depth of 12 inches)  
(21 samples have depth of 10 inches)

Manual classification, 8 classes, breaks on sample-set frequency diagram

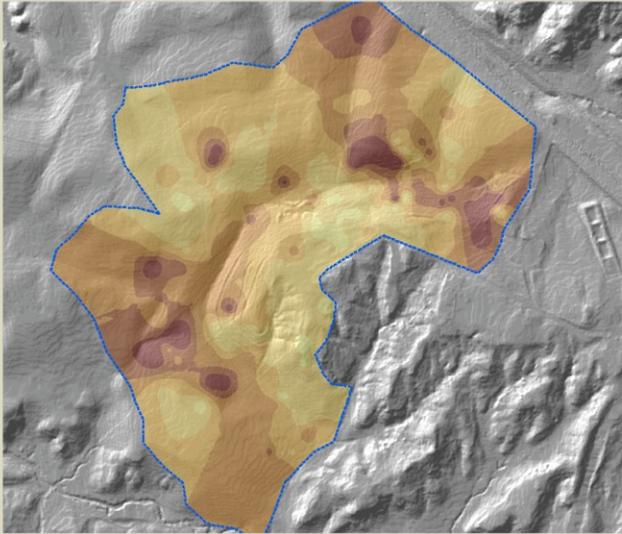


Combine the last three bins into a single class.

Manual classification, 6 classes, three highest bins combined



“Show me some cartography”



Color Ramp:  
Yellow to Dark Red

Transparency:  
60%

Overlay on hillshade of  
regional area

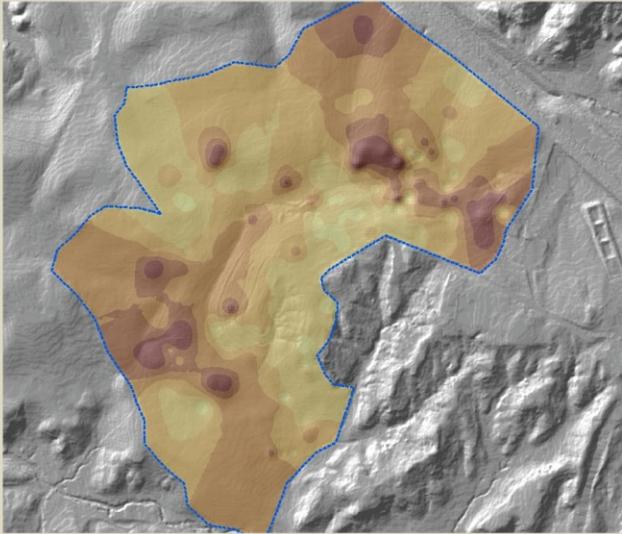
Adjust Legend precision

IDW Default Manual 6 Classes

Topsoil Depth inches

7.0 - 10.0
10.1 - 14.0
14.1 - 18.0
18.1 - 22.0
22.1 - 26.0
26.1 - 39.0

“Show me some cartography”



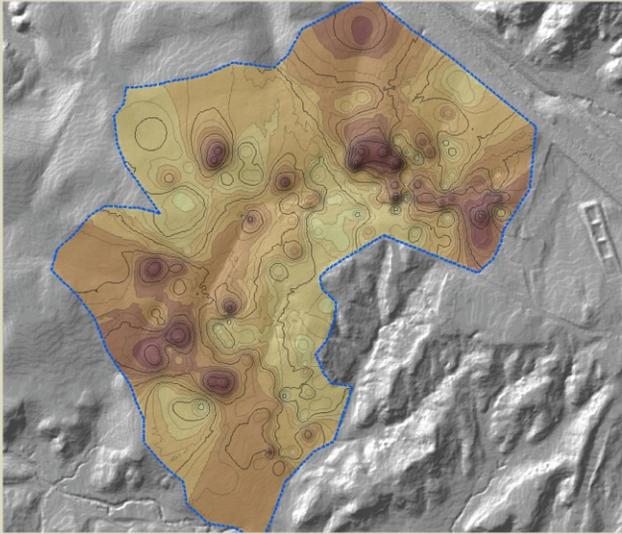
50 % transparent  
Hillshade of topsoil surface  
set in-between

IDW Default Manual 6 Classes

Topsoil Depth inches

- 7.0 - 10.0
- 10.1 - 14.0
- 14.1 - 18.0
- 18.1 - 22.0
- 22.1 - 26.0
- 26.1 - 39.0

### 2008 Topsoil Depth Surface J-16 Blackmesa Mine Complex



1-inch contours  
80% Gray, width 1  
65% transparent

4-inch contours  
Black, width 0.40  
40% transparent

IDW Default Manual 6 Classes

Topsoil Depth inches

- 7.0 - 10.0
- 10.1 - 14.0
- 14.1 - 18.0
- 18.1 - 22.0
- 22.1 - 26.0
- 26.1 - 39.0

## Evaluate Interpolation Performance

### Residual Analysis

Empirical verification technique

Summarizes differences between interpolation estimates and actual measurements for test locations

Starting point for determining accuracy

29

How accurate is the map. A pretty surface does not necessarily imply a valid surface!

Choose test set that contains at least one point for each unique data group. In this IDW interpolated surface there were 11 unique groups, so I chose 25 test points.

ALSO, must assure test points are spatially distributed.

In a strict, rigorous analysis you would carry out this performance evaluation on other interpolation methods and choose the best.

### Determine Residuals for Test Set

The screenshot displays the ArcGIS interface. On the left is a contour map. The 'Identify' window is open, showing the selected point ID '38.893566' in a red box. An arrow points from this box to the 'Attributes of J16\_Residual\_Analysis\_selected' window. This window contains a table with the following data:

OBJECTID	Shape	Topsoil_Depth	Surface_Prediction	Residual
1	Point ZM	28	27.65	-0.35
2	Point ZM	38	37.96	-0.04
3	Point ZM	12	12.18	-0.18
4	Point ZM	14	13.96	-0.04
5	Point ZM	20	19.84	-0.16
6	Point ZM	12	12.03	0.03
7	Point ZM	8	8.29	-0.29
8	Point ZM	7	7.85	0.85
9	Point ZM	9	9.11	0.11
10	Point ZM	13	13.01	0.01
11	Point ZM	22	21.84	-0.16
12	Point ZM	19	19.01	0.01
13	Point ZM	10	10.12	0.12
14	Point ZM	30	29.61	-0.39
15	Point ZM	27	26.96	-0.04
16	Point ZM	11	11.01	0.01
17	Point ZM	23	23	0
18	Point ZM	39	38.89	-0.11
19	Point ZM	24	23.72	-0.28
20	Point ZM	18	18.03	0.03
22	Point ZM	15	15.48	0.48
23	Point ZM	36	35.95	-0.05
24	Point ZM	13	13.02	0.02
25	Point ZM	25	24.85	-0.15

Residual = (Surface Prediction – Topsoil Depth)

## Calculate Statistics for Test Samples

	A	B	C	D	E	F
1	TEST SAMPLE ID	Topsoil_Depth	Surface_Prediction	Residual		
2	1	28	27.65	-0.35		
3	2	38	37.96	-0.039999		
4	3	12	12.18	0.18		
5	4	14	13.96	-0.039999		
6	5	20	19.84	-0.16		
7	6	12	12.03	0.029999		
8	7	8	8.29	0.289999		
9	8	7	7.85	0.85		
10	9	9	9.11	0.109999		
11	10	13	13.01	0.009999		
12	11	22	21.84	-0.16		
13	12	19	19.01	0.01		
14	13	10	10.12	0.119999		
15	14	30	29.61	-0.39		
16	15	27	26.96	-0.039999		
17	16	11	11.01	0.009999		
18	17	23	23	0		
19	18	39	38.89	-0.109999		
20	19	24	23.72	-0.28		
21	20	18	18.03	0.03		
22	22	15	15.48	0.48		
23	23	36	35.95	-0.049999		
24	24	13	13.02	0.019999		
25	25	25	24.85	-0.149999		
26	Average value =	19.71	19.72			
27	Residual sum =			0.37		
28	Average error =			0.02		
29	Normalized error =			0.04	0.02 / 19.72	

31

Residual = (Surface Prediction – Topsoil Depth)

Average value is actual measured topsoil depth

Residual sum is a measure of bias. A negative value indicates underestimation.

Average error is absolute value of (bias/n)

Normalized error is (Average error/Average value). It calculates average error as a proportion of the average value for the set of test samples. It is the most useful index because it enables the comparison of the relative map accuracies between different maps.

Generally speaking, maps with normalized errors of ore than .30 are suspect and one might not want to make important decisions using them.

In a rigorous analysis you would map the surface of residuals to determine WHERE the interpolated surface is over or under estimating.

**IDW Interpolated Surface is Accurate**

**Classification Scheme and Cartography to Aid Visual Interpretation**

**Have Confidence in Using Surface for Decision Making**

**Put the Surface to Work!**

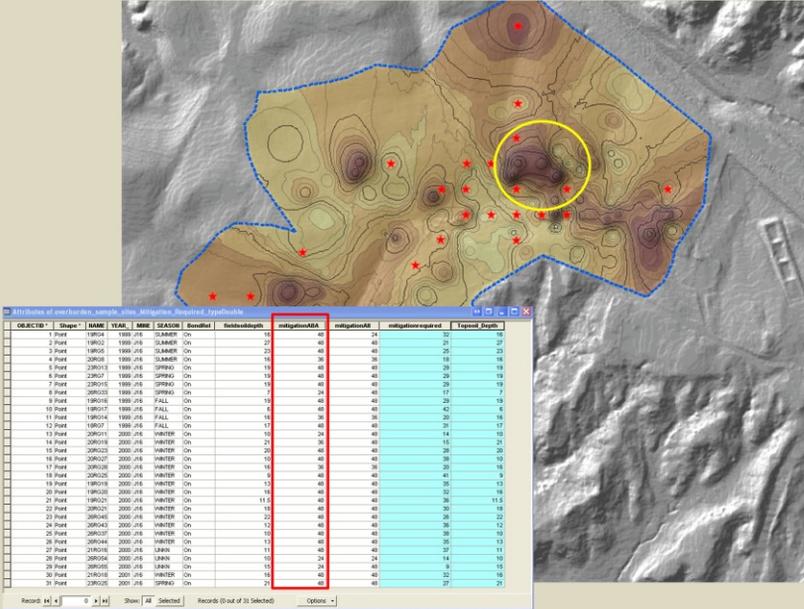
## Current Concerns

Acid Base Accounting (ABA) poor in many locations

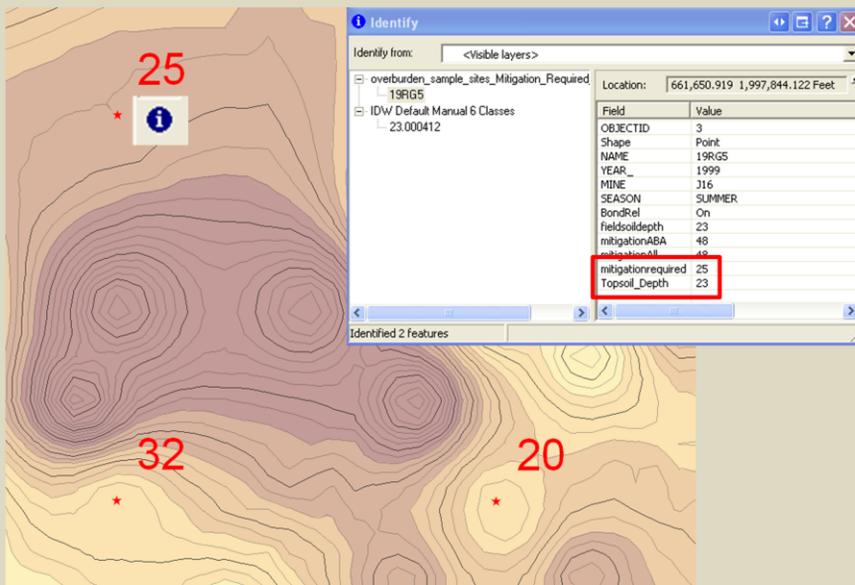
Mitigation: additional soil required at problem sites



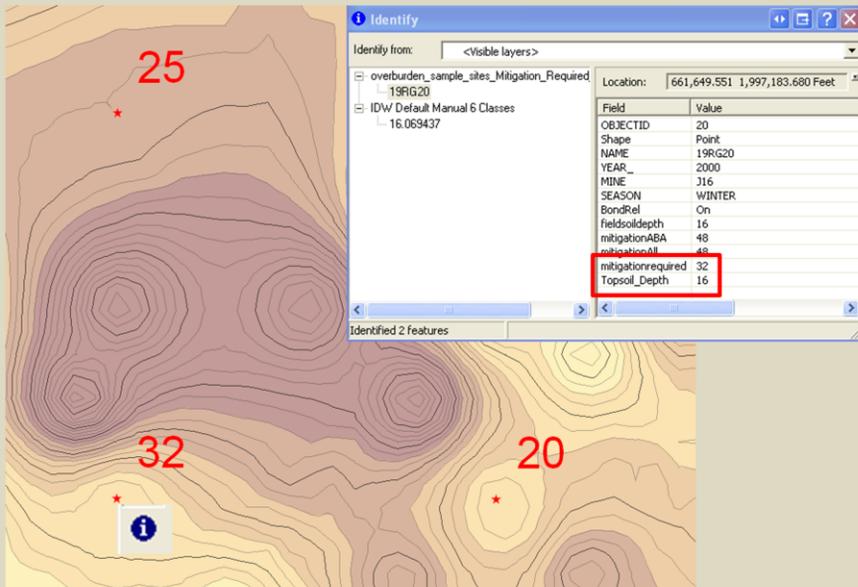
31 of the topsoil depths are problematic and require mitigation



# Problematic and require mitigation



# Problematic and require mitigation





## Merge excluded sites with mitigation sites

Attributes of J16\_OSM\_PWCC\_merge\_2007\_2008\_less\_mitigation

OBJECTID	Shape	DATE_GPS	Topsoil_Depth	YEAR	Whom
1	Point ZM	6/13/2007	12	<Null>	OSM
2	Point ZM	6/13/2007	14	<Null>	OSM
3	Point ZM	6/13/2007	6	<Null>	OSM
4	Point ZM	6/13/2007	31	<Null>	OSM
5	Point ZM	6/13/2007	26	<Null>	OSM
6	Point ZM	6/13/2007	26	<Null>	OSM
7	Point ZM	6/13/2007	12	<Null>	OSM
8	Point ZM	6/13/2007	23	<Null>	OSM
9	Point ZM	6/13/2007	17	<Null>	OSM
10	Point ZM	6/13/2007	31	<Null>	OSM
11	Point ZM	6/13/2007	26	<Null>	OSM
12	Point ZM	6/13/2007	26	<Null>	OSM
13	Point ZM	6/13/2007	26	<Null>	OSM
14	Point ZM	6/13/2007	20	<Null>	OSM

Record: 14 | 0 | Show: All Selected | Records (0 out of 165 selected) | Options

Use mitigation depth for new Topsoil\_Depth

Still have 216 samples

Attributes of overburden\_sample\_sites\_Mitigation\_Required\_typeDouble

OBJECTID	Shape	NAME	YEAR	MINE	SEASON	BondRel	fieldsoildepth	mitigationABA	mitigationAll	mitigationrequired	Topsoil_Depth
1	Point	19RG4	1999	J16	SUMMER	On	16	48	24	32	16
2	Point	19RG2	1999	J16	SUMMER	On	27	48	48	21	27
3	Point	19RG5	1999	J16	SUMMER	On	23	48	48	25	23
4	Point	20RG8	1999	J16	SUMMER	On	16	36	36	16	16
5	Point	23RG13	1999	J16	SPRING	On	19	48	48	29	19
6	Point	23RG7	1999	J16	SPRING	On	19	48	48	29	19
7	Point	23RG15	1999	J16	SPRING	On	19	48	48	29	19
8	Point	26RG33	1999	J16	SPRING	On	7	24	48	17	7
9	Point	19RG16	1999	J16	FALL	On	19	48	48	29	19
10	Point	19RG17	1999	J16	FALL	On	6	48	48	42	6
11	Point	19RG14	1999	J16	FALL	On	16	36	36	20	16
12	Point	18RG7	1999	J16	FALL	On	17	48	48	31	17
13	Point	20RG11	2000	J16	WINTER	On	10	24	48	14	10

Record: 14 | 0 | Show: All Selected | Records (0 out of 31 selected) | Options

In other words...

OBJECTID	Shape	DATE_GPS	Topsoil_Depth	YEAR	Whom	mitigationABA	mitigationrequired
177	Point ZM	6/11/2008	10	<Null>	Amy	<Null>	<Null>
178	Point ZM	6/11/2008	11	<Null>	Amy	<Null>	<Null>
179	Point ZM	6/11/2008	11	<Null>	Amy	<Null>	<Null>
180	Point ZM	6/11/2008	13	<Null>	Amy	<Null>	<Null>
181	Point ZM	6/11/2008	25	<Null>	Amy	<Null>	<Null>
182	Point ZM	6/11/2008	22	<Null>	Amy	<Null>	<Null>
183	Point ZM	6/11/2008	19	<Null>	Amy	<Null>	<Null>
184	Point ZM	6/11/2008	21	<Null>	Amy	<Null>	<Null>
185	Point ZM	6/11/2008	21	<Null>	Amy	<Null>	<Null>
186	Point ZM	<Null>	16	1999	<Null>	48	32
187	Point ZM	<Null>	27	1999	<Null>	48	21
188	Point ZM	<Null>	23	1999	<Null>	48	25
189	Point ZM	<Null>	16	1999	<Null>	36	18
190	Point ZM	<Null>	19	1999	<Null>	48	29
191	Point ZM	<Null>	19	1999	<Null>	48	29
192	Point ZM	<Null>	19	1999	<Null>	48	29
193	Point ZM	<Null>	7	1999	<Null>	24	17
194	Point ZM	<Null>	19	1999	<Null>	48	29
195	Point ZM	<Null>	6	1999	<Null>	48	42
196	Point ZM	<Null>	16	1999	<Null>	36	20
197	Point ZM	<Null>	17	1999	<Null>	48	31
198	Point ZM	<Null>	10	2000	<Null>	24	14
199	Point ZM	<Null>	21	2000	<Null>	36	15
200	Point ZM	<Null>	20	2000	<Null>	48	28
201	Point ZM	<Null>	10	2000	<Null>	48	38
202	Point ZM	<Null>	16	2000	<Null>	36	20
203	Point ZM	<Null>	9	2000	<Null>	48	41
204	Point ZM	<Null>	13	2000	<Null>	48	35
205	Point ZM	<Null>	16	2000	<Null>	48	32
206	Point ZM	<Null>	11.5	2000	<Null>	48	36
207	Point ZM	<Null>	18	2000	<Null>	48	30
208	Point ZM	<Null>	22	2000	<Null>	48	26
209	Point ZM	<Null>	12	2000	<Null>	48	36
210	Point ZM	<Null>	10	2000	<Null>	48	38
211	Point ZM	<Null>	13	2000	<Null>	48	35
212	Point ZM	<Null>	11	2000	<Null>	48	37
213	Point ZM	<Null>	10	2000	<Null>	24	14
214	Point ZM	<Null>	15	2000	<Null>	24	9
215	Point ZM	<Null>	16	2001	<Null>	48	32
216	Point ZM	<Null>	21	2001	<Null>	48	27

Create interpolated surface which includes mitigation and will represent "should-be"

OBJECTID	Shape	DATE_GPS	Topsoil_Depth	YEAR	Whom	mitigationABA	mitigationrequired
178	Point ZM	6/11/2008	11	Nub	Amy	<Nub>	<Nub>
179	Point ZM	6/11/2008	11	Nub	Amy	<Nub>	<Nub>
180	Point ZM	6/11/2008	13	Nub	Amy	<Nub>	<Nub>
181	Point ZM	6/11/2008	25	Nub	Amy	<Nub>	<Nub>
182	Point ZM	6/11/2008	22	Nub	Amy	<Nub>	<Nub>
183	Point ZM	6/11/2008	19	Nub	Amy	<Nub>	<Nub>
184	Point ZM	6/11/2008	21	Nub	Amy	<Nub>	<Nub>
185	Point ZM	6/11/2008	21	Nub	Amy	<Nub>	<Nub>
186	Point ZM	<Nub>	48	1999	<Nub>	48	32
187	Point ZM	<Nub>	48	1999	<Nub>	48	21
188	Point ZM	<Nub>	48	1999	<Nub>	48	25
189	Point ZM	<Nub>	36	1999	<Nub>	36	18
190	Point ZM	<Nub>	48	1999	<Nub>	48	29
191	Point ZM	<Nub>	48	1999	<Nub>	48	29
192	Point ZM	<Nub>	48	1999	<Nub>	48	29
193	Point ZM	<Nub>	24	1999	<Nub>	24	17
194	Point ZM	<Nub>	48	1999	<Nub>	48	29
195	Point ZM	<Nub>	48	1999	<Nub>	48	42
196	Point ZM	<Nub>	36	1999	<Nub>	36	20
197	Point ZM	<Nub>	48	1999	<Nub>	48	31
198	Point ZM	<Nub>	24	2000	<Nub>	24	14
199	Point ZM	<Nub>	36	2000	<Nub>	36	15
200	Point ZM	<Nub>	48	2000	<Nub>	48	28
201	Point ZM	<Nub>	48	2000	<Nub>	48	38
202	Point ZM	<Nub>	36	2000	<Nub>	36	20
203	Point ZM	<Nub>	48	2000	<Nub>	48	41
204	Point ZM	<Nub>	48	2000	<Nub>	48	35
205	Point ZM	<Nub>	48	2000	<Nub>	48	32
206	Point ZM	<Nub>	48	2000	<Nub>	48	36
207	Point ZM	<Nub>	48	2000	<Nub>	48	30
208	Point ZM	<Nub>	48	2000	<Nub>	48	26
209	Point ZM	<Nub>	48	2000	<Nub>	48	36
210	Point ZM	<Nub>	48	2000	<Nub>	48	36
211	Point ZM	<Nub>	48	2000	<Nub>	48	35
212	Point ZM	<Nub>	48	2000	<Nub>	48	37
213	Point ZM	<Nub>	24	2000	<Nub>	24	14
214	Point ZM	<Nub>	24	2000	<Nub>	24	9
215	Point ZM	<Nub>	48	2001	<Nub>	48	32
216	Point ZM	<Nub>	48	2001	<Nub>	48	27

Record: 14 | Show: All Selected | Records (0 out of 216 Selected) | Options

Manual classification, 6 classes, use same breaks as previous classification

Attributes of J16\_Mitigation

OBJECTID	Shape	DATE_GPS	Topsoil_Depth	YEAR	Whom	mitigationABA	mitigationrequired
1	Point ZM	6/13/2007	12	<Null>	OSM	<Null>	<Null>
2	Point ZM	6/13/2007	14	<Null>	OSM	<Null>	<Null>
3	Point ZM	6/13/2007	6	<Null>	OSM	<Null>	<Null>
4	Point ZM	6/13/2007	31	<Null>	OSM	<Null>	<Null>
5	Point ZM	6/13/2007	26	<Null>	OSM	<Null>	<Null>
6	Point ZM	6/13/2007	26	<Null>	OSM	<Null>	<Null>
7	Point ZM	6/13/2007	12	<Null>	OSM	<Null>	<Null>
8	Point ZM	6/13/2007	23	<Null>	OSM	<Null>	<Null>
9	Point ZM	6/13/2007	17	<Null>	OSM	<Null>	<Null>
10	Point ZM	6/13/2007	31	<Null>	OSM	<Null>	<Null>
11	Point ZM	6/13/2007	28	<Null>	OSM	<Null>	<Null>
12	Point ZM	6/13/2007	28	<Null>	OSM	<Null>	<Null>
13	Point ZM	6/13/2007	26	<Null>	OSM	<Null>	<Null>
14	Point ZM	6/13/2007	20	<Null>	OSM	<Null>	<Null>
15	Point ZM	6/13/2007	12	<Null>	OSM	<Null>	<Null>
16	Point ZM	6/13/2007	12	<Null>	OSM	<Null>	<Null>
17	Point ZM	6/13/2007	38	<Null>	OSM	<Null>	<Null>
18	Point ZM	6/13/2007	12	<Null>	OSM	<Null>	<Null>
19	Point ZM	6/13/2007	28	<Null>	OSM	<Null>	<Null>

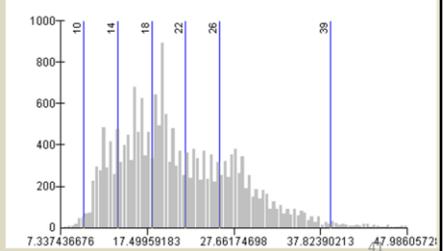
Record: 14 | 0 | Show: All Selected

Statistics of J16\_Mitigation

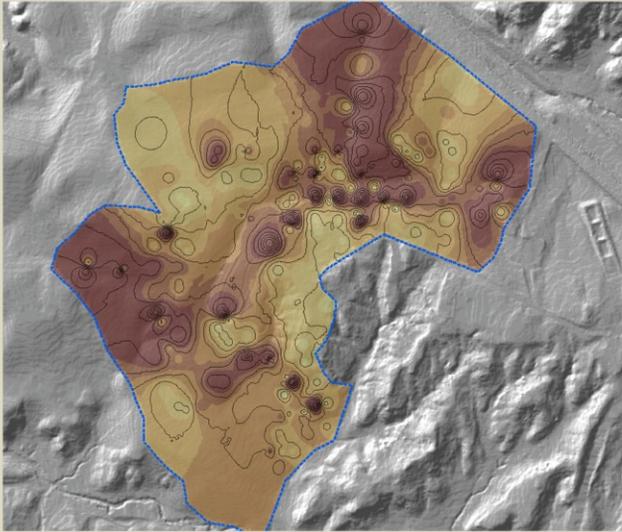
Field: Topsoil\_Depth

Statistics:

- Count: 216
- Minimum: 6
- Maximum: 48
- Sum: 4579
- Mean: 21.199074
- Standard Deviation: 11.802373



"Should-be" Topsoil Depth Surface J-16 Blackmesa Mine Complex



50 % transparent  
Hillshade of topsoil surface  
set in-between

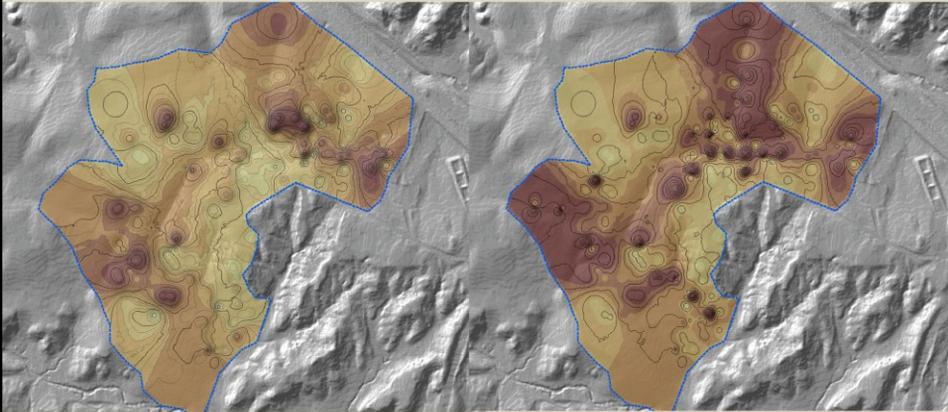
4-inch contours  
Black, width 0.40  
40% transparent

IDW of J16\_Mitigation

Topsoil Depth inches	
7.0 - 10.0	Lightest yellow
10.1 - 14.0	Yellow
14.1 - 18.0	Light orange
18.1 - 22.0	Orange
22.1 - 26.0	Dark orange
26.1 - Greater than 39.0	Dark red

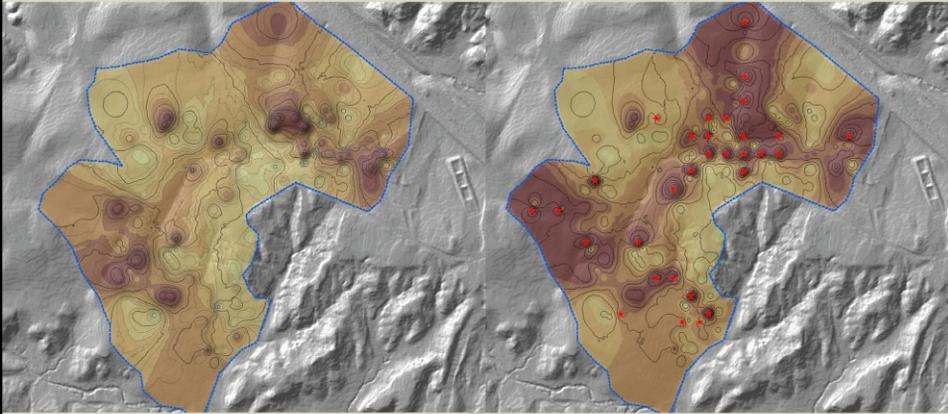
As-built

“Should-be”



As-built

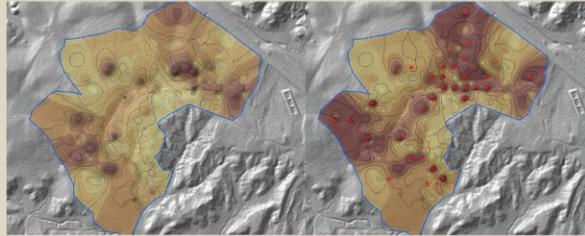
“Should-be”



## Conclusion

Science and the proper application of technology are foundations for effectively implementing SMCRA

GIS technology and ESRI's Spatial Analyst extension software can be used to create a visually pleasing, easily interpreted topsoil depth distribution surface from interpolated points

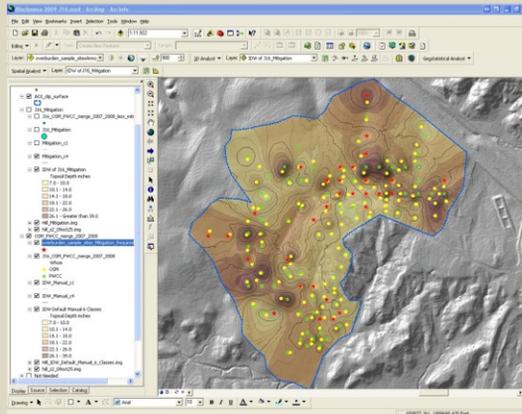


Sound  
Science

+

Accurate  
Technology

=



## Best Practices



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Thank-you for your attention

