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MINTEK

Optimising blend ratios, grinds and reagent schemes to recover PGMs from LG reef spiral tailings

T.L Moodley*[1,2], I Govender[1,2,3], S. Pikinini[1], J. Sehata[1], J. Tshilongo[1], M Raedani

[1]School of Engineering, University of KwaZulu-Natal, Durban, South Africa

[2]Mintek, P/Bag X3015, Randburg, Gauteng, 2121, South Africa

[3]Department of Chemical Engineering, University of Cape Town, Rondebosch, 7701

Background

- The Bushveld Igneous Complex (BIC) is home to the world's largest vanadium, chrome and platinum reserves.
- Consists of different reefs: Merensky, UG2, MG and LG
- South African mining houses have historically processed LG+ MG reefs for <u>chrome</u> and UG-2 & Merensky reefs for <u>PGMs.</u>
- LG reefs are particularly problematic
  - lower PGM grades = bulk mining methods, which increase operational costs
  - the high chromite content complicates PGM recovery, as chromite-hosted PGMs like laurite (RuS) resist flotation treatments

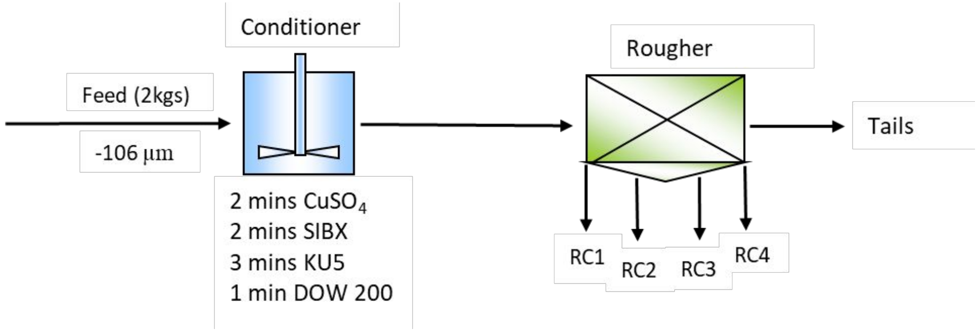
Objectives

- The aim of this study is to evaluate flotation performance of LG spiral tailings and blends, to balance PGM recovery with chrome rejection

NB: Smelter tolerate about 1% chrome for every 80g/t 4E PGM

Methodology

- Collectors (SIBX xanthate) enhance the hydrophobicity of PGM minerals
- Depressants (KU5) selectively suppress gangue minerals, including naturally floatable silicates and talc
- Frother (Dow 200) stabilises the froth phase, reducing bubble surface tension and improving froth recovery
- $CuSO_4$ activator, to enhance pentlandite (NiS) recovery, but also to be a froth modifier
- A series of rougher kinetic flotation tests was conducted to investigate the behaviour of PGMs and Cr_2O_3 within the LG spiral tailings.



Baseline	Condition A	Condition B	Condition C
40g/t $CuSO_4$	60g/t $CuSO_4$	40g/t $CuSO_4$	40g/t $CuSO_4$
150g/t SIBX	150g/t SIBX	200g/t SIBX	150g/t SIBX
40g/t KU5	40g/t KU5	40g/t KU5	60g/t KU5
30g/t Dow 200	30g/t Dow 200	30g/t Dow 200	30g/t Dow 200

Sample Characterisation

- The material used in this study was obtained from a large LG chrome operation.

- Two primary streams were sampled: a spiral tailings stream and a cyclone overflow stream. In this work, these are referred to as Sample A (size fraction +425–106 µm) and Sample B (size fraction −106 µm) respectively.

- In addition, two blended samples were prepared by mixing A and B at fixed mass ratios: 90:10 (denoted Sample C1) and 80:20 (denoted Sample C2).

- Because of confidentiality agreements, the feed grades cannot be disclosed directly.
  - PGMs in Sample A =0,33×Sample B
  - Cr_2O_3 in Sample A =0,67×Sample B

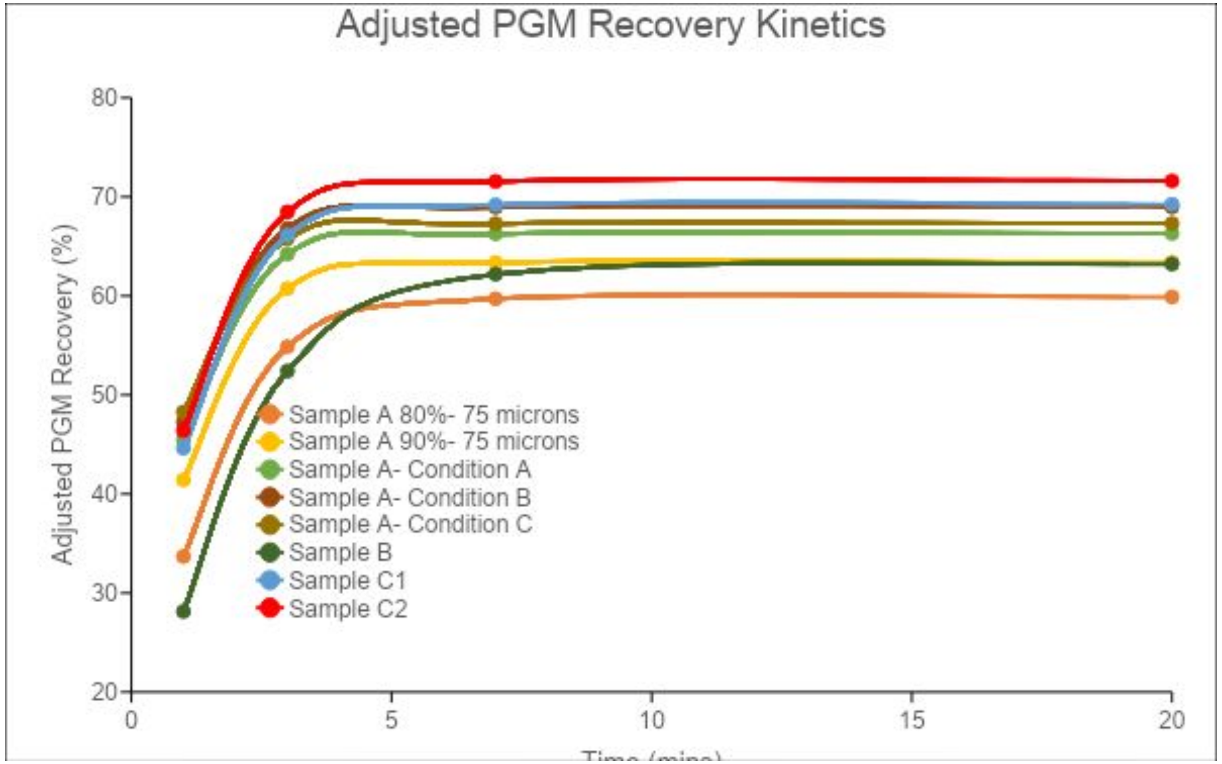
Data Confidentiality

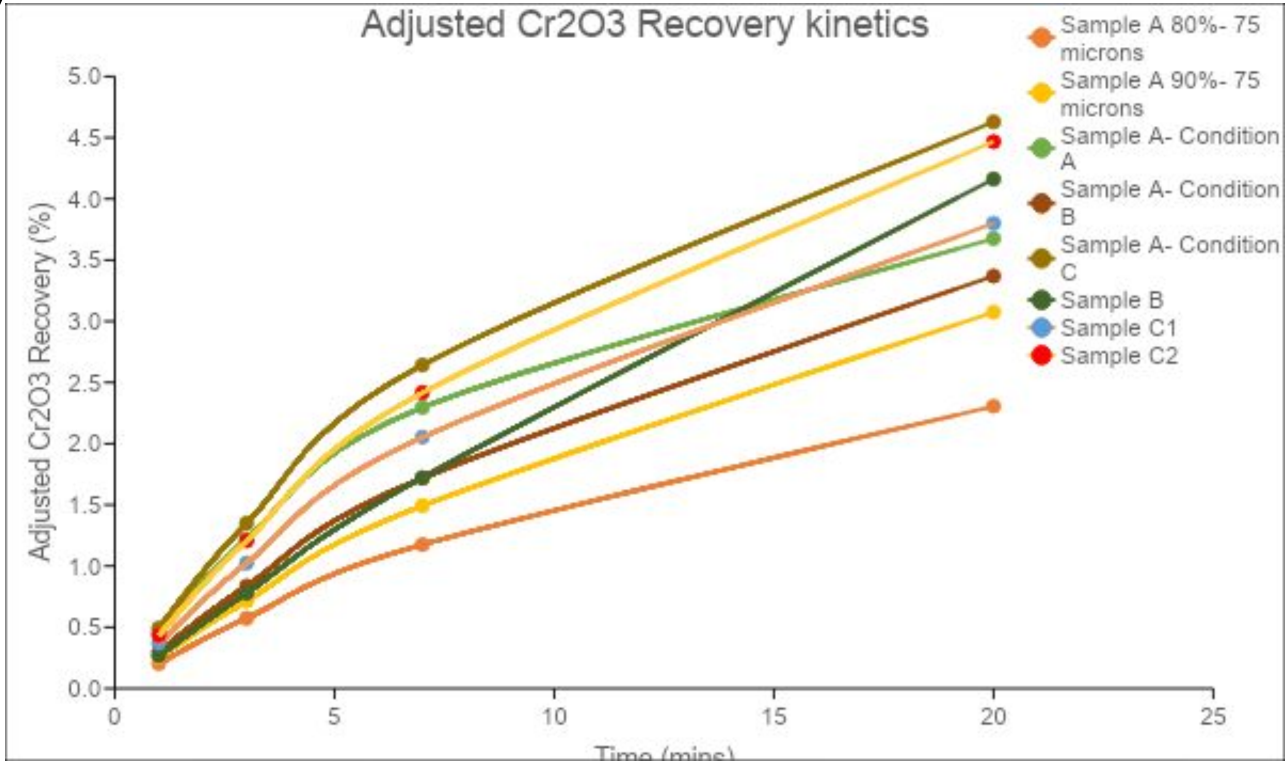
Due to confidentiality agreements, the reported recoveries are normalised. To protect client data, Kelsall model parameters (R_m and k) were perturbed within ±10% while maintaining the physical trends in flotation kinetics. This adjustment prevents back-calculation of absolute grades or recoveries.

$$R_c = R_m\left(1 + R_p\right) \times \left[1 - e^{-k\left(1-k_p\right)\times t}\right]$$

R_c normalised recovery of PGMs or Cr_2O_3 (%), R_m is the maximum recovery parameter (%), k is the first-order flotation rate constant (min^{-1}) and R_p and k_p are the perturbation constants introduced for confidentiality.

Recovery kinetics





The PGM recovery curves exhibit the typical two-stage trend: a steep initial rise in the first three minutes, indicating recovery of readily floatable PGMs, followed by a plateau around 70% as slower-floating or poorly liberated particles dominate

In contrast, the Cr_2O_3 recovery curves are nearly linear with little curvature, consistent with recovery by entrainment rather than true flotation

Baseline	Condition A	Condition B	Condition C
40g/t $CuSO_4$	60g/t $CuSO_4$	40g/t $CuSO_4$	40g/t $CuSO_4$
150g/t SIBX	150g/t SIBX	200g/t SIBX	150g/t SIBX
40g/t KU5	40g/t KU5	40g/t KU5	60g/t KU5
30g/t Dow 200	30g/t Dow 200	30g/t Dow 200	30g/t Dow 200

Fitting parameters

Table 1: Summary of Kelsall fitted parameters characterising PGM and Cr_2O_3

	PGM			Cr_2O_3		
Test	R_m (%)	k (min^{-1})	MAPE (%)	R_m (%)	k (min^{-1})	MAPE (%)
Sample A 80%-75 microns	57	0,87	7	3,0	0,07	3
Sample A 90%-75 microns	60	1,11	7	4,3	0,06	16
Sample A - Condition A	63	1,22	6	3,9	0,13	13
Sample A - Condition B	66	1,22	5	4,3	0,07	12
Sample A - Condition C	64	1,33	5	5,2	0,10	1
Sample C1	66	1,09	5	4,5	0,09	6
Sample C2	68	1,10	5	5,3	0,09	5
Sample B	60	0,62	11	9,4	0,03	10

For PGMs, most MAPE values < 10%, indicating that the Kelsall model sufficiently captures the kinetics. The exception is Sample B, which contains more fines, where entrainment likely the dominant mechanism.

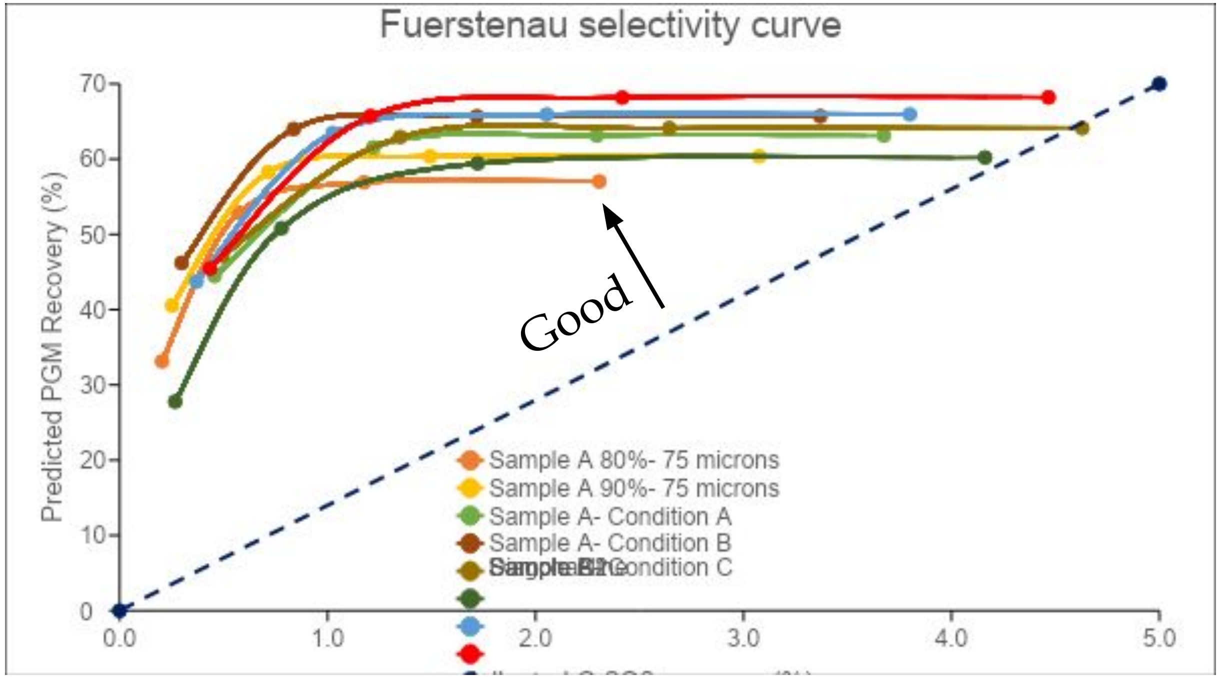
For Cr_2O_3, many MAPE values > 10%

PGM rate constants (*k*) >> Cr_2O_3, PGMs are preferentially fast floating, while Cr_2O_3 reports slowly to concentrate. This behaviour is desirable and results in high PGM recovery with minimal chromite entrainment.

PGM R_m values are higher in blended samples (C1, C2), while Cr_2O_3 recoveries remain relatively low, indicating that blends may provide a practical compromise between recovery and concentrate quality.

Can one consider Cr_2O_3 and PGM data simultaneously? ???

Fuerstenau Selectivity Curve



$$R_c = R_m\left(1 + R_p\right) \times \left[1 - e^{-k\left(1-k_p\right)\times t}\right]$$

$$R_{PGM} = R_{m,PGM} \times \left[1 - \frac{R_C}{R_{m,C}}\right]^{k_{PGM}/k_C}$$

Baseline	Condition A	Condition B	Condition C
40g/t $CuSO_4$	60g/t $CuSO_4$	40g/t $CuSO_4$	40g/t $CuSO_4$
150g/t SIBX	150g/t SIBX	200g/t SIBX	150g/t SIBX
40g/t KU5	40g/t KU5	40g/t KU5	60g/t KU5
30g/t Dow 200	30g/t Dow 200	30g/t Dow 200	30g/t Dow 200

The most selective conditions were:

(i) Sample A – Condition B, (ii) Sample C1 and (iii) Sample C2.

In contrast, Sample B showed the poorest selectivity, consistent with its fine particle size distribution and higher entrainment

Conclusions

- PGM recoveries follow first-order kinetics well, while Cr_2O_3 recovery is dominated by entrainment.
- Nonlinear regression of the Kelsall model, solved using gradient-based optimisation, provides a basis for quantifying flotation recovery kinetics
- The Fuerstenau curve provides a clear metric for selectivity: higher k_{PGM}/k_C ratios imply better separation.
- Sample B showed poor selectivity compared to other tests.
- Blends (C1, C2) and Condition B offer the best balance between PGM recovery and gangue selectivity. Further work will investigate their behaviour

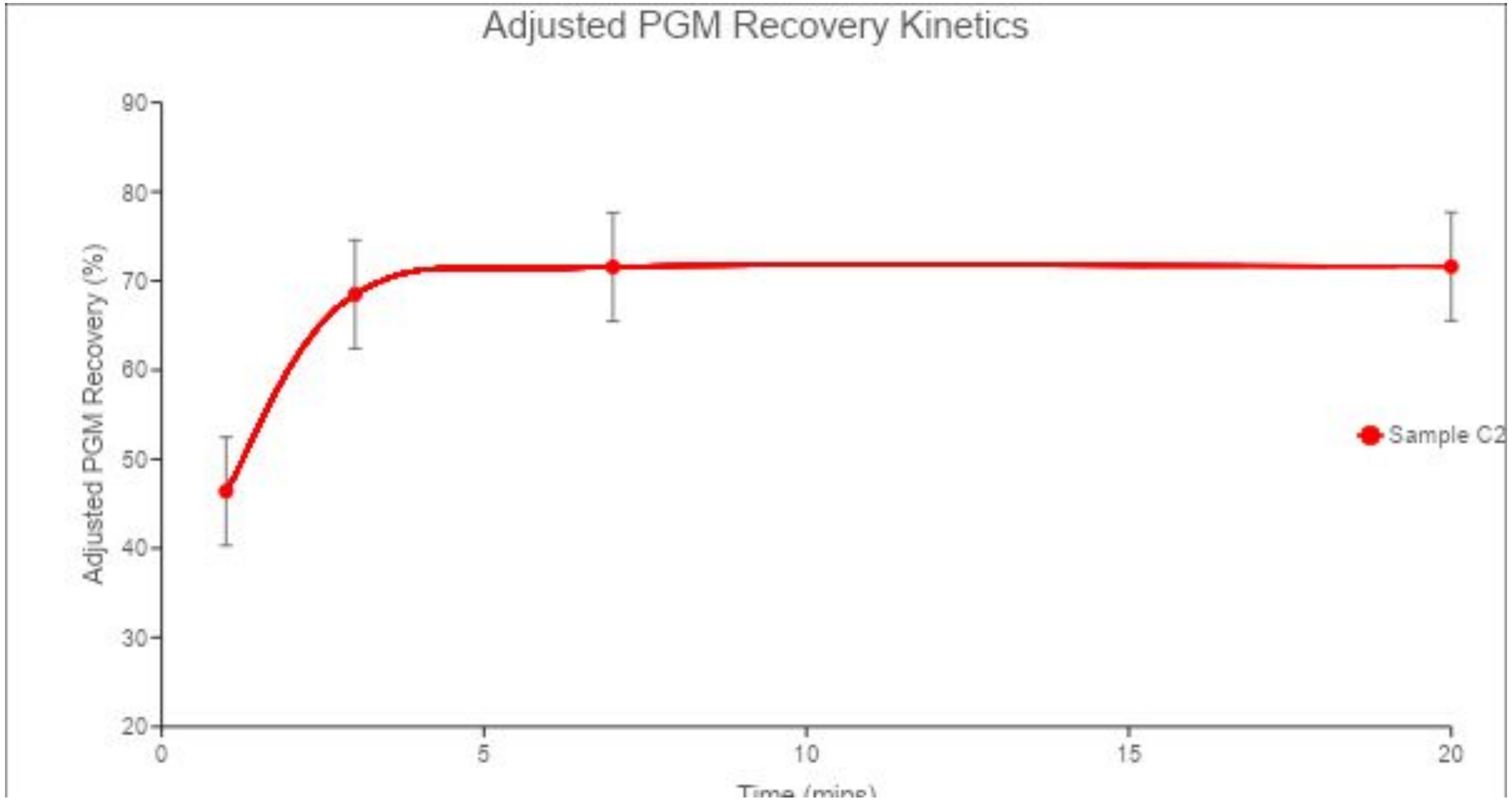
Idea 1

Pilot plants typically 1tph—we wait ~4hrs for PGM assays- we can use the Fuerstenau relationship to predict the PGM recovery using XRF instead—reduces to ~minutes

$$R_{PGM} = R_{m,PGM} \times \left[1 - \frac{R_C}{R_{m,C}}\right]^{k_{PGM}/k_C}$$

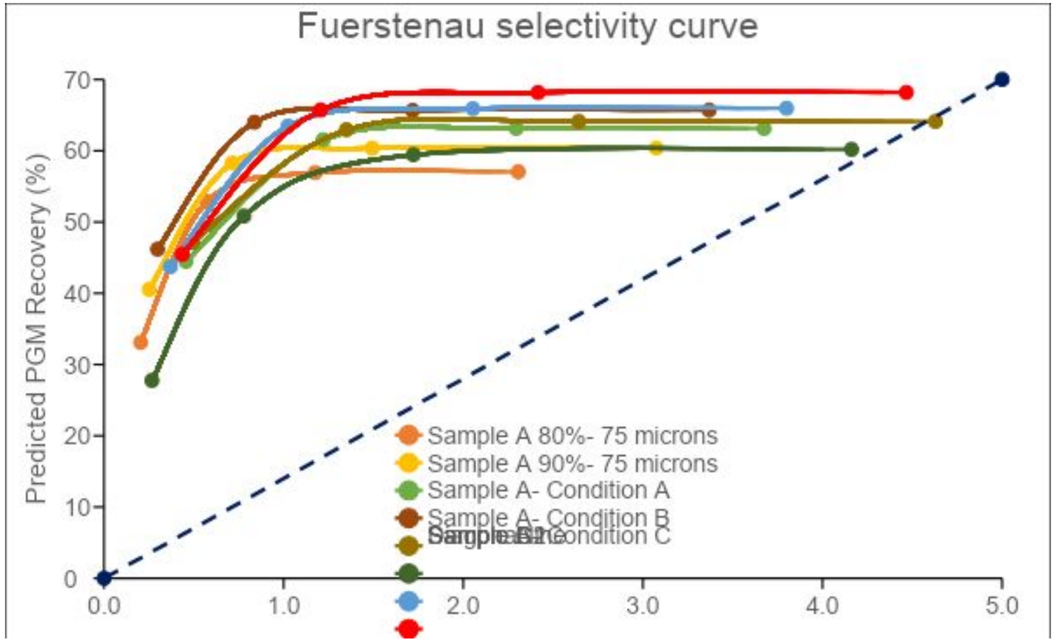
Idea 2--- incorporating assay uncertainty

Sample Name	Description	Rep	Pt ppm	Pd ppm	RH_ICP_OES_S Rh ppm	MINPGM3E_S ASD-MET-SPT-007* Au ppm	Cr2O3 %
W0121382/1	CT_6C_CO_RT	1	0.2	0.11	0.04	0.04	5.48
W0121382/1	CT_6C_CO_RT	2				0.04	5.37
W0121382/1	CT_6C_CO_RT	3	0.23	0.11	0.04		



Instead of averaging and using the mean, we can incorporate all readings into our analysis and develop error bars based on the assay uncertainty---this will enable us to make more accurate predictions

Idea 3 – float predictor



Base Metal Sulphides Relative Abundance		Sibanye 1B
Phase	**Chemical Formula**	**Mass %**
Pentlandite	$(Fe,Ni)_9S_8$	12.31
Chalcopyrite	$CuFeS_2$	8.48
Pyrrhotite	$Fe_{(1-x)}S$	41.13
Pyrite	FeS_2	12.84
Millerite	NiS	1.21
*Other BMS	-	24.03
Total		**100.0**

We can choose the gangue mineral to track according to MNL info. The curve does not force one to use chrome—we can look at our MNL info and select any other mineral

Currently, the float predictor does not consider the gangue minerals behaviour simultaneously---it looks at historic floatability of the sample (UG2 or Merensky) and then assumes a certain recovery based on that