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INTRODUCTION TO SAMPLING FOR MINERAL PROCESSING

Part 7 in a series "Effects on Recovery and NSR"

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Detrimental effects to operations

The assays from samples are used for control and accounting purposes:

- Planning
  - Production targets
  - Plant need to make a certain amount of money to pay its bills and make a profit. This effects how much tonnage to push through a mill.
- Plant control
  - Grade / Recoveries
  - Target values for these are set and accurate, non-biased, assays are required to achieve this.
- Metallurgical Accounting
  - Unbalanced results (poor sampling, assaying or weighing of stream)
  - Unaccounted loss (lack of measurement accuracy)

How is sampling inaccurate

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Problem with samplers which do not adhere to sampling theory:

- Launder and pressure samplers contain a bias, or errors, which can be constant (biased) or fluctuating (random). The ratio of fines:coarse, or light:heavy, particles entering the fixed cutter or nozzle will vary even without fluctuations in the process.
- Segregation by particle size, density, etc. is always present as there can be no guarantee that the slurry to be sampled is homogenous
- Segregation caused by pipe bends or intersections, etc.
- Unfortunately these errors change over time due to fluctuations in feed tonnages, particle size, densities, flow rates, pressure, etc. which can cause precision errors

OSA and Sampler Errors (On-line Assays)

- On-Stream Analyzers (OSA) only analyze the samples it is presented
- Normal OSA accuracies, as 1-SD (depends on application)
  -Feed ~ 4-6% (Aver 5%), Conc ~ 2-4% (Aver 3%), Tails ~ 7-9% (Aver 8%)
- Measurement result error (1-SD):
  - : $$s^2_{meas} = s^2_{sampling} + s^2_{analytical}$$
  - : $$s_{meas} = \sqrt{s^2_{sampling} + s^2_{analytical}}$$
- If the sample feed to the OSA is biased, the results are biased

Error Propagation - Recovery

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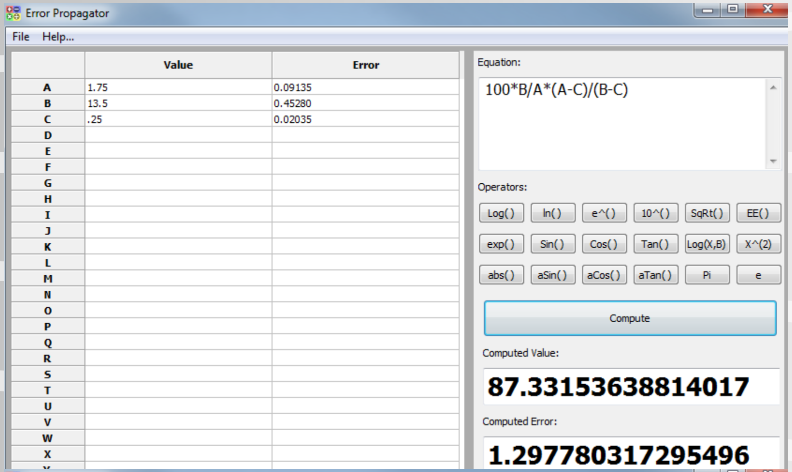

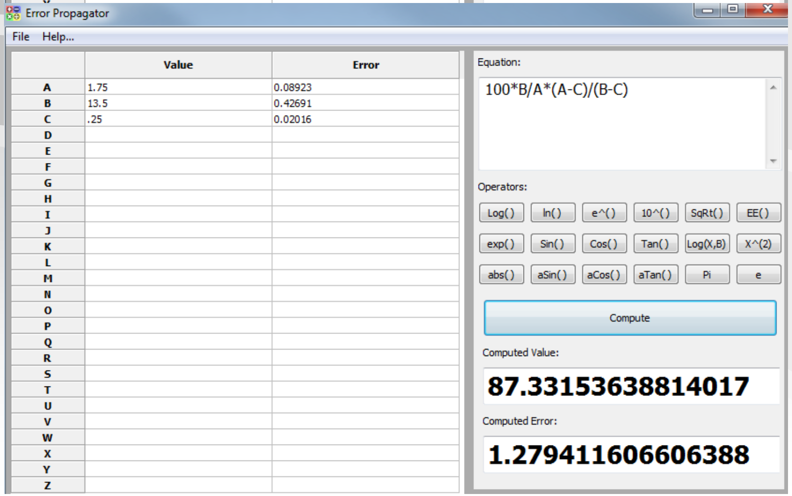

A is Feed
B is Conc
C is Tail

CASE1

Feed%	Conc%	Tail%	Rec%
1.75	13.50	0.25	87.33

Errors % (1-SD)	Case1	OSA	ABSTotal
Feed	1.50	5	0.09135
Conc	1.50	3	0.45280
Tails	1.50	8	0.02035

Recovery error 1.2978

CASE2

Feed%	Conc%	Tail%	Rec%
1.75	13.50	0.25	87.33

Errors % (1-SD)	Case2	OSA	ABSTotal
Feed	1.00	5	0.08923
Conc	1.00	3	0.42691
Tails	1.00	8	0.02016

Recovery error 1.2794

Recovery Error Difference
0.0184 (1-SD)

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Grade / Recovery

- This statement can be found in the Will’s Mineral Processing Technology book:

“The aim (of a flotation control system) should be to improve the metallurgical efficiency, i.e. to produce the best possible grade-recovery curve, and to *stabilize the process at the concentrate grade* which will produce the most economic return from the throughput.”

- This statement has a few key points:
  - A concentrate grade is decided upon (could be by planer, metallurgist, control system or other and depends on feed grade)
  - Keep the process stable (upsets are not good)
  - Increase the recovery as close as possible, to the best grade-recovery curve, without de-stabilizing (upsetting) the circuit
  - Maximize recovery at a target grade

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Assay errors and Grade/Recovery curve

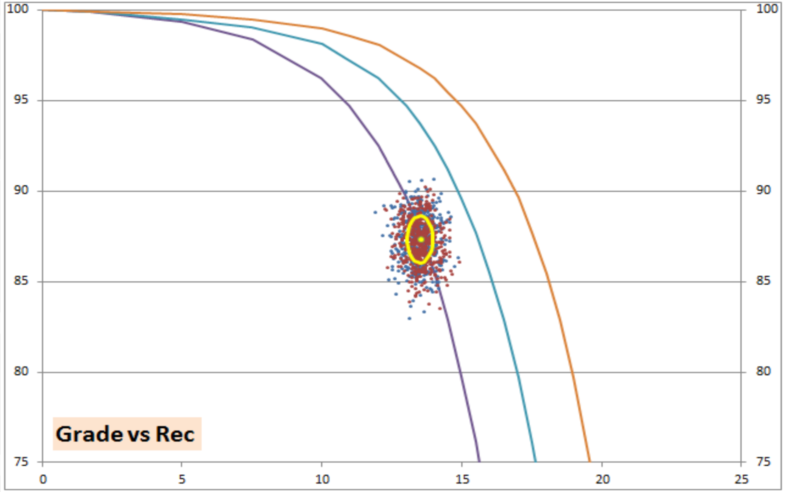
Feed %1.75, Conc. %13.5 Tail %0.25, Rec. %87.33

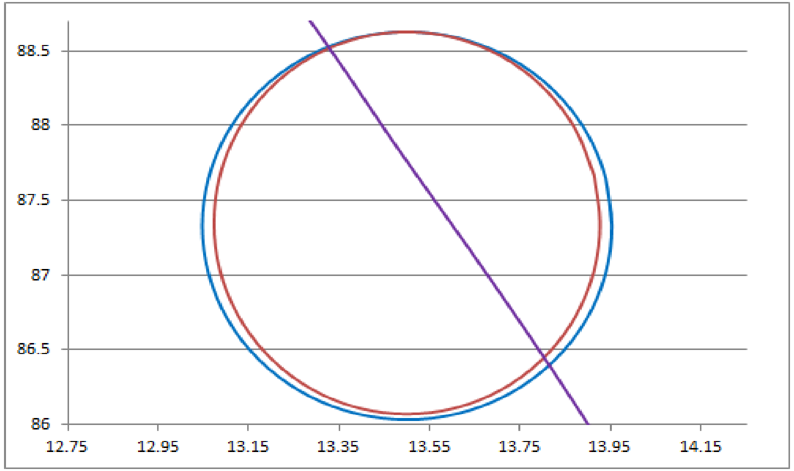
	Case 1(1.5%)	**Case 2**(1.0%)
Recovery error	1.2978	1.2794

Recovery Error Difference 0.0184 (1-SD)

Uncertainty Ellipse Area		
%Grade x %Rec	1.85	1.72

Control Area Improvement % 7.06





COMMENTS

- With the slightly better samplers in Case 2, the recovery target can be moved upwards the 0.0184% (*or 0.0368% with 2-SD*) error difference with the same probability of detecting an upset in the circuit as in Case1
- As the target for grade / recovery changes, due to feed changes, the error difference changes only slightly (~10%).

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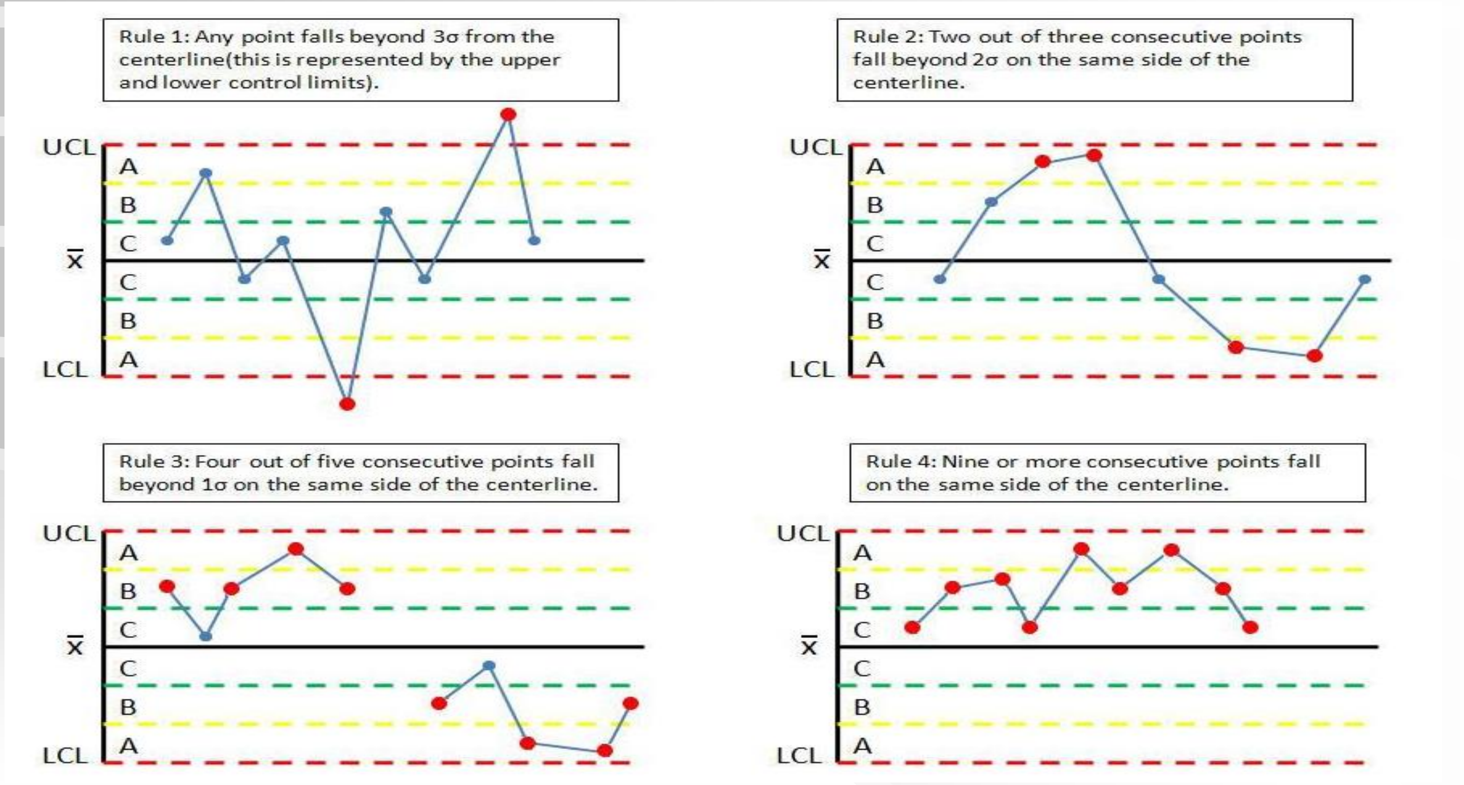
Introduction to SPC

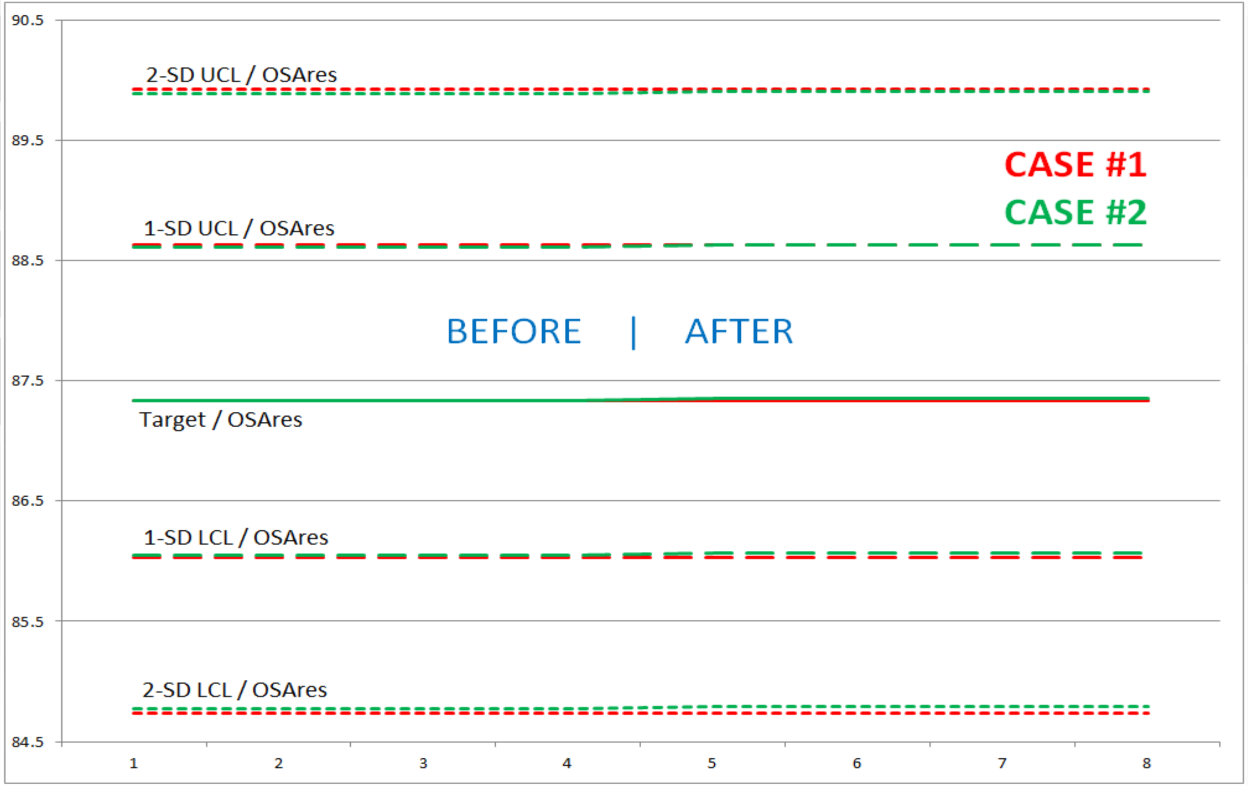
"All control starts with measurement and the quality of control can be no better than the quality of the measurement input." (Connell [1988])



https://controls.engin.umich.edu/wiki/index.php/SPC:_Basic_control_charts:_theory_and_construction,_sample_size,_x-bar,_r_charts,_s_charts

Introduction to SPC

- Control limits for grade / recovery depend upon the accuracy of the analyzer / samplers
- Example chart of recovery control, target shifted up 1-SD difference, 0.0184%



Probability of error detection over 2-SD UCL is the still better than in Case #1

Probability of error detection over 1-SD UCL is the same in both cases

Target moved up 1-SD difference (0.0184)

Tighter control limits at 1-SD LCL and 2-SD LCL

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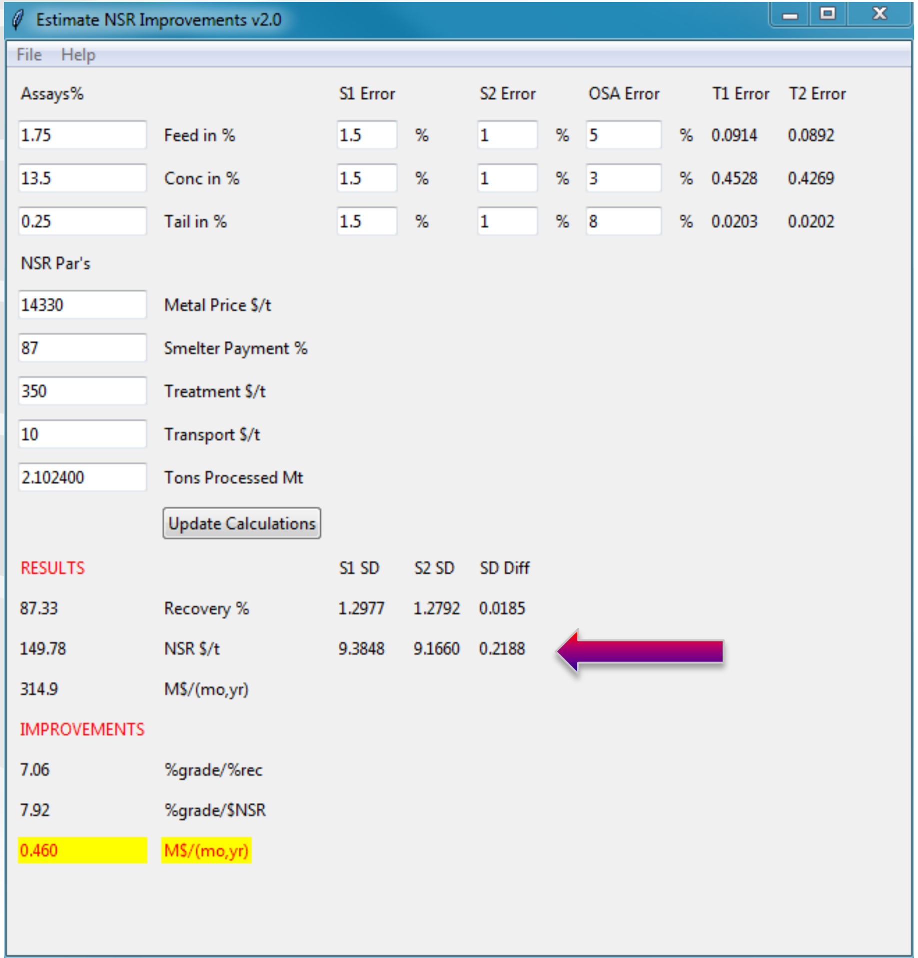
Error Propagation - $NSR/t

- Feed %1.75, Conc. %13.5 Tail %0.25
- $NSR/t $149.78

	Case 1(1.5%)	**Case 2**(1.0%)
$NSR/t error	9.3848	9.1660

$NSR/t Error Difference 0.2188 (1-SD)



Uncertainties: a Python package for calculations with uncertainties, Eric O. LEBIGOT, http://pythonhosted.org/uncertainties/

Estimating Assay Error Effects on NSR

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Feed %1.75, Conc. %13.5 Tail %0.25, Rec. %87.33

	Case 1(1.5%)	**Case 2**(1.0%)
$NSR/t error	9.3848	9.1660

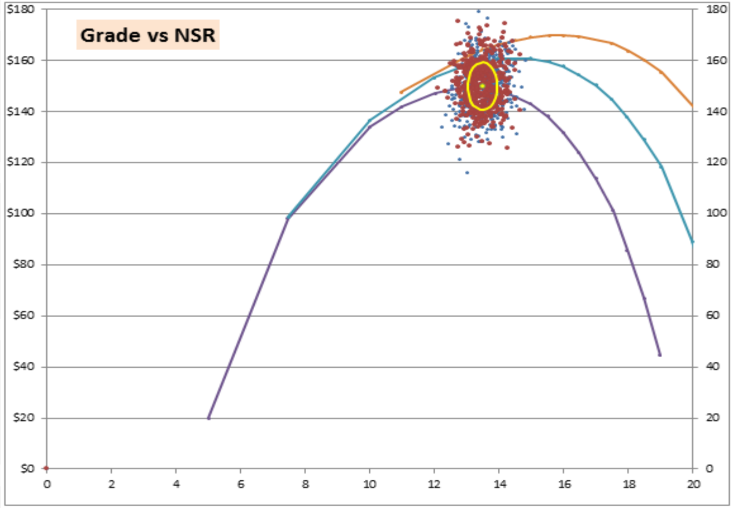
$NSR/t Difference 0.2188 (1-SD)

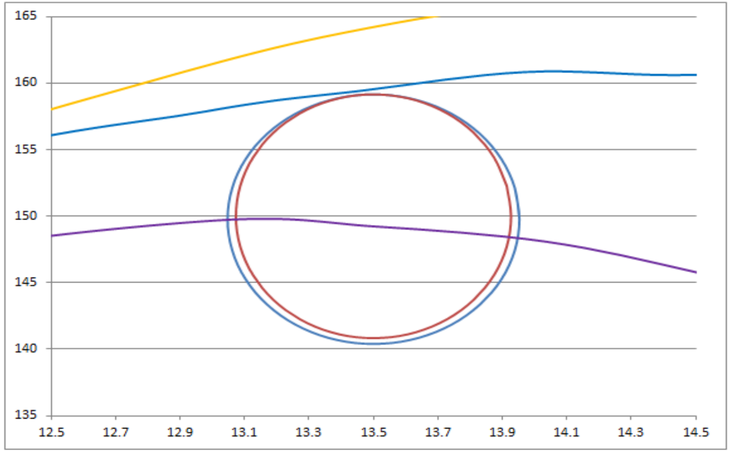
Uncertainty Ellipse Area		
%Grade x $NSR/t	13.35	12.29

Control Area Improvement % 7.92

COMMENTS

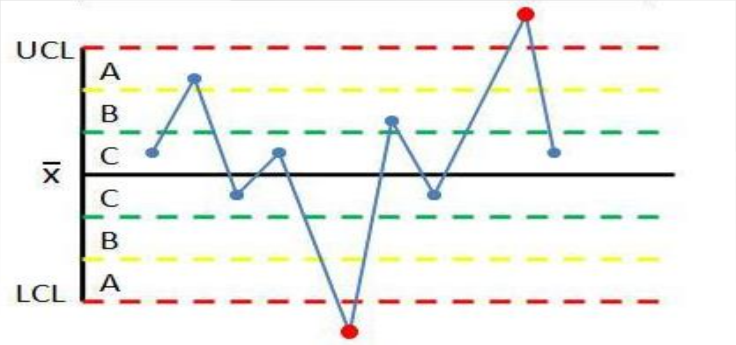
- With the slightly better samplers in Case 2, the $NSR/t can be moved upwards the $0.2188 (*or $0.4376with 2-SD*) error difference with the same likelihood of detecting an upset circuit as in Case1. This is done by the recovery control.
- **At 2,102,400 t/year this is:**
  - ***$459,786.00 @ 1-SD Error Diff***
  - ***$919,572.00 @ 2-SD Error Diff***

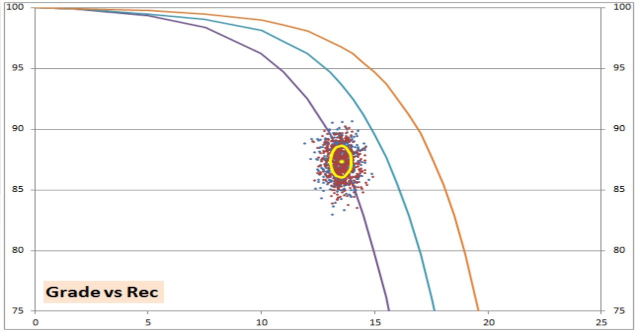




Estimating where your process operates

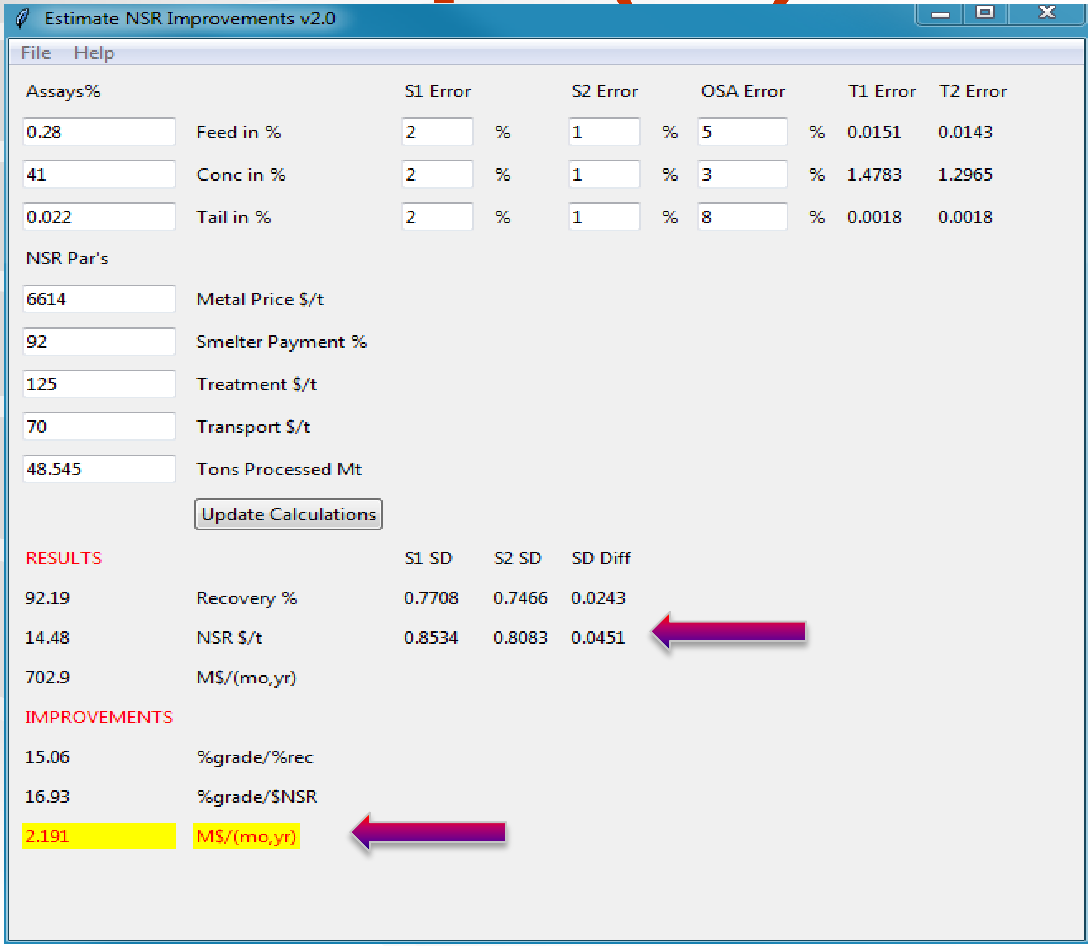
- The probability of process upset as a result of analysis errors at the UCL's are, 1-SD is 16%, 2-SD is 2.25%, 3-SD is 0.15%. An upset occurs where your process crosses the grade / recovery curve.
- Your OSA has about 100 cycles a day , roughly a 15 minute cycle time (4/hr x 24hr ~ 100)
- How often a day does you process get upset?
  - At 8/shift (16/day) your SD is about 1 (*x*)
  - At 2-3/shift (5-6/day) your SD is somewhere around 1.5 (*x*)
  - At 1-2/shift (2-4/day) your SD is somewhere around 2 (*x*)
  - Once every several days, your SD is somewhere around 3
- This gives you an idea of how much you can increase your recovery / NSR target (*x* * 1-SDdiff)





Another example (1/2)

- Low grade Cu mine with large tonnages (140,000t/day)
- Comparing 2% and 1% sampler errors
- ***$0.045/t*** estimated improvement
- ***$2.19M/yr*** estimated improvement
- Control improvements 15.06% and 16.93%



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Another example (2/2)

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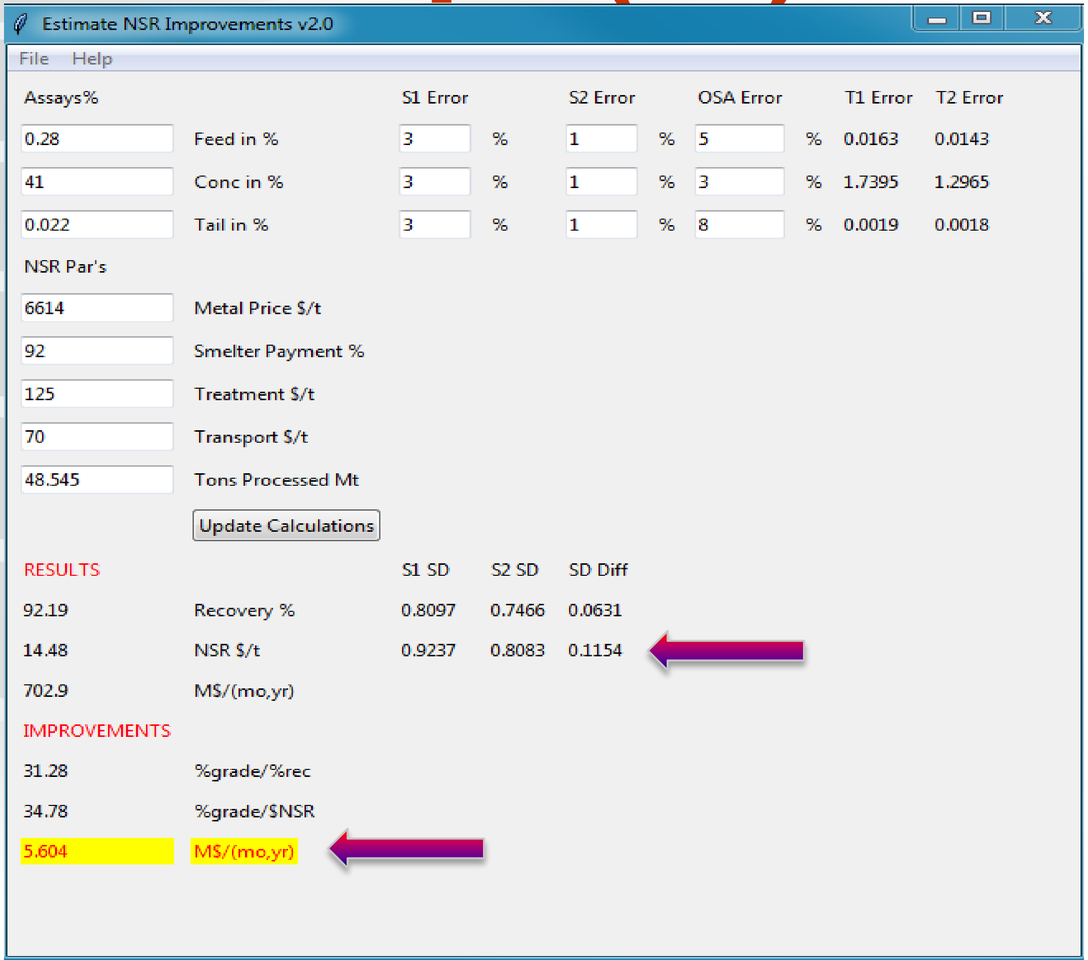
- Low grade Cu mine with large tonnages (140,000t/day)
- Comparing **3% and 1%** sampler errors
- ***$0.115/t*** estimated improvement
- ***$5.60M/yr*** estimated improvement
- Control improvements 31.28% and 34.78%



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