

Presentation:

# Digability – A New Take on an Old Topic

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INTELLIGENT SOLUTIONS  
OPTIMUM SERVICE

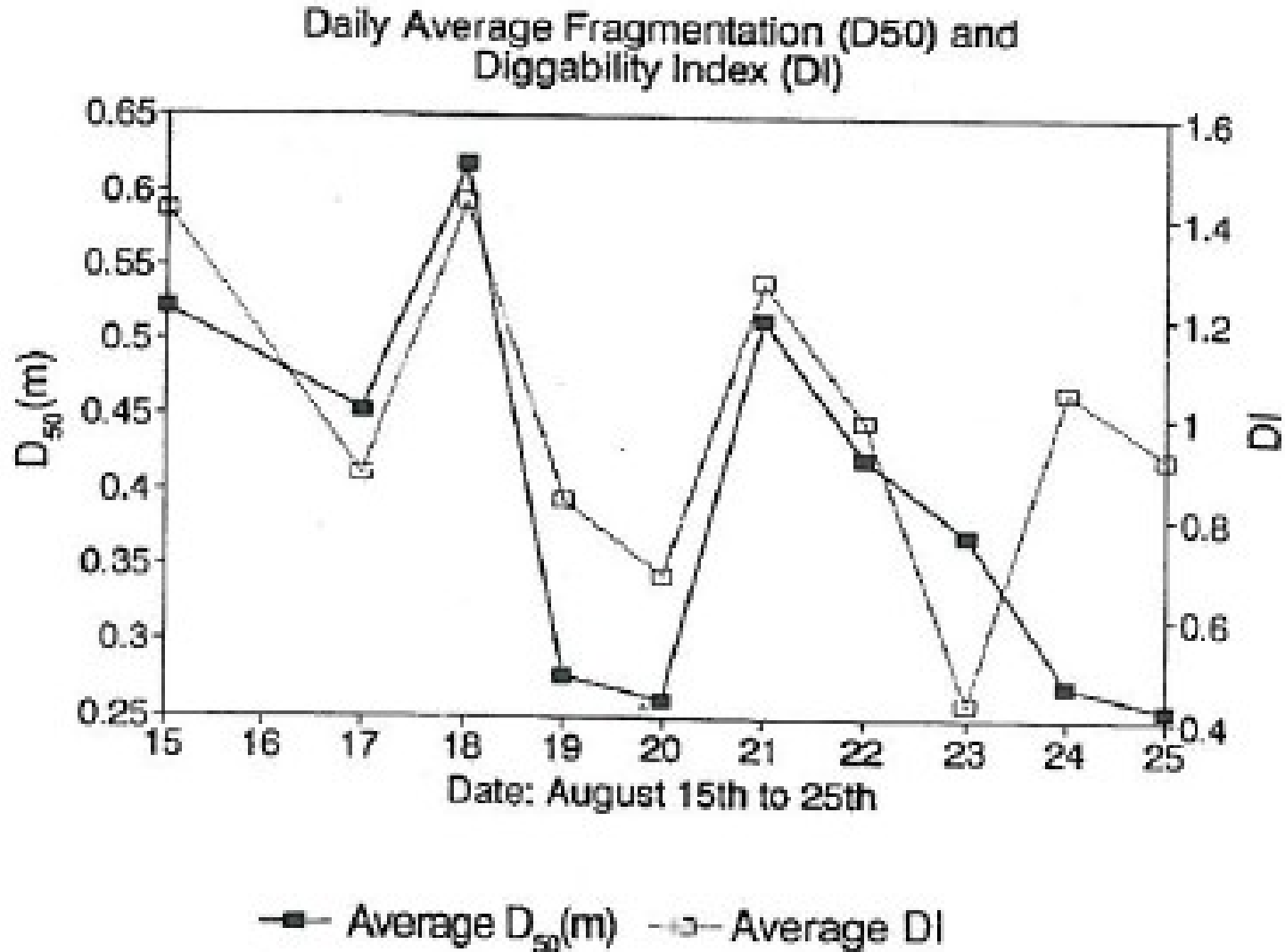
# Digability

1. History of Digability
2. Current Interpretation of Digability
3. How the Digability Index (DI) Metric is being used today
4. Future Possibilities of Digability



Excavation class	Ease of digging	Index ( $W+S+J+B$ )	Excavation method	Equipment type (without resort to blasting)
I	Very Easy	<40	1. Ripping	(A) Ripper-Scraper Caterpillar D8
			2. Dragline cast	(B) Dragline > 5 m <sup>3</sup> Lima 2400
			3. Shovel digging	(C) Rope Shovel > 3 m <sup>3</sup> Ruston Bucyrus 71 RB
II	Easy	40–50	1. Ripping	(A) Ripper-Scraper Caterpillar D9
			2. Dragline cast	(B) Dragline > 8 m <sup>3</sup> Marion 195
			3. Shovel digging	(C) Rope Shovel > 3 m <sup>3</sup> Ruston Bucyrus 150 RB
III	Moderately Difficult	50–60	1. Ripping	(A) Ripper-Shovel Caterpillar D9
			2. Shovel digging	(B) Hydraulic Shovel > 3 m <sup>3</sup> Caterpillar 245
IV	Difficult	60–70	1. Ripping	(A) Ripper-Shovel Caterpillar D10
			2. Shovel digging	(B) Hydraulic Shovel > 3 m <sup>3</sup> Cat. 245 or O&K RH 40
V	Very Difficult	70–95	Shovel digging	(A) Hydraulic Shovel > 3 m <sup>3</sup> Cat. 245 or O&K RH 40
VI	Extremely Difficult	95–100	Shovel digging	(A) Hydraulic Shovels > 7 m <sup>3</sup> Demag H111 Poclain 1000CK P&H 1200 O&K RH 75
VII	Marginal Without Blasting	>100	Shovel digging	(A) Hydraulic Shovels > 7 m <sup>3</sup> Demag H111, H241 O&K RH 300

# History of Digability



# Current Interpretation

The Digital / Computer improvements over the last decade has allowed for amazing ability of monitoring systems to:

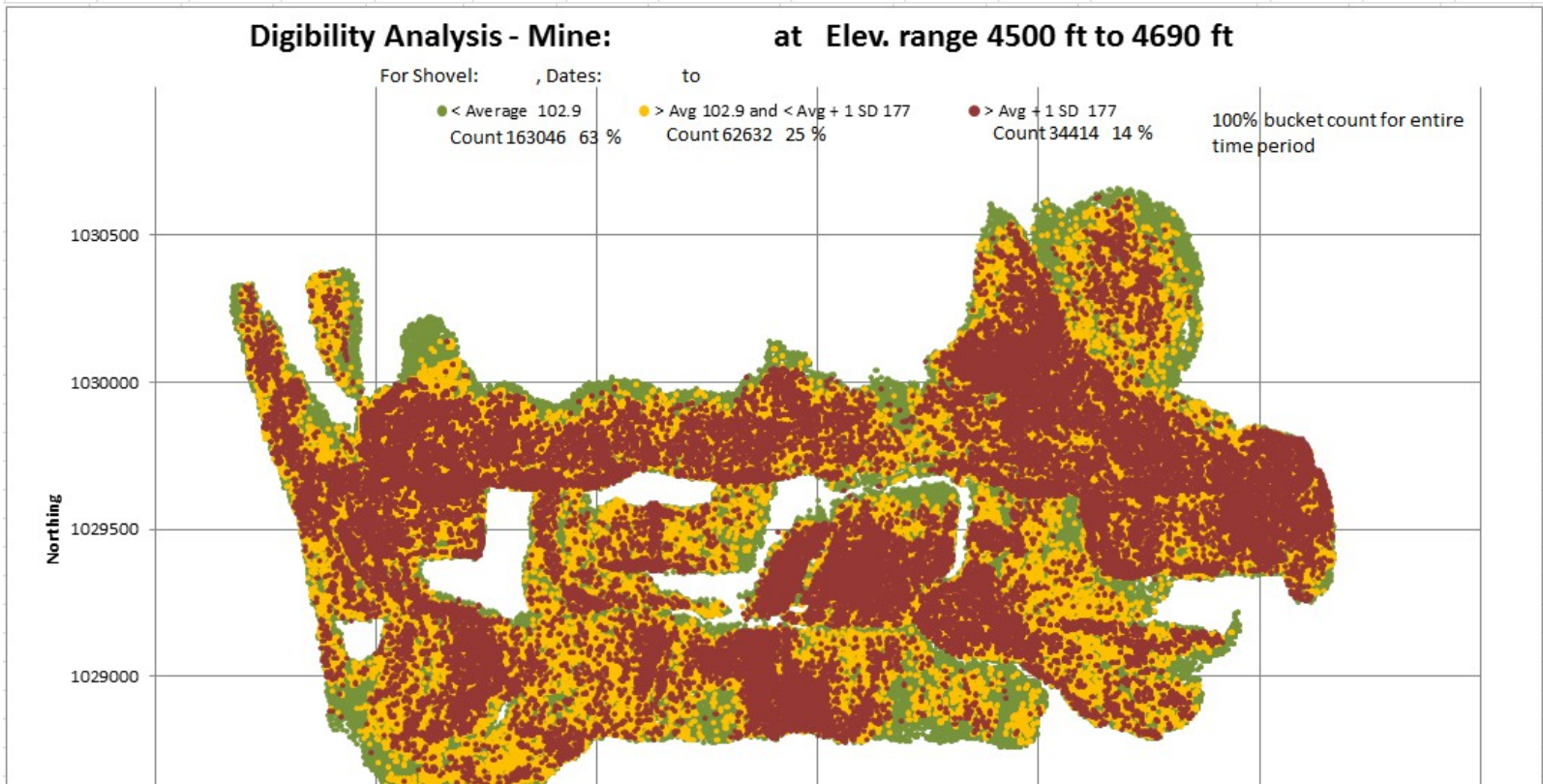
- Record accurate data for almost every aspect of shovels & draglines
- Make complex calculations within milliseconds of cycle completion
- Share and store all data on Machine, in Mine Office and at Corporate Head Quarters for easy trending

## Basic Equation

$$\text{Digability Index} = \frac{\textit{Fill Energy}}{\textit{Payload}}$$

# Today's Usage

## Analysis & Plotting



### Digability Production Evaluation Estimated Costs for Loss of Production @2 \$/BCY (75% Capture Rate)

Affect on Production	Green	Yellow	Red	Total Lost Yards @ 5000 BCY/hr	Costs Estimate
Bucket cycle times (sec)	32.9	35.9	42.1	521,168	\$1,042,335
Bucket payload (tons)	85.1	87.2	87.0	(201,620)	-\$403,239
					<b>\$639,096</b>

# Today's Usage

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<u>Operator #</u>	<u>Cycles</u>	<u>Average Digability</u>	<u>Digability: &lt; AVG</u>	<u>Digability: Avg &gt; +1</u>	<u>Digability: &gt; +1 SD</u>
Average	4187	101	60%	24%	12%
100	8153	79.6	72%	16%	7%
86	3626	122.1	46%	32%	18%
71	3030	117.9	52%	30%	15%
59	573	125.9	50%	23%	21%
96	551	90.8	66%	26%	6%
65	8050	77.7	73%	15%	6%
0	5326	102.2	58%	28%	11%
84	3496	132.7	45%	27%	20%
62	205	67.1	83%	10%	5%
99	6576	116.7	52%	28%	16%
98	921	92.9	63%	29%	6%

<u>Load</u>	<u>Production Rate</u>	<u>Fill Energy</u>
	6189	2557.4
7	6731.4	3531.7
	6090.0	2142.6
	6517.0	2728.8
5	5997.0	2637.4
	5206.0	3084.4
5	7169.0	2908.3
	6522.0	2729.8
	6334.0	2529.2
9	5606.0	2478.7
5	6687.0	2466.8

Operator
Average
Avg + 1 S

99	83.5	9.9	6.6	15.6	35.0	49.0	-60.4	2299.6	88.2	6069.0	2722.8
98	86.7	8.6	6.9	15.0	33.4	54.0	-66.5	2310.0	89.1	6607.0	2579.5
0	85.9	9.3	7.0	15.2	34.5	49.9	-59.4	2179.3	93.9	6334.0	2529.2
84	84.6	10.7	8.4	16.5	38.4	59.8	-69.9	2261.1	100.9	5606.0	2478.7
62	96.1	9.6	6.9	17.2	36.5	53.8	-67.9	2150.1	101.5	6687.0	2466.8
99	83.5	9.9	6.6	15.6	35.0	49.0	-60.4	2299.6	88.2	6069.0	2722.8
98	86.7	8.6	6.9	15.0	33.4	54.0	-66.5	2310.0	89.1	6607.0	2579.5





# Today's Usage

## Operator Digability Analysis

### One Page Manager to One Number Manager

Operator #	Cycles	Average Digability	Digability: < AVG	Digability: Avg > +1	Digability: > +1 SD
Average	4187	101	60%	24%	12%
100	8153	79.6	72%	16%	7%
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Operator #	Payload	Fill Time	Swing Time	Return Time	Cycle Time	Swing Angle	Return Swing	Stress Index	Trk Payload Compliance	Production Rate	Fill Energy
Average	86.8	9.6	7.5	15.7	35.6	39.0	-46.8	2251.0	94.4	6189	2557.4
Avg + 1 S.D.	102.7	14.0	10.0	21.3	41.6	83.7	-99.6	2818.5	122.7	6731.4	3531.7
100	83.1	8.0	8.0	15.7	34.7	50.2	-55.8	2155.0	93.0	6090.0	2142.6
86	90.4	10.4	6.6	15.4	35.3	48.4	-60.0	2249.9	95.0	6517.0	2728.8
71	86.1	10.2	8.6	14.7	36.5	30.5	-36.8	2209.0	100.5	5997.0	2637.4
59	85.7	11.4	8.2	17.4	39.9	59.8	-69.9	2317.2	98.5	5206.0	3084.4
96	97.6	10.1	7.0	14.6	34.6	50.5	-62.5	2386.5	102.6	7169.0	2908.3
65	93.1	9.8	7.6	16.0	36.1	27.5	-34.3	2344.1	96.3	6522.0	2729.8
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98	86.7	8.6	6.9	15.0	33.4	54.0	-66.5	2310.0	89.1	6607.0	2579.5



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# Today's Usage

## Operator Digability Analysis

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100	83.1	8.0	8.0	15.7	34.7	50.2	-55.8	2155.0	93.0	6090.0	2142.6
86	90.4	10.4	6.6	15.4	35.3	48.4	-60.0	2249.9	95.0	6517.0	2728.8
71	86.1	10.2	8.6	14.7	36.5	30.5	-36.8	2209.0	100.5	5997.0	2637.4
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99	83.5	9.9	6.6	15.6	35.0	49.0	-60.4	2299.6	88.2	6069.0	2722.8
98	86.7	8.6	6.9	15.0	33.4	54.0	-66.5	2310.0	89.1	6607.0	2579.5



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# Today's Usage

## Operator Digability Analysis One Page Manager to One Number Manager

Operator #	Cycles	Average Digability	Digability: < Avg %	Digability: Avg > +1 SD	Digability: > +1 SD
Average	4187	101	60%	24%	12%
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98	921	92.9	63%	29%	6%
96	551	90.8	66%	26%	6%
100	8153	79.6	72%	16%	7%
65	8050	77.7	73%	15%	6%
62	205	67.1	83%	10%	5%

Operator #	Payload	Fill Time	Swing Time	Return Time	Cycle Time	Swing Angle	Return Swing Angle	Stress Index	Fill Energy	Trk Payload Compliance	Productio n Rate
Average	86.8	9.6	7.5	15.7	35.6	39.0	-46.8	2251.0	2557.4	94.4	6189
Avg +1 SD	102.7	14.0	10.0	21.3	41.6	83.7	-99.6	2818.5	3531.7	122.7	6731.4
84	84.6	10.7	8.4	16.5	38.4	57.8	-67.9	2261.1	2478.7	100.9	5606.0
59	85.7	11.4	8.2	17.4	39.9	59.8	-69.9	2317.2	3084.4	98.5	5206.0
86	86.4	10.4	8.0	15.4	35.0	48.4	-68.0	2240.0	2728.0	95.0	5517.0
71	86.1	10.2	8.6	14.7	36.5	30.5	-36.8	2209.0	2637.4	100.5	5997.0
99	83.5	9.9	6.6	15.6	35.0	49.0	-60.4	2299.6	2722.8	88.2	6069.0
0	85.9	9.3	7.0	15.2	34.5	49.9	-59.4	2179.3	2529.2	93.9	6334.0
98	86.7	8.6	6.9	15.0	33.4	54.0	-66.5	2310.0	2579.5	89.1	6607.0
96	97.6	10.1	7.0	14.6	34.6	50.5	-62.5	2386.5	2908.3	102.6	7169.0
100	83.1	8.0	8.0	15.7	34.7	50.2	-55.8	2155.0	2142.6	93.0	6090.0
65	93.1	9.8	7.6	16.0	36.1	27.5	-34.3	2344.1	2729.8	96.3	6522.0
62	96.1	9.6	6.9	17.2	36.5	53.8	-67.9	2150.1	2466.8	101.5	6687.0



# Today's Usage

## Operator Digability Analysis One Page Manager to One Number Manager

### Operator Performance Summary

Start Date:

End Date:



Mine:

Machine: Shovel



#### Operator Performance

Operator ID	Cycles	Cycle Time (s)	Fill Time (s)	Swg Angle (deg)	Payload (Ton)	Bkt Load (BCYs)	Prod Rate (BCYs/hr)	Payload Comp (%)	Avg Passes	Stress Index (PSI)
0	5328	34.5	9.3	50.2	85.9	60.7	6334	93.3	3.7	2179.3
59	583	38.1	9.8	51.5	78.0	55.1	5206	82.6	4.2	2329.8
62	205	36.5	9.6	53.8	96.1	67.8	6687	101.8	4.3	2150.1
65	7887	36.1	9.8	58.7	92.6	65.4	6522	103.6	3.9	2341.3
71	3030	36.5	10.2	63.7	86.1	60.8	5997	101.2	3.8	2209.0
84	3503	38.4	10.7	57.1	84.6	59.8	5606	99.5	4.0	2260.6
86	3635	35.3	10.4	48.6	90.4	63.9	6517	95.4	3.9	2249.4
96	552	34.6	10.1	50.5	97.5	68.9	7169	103.4	4.2	2387.7
98	922	33.4	8.7	54.2	86.7	61.3	6607	92.1	4.3	2310.9
99	6578	35.0	9.9	49.1	83.5	59.0	6069	89.0	4.1	2299.6
100	8160	34.7	8.0	58.2	83.1	58.7	6090	99.5	4.3	2155.0
103	574	39.9	11.4	60.3	85.7	60.5	5459	98.4	4.3	2315.3
All Operators	40957	35.6	9.6	55.0	86.7	61.2	6189	96.7	4.0	2250.0
Target		<35.3	<10.8	<63.9	94.1-110.6			95-105		<2395.7
Acceptable		35.3-40.6	10.8-15	63.9-85.5						2395.7-3001.2
Needs Improvement		>40.6	>15	>85.5	>110.6 or <94.1			>105 or <95		>3001.2

# Today's Usage

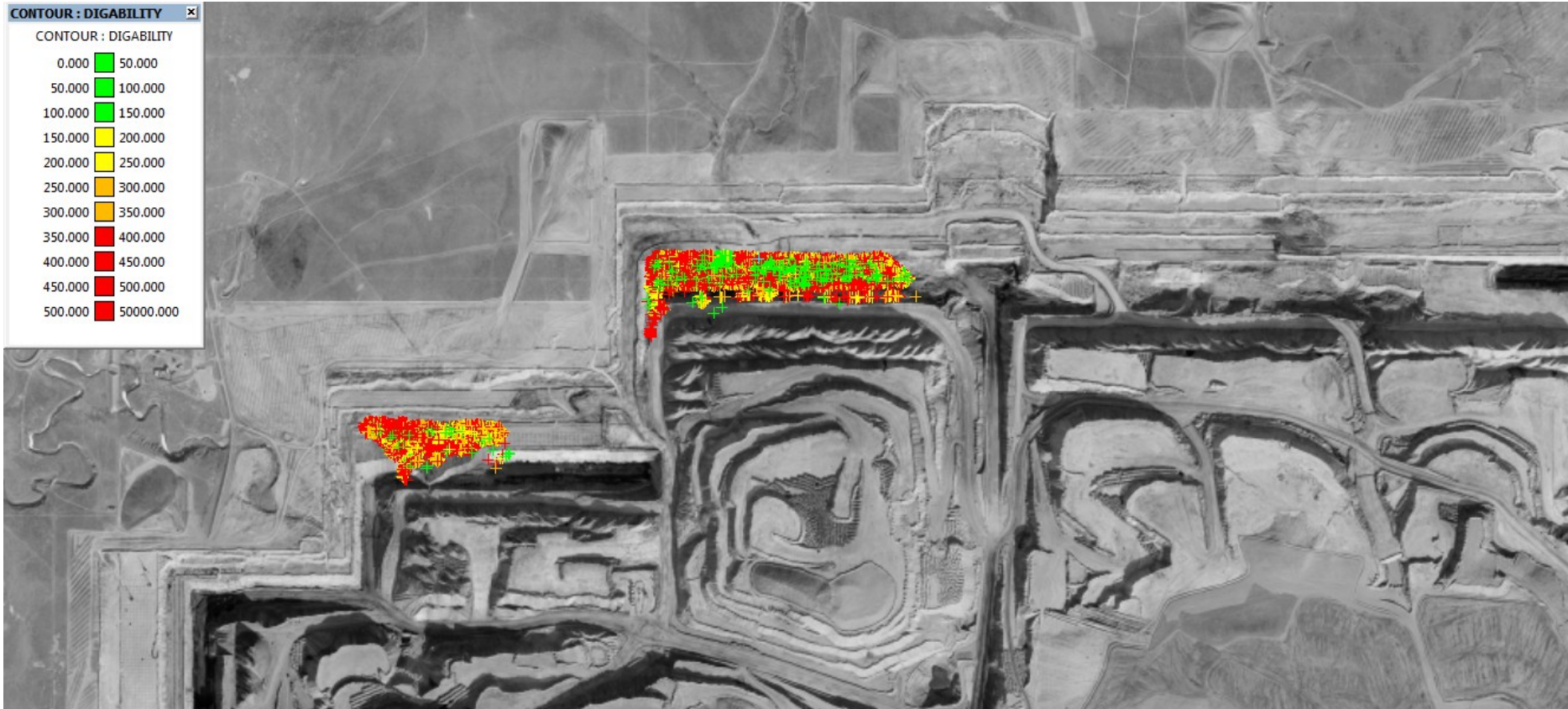
## Operator Digability Analysis One Page Manager to One Number Manager

	<u>Average</u>
<u>Operator #</u>	<u>Digability</u>
Average	101
100	79.6
86	122.1
71	117.9
59	125.9
96	90.8
65	77.7
0	102.2
84	132.7
62	67.1
99	116.7
98	92.9



# Today's Usage

## Plotting

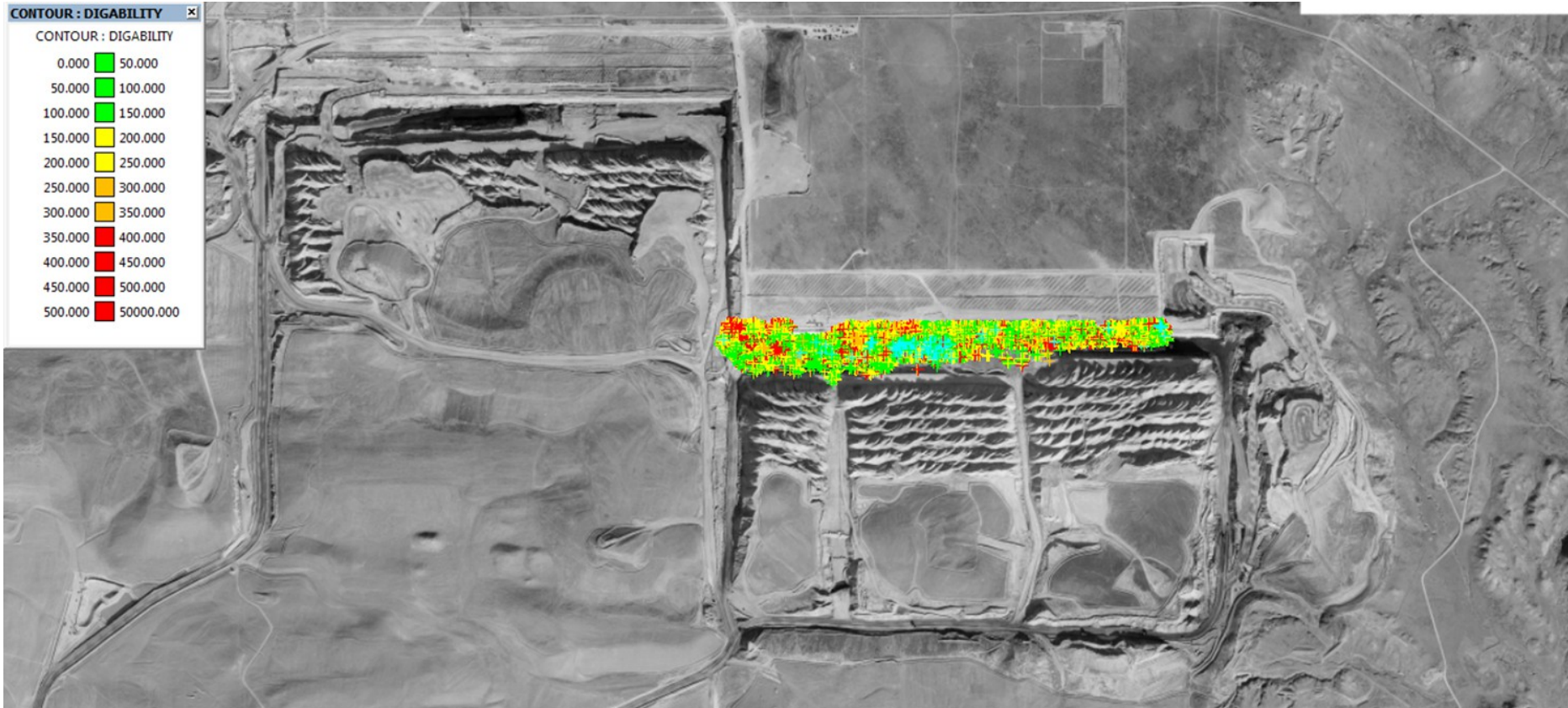


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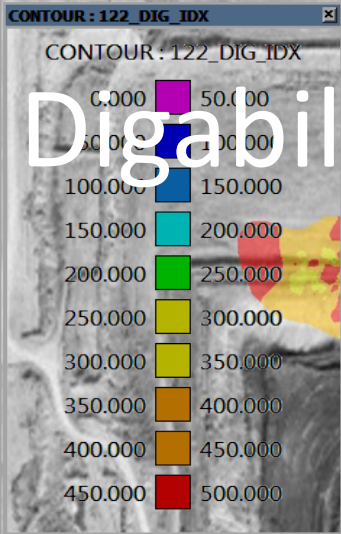


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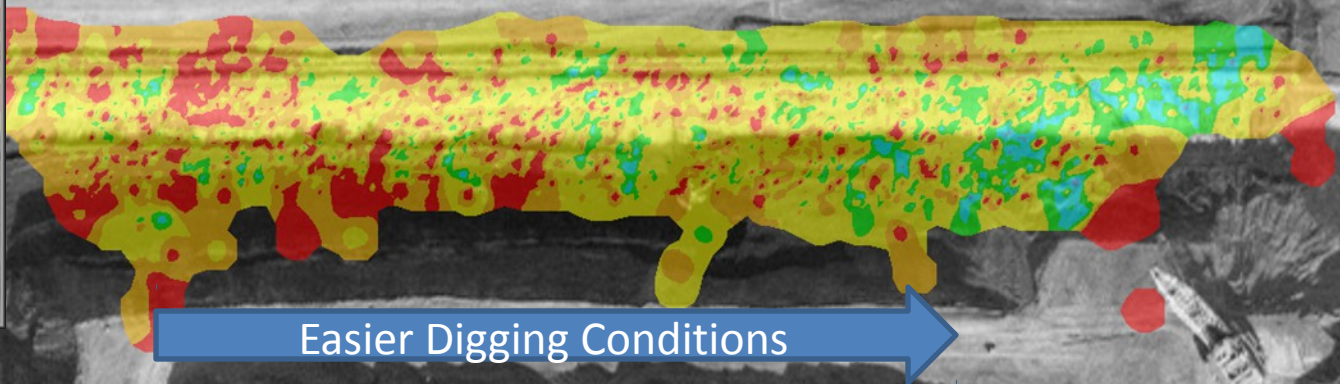
## Plotting



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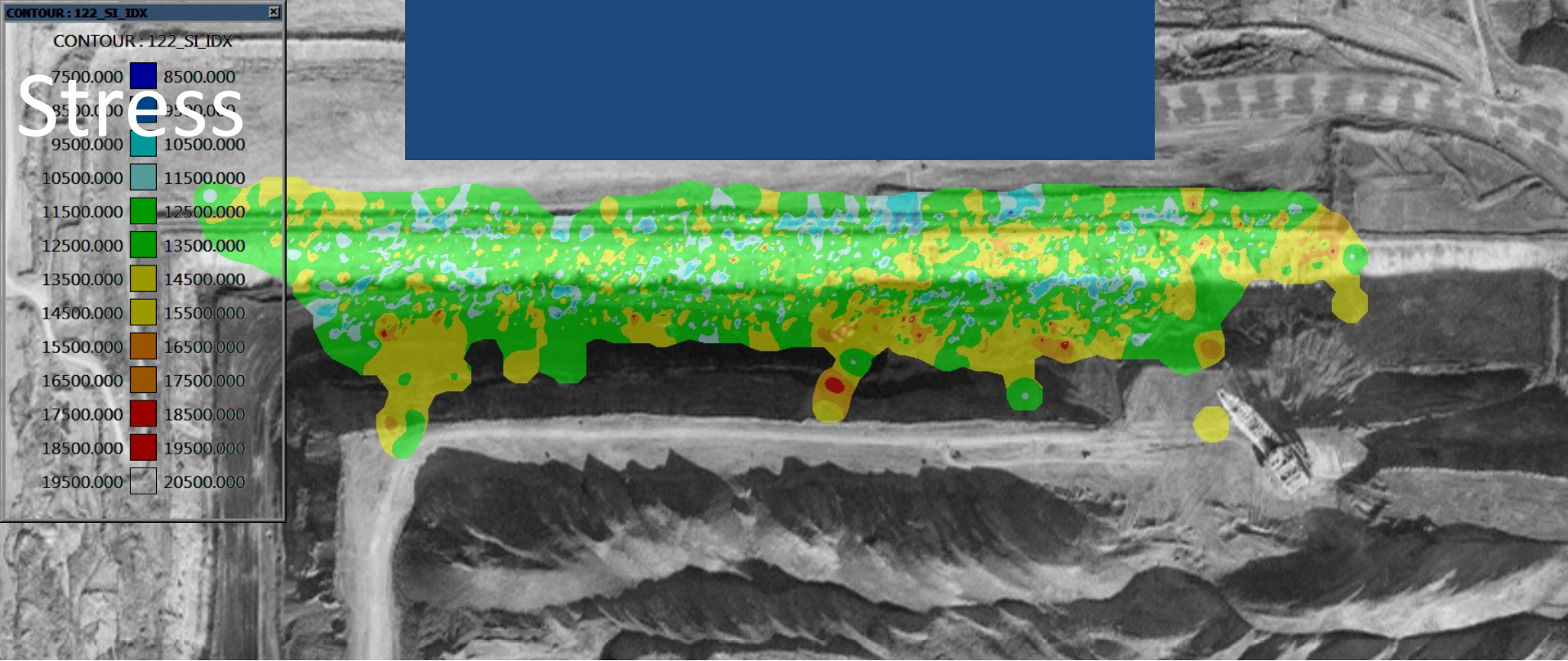


# Digability



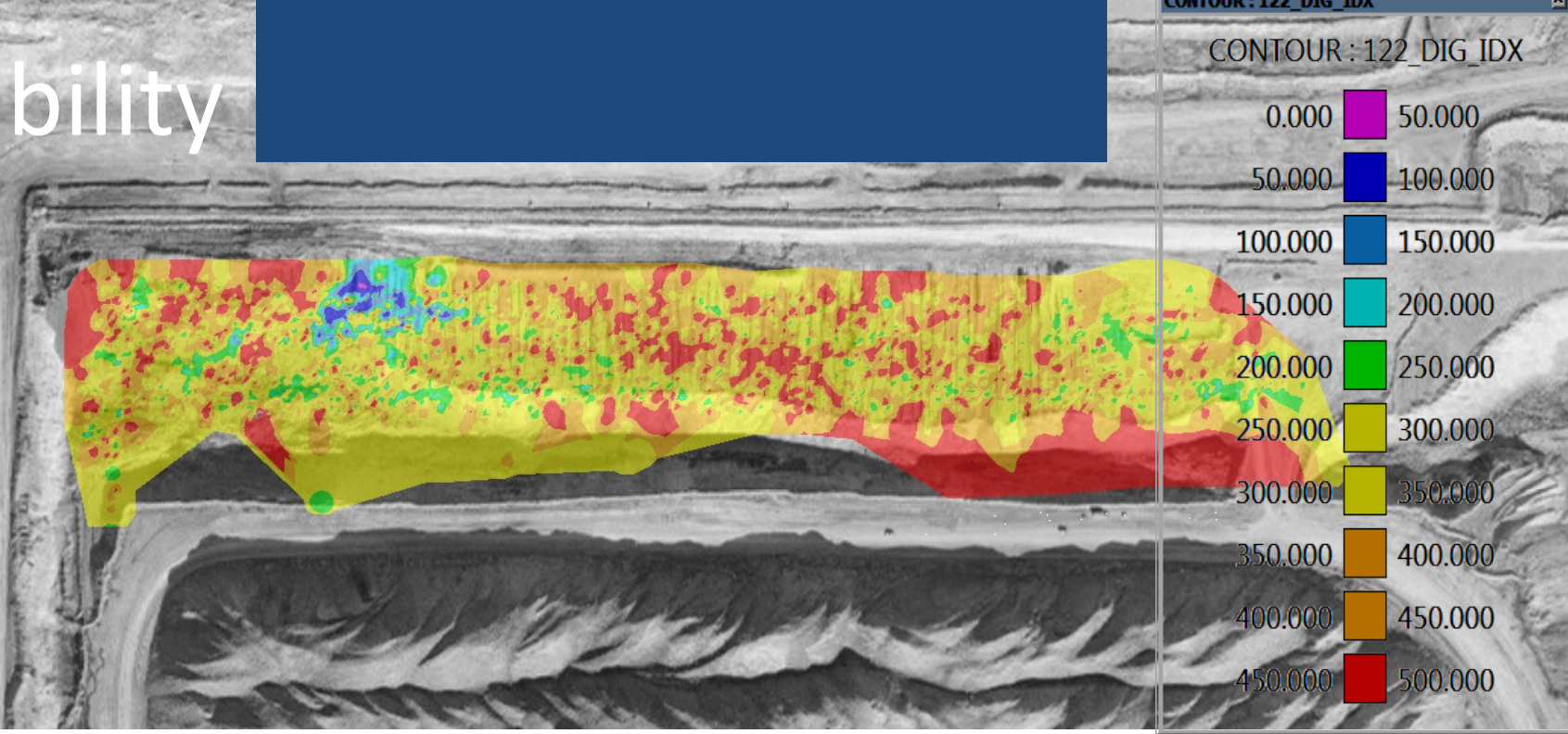
	digability	fill_energy	gross_weight	payload	fill_time	fill_length	Delta_Fill	stress_index
<b>Average</b>	<b>315.23</b>	<b>13,053.10</b>	<b>215.38</b>	<b>139.39</b>	<b>10.17</b>	<b>57.36</b>	<b>12.37</b>	<b>12,799.15</b>
Median	279.31	13,018.74	216.59	140.60	9.80	58.71	11.60	12,664.32
Stdev	230.70	2,439.19	21.42	21.42	1.56	11.23	7.68	2,391.66
Avg +Stdev	545.92	15,492.29	236.80	160.81	11.72	68.59	20.05	15,190.81
Avg - Stdev	84.53	10,613.91	193.97	117.98	8.61	46.14	4.69	10,407.50





	digability	fill_energy	gross_weight	payload	fill_time	fill_length	Delta_Fill	stress_index
Average	315.23	13,053.10	215.38	139.39	10.17	57.36	12.37	12,799.15
Median	279.31	13,018.74	216.59	140.60	9.80	58.71	11.60	12,664.32
Stdev	230.70	2,439.19	21.42	21.42	1.56	11.23	7.68	2,391.66
Avg +Stdev	545.92	15,492.29	236.80	160.81	11.72	68.59	20.05	15,190.81
Avg - Stdev	84.53	10,613.91	193.97	117.98	8.61	46.14	4.69	10,407.50

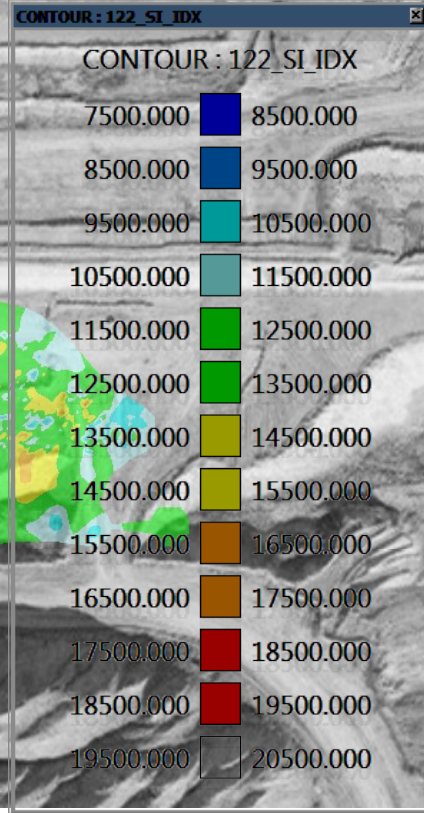
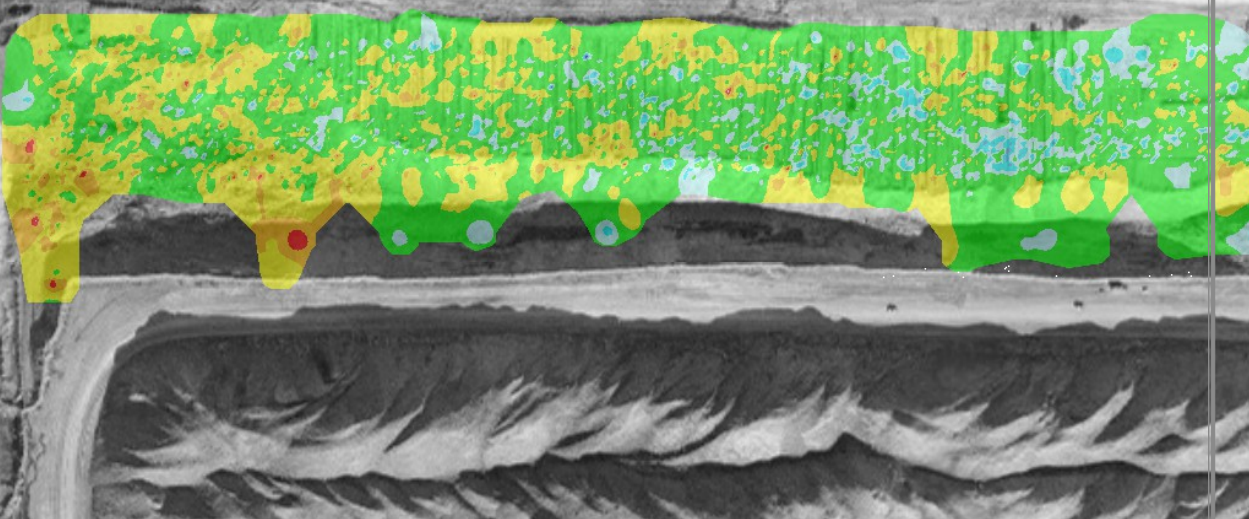
# Digability



Dragline	Digability (IDX)	Fill_Energy	Gross_Weight (TSL)(tons)	Payload (tons)	Fill_Time (sec)	Fill_Length (ft)	Fill_Height (ft)	Stress_Index
<b>Average</b>	<b>358.71</b>	<b>13,481.38</b>	<b>215.91</b>	<b>139.92</b>	<b>10.37</b>	<b>55.54</b>	<b>12.50</b>	<b>12,656.41</b>
Median	320.71	13,552.72	217.53	141.54	10.10	56.40	10.99	12,461.80
Stdev	209.12	3,171.72	20.89	20.89	1.60	11.64	8.43	2,300.38
Average + STDEV	567.83	16,653.10	236.80	160.81	11.97	67.17	20.93	14,956.79
Average - STDEV	149.59	10,309.66	195.02	119.03	8.77	43.90	4.07	10,356.03



# Stress



Dragline	Digability (IDX)	Fill_Energy	Gross_Weight (TSL)(tons)	Payload (tons)	Fill_Time (sec)	Fill_Length (ft)	Fill_Height (ft)	Stress_Index
<b>Average</b>	<b>358.71</b>	<b>13,481.38</b>	<b>215.91</b>	<b>139.92</b>	<b>10.37</b>	<b>55.54</b>	<b>12.50</b>	<b>12,656.41</b>
Median	320.71	13,552.72	217.53	141.54	10.10	56.40	10.99	12,461.80
Stdev	209.12	3,171.72	20.89	20.89	1.60	11.64	8.43	2,300.38
Average + STDEV	567.83	16,653.10	236.80	160.81	11.97	67.17	20.93	14,956.79
Average - STDEV	149.59	10,309.66	195.02	119.03	8.77	43.90	4.07	10,356.03

# Potential Areas for Improvement through Digability Evaluation

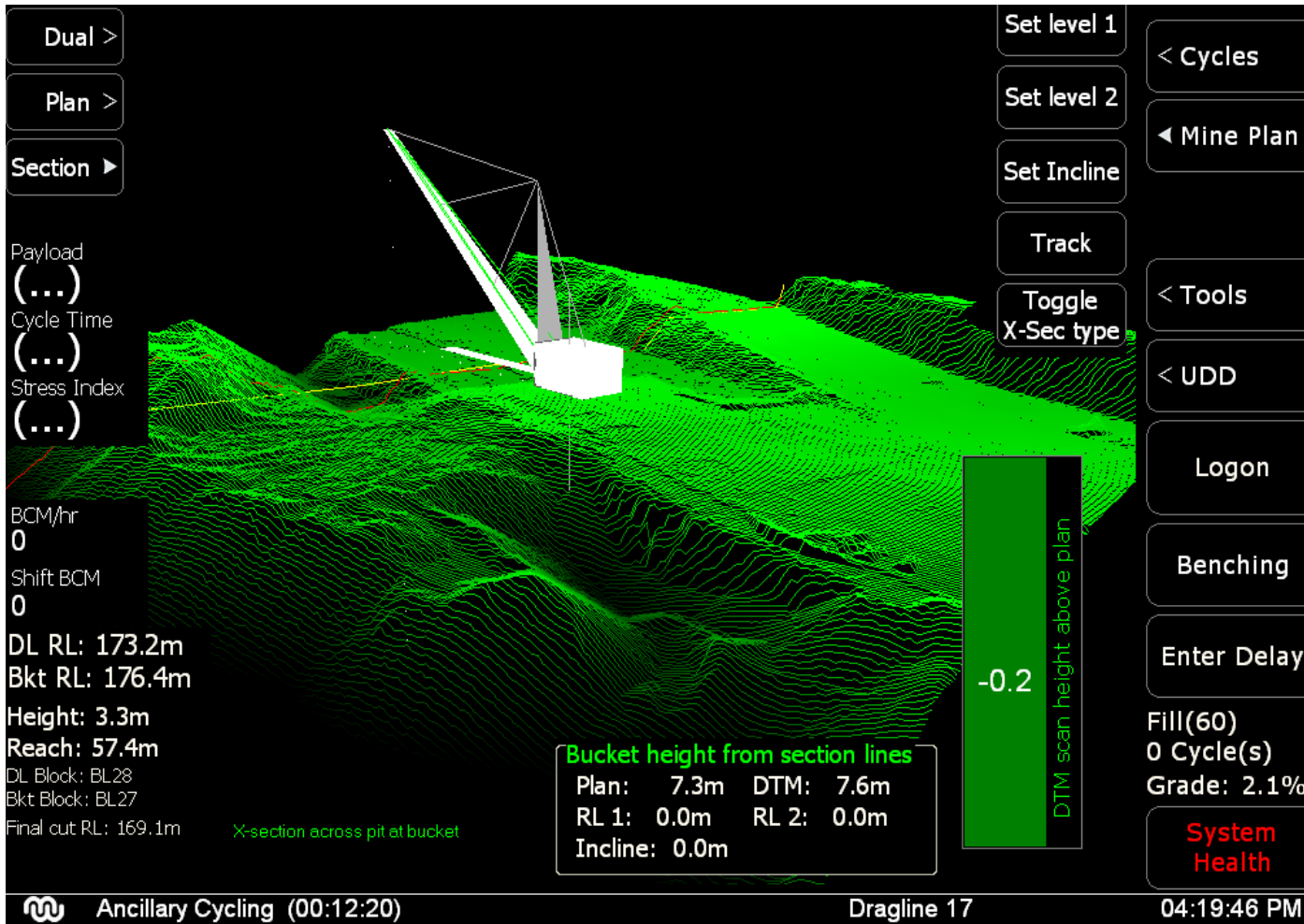


- Dipper/Bucket comparisons
- Ground Engaging Tool Analysis
- Operator Performance Measurement
- Drill & Blast Performance Measurement
- Improve Reliability
  - Reduced Maintenance Costs
- Improve Productivity
  - Measurable



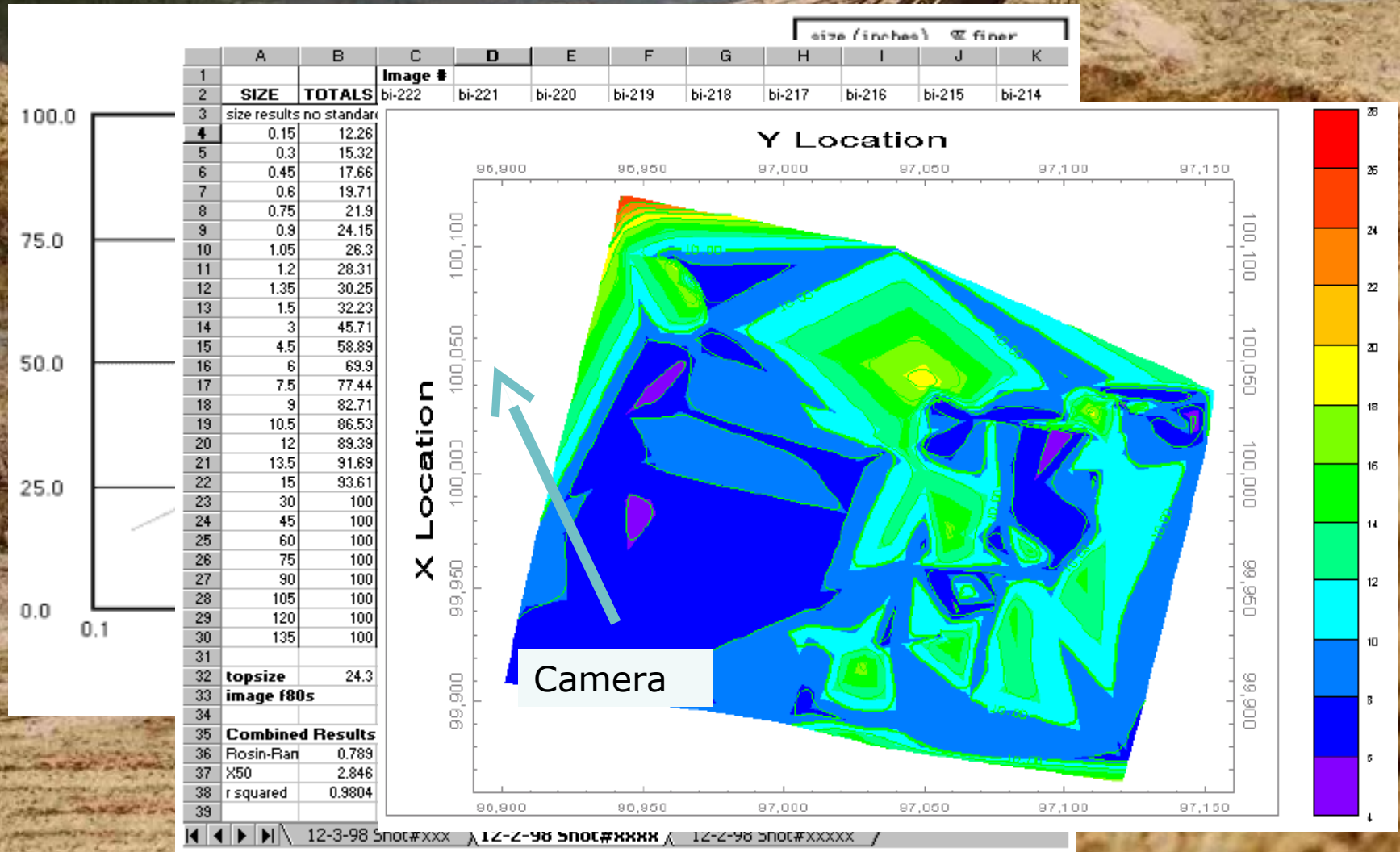
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# Future Possibilities – Integration LASER Scanning (currently a pilot study)

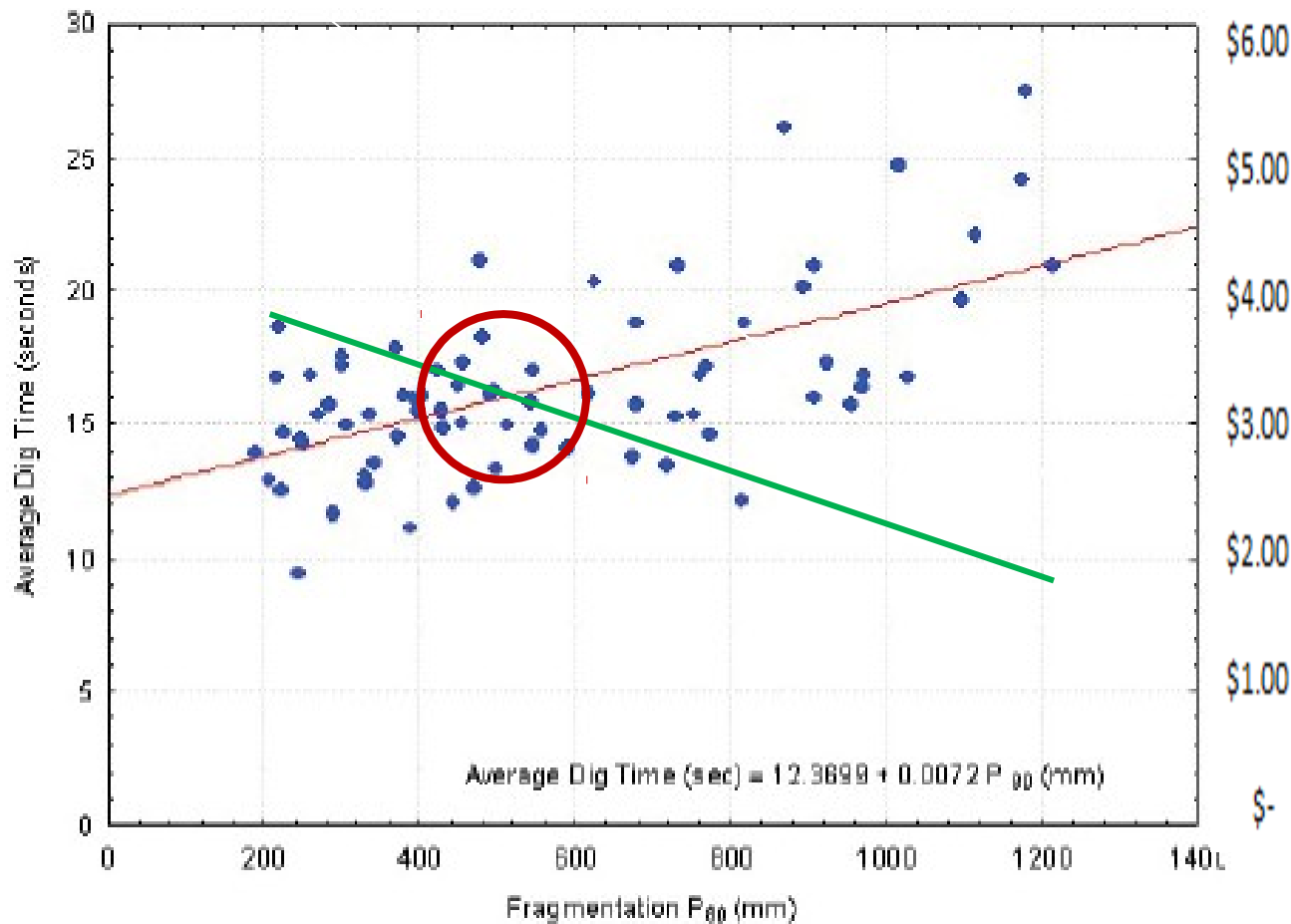




# Future Possibilities - Possible Integration of Fragmentation Software on front Cameras.



# Future Possibilities - Possible Analysis of Fragmentation, Dig Rates and Blasting Costs



D & B  
\$/BCY





# Review – Digability Analysis Benefits

DI is a more comprehensive metric that incorporates several aspects of a Shovel/Dragline operation that allows for an easy, single score comparison of:

- Operators
- Buckets & Dippers
- Ground Engaging Tools (GET)
- Hoist & Drag motors

DI gives real feedback to the Drill & Blast crew. Hopefully turning a lagging indicator into a leading one.



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# Acknowledgements & References

Peabody Energy

Kemeny, Mofya, Kaunda & Lever, 2001, Improvements in Blast Fragmentation Models Using Digital Image Processing

Hansen, 2001, Electric Rope Shovel Monitoring

Onederra, Brunton, Battista & Grace, 2004, 'Shot to Shovel' – Understanding the Impact of Muckpile Conditions and Operator Proficiency on Instantaneous Shovel Productivity

Bobo, Norton, Jeremy and Taylor, 2004, Split-Online Digital Image Analysis System to Quantify Particle Size for the Industrial Mineral Industry

Hendricks, Peck, Scobie, 1991, Machine Performance Monitoring in Surface Mines

Mol, Leung, 1987, Studies of Rock Fragmentation by Drilling & Blasting in Open Cut Mines



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# Thank you

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