PO Box 2151, Toowong, Qld 4066, Australia.
Telephone :(61) 07 3721 0100 | Fax (61) 07 3721 0151 | Email info@hydrobiology.biz

Memorandum

To: Tania Laurencont

From: Ross Smith

CC: Andy Markham, Corinne Unger

Date: 29 June 2016

Re: Revised LDWQOs and Construction-phase LDWQO Sensitivity Analysis

---

This memorandum is pre-emptive of the planned Updated Impact Assessment Report due in October. I have developed the analyses in this to provide earlier inputs to the rehabilitation design and to provide some indication of potential construction phase water quality objectives.

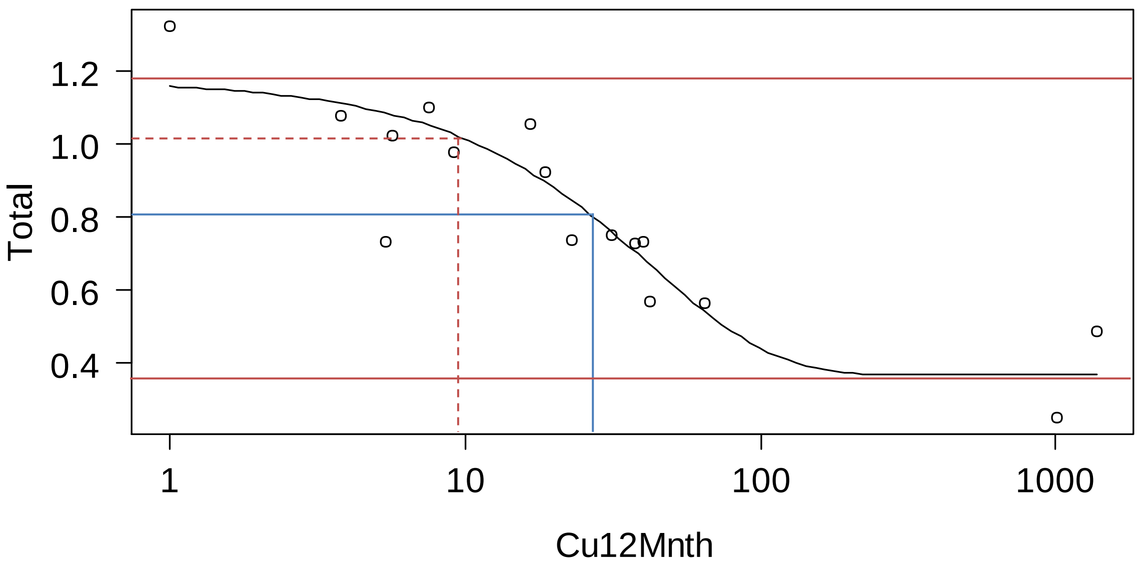
1.1 Error Detected in Previous Workings

In developing the construction phase sensitivity analysis, I had to develop a tool to back-calculate potential species protection percentages from the curves developed to derive locally derives water quality objectives as reported to the FMEA in July and Traditional Owners in August. In doing that I determined an error in the previous calculations.

What was reported by the drc package in the statistics program R as dose response percentiles (in terms of this use of the software, the concentration associated with a certain percentage reduction in the proportion of the average number of taxa from reference sites) was not, as the output appeared to indicate (and the software documentation did not indicate otherwise), the percentage in absolute terms. It was actually the percentage change from the fitted upper and lower asymptotes of the cumulative frequency distribution. In other words, the 20% effective dose was not equivalent to the point on the curve that related to 80% of species being present, but was actually 20% of the difference between the upper and lower asymptote below the upper asymptote, as shown in the figure below (the blue line indicates what was presumed that the software was reporting, the dashed red line indicates the actual figure and the solid red lines indicate the approximate asymptotes).

The implementation in the software did not follow normal conventions in reporting dose-response relationships, and in fact provided values of little practical use, hence the confusion in its initial use.

```
     Estimate Std. Error   Lower  Upper
1:5    2.4373     4.1205 -6.1082 10.983
1:10   4.8841     6.3537 -8.2926 18.061
1:20  10.0810     9.0732 -8.7357 28.898
1:30  15.8563    10.4149 -5.7430 37.456
> plot(model)
```

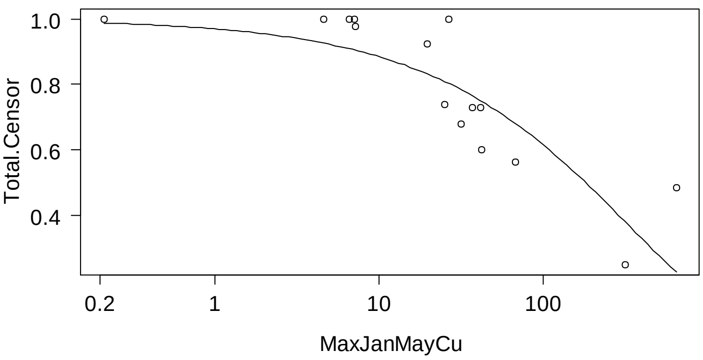


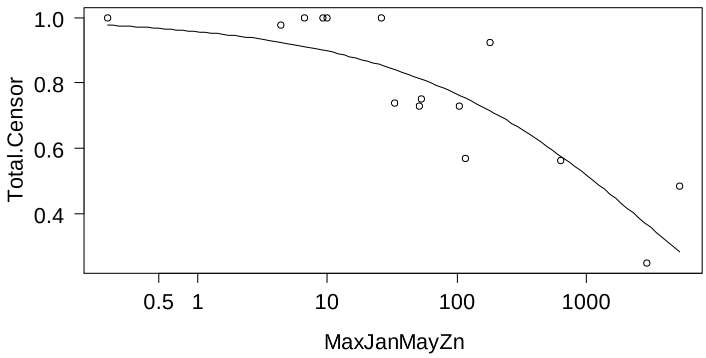
Note that this above example curve had not been used before, and was selected just for illustrative purposes.

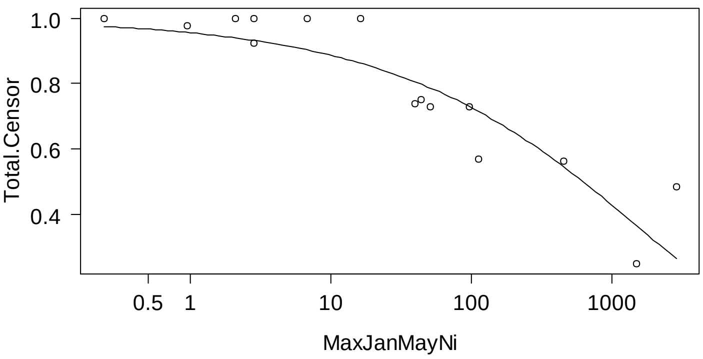
The problem arose because some reference sites had more than the average number of taxa across all reference sites (as must occur), and so the input data included values above 1. By censoring the data to a maximum of 1, and forcing the curve to be fitted through 1 and 0, the output dose response percentiles were then as they were anticipated to be, and reflecting of the agreed percentages of taxa used to set water quality objectives for each river zone.

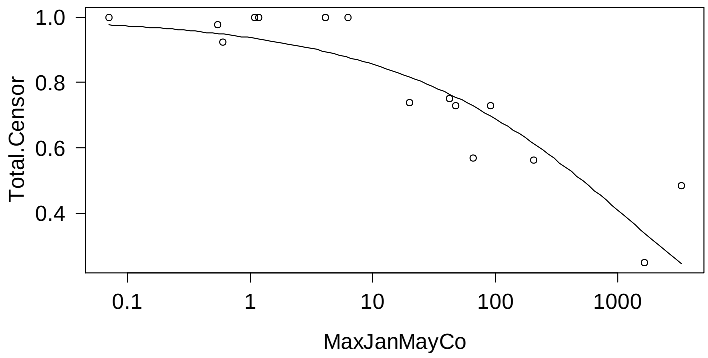
1.2 Calculation of LDWQOs for all parameters

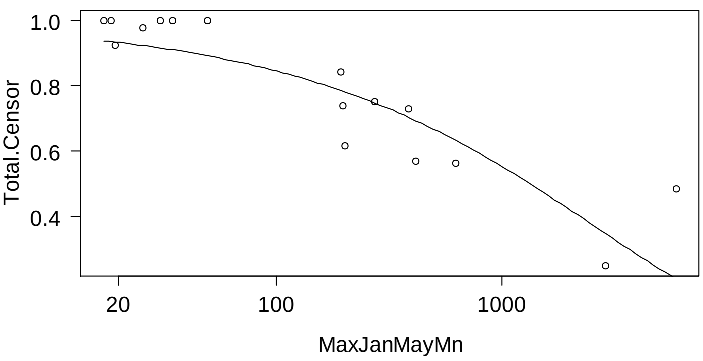
Having made this correction, LDWQOs were derived for all parameters for which there were available water quality measurement data for time periods relevant to the biological sampling in 2014 and 2015, and for which there was a gradient of taxonomic richness declining with increasing parameter concentration (or reducing value for pH). The resulting curves are shown below for all parameters. As was reported in July, the best fit to the biological dataset for metals was found for the maximum concentration measured in monthly sampling at each site between January and May (the month of biological sampling) at each site, and so that value was used for all parameters.

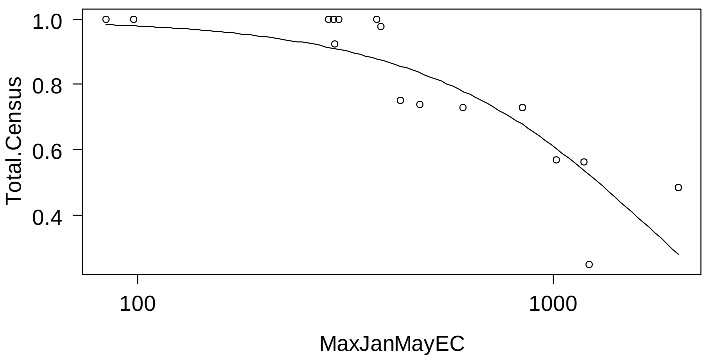

Total.Censor
1.0
0.8
0.6
0.4
0.2
1
10
100
MaxJanMayCu

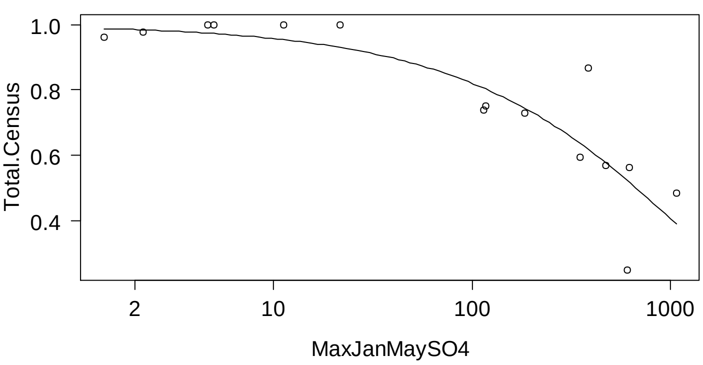

Total.Censor
1.0
0.8
0.6
0.4
0.5
1
10
100
1000
MaxJanMayZn

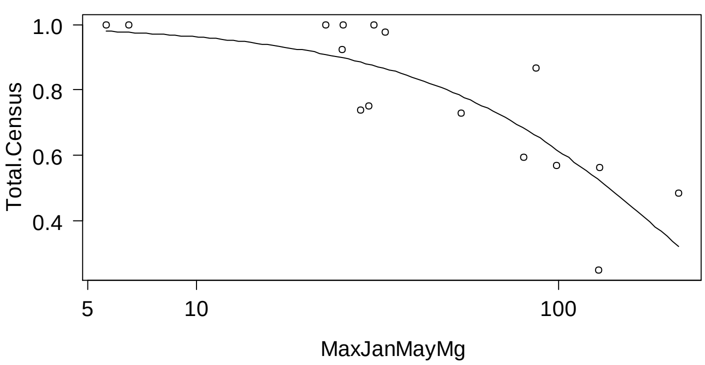

Total.Censor
1.0
0.8
0.6
0.4
0.5
1
10
100
1000
MaxJanMayNi


Total.Censor
1.0
0.8
0.6
0.4
0.1
1
10
100
1000
MaxJanMayCo


Total.Censor
1.0
0.8
0.6
0.4
20
100
1000
MaxJanMayMn


Total.Census
1.0
0.8
0.6
0.4
100
1000
MaxJanMayEC


Total.Census
1.0
0.8
0.6
0.4
2
10
100
1000
MaxJanMaySO4


Total.Census
1.0
0.8
0.6
0.4
5
10
100
MaxJanMayMg

Poor fits or no decline in percentile with increasing concentration were found for aluminium, iron, cadmium, uranium and pH. As aluminium and iron are commonly substantial constituents of acid rock drainage, the threshold response method (described in the impact assessment report) was used to seek LDWQOs for those parameters, but the other parameters were not considered further and the default WQOs for them should continue to be used.

The model fits for zinc, sulphate and magnesium were significantly poor (i.e. deviated significantly from a good fit), but the relationships were nonetheless used to examine whether the fitted trend line provided higher recommended LDWQOs than either the default WQOs or the threshold approach LDWQOs.

I then calculated the LDWQOs for each parameter in each river zone using the approach developed for the last impact assessment report where:

- If a good model fit was achieved, and the percentile response concentration was higher than the default WQO, the model fit figure was used;
    - If the percentile response concentration was lower than the default WQO but the threshold response figure was greater than the default WQO, the threshold LDWQO was used; or else
    - The default WQO was retained
- If a poor model fit was achieved, but the percentile response concentration was higher than the default WQO, then if the percentile response concentration was greater than the threshold response LDWQO, the fitted percentile response concentration was used;
    - If the threshold response LDWQO was higher than both the fitted percentile response concentration and the default WQO it was used; but
    - If the default WQO was higher than the threshold response LDWQO, the default WQO was retained.

The resulting derivation of the recommended LDWQOs is shown in the following table. Red text indicates values derived for parameters with poor statistical fit or no statistical fit.

All Taxa

	Site	WQO PC%	Current Recommended WQOs Cu	Zn	Ni	Co	Al	Fe	Mn	EC	SO4	Mg	W1.4 fit WQO for all taxa Cu	Zn	Ni	Co	Al	Fe	Mn	EC	SO4	Mg
East Branch	FC@LB	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	EB@LB	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	EB@G_Dys	<80%	8	142.5	55	2.8	236	300	759	2985	1192	42	60.2	210.5	130.4	89	no fit	no fit	394.6	790.9	245.2	75.5
	EB@GS200	<80%	8	142.5	55	2.8	236	300	795	2985	1192	42	60.2	210.5	130.4	89	no fit	no fit	394.6	790.9	245.2	75.5
	EB@GS327	80%	6.25	77.5	42.5	2.8	150	300	443	2985	997	21	27.5	63.8	43.1	25.9	no fit	no fit	167.7	560.7	120.3	49.3
	EBdsRB	80%	6.25	77.5	42.5	2.8	150	300	443	2985	997	21	27.5	63.8	43.1	25.9	no fit	no fit	167.7	560.7	120.3	49.3
	EB@GS097	80%	6.25	77.5	42.5	2.8	150	300	443	2985	997	21	27.5	63.8	43.1	25.9	no fit	no fit	167.7	560.7	120.3	49.3
	EBusHS	80%	6.25	77.5	42.5	2.8	150	300	443	2985	997	21	27.5	63.8	43.1	25.9	no fit	no fit	167.7	560.7	120.3	49.3
	EBdsHS	90%	4.5	37.5	32.5	2.8	80	300	228	427	761	7.1	7.86	9.45	7.35	3.6	no fit	no fit	42.6	323.3	38.5	25
	EBusFR	90%	4.5	37.5	32.5	2.8	80	300	228	427	761	7.1	7.86	9.45	7.35	3.6	no fit	no fit	42.6	323.3	38.5	25
Finniss River	FRusMB	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FRdsMB	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FR@GS204	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FR3	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FRusFC	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FRdsFC	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13
	FR0	95%	3.4	20	20	2.8	55	300	140	126	594	2.7	2.36	1.51	1.34	0.54	no fit	no fit	11.5	190.7	12.9	13

	Site	WQO PC%	Threshold Cu	Zn	Ni	Co	Al	Fe	Mn	EC	SO4	Mg	Recommended WQO (All taxa) Cu	Zn	Ni	Co	Al	Fe	Mn	EC	SO4	Mg
East Branch	FC@LB	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	EB@LB	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	EB@G_Dys	<80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	60.2	210.5	130.4	89	236	300	759	2985	1192	86.6
	EB@GS200	<80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	60.2	210.5	130.4	89	236	300	795	2985	1192	86.6
	EB@GS327	80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	27.5	180	43.1	25.9	150	300	443	2985	997	86.6
	EBdsRB	80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	27.5	180	43.1	25.9	150	300	443	2985	997	86.6
	EB@GS097	80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	27.5	180	43.1	25.9	150	300	443	2985	997	86.6
	EBusHS	80%	41.8	180	97.3	91.6	117	262	385	845	387	86.6	27.5	180	43.1	25.9	150	300	443	2985	997	86.6
	EBdsHS	90%	26.9	180	16.2	6.28	117	262	49.4	384.5	21.7	33.2	7.86	180	32.5	3.6	117	300	228	427	761	33.2
	EBusFR	90%	26.9	180	16.2	6.28	117	262	49.4	384.5	21.7	33.2	7.86	180	32.5	3.6	117	300	228	427	761	33.2
Finniss River	FRusMB	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FRdsMB	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FR@GS204	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FR3	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FRusFC	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FRdsFC	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2
	FR0	95%	26.9	26.1	16.2	6.28	117	262	49.4	384.5	21.7	33.2	3.4	26.1	20	2.8	117	300	140	190.7	594	33.2

1.3 Construction Phase LDWQO Sensitivity Analysis

The fitted statistical distribution curves were used to examine how potential deterioration of water quality during construction of the rehabilitation might affect the aquatic ecosystem biodiversity relative to calculated current biodiversity at each site.

However, since construction might affect water quality at any time of the year (although only via groundwater and direct discharges during the dry season), not just the January to May period of each year used to derive the statistical fits, and given construction is expected to last for up to eight years, the 95%ile of the measured concentrations of each parameter for the full dataset at each site (as provided to Hydrobiology for sampling back to 2012) was used as the representation of "current" condition. Note that in general that 95%ile was higher than the maximum concentrations in the two time periods in 2014 and 2015 used to fit the data, and so indicated lower biodiversity at most sites that was found in the May/June sampling in those years.

The 95%ile for each parameter at each site was then multiplied by 1.25 and 1.5 to see how increases in the 95%ile concentration of those magnitudes might affect the expected biodiversity at each site. The results of the analysis are shown in the following table. Again, red text indicates predictions made on the basis of a poor statistical fit.

For most parameters, an up to 50% increase in the 95%ile concentration resulted in a less than 6% reduction in biodiversity expected, but higher differences were found for conductivity, sulphate and magnesium (the latter two parameters with poor distribution fits). Note that for the latter three parameters, the curve fits are unlikely to have actually been reflective of toxicity, because the derived percentile reduction concentrations were less than the default WQO, or in the case of magnesium slightly higher than the default WQO that was derived for much softer waters by ERISS, but lower than the threshold response levels from the field data. That is, the predicted responses to increased concentrations of those parameters were much greater than would actually be expected to occur.

It should be noted that as the East Branch is intermittent, most recruitment to sites on that tributary is driven by upstream movement or aerial recruitment from the perennial waters of the main Finniss River. Therefore, a temporary reduction in biodiversity during construction at a site due to deterioration of water quality would be rapidly recovered if, as expected, water quality improves when construction stops, and should be able to recover to the targeted levels of biodiversity if the overall LDWQOs are achieved post rehabilitation.

Depending on the NTEPA acceptance of the principle of short-term reduced biodiversity during construction in order to achieve long term improvement in biodiversity, this sensitivity analysis should provide them with guidance on acceptable increases in the concentrations of the parameters in the table. If the NTEPA expresses a preference for a maximum percentile of biodiversity deterioration, I would be able to use the derived equations to calculate what that would equate to in terms of parameter concentrations.

Parameter	Site	GS200	GS327	GS97	GS204
Copper (µg/L)	Measured	**767**	**57**	**37.2**	**9.44**
	Current %PC	*19.5%*	*70.8%*	*76.5%*	*88.9%*
	Current+25%	*15.4%*	*67.4%*	*73.6%*	*87.4%*
	Current+50%	*12.4%*	*64.4%*	*71.1%*	*86.1%*
Zinc (µg/L)	Measured	**10142**	**347.4**	**122.6**	**21.8**
	Current %PC	*19.5%*	*64.8%*	*74.9%*	*86.4%*
	Current+25%	*16.8%*	*62.2%*	*73.0%*	*85.2%*
	Current+50%	*14.7%*	*60.0%*	*71.3%*	*84.2%*
Nickel (µg/L)	Measured	**4571**	**289.7**	**108.7**	**13.1**
	Current %PC	*20.0%*	*60.6%*	*71.9%*	*87.4%*
	Current+25%	*17.0%*	*57.7%*	*69.6%*	*86.2%*
	Current+50%	*14.8%*	*55.2%*	*67.6%*	*85.2%*
Cobalt (µg/L)	Measured	**5329**	**201.7**	**94.54**	**6.22**
	Current %PC	*18.4%*	*61.5%*	*69.4%*	*87.8%*
	Current+25%	*15.9%*	*58.9%*	*67.2%*	*86.8%*
	Current+50%	*13.9%*	*56.7%*	*65.3%*	*86.0%*
Manganese (µg/L)	Measured	**7980**	**620**	**477.5**	**102.8**
	Current %PC	*15.7%*	*63.3%*	*67.3%*	*84.3%*
	Current+25%	*12.3%*	*59.7%*	*63.9%*	*82.5%*
	Current+50%	*9.9%*	*56.5%*	*61.0%*	*80.8%*
Conductivity (µS/cm)	Measured	**2294.4**	**1184.5**	**873.1**	**472**
	Current %PC	*21.8%*	*53.9%*	*66.5%*	*83.8%*
	Current+25%	*12.7%*	*43.2%*	*57.5%*	*78.7%*
	Current+50%	*7.1%*	*34.1%*	*49.2%*	*73.6%*
Sulphate (mg/L)	Measured	**1452**	**471**	**433.3**	**23.4**
	Current %PC	*31.6%*	*57.8%*	*59.5%*	*92.7%*
	Current+25%	*26.3%*	*53.0%*	*54.8%*	*91.6%*
	Current+50%	*22.2%*	*48.9%*	*50.8%*	*90.6%*
Magnesium (mg/L)	Measured	**297.1**	**98.9**	**95.74**	**39.47**
	Current %PC	*19.9%*	*61.8%*	*62.9%*	*84.0%*
	Current+25%	*12.7%*	*54.1%*	*55.3%*	*80.0%*
	Current+50%	*8.0%*	*47.2%*	*48.4%*	*76.1%*

I trust that this memorandum is of assistance with both rehabilitation design and discussions of construction phase water quality objectives with the NTEPA. If you have any queries please do not hesitate to ask.

Ross Smith