Grassy Mountain Coal Project: review of hydrogeology, groundwater-surface water interactions and geochemistry

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On behalf of the Coalition of Alberta Wilderness Association and Grassy Mountain Group

November 19, 2020

Concerns with Benga EIA results

1. Knowledge of the geological and hydrogeological regime and its influences *(with a heavy reliance on models attempting to mimic complex systems)*
2. The use of “average” conditions *(that do not honour the considerable range of variability in historical records resulting in “not significant” impact ratings)*
3. Geochemical implications for waste rock areas, SBZs, and mine related water bodies *(without a full exploration of potential effects and/or viability)*
4. Certainty that mitigation measures will be successful *(without clear evidence or exploration of long-term feasibility)*
5. Climate change considerations *(that are not fully representative of conditions that could occur and negatively impact the water balance and reliant ecosystems)*

Benga’s assessment of impacts is predicated on modelled results

Models in the context of decision-making

1. Models are a gross simplification of natural geological, hydrogeological, hydrological, and geochemical conditions *(it is hard to mimic nature with high degree of accuracy).*

2. Models require a suitable amount of base information to reduce assumptions and lead to better results *(less data = less accuracy).*

3. Model outputs are highly influenced by complexities in actual conditions, and are subject to propagating errors where conditions are not well-known or constrained.

4. Models produce non-unique results, with similar results being achieved using different combinations of input parameters *(i.e. curve-fitting).*

5. Models can be helpful in determining the direction things may go, but are challenged when trying to simulate absolute magnitude.

6. Models are only as good as the individuals building them, and are not meant to replace human intelligence *(different results will be obtained by different modellers, and some modellers are better than others).*

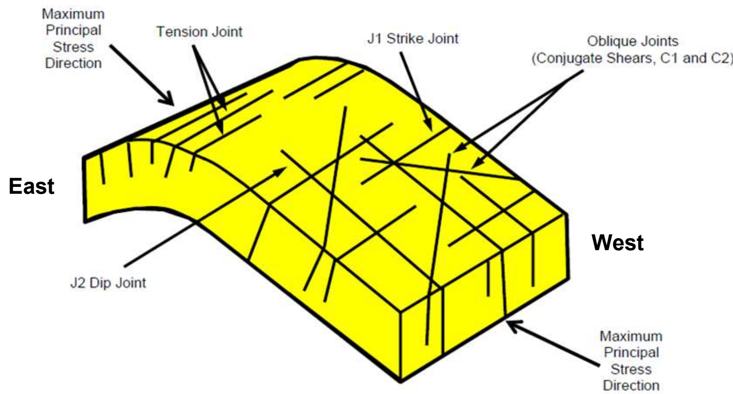
Model assumptions used by Benga (CR #3, pdf pg. 36, CIAR #42)

- *"For the purposes of the assessment, the entire rock/sediment package may be treated effectively as a homogeneous, anisotropic medium".*
  - *an understandable assumption; however, the complexity of the strata and likely presence of active and open faults and fractures will adversely affect this condition*
- *"The system will largely behave as a confined aquifer, although it can effectively represent unconfined conditions where these occur".*
  - *a reasonable assumption*
- *"On the scale of the assessment, groundwater system flow, which is expected to occur dominantly via fracture flow, can be approximated by an Equivalent Porous Media (EPM) model".*
  - *a reasonable assumption*
- *"K (hydraulic conductivity) is largely anisotropic, with highest K parallel to bedding planes/coal seams and to thrust fault strike with lowest K perpendicular to bedding. In general terms, K, in all orientations, decreases with depth, according to the model proposed by Wei et al. 1995".*
  - *the presence of faults and fracture networks acting a groundwater flow pathways will adversely affect this assumption*

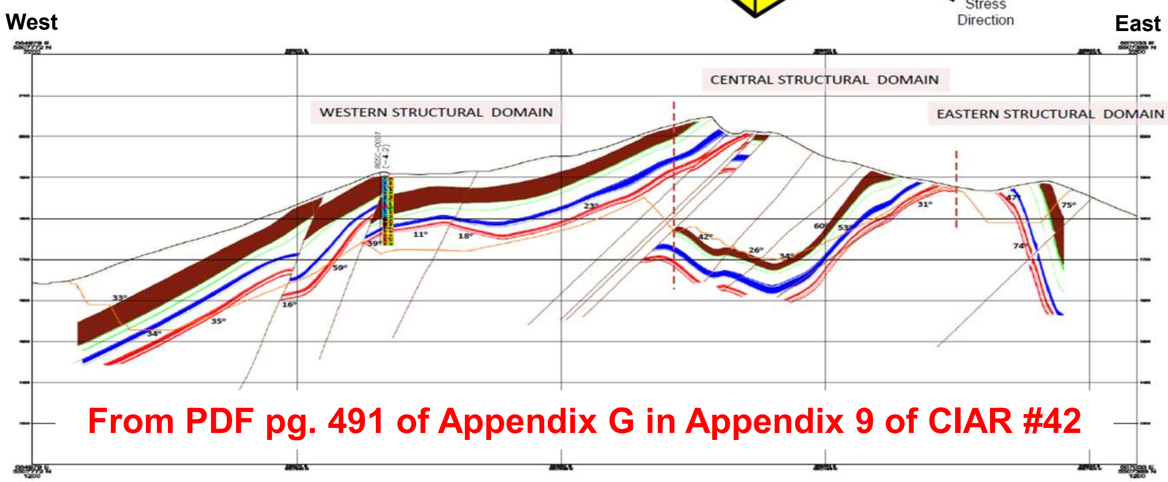
Model assumptions (continued)

- *"Apart from preferential flow parallel to fault strike, there is no major fault acting as a significant conduit and no major regional deep flow influences".*
  - *this is an unrealistic assumption; there is no proof to substantiate this claim as no investigation was conducted*
- *"Recharge follows the same spatial trend with elevation as precipitation. The precipitation, evaporation and evapotranspiration mechanisms are not explicitly modeled but assumed to be integrated as "net recharge". It is assumed that this approach will not unduly bias the model".*
  - *the assumption of recharge has not been substantiated with any documented or field-based evidence*
- *"Water level data and creek flow data collected between late 2013 and early 2016 are representative of the pre-mining steady-state conditions and long-term trends".*
  - *the time horizon used is in no way representative given the extreme variability noted in creek flows as evidenced by the Water Survey of Canada gauging station "Gold Creek near Frank"*

Complex geological setting



From PDF pg. 573 of Appendix B in Appendix 9 of CIAR #42



From PDF pg. 491 of Appendix G in Appendix 9 of CIAR #42

Example rock core photo

(from PDF pg. 575-689 of Appendix C in Appendix 9 of CIAR #42)

Benga has indicated that the Project area is geologically and structurally complex, with fault and fracture control on groundwater flow, including west-east faults (as reinforced by AQ#5 - Coalition - Cooley_veins_AAPG - Water Topics.pdf). This type of conditions is nearly impossible to mimic accurately within a modelling framework.

Drainage patterns as evidence of fault patterns

"A drainage pattern in which tributaries join at high angles, often approaching right angles, which is common in areas with rocks of different strengths (thus resistance to erosion) and in areas with regular series of folds (anticlines and synclines)."

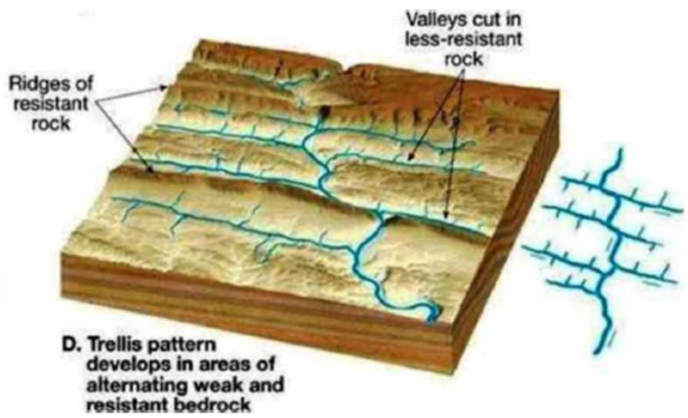
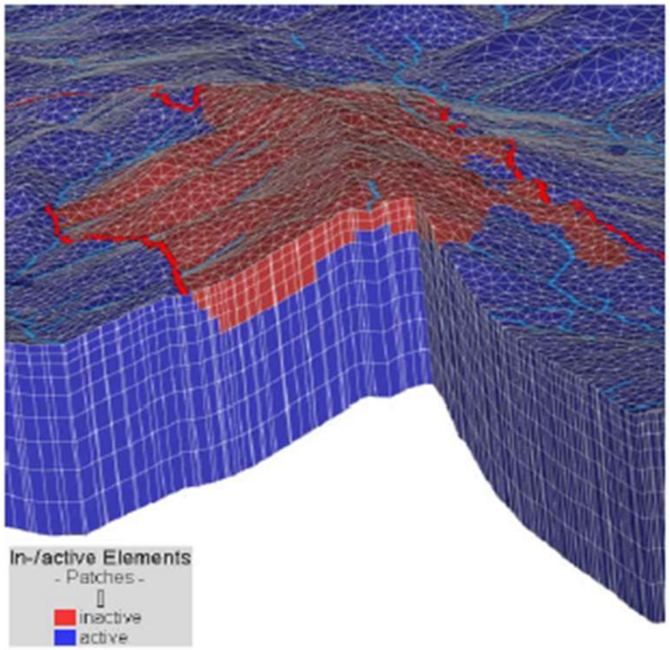


Figure 1, PDF pg. 72 of CIAR #553

The occurrence of trellis-style drainage in the Project area is direct evidence of north-south and west-east trending fault systems, which is consistent Benga's site investigations. West-east faults have not been included, explicitly, in Benga's modelling.

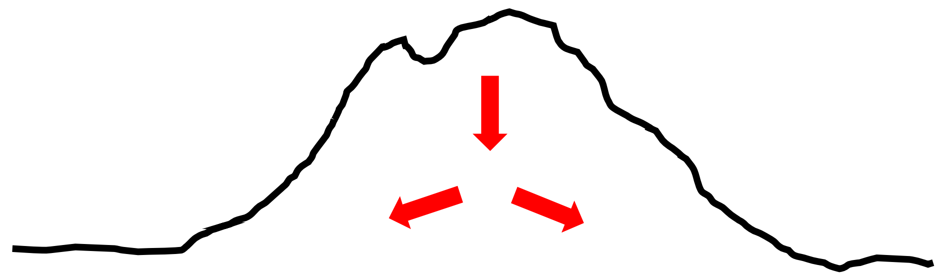
Changing hydraulic conductivity conditions

From Figure 3-4, PDF pg. 214 of CR#3 in CIAR #42

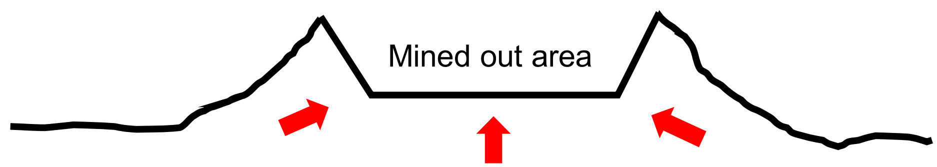


FEFLOW (R)

3D Zoom of the Inactive Cells in the Pit Excavation



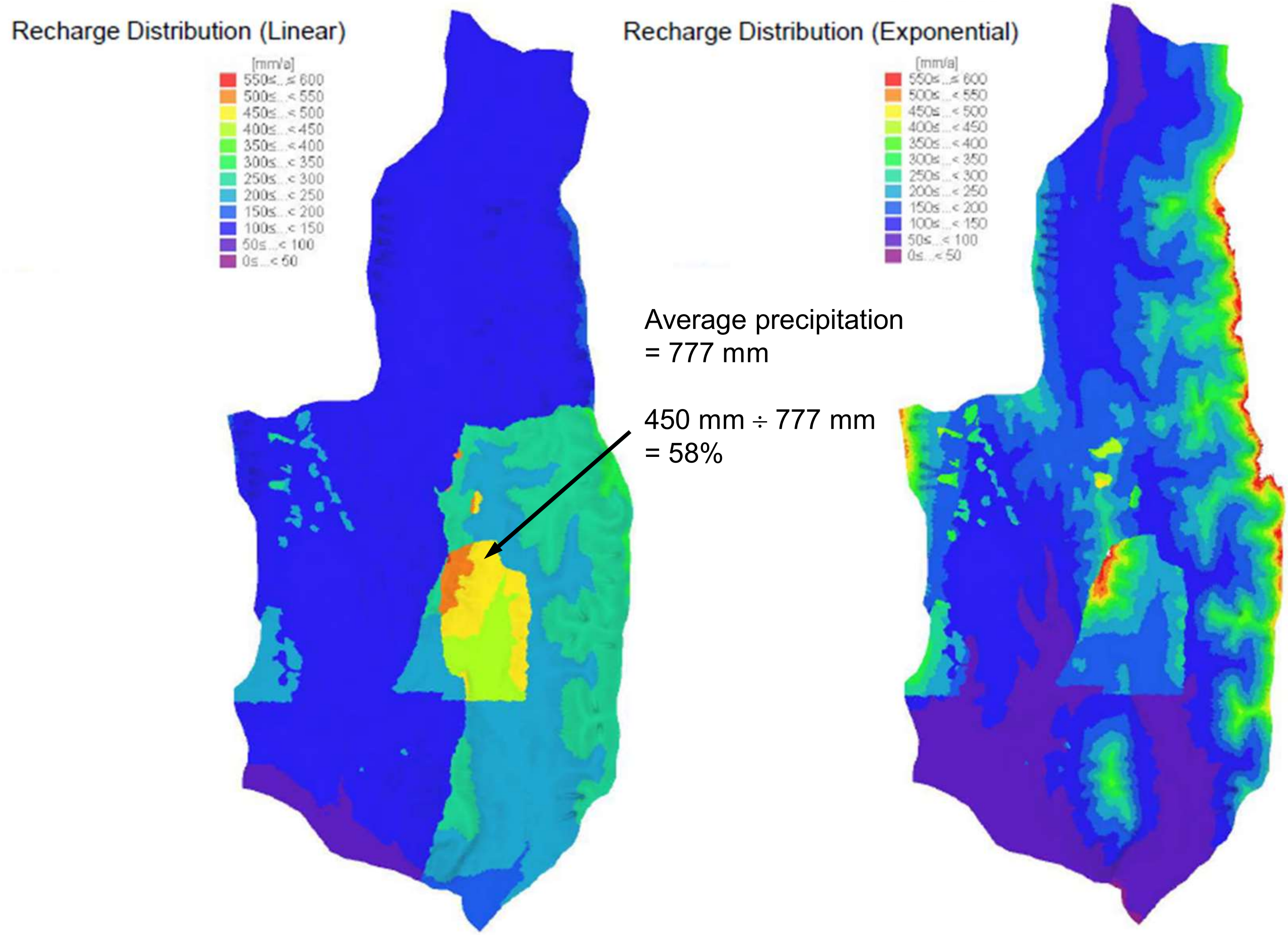
Downward and outward pressure from overlying rock reduces hydraulic conductivity values with increasing depth



Removal of overlying rock relaxes overlying pressure leading to hydraulic conductivity increase along base and sides of

Benga's groundwater modelling has not sufficiently considered the increase in hydraulic conductivity that will occur when the mine pit is excavated (i.e. an order of magnitude or so vs. ±50% used in model sensitivity analysis). The K values in the model have been dominated by measurements in the coal zone (to be removed), but information is lacking for the other formations.

Groundwater recharge



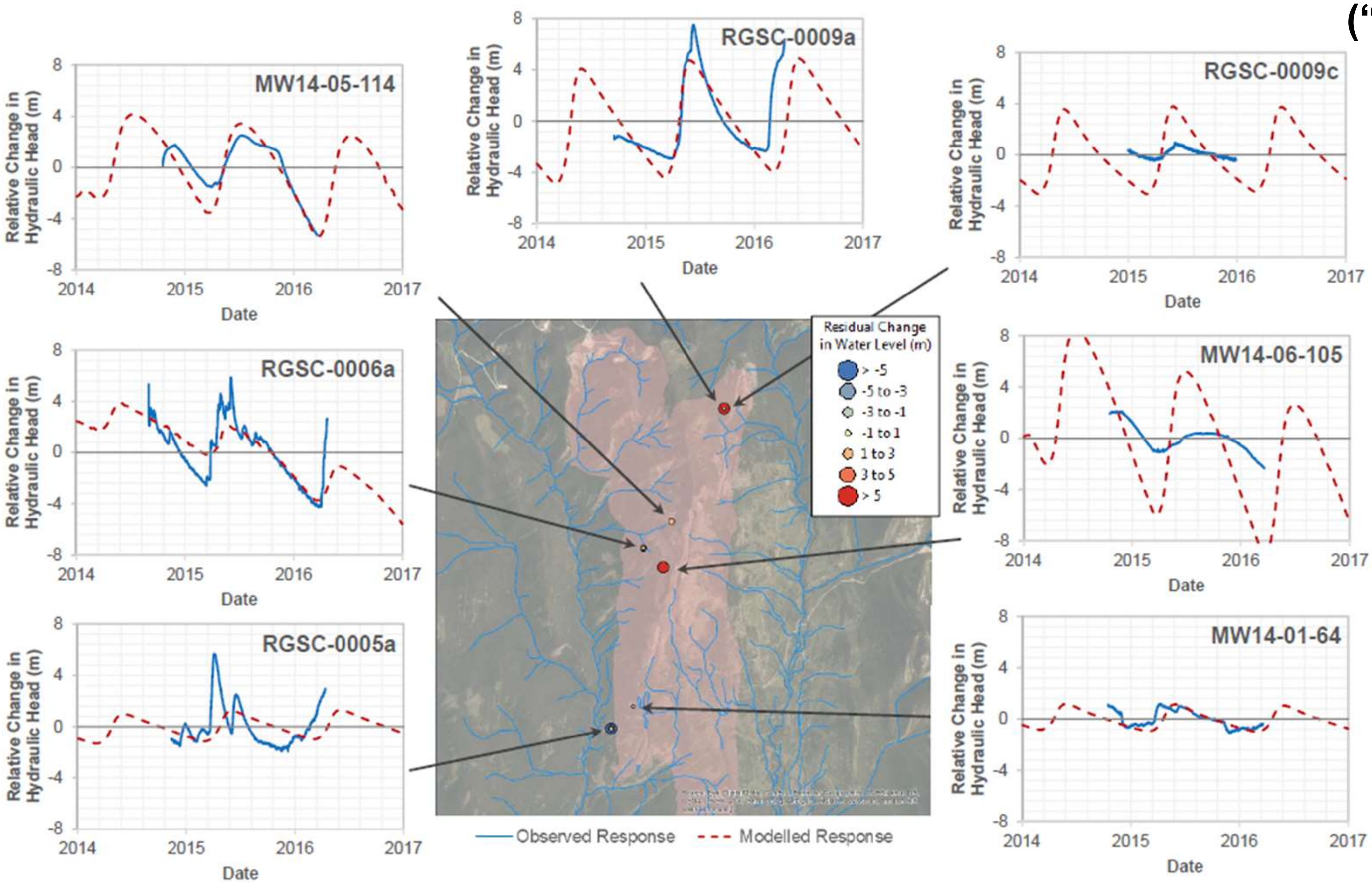
From Figure 3-5, PDF pg. 215 of CR#3 in CIAR #42

re-oriented for easier viewing

Benga has applied too much recharge (up to 50% or more) to certain parts of the model domain, which will reduce the effects and extent of drawdown, and lead to lower magnitude baseflow reductions in some locations.

Transient Calibration: Monthly Hydraulic Heads

(“Linear” Calibration)

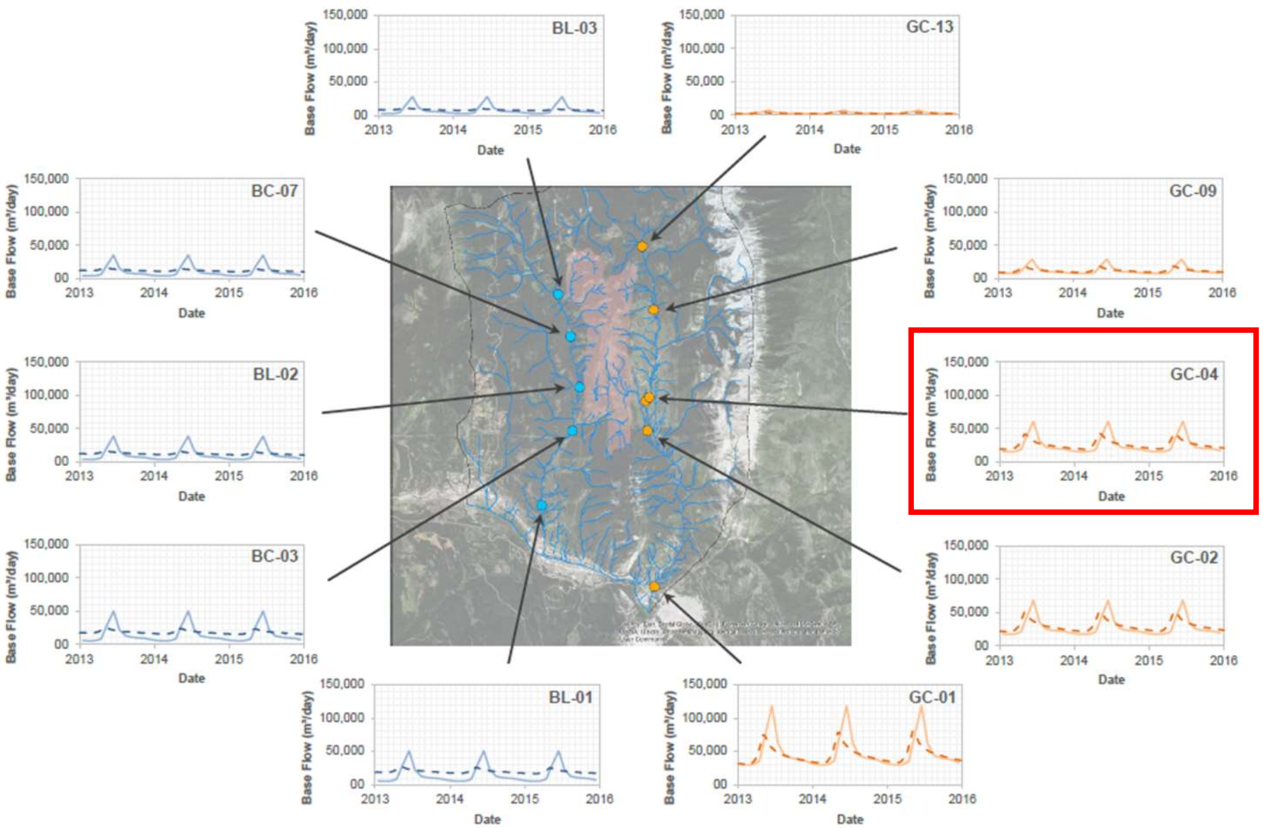


From Figure 3-12, PDF pg. 226 of CR#3 in CIAR #42

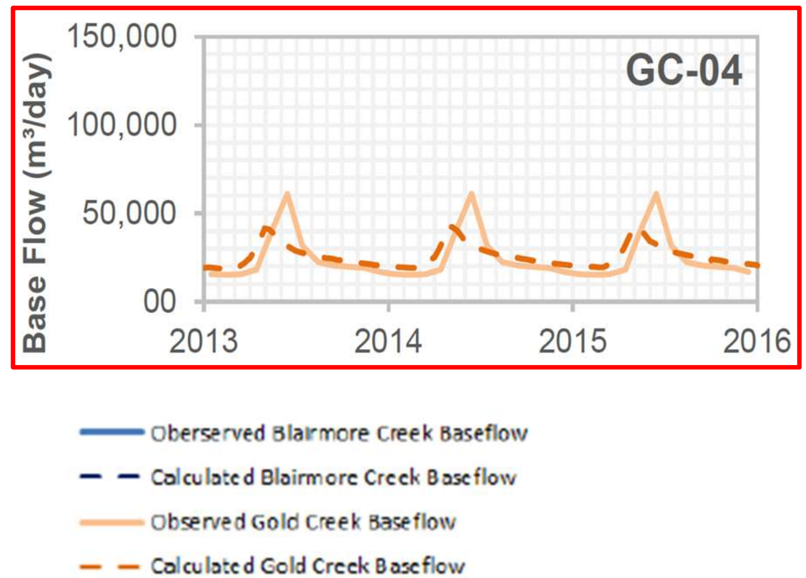
Despite Benga’s contention that the model calibration is acceptable, comparisons of modelled vs. observed hydraulic heads is not very good in some parts of the model domain. This leads to concern regarding the ability of the model accurately simulate future conditions.

Transient Calibration: Monthly Baseflow Variability

(“Linear” Calibration)

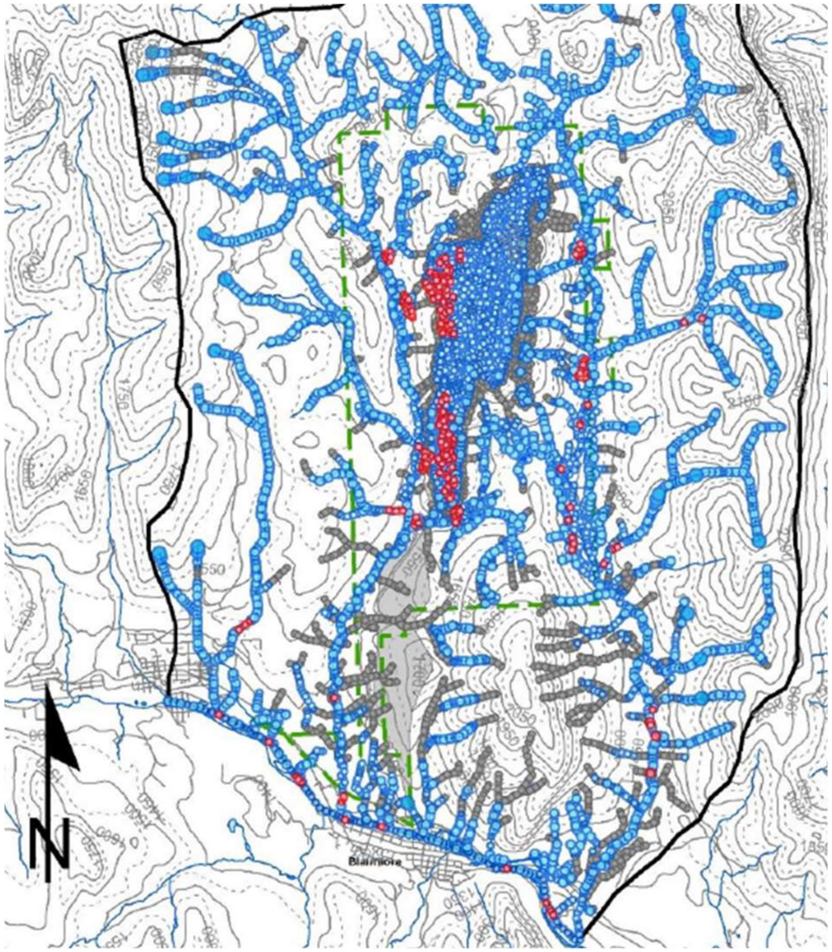


From Figure 3-14, PDF pg. 228 of CR#3 in CIAR #42



Baseflow estimation is challenging at the best of times, and subject to a number estimation techniques that infer rates from existing streamflow data (i.e. indirect method). Benga’s comparisons of modelled vs. observed results over- or under-represents peaks and lows indicating that the model is not accurately representing timing and rate.

End of Mine conditions

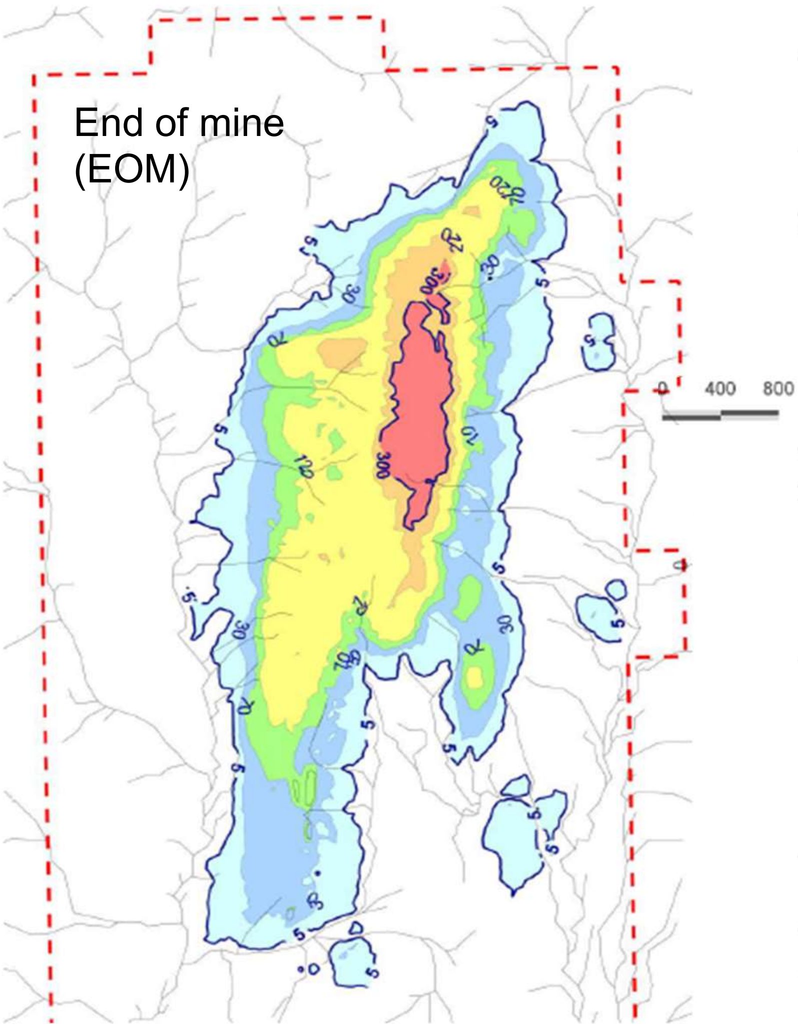


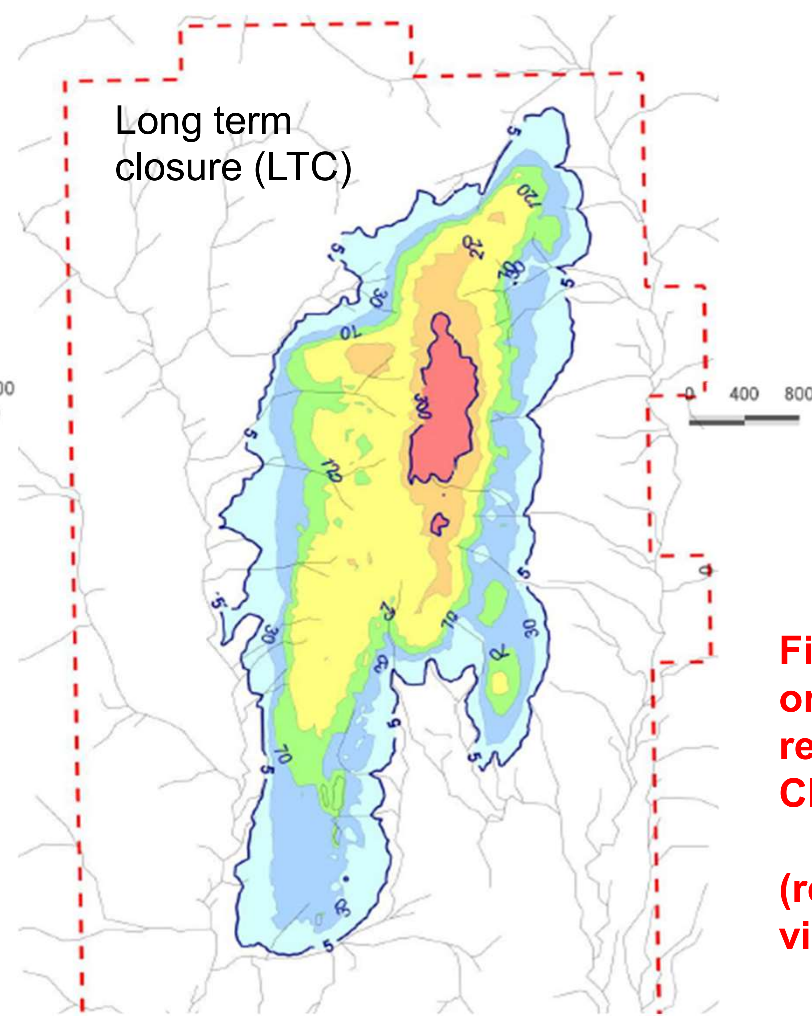
From Figure 22-1, PDF pg. 221 of Addendum 6 in CIAR #70

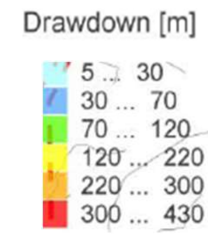
(re-oriented for easier viewing)

Removal of Grassy Mountain will permanently decrease the watertable by up to 430 m and “dry up” springs and wetlands, but the model suggests sustained flow immediately adjacent de-activated seepage nodes which is difficult to rationalize.

Projected drawdown





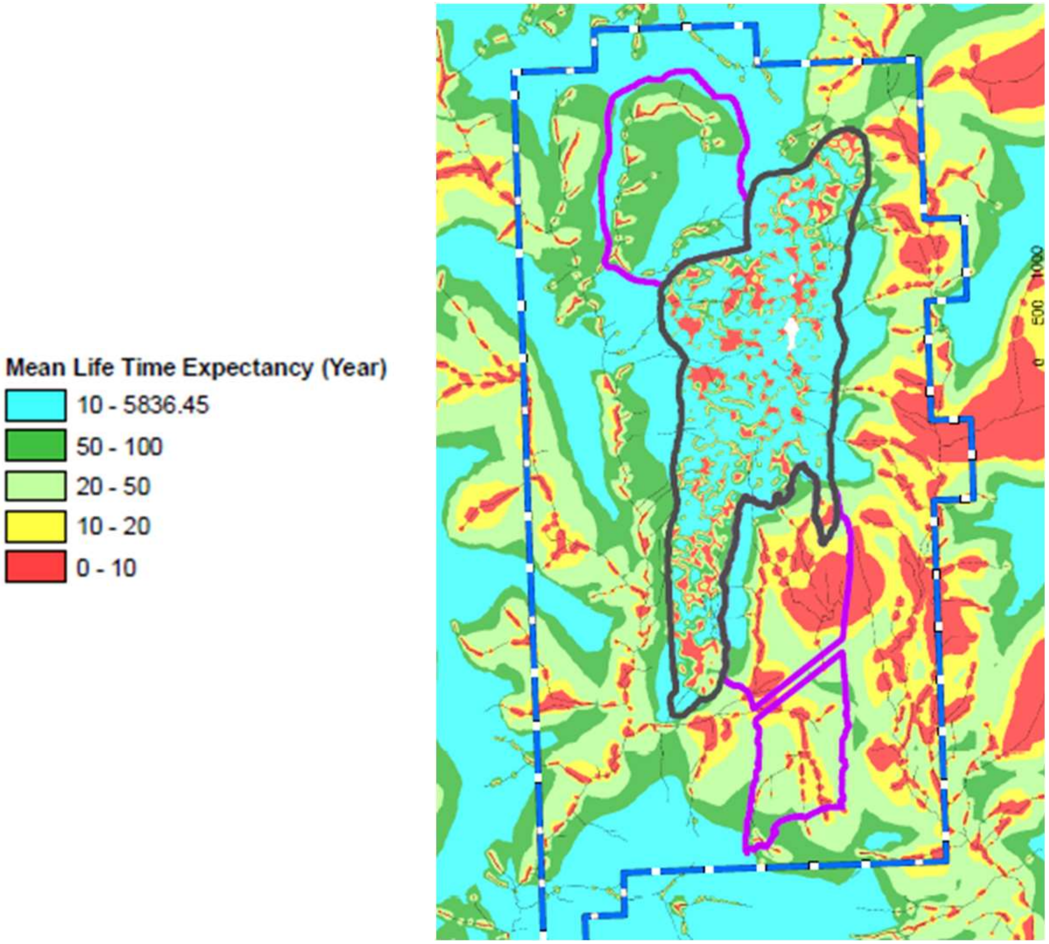


Figures 3-22 (left) and 3-25 on PDF pg. 242 and 246, respectively of CR#3 in CIAR #42

(re-oriented for easier viewing)

Benga’s 400 m limit of drawdown around mine pit is overfly optimistic, and the occurrence of isolated areas of drawdown outside the main area of drawdown is difficult to rationalize. The limit of 0-5 m drawdown is not defined.

Projected groundwater residence time

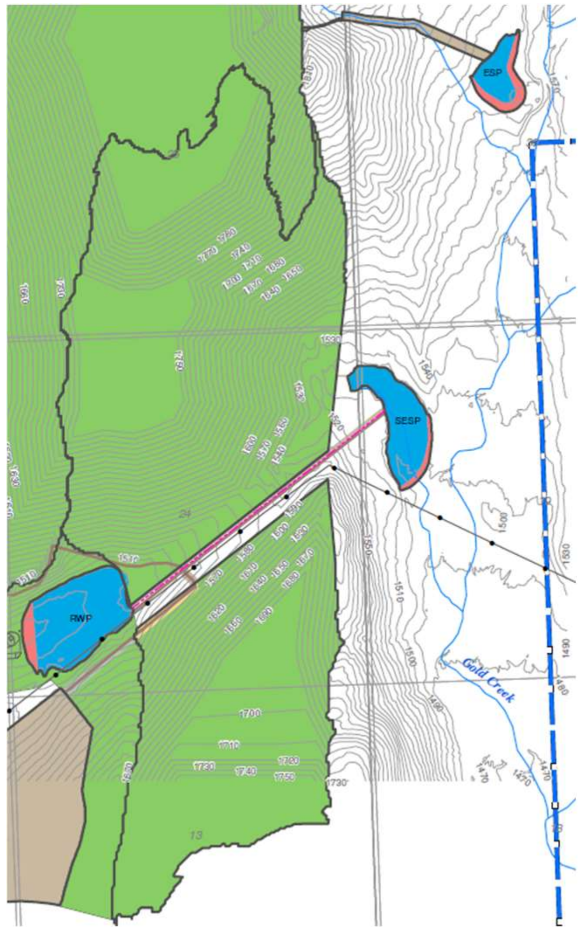


From PDF pg. 112 of CR#3 in CIAR #42

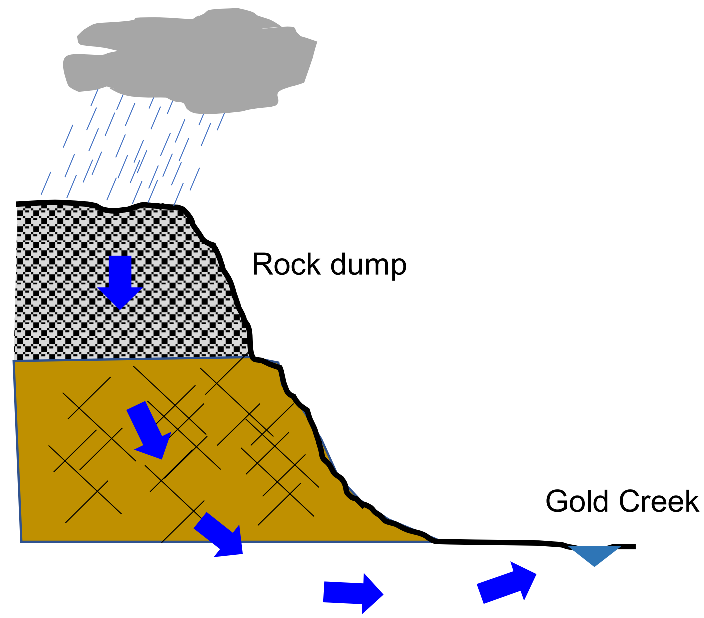
(and referred to in Figure 3, PDF pg. 76 in CIAR #553)

Benga's Mean Life Time Expectancy (or residence time) of groundwater in the area of the Central and South rock dumps, Sedimentation Ponds east of the mine, and the End Pit Lake is on the order of 0-10 years, meaning contaminants originating from these areas could reach Gold Creek in a relatively short period of time.

Seepage risk



Excerpt from Figure C.1.3-26, PDF pg. 217, Section C of Project Description in CIAR #42



Unlined rock dumps are situated in upland areas, up to 200 m above the creek valleys, which promotes a significant downward flow potential. Unlined ponds are also located near, or on top of, tributary streams. Both are situated on top of heavily fractured rock which translates to “high risk” for contaminant movement.

Modeled reduction in baseflow

Table 3-6: Monthly Base Flow Reduction, Baseline to LTC

Month	D1	BL03	BC07	BL02	BC03	BL01	Blairmore Creek	GC13	GC09	GC04	GC02	GC01	Gold Creek
	15	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
	Percent Change	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**	**Percent Change**
January	0.14%	0.36%	-13.5%	-16.8%		-10.0%	-9.7%	-11.7%	-10.0%	-7.2%	-15.2%	-5.2%	-5.1%
February	0.14%	0.29%	-13.5%	-16.9%	-11.0%	-10.0%	-9.7%	-11.7%	-9.8%	-7.0%	-14.9%	-5.1%	-5.0%
March	0.14%	0.29%	-13.4%	-16.7%	-11.1%	-10.1%	-9.8%	-11.3%	-10.2%	-7.4%	-15.8%	-5.3%	-5.2%
April	0.12%	0.23%	-12.9%	-16.0%	-11.4%	-10.4%	-10.0%	-9.1%	-11.9%	-8.8%	-18.62	-5.9%	-5.8%
May	0.12%	0.20%	-12.6%	-15.7%	-11.3%	-10.2%	-9.8%	-8.2%	-12.5%	-9.6%	-20.0%	-6.3%	-6.2%
June	0.12%	0.21%	-12.8%	-16.0%	-11.1%	-10.1%	-9.7%	-9.6%	-12.5%	-9.5%	-19.3%	-6.4%	-6.3%
July	0.12%	0.21%	-13.1%	-16.2%	-11.1%	-10.1%	-9.7%	-10.3%	-12.2%	-9.2%	-18.6%	-6.3%	-6.2%
August	0.12%	0.21%	-13.2%	-16.3%	-11.1%	-10.1%	-9.7%	-10.8%	-11.9%	-8.9%	-17.9%	-6.2%	-6.1%
September	0.12%	0.21%	-13.3%	-16.5%	-11.0%	-10.0%	-9.7%	-11.1%	-11.5%	-8.6%	-17.4%	-6.0%	-5.9%
October	0.12%	0.21%	-13.4%	-16.6%	-11.1%	-10.1%	-9.8%	-11.4%	-11.2%	-8.2%	-16.8%	-5.8%	-5.8%
November	0.12%	0.18%	-13.5%	-16.7%	-11.1%	-10.1%	-9.8%	-11.6%	-10.8%	-7.9%	-16.3%	-5.7%	-5.6%
December	0.11%	0.21%	-13.5%	-16.8%	-11.1%	-10.1%	-9.8%	-11.7%	-10.6%	-7.8%	-16.0%	-5.6%	-5.5%
Average Transient Change	0.12%	0.23%	-13.2%	-16.4%	-11.1%	-10.1%	-9.8%	-10.7%	-11.3%	-8.4%	-17.2%	-5.8%	-5.7%
Steady State Change	-0.03%	-0.02%	-13.1%	-16.2%	-10.7%	-9.6%	-9.2%	-9.5%	-11.3%	-8.5%	-17.5%	-6.0%	-5.9%

From PDF pg. 250 of CR#3 in CIAR #42

and

Table 2, PDF pg. 80 in CIAR #553

Benga's reliance on "average" conditions under-represents the higher magnitude modeled impacts that occur to certain stream reaches during critical times of the year (i.e. July to March low flow period).

Model sensitivity

Table 3-8: Sensitivity of Baseline "Linear" Model

Parameter	Parameter variation	Effect on Hydraulic Head % NRMSE	Effect on Base Flow
K & R	Reduced by 50%	Null	High
	Increased by 50%	Null	High
K	Reduced by 50%	Null	Null
	Increased by 50%	Medium	Null
Recharge	Reduced by 50%	High	High
	Increased by 50%	Null	High
K anisotropy	Isotropic ($K_{xy} = K_z$, K_{xy} oriented horizontally)	Null	Null
	Isotropic within layers: K decreasing with depth. No influence from bedding and coal seam orientation	High	Null
	Anisotropic: primary K (K_x and K_y) parallel to bedding. No influence from thrust faults	Null	Null
Geological Structure	Low K Thrust faults (barrier to flow): 2.5 order of magnitude lower than background	Null	Null
	Low K Thrust faults (conduit to flow): 2.5 order of magnitude lower than background	Low	Null

From Table 3-9, PDF pg. 258 of CR#3 in CIAR #42

and

Table 1, PDF pg. 74 of CIAR #553

Benga's model is highly sensitive to recharge, so not getting this parameter correct will have serious ramifications for the water balance calculations, baseflow reduction estimates, and resulting water quality modelling.

Impact to modeled outputs

PDF pg. 295 of CR#3 in CIAR #42

Table C-20: Relative difference (%) : Long-term closure sensitivity models to the long-term closure base case model

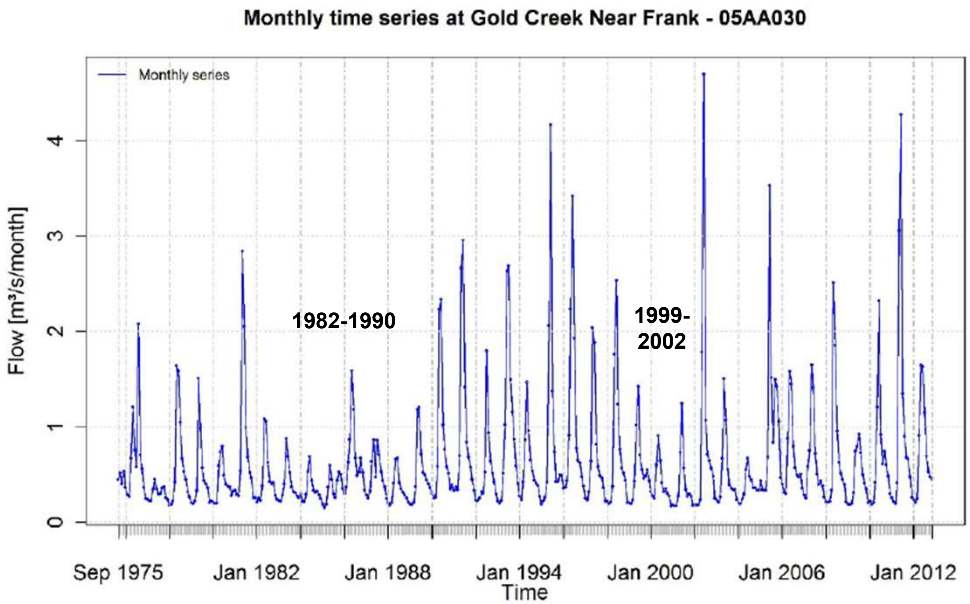
File name	RIVER / CREEKS															
	D1	BL03	BC07	BL02	BC03	BL01	Blairmore Creek	GC13	GC09	GC04	GC02	GC01	Gold Creek	Small Creeks	West Creek	Crowsnest River
Sensitivity: K/R ratio increased by 50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	49%	50%	50%
Sensitivity: K/R ratio reduced by 50%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-33%	-34%	-33%	-33%
Sensitivity: Isotropic layer K distribution	0%	-5%	-3%	-3%	-7%	-4%	-4%	1%	2%	2%	2%	4%	4%	-17%	-4%	-9%
Sensitivity: No influence from bedding / K decrs. With depth	2%	-3%	-2%	-2%	-4%	-2%	-1%	1%	-8%	-3%	-3%	1%	1%	-9%	-7%	-38%
Sensitivity: Kx = Ky (no influence from thrust faults)	1%	-1%	0%	-1%	-1%	0%	0%	4%	-1%	0%	0%	0%	0%	-5%	-2%	-22%
Sensitivity: Faults with low K (Kxyz /2.5)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	1%
Sensitivity: Faults with high K (Kxyz x2.5)	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	-1%
Sensitivity: K increased by 50%	1%	0%	0%	0%	0%	-1%	-2%	-4%	0%	0%	0%	0%	0%	1%	1%	23%
Sensitivity: K reduced by 50%	0%	0%	0%	0%	0%	1%	1%	3%	0%	0%	0%	0%	0%	-3%	-1%	-16%
Sensitivity: R increased by 50%	51%	50%	51%	50%	50%	52%	52%	54%	49%	50%	50%	50%	50%	46%	48%	26%
Sensitivity: R reduced by 50%	-33%	-34%	-34%	-33%	-34%	-34%	-34%	-36%	-33%	-34%	-33%	-33%	-33%	-33%	-33%	-18%
Sensitivity: R Dump increased by 50%	0%	0%	6%	5%	6%	6%	5%	0%	0%	0%	0%	1%	1%	-1%	0%	0%
Sensitivity: R Dump reduced by 50%	0%	0%	-4%	-4%	-4%	-4%	-4%	0%	0%	0%	0%	-1%	-1%	-1%	0%	0%

PDF pg. 261 of CR#3: *"It is conceivable that recharge values, and hence, base flow could vary by as much as 50% higher or 33% lower than currently estimated values, hence base flow reductions due to mining could vary by a similar amount."*

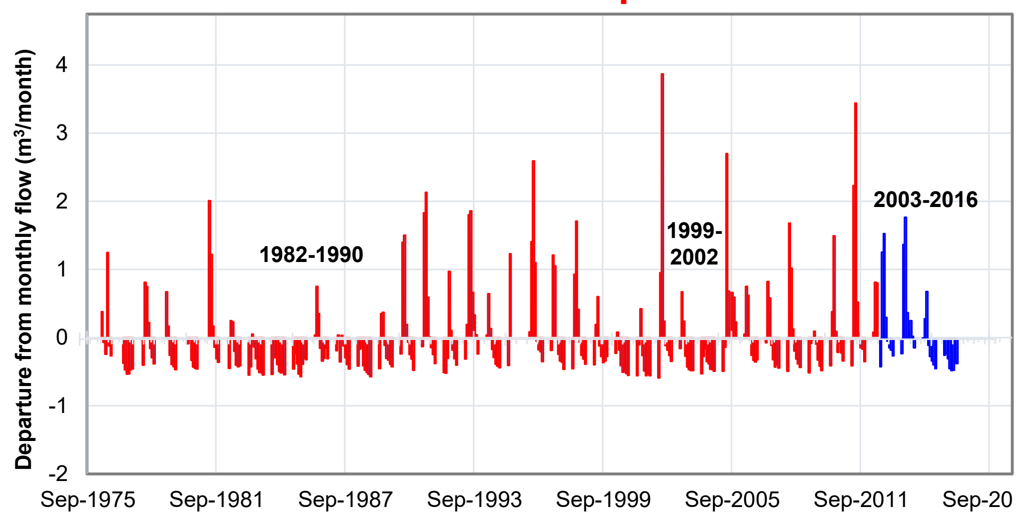
Reducing recharge by 50%, which is more reasonable given documented values (i.e. less than 11%), results in a decrease of 33-36% in modelled projections. This produces a further reduction in baseflow estimates provided in the impact assessment (e.g. -20% becomes -27%).

Monthly flow at Gold Creek near Frank – 05AA030

From PDF pg. 66 of CR#4 in CIAR #42



same Gold Creek data from Water Survey of Canada data portal



Benga's reliance on a protracted flow period (2013-2016) to capture pre-mining steady-state conditions and long-term trends (or the range of variability) in stream flows is not sufficient to capture the magnitude and duration of historical low flow conditions. This produces overly optimistic model results for baseflow reductions and future water quality impacts.

Change in June snow cover over N. America

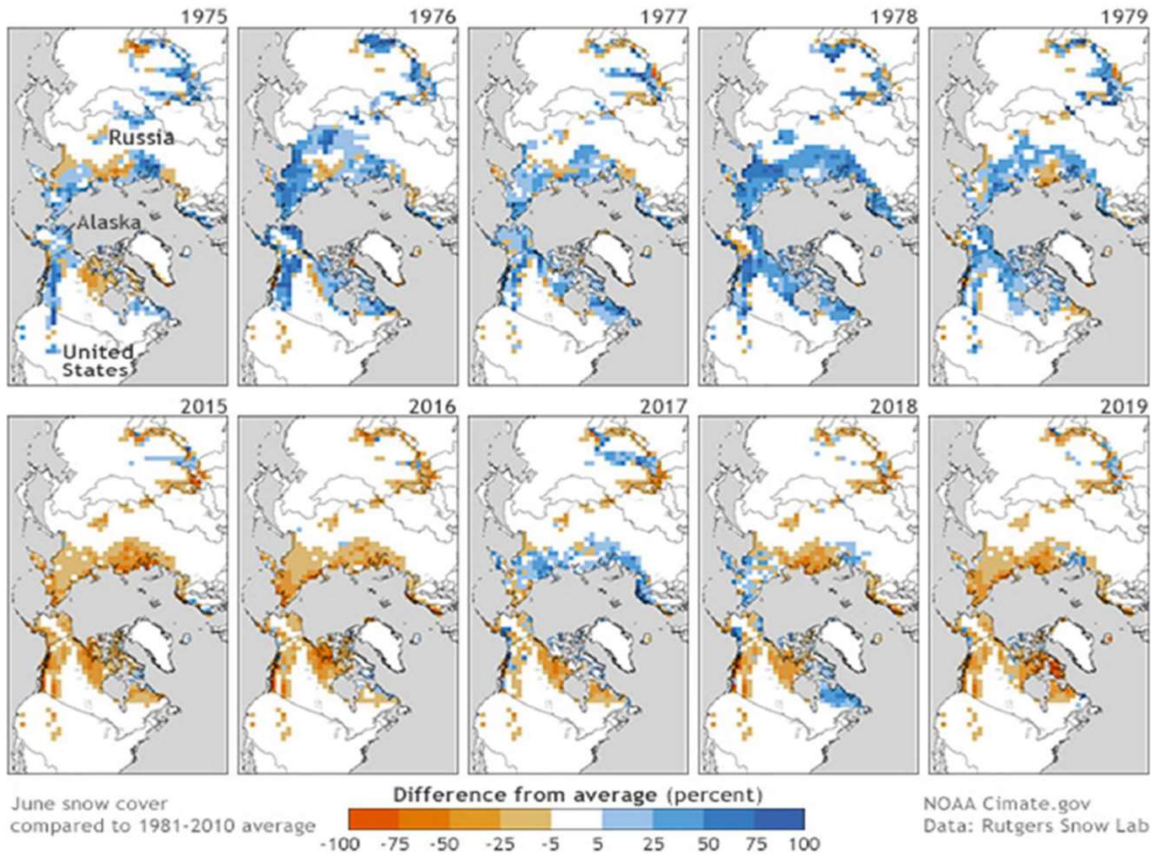
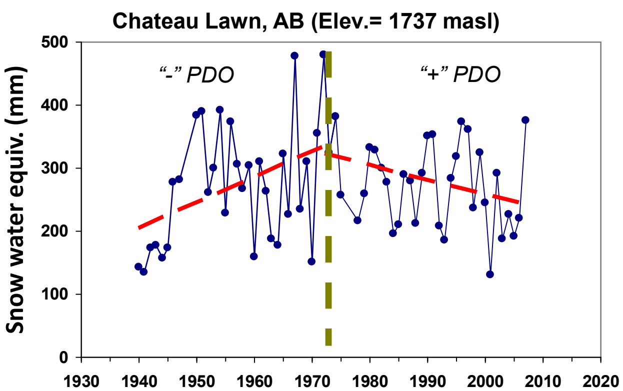


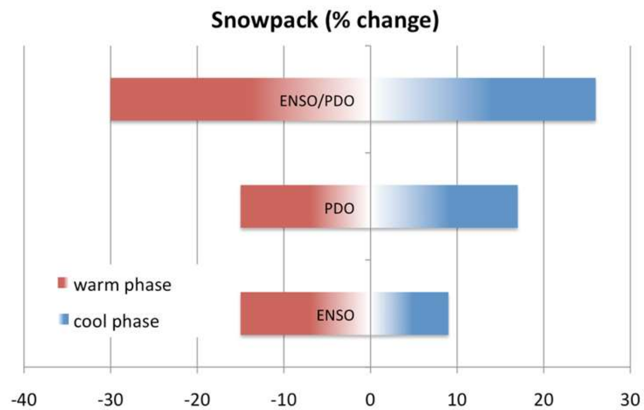
Figure 5, PDF pg. 81 of CIAR #553

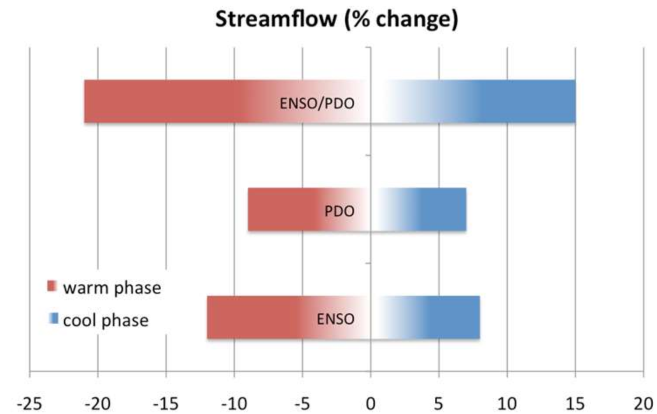
Benga has not considered how the continued loss of snowpack and increase in rain-on-snow events (resulting in shorter & higher magnitude runoff periods and longer low flow periods) will influence future hydrologic conditions and resulting water quality in Blairmore and Gold creeks.

Influence of ENSO and PDO on snowpack & streamflow

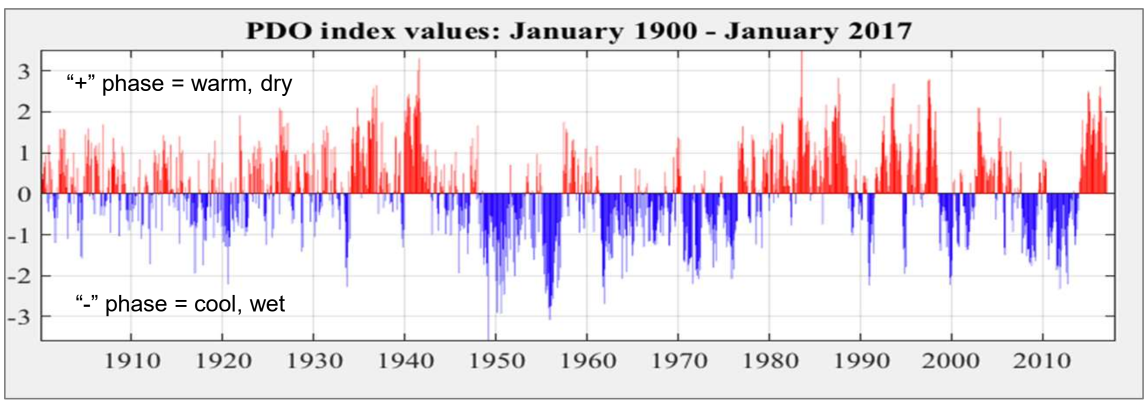


Source: Alberta Environment





Source: Climate Impacts Group, U. of Washington; https://cig.uw.edu/learn/climate-impacts-in-brief/



Source: http://research.jisao.washington.edu/pdo/

Benga has not considered the effects of recurring climate phenomena on their model projections for baseflow reduction and future water quality in Blairmore and Gold creeks.

Tree-ring reconstruction of water-year flow

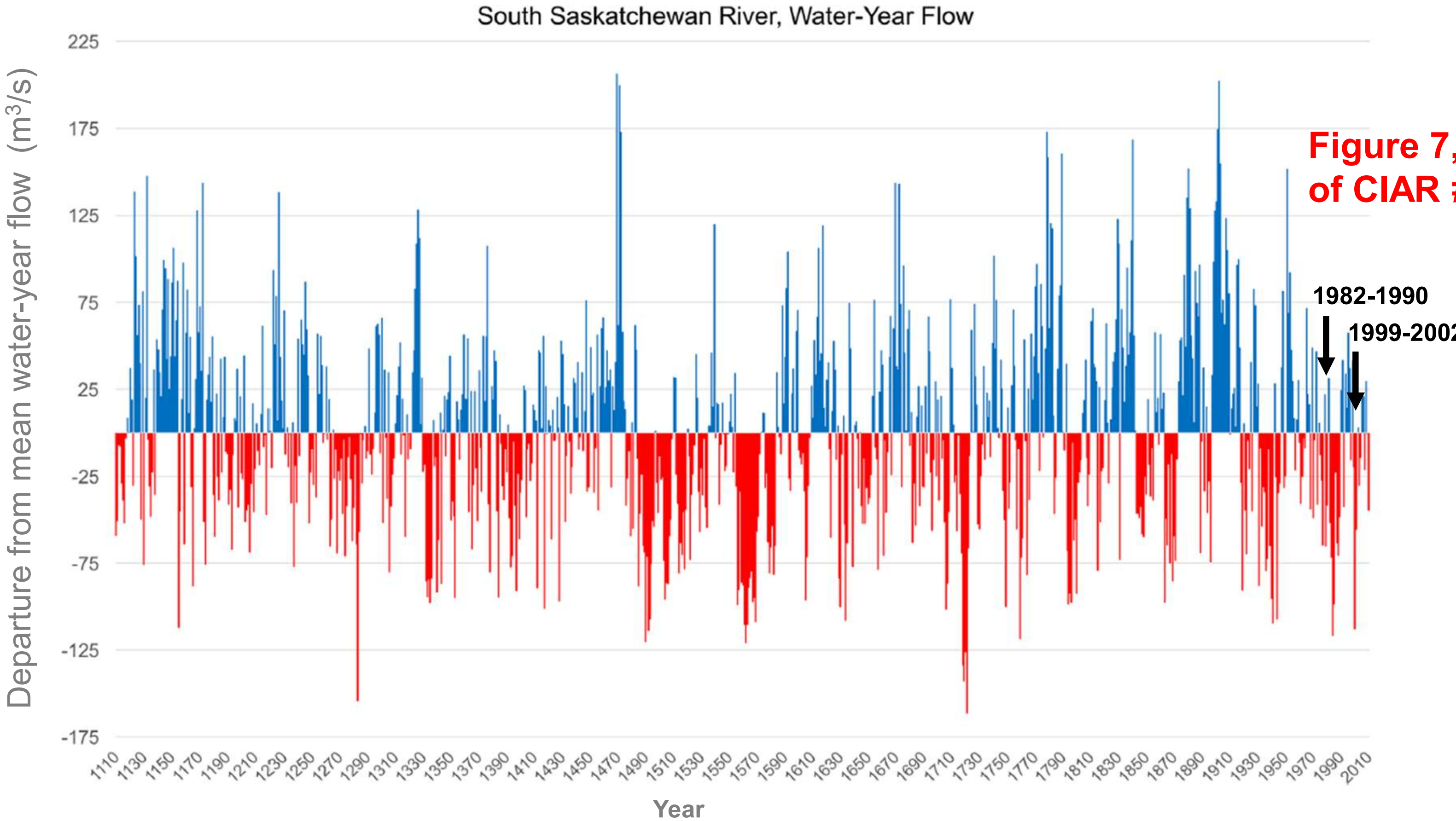
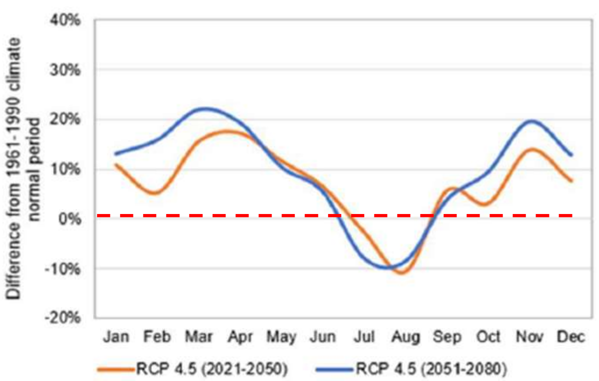
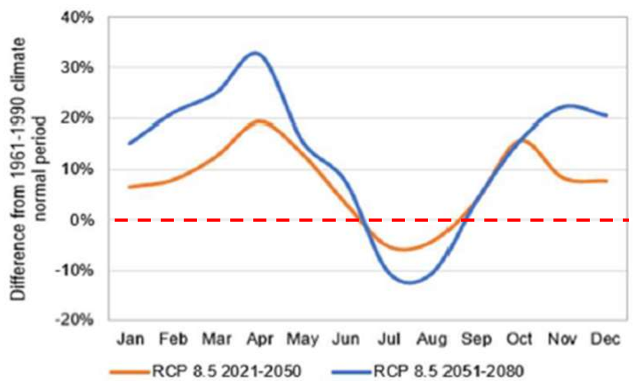


Figure 7, PDF pg. 83 of CIAR #553

Benga has relied on selected return periods to bracket climate extremes. They have not considered, in their model projections, results from paleo-records in southern Alberta that indicate significant periods (multiple decades) of above and below average conditions.

Climate model projections for precipitation and streamflow





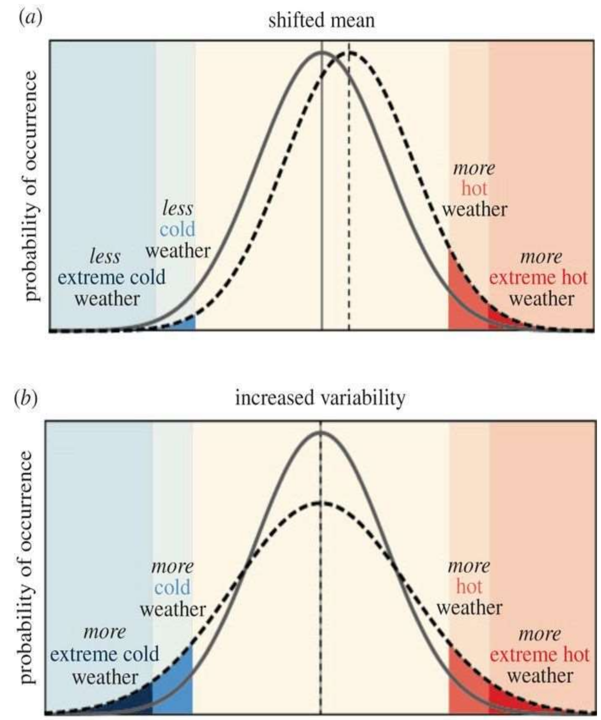


Figure 6, PDF pg. 82 of CIAR #553

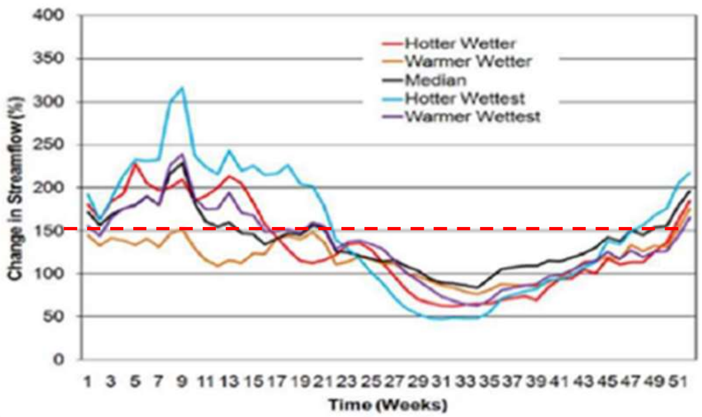


Figure 9, PDF pg. 89 of CIAR #553

Benga has not adequately addressed the anticipated shift in timing and magnitude of precipitation and streamflow conditions in response to future climate change, and how this will affect their model projections. This includes implications for shortening of return periods for extreme events (i.e. increased probability).

Threats to aquatic environment

BC Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture 2019

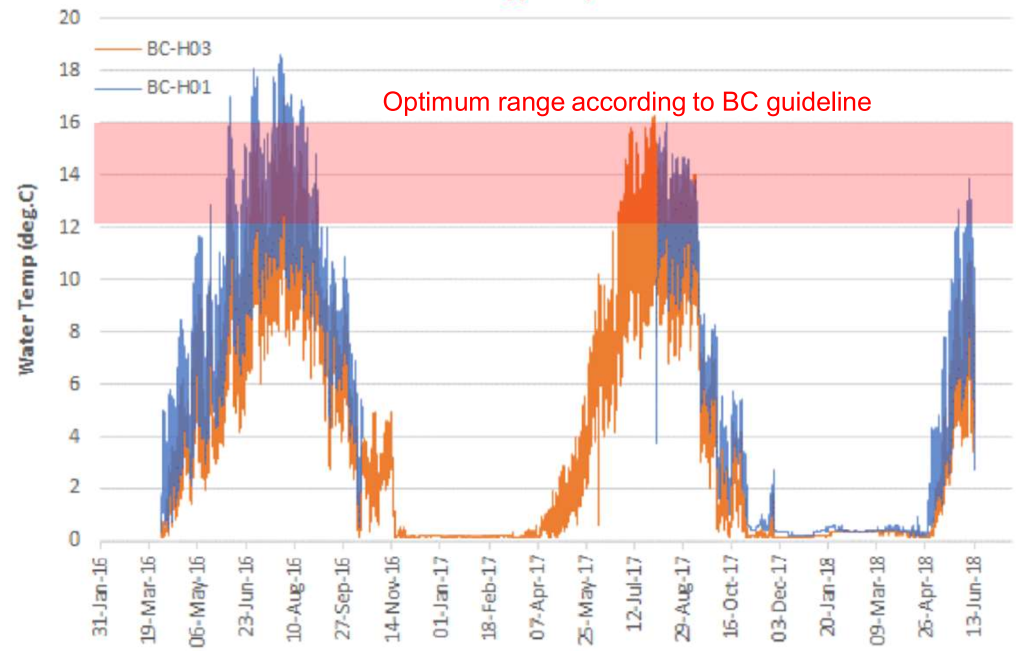
Table 42B. Optimum temperature ranges of specific life history stages of salmonids and other cold-water fishes for water quality guideline application.

Species	Incubation (°C)	Rearing (°C)	Migration (°C)	Spawning (°C)
Salmon				
Chinook	5.0-14.0	10.0-15.5	3.3-19.0	5.6-13.9
Chum	4.0-13.0	12.0-14.0	8.3-15.6	7.2-12.8
Coho	4.0-13.0	9.0-16.0	7.2-15.6	4.4-12.8
Pink	4.0-13.0	9.3-15.5	7.2-15.6	7.2-12.8
Sockeye	4.0-13.0	10.0-15.0	7.2-15.6	10.6-12.8
Trout				
Brown	1.0-10.0	6.0-17.6		7.2-12.8
Cutthroat	9.0-12.0	7.0-16.0		9.0-12.0
Rainbow	10.0-12.0	16.0-18.0		10.0-15.5
Char				
Arctic Char	1.5-5.0	5.0-16.0		4.0
Brook Trout	1.5-9.0	12.0-18.0		7.1-12.8
Bull Trout	2.0-6.0	6.0-14.0		5.0-9.0
Dolly Varden		8.0-16.0		
Lake Trout	5.0	6.0-17.0		10.0
Grayling				
Arctic Grayling	7.0-11.0	10.0-12.0		4.0-9.0
Whitefish				
Lake Whitefish	4.0-6.0	12.0-16.0		> 8.0
Mountain Whitefish	< 6.0	9.0-12.0		< 6.0
Other Species				
Burbot	4.0-7.0	15.6-18.3		0.6-1.7
White Sturgeon	14.0-17.0			14.0

- *Source: Water Quality Guidelines for Temperature: Overview Report (2001).*

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

From Figure 5.20-1, PDF pg. 283 of Addendum 10, Package 5, CIAR #251



Benga has not adequately assessed the impact to stream temperatures, DO conditions, and implications to WSCT considering the anticipated increase in “Long Spells of +30°C Days” (AQ#2 - Coalition - region-crowsnest 30 degree days - Geology Topics) and number of “Extremely Hot Days” (AQ#3 - Coalition - region-crowsnest +32 degree days - Geology Topics) combined with changing flow conditions, longer low flow periods, and baseflow reduction from mine dewatering and permanent lowering of the water table.

Influence of redox conditions on element speciation, mobility, and toxicity

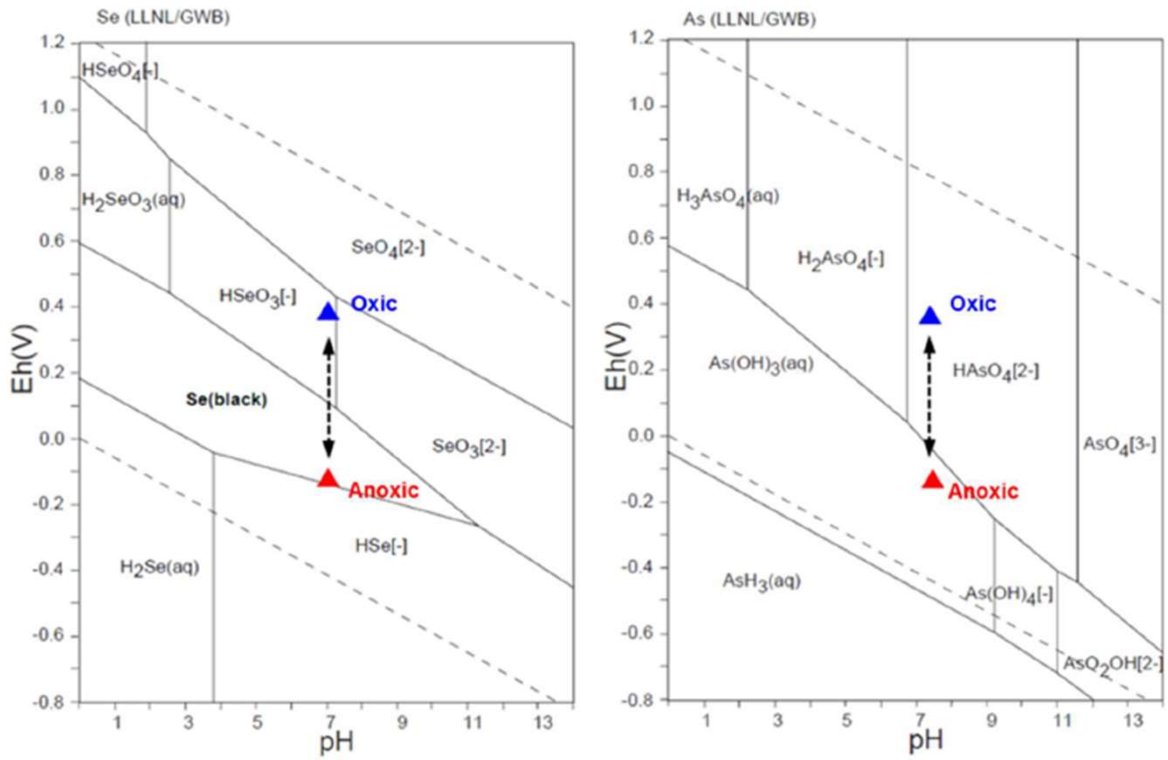
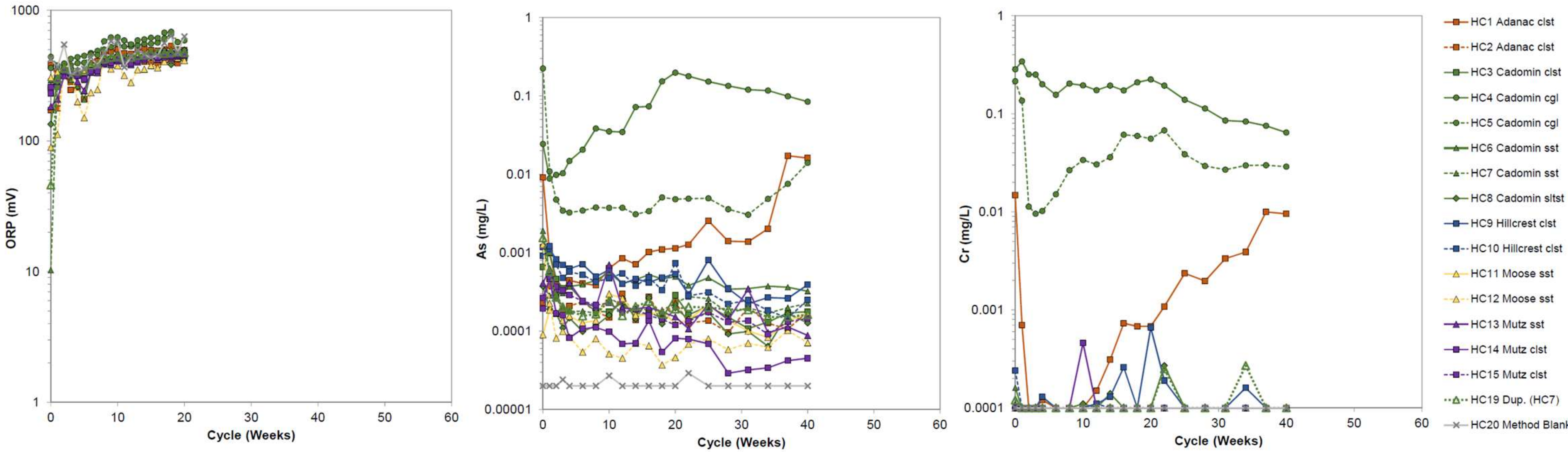


Figure 8, PDF pg. 85 of CIAR #553

Benga proposes to create and maintain sub-oxic conditions in the SBZs to sequester Se (with high efficiency), but they have not considered how this might mobilize other harmful trace elements that will eventually discharge to local water bodies. They have also not explored how Se mitigation success might be hampered by lower than anticipated redox, or Eh, conditions (e.g. HSe^-, hydrogen selenide).

Humidity cell tests



Appendix 10, Appendix H, PDF pg. 117-216 of CIAR #42

Benga's testing of the various bedrock formations indicates that mobilization of harmful trace elements is possible under oxic conditions, but they did not investigate mobilization potential under sub-oxic or anoxic conditions. They also did not assess mobilization potential from formations beneath the mine footprint, unlined rock dumps and water management ponds.

Table B6, PDF pg. 127 of CIAR #3 in CIAR #42

Baseline water quality

Table B6. Field Measured Parameters.

Location	Type	Data Source	Date mm/dd/yyyy	Dissolved Oxygen mg/L
MW14-01-64	GW	MEMS	2/2/2014	-
		MEMS	10/16/2014	-
		MEMS	3/21/2016	2.72
MW14-02-74	GW	MEMS	2/4/2014	-
		MEMS	10/17/2014	-
		MEMS	3/21/2016	3.2
MW14-03-90	GW	MEMS	2/4/2014	-
		MEMS	10/17/2014	-
		MEMS	3/22/2016	5.75
MW14-04-93	GW	MEMS	10/16/2014	-
MW14-05-114	GW	MEMS	10/17/2014	-
		MEMS	3/24/2016	6.8
MW14-06-32	GW	MEMS	3/23/2016	3.24
MW14-06-105	GW	MEMS	10/16/2014	-
		MEMS	3/23/2016	5.53
MW14-07-48	GW	MEMS	10/17/2014	-
		MEMS	3/22/2016	6.54
MW14-08-79	GW	MEMS	10/17/2014	-
		MEMS	3/23/2016	7.6
MW15-11-9	GW	MEMS	3/23/2016	9.28
MW15-11-18.5	GW	MEMS	3/23/2016	2.08
MW15-12-7	GW	MEMS	3/21/2016	11.71
MW15-12-14	GW	MEMS	3/21/2016	6.69

Notes:

Value exceeds freshwater aquatic life and drinking water guidelines

Value exceeds freshwater aquatic life guidelines

Value exceeds drinking water guidelines

Data Considered Unreliable (ion balance is <90% or >110% or pH is outside guidelines)

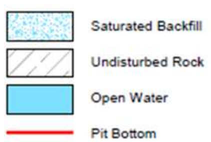
Table B8. Dissolved Metals Results

Location	Type	Data Source	Date	Laboratory	Sample Type	Dissolved Metals																
						Aluminium	Antimony	Arsenic	Barium	Boron	Cadmium	Chromium (III+VI)	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Uranium	Zinc
			mm/dd/yyyy			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CDW (Canadian Drinking Water MAC and AO)						0.1	0.006	0.01	1	5	0.005	0.05	1	0.3	0.01	0.05	0.001		0.05	-	0.02	5
FWAL (ESRD Aquatic Life 2014)						0.05*	-	0.005	-	1.5	0.00025-0.00037*	-	0.007	0.3	0.0063-0.007*	-	0.000005	0.082-0.170*	0.001	0.0001	0.015	0.03
MW14-01-64	GW	MEMS	2/2/2014	ALS	N	0.0212	0.00179	0.00103	0.539	0.142	<0.0001	<0.005	0.0027	0.497	0.0001	1.71	<0.00002	0.0104	<0.0004	<0.0001	0.00617	0.0222
		MEMS	10/16/2014	ALS	N	0.0053	<0.0001	0.00015	2.16	0.121	<0.00001	0.0001	0.00029	1.35	<0.00005	0.075	0.0000309	0.00194	0.00022	<0.00001	0.000078	<0.005
		MEMS	3/21/2016	ALS	N	0.0184	<0.0001	0.00018	1.6	0.162	<0.000005	0.00092	0.00024	1.41	0.000053	0.0554	<0.000005	0.00138	0.00081	<0.00001	0.000045	0.0041
MW14-02-74	GW	MEMS	2/4/2014	ALS	N	0.288	0.00105	0.00113	0.243	0.05	<0.0001	<0.005	0.0027	0.217	0.00037	0.141	<0.00002	0.0069	<0.0004	<0.0001	0.00081	0.0061
		MEMS	10/17/2014	ALS	N	0.017	<0.0001	<0.0001	0.583	0.056	<0.00001	0.00014	0.00023	3.39	<0.00005	0.256	0.0000357	0.00385	0.00016	<0.00001	0.000083	<0.005
		MEMS	3/23/2016	ALS	N	0.0362	<0.0001	0.0001	0.496	0.06	<0.000005	0.00019	0.00039	1.31	0.000055	0.212	<0.000005	0.00123	0.00267	<0.00001	0.000043	0.0033
MW14-03-90	GW	MEMS	2/4/2014	ALS	N	0.0591	0.00053	<0.0004	0.261	<0.05	<0.0001	0.0592	0.0029	<0.02	<0.0001	<0.002	<0.00002	<0.002	0.00149	<0.0001	<0.0001	0.004
		MEMS	10/17/2014	ALS	N	0.0023	0.00038	<0.0001	0.129	0.018	<0.00001	0.00226	0.00096	<0.03	0.000052	<0.005	0.0000333	0.00195	0.00012	<0.00001	<0.00001	<0.005
		MEMS	3/24/2016	ALS	N	0.0277	0.00125	0.00069	0.283	0.03	<0.000005	0.00038	0.00043	0.041	<0.00005	0.0054	<0.000005	0.00068	0.000175	<0.00001	0.000178	0.0013
MW14-04-93	GW	MEMS	10/16/2014	ALS	N	0.0067	0.00074	0.00087	0.983	0.06	<0.00001	0.00046	0.0026	<0.03	<0.00005	0.0076	<0.000005	0.00215	0.00017	<0.00001	0.000967	<0.005
MW14-05-114	GW	MEMS	10/17/2014	ALS	N	0.135	0.00276	0.00076	0.322	<0.01	<0.00001	0.023	0.00099	<0.03	0.000051	<0.005	0.0000269	0.00027	0.00115	<0.00001	<0.00001	<0.005
		MEMS	10/17/2014	ALS	FD	0.138	0.00284	0.00074	0.322	<0.01	<0.00001	0.0224	0.00176	<0.03	0.000112	<0.005	0.0000275	0.00064	0.00117	<0.00001	<0.00001	<0.005
		MEMS	3/24/2016	ALS	N	0.0602	0.00928	0.0012	0.172	0.048	<0.000005	0.00776	0.00146	<0.03	0.000069	<0.005	<0.000005	0.00115	0.000392	<0.00001	<0.00001	0.0026
MW14-06-32	GW	MEMS	3/24/2016	ALS	N	0.139	<0.0001	0.00041	0.146	0.013	0.0000794	0.00031	0.00575	0.036	0.000468	0.0977	<0.000005	0.0018	0.000065	<0.00001	0.000094	0.0106
MW14-06-105	GW	MEMS	10/16/2014	ALS	N	0.012	0.00294	0.00127	0.413	0.041	<0.00001	0.00053	0.00169	<0.03	<0.00005	<0.005	<0.000005	0.00089	0.00042	<0.00001	0.000232	<0.005
		MEMS	3/24/2016	ALS	N	0.220	0.00322	0.00237	1.37	0.06	0.0000165	0.00446	0.00597	0.242	0.000489	0.0157	<0.000005	0.00309	0.000348	<0.00001	0.000211	0.0158
MW14-07-48	GW	MEMS	10/17/2014	ALS	N	0.039	0.00165	0.0007	0.0813	0.035	<0.00001	0.0102	0.00404	<0.03	<0.00005	<0.005	0.000011	0.00147	0.00252	<0.00001	0.000382	<0.005
		MEMS	3/22/2016	ALS	N	0.718	0.0026	<0.0005	0.692	<0.05	<0.000025	0.00753	0.0051	<0.03	<0.00025	<0.005	<0.000005	<0.0025	0.00096	<0.00005	<0.00005	<0.005
MW14-08-79	GW	MEMS	10/17/2014	ALS	N	0.124	0.00051	0.00079	0.177	<0.05	0.000054	0.258	0.0105	0.06	<0.00025	<0.005	0.000032	0.0013	0.017	<0.00005	<0.00005	<0.02
		MEMS	3/23/2016	ALS	N	0.021	<0.002	<0.002	0.125	<0.2	0.00021	0.443	0.0328	<0.3	0.0013	<0.05	<0.000005	<0.01	0.0257	<0.0002	<0.0002	<0.02
MW15-11-18.5	GW	MEMS	7/29/2015	Exova	N	0.007	0.0004	0.0029	3.42	0.08	0.00001	<0.0005	0.002	0.27	<0.0001	0.325	<0.000005	0.0022	0.0005	0.00004	0.0012	0.004
		MEMS	3/23/2016	ALS	N	0.0218	<0.0005	0.00076	2.47	0.1	<0.000025	<0.0005	<0.001	0.856	<0.00025	0.368	<0.000005	<0.0025	0.00135	<0.00005	0.00027	<0.005
		MEMS	3/23/2016	ALS	FD	0.0285	<0.0005	0.00091	2.5	0.101	<0.000025	<0.0005	<0.001	0.86	<0.00025	0.363	<0.000005	<0.0025	0.00122	<0.00005	0.000265	<0.005
MW15-11-9	GW	MEMS	7/29/2015	Exova	N	0.218	0.0003	0.0002	0.154	0.072	0.00002	0.0006	0.002	0.14	0.0002	0.141	<0.000005	0.0022	0.0004	<0.00001	0.0009	0.004
		MEMS	3/23/2016	ALS	N	0.596	<0.0005	0.00061	0.258	0.079	0.000071	0.00189	0.0019	<0.03	0.00165	0.129	<0.000005	0.0032	0.00064	<0.00005	0.00255	0.0064
MW15-12-14	GW	MEMS	7/29/2015	Exova	N	0.008	0.0005	0.0002	0.096	0.053	0.00009	<0.0005	0.003	0.01	<0.0001	0.026	<0.000005	0.0012	0.0038	<0.00001	0.0013	0.003
		MEMS	3/21/2016	ALS	N	0.0164	<0.0005	<0.0005	0.103	<0.05	<0.000025	<0.0005	<0.001	0.047	<0.00025	0.0093	<0.000005	<0.0025	0.00508	<0.00005	0.00107	<0.005
MW15-12-7	GW	MEMS	7/29/2015	Exova	N	0.094	<0.0002	<0.0002	0.119	0.031	0.00009	<0.0005	0.001	0.12	<0.0001	0.207	<0.000005	0.0014	0.00530	<0.00001	0.0012	0.003
		MEMS	3/21/2016	ALS	N	8.83	<0.0005	0.00064	0.455	<0.05	0.0004	0.0203	0.0106	<0.03	0.0044	<0.005	<0.000005	0.013	0.00358	0.000289	0.00188	0.0552

Table B8, PDF pg. 137 of CR #3 in CIAR #42

Benga has identified that the groundwater is quite oxygenated (oxic), and that there are already elevated concentrations of harmful trace elements present in the area. This is an indication of their ability to be mobilized under the right geochemical conditions.

Viability of the end pit lake & ponds



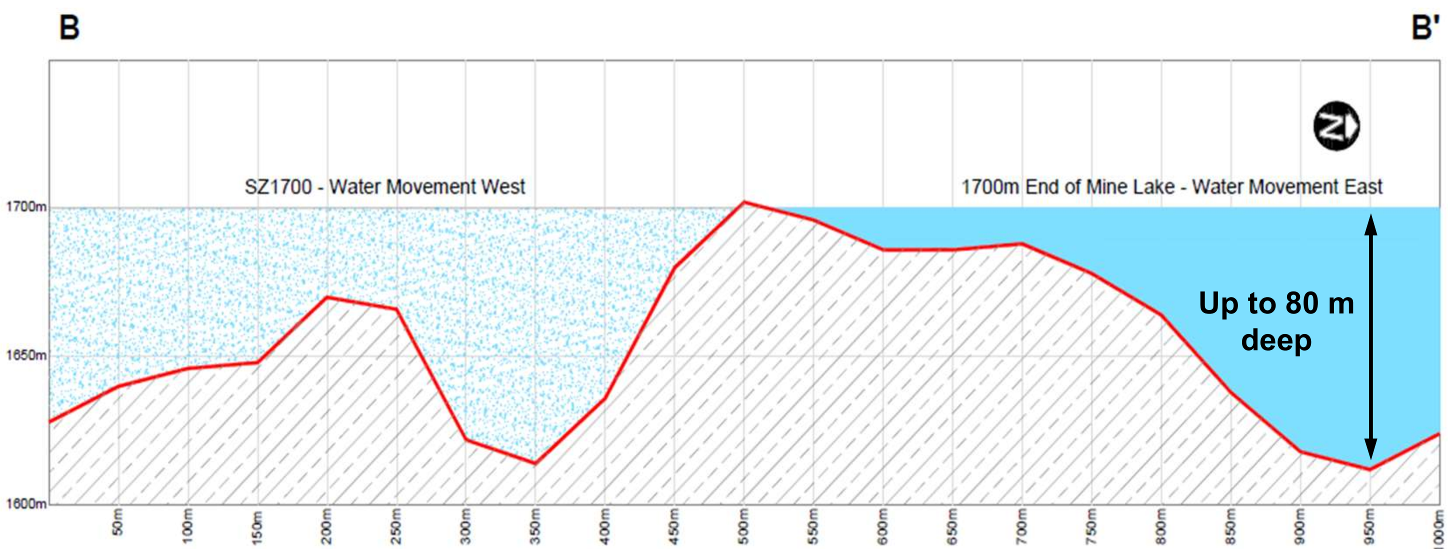


Figure C.5.3-7, PDF pg. 253 of Project Description in CIAR #42 (annotated)

Benga has not assessed the dynamics of the water management ponds & end pit lake in relation to nutrient cycling (e.g. nitrate and phosphorous), stratification and the creation of sub-oxic to anoxic conditions (including generation of GHGs), shift in trophic levels, and potential mobilization of redox-sensitive (and harmful) trace elements.

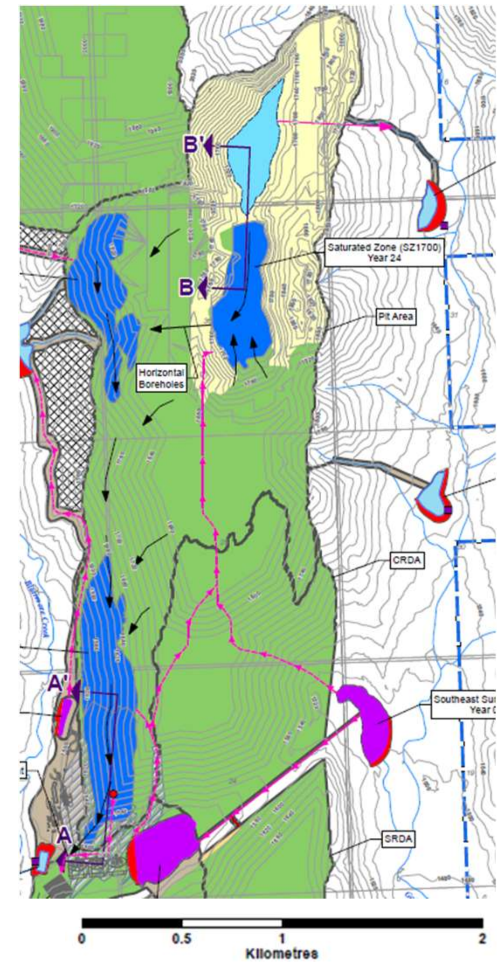
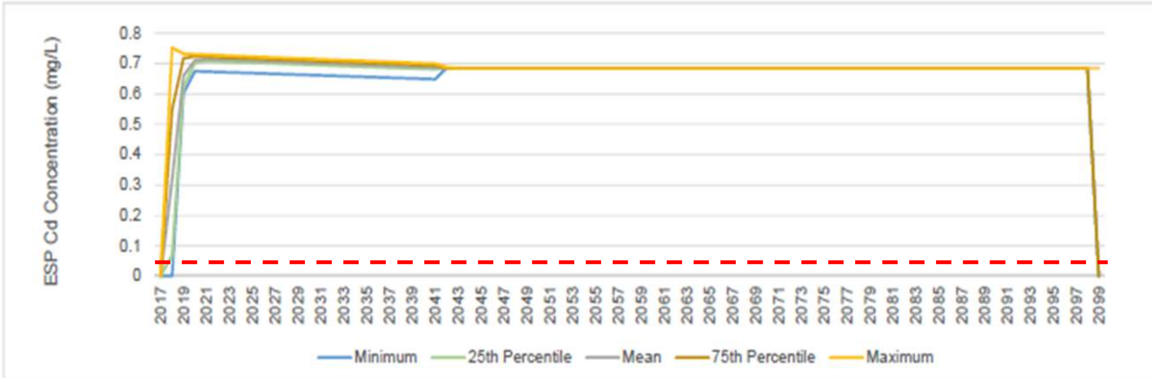


Figure C.5.3-5, PDF pg. 251, Section C of CIAR #42

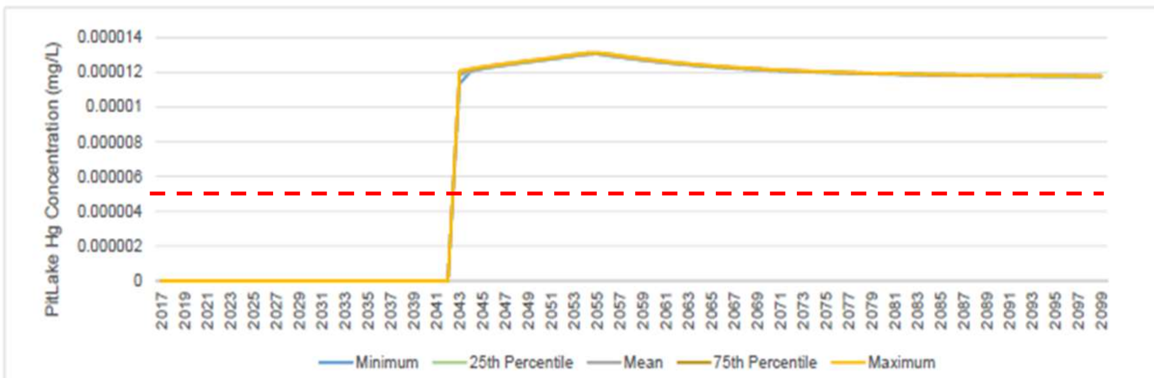
GoldSim modelling

Appendix D, PDF pg. 370 of Appendix 10 in CIAR #42



AB 2018 chronic guideline = 0.00034 mg/L

Appendix D, PDF pg. 380 of Appendix 10 in CIAR #42



AB 2018 chronic guideline = 0.00005 mg/L (total)

Unlike the groundwater numerical model, Benga has not provided a satisfactory explanation of how the GoldSim model was configured, or how hydrologic and climatic variability has been included. Contaminant capture efficiencies are also overly optimistic. Elevated levels of some harmful elements are noted for the water management ponds, with levels approaching harmful values in the creeks.

Permit 107517

Annual Water Quality Monitoring Report

March 29, 2019

Teck experience in the Elk Valley

AQ#4 - Coalition - Elk-Valley-Water-Quality-2018-Annual-Report - Water Topics.pdf; See also CIAR #854, Transcript Vol. 17, pdf pg. 195-202

In addition to Se: excursions of Cd, Cr, Co, Ni, U, and Zn above Alberta guidelines for protection of freshwater aquatic life (stations listed as "Receiving Environment" are shown in red):

e.g.
- Coal Mountain: CM_CC1, CM_CCPD, CM_MC1, CM_MC2, CM_SOW, CM_SPD
- Elk Valley: EV_BC1, EV_GT1, EV_SP1
- Fording River: FR_CC1, FR_EC1, FR_EC1H, FR_FRCP1, FR_KC1, FR_LMP1, FR_LP1, FR_NL1H
- Greenhill: GH_CC1, GH_SC1, GH_WC1
- Line Creek: LC_LC3, LC_LCUSWLC, **LC_WLC**
- Lake Koocanusa: RG_DSELK, RG_ELKORES, RG_USGOLD

Note: Station LC_WLC (Receiving Environment – West Line Creek), in bold red text above, is listed in Table 4 of AQ#4 on pdf pg. 25 as "Receiving Environment – West Line Creek", and is also located in the lower left inset panel on Map 3 (pdf pg. 160 of AQ#4) at the south end of the Tech Operation. Concentration exceedances for freshwater aquatic guidelines are noted at this surface water monitoring station for Cadmium (pdf pg. 4858), Mercury (pdf pg. 4860), Selenium (pdf pg. 4862), and Uranium and Zinc (pdf pg. 4864).

Benga has placed considerable focus on Se, and less so on others. However, there is direct evidence at other nearby metallurgical coal operations mining the same rocks (Mist Mnt. Fm.) that the release of other harmful trace elements is occurring, and at concentrations exceeding freshwater aquatic guidelines (including NORMS).

Major conclusions

1. Benga's conceptual models of the Grassy Mountain area are not consistent with actual conditions, which are much more complex and variable than considered.
2. Benga's findings are predicated on model simulations that are subject to many assumptions and limitations that substantially affect the final results (e.g. overly optimistic capture efficiency for Se in SBZs).
3. Benga's physical and chemical models are constrained with limited information (i.e. control points), and do not honour the range of variability expected for the geologic, hydrogeologic, hydrologic, and climatic conditions of the area.
4. Benga's models have concluded that the effect of drawdown from the mine development, and release of contaminants to the local water bodies, will not results in adverse impacts. This is predicated on overly optimistic conclusions.

Major conclusions

5. Benga has not used a suitable range of variability in their assessment of hydrology and climate consistent with historically-measured values or paleo-records.

6. Benga has not fully assessed how geochemical conditions will influence the mobility and toxicity (i.e. speciation) of metals and trace elements likely to be released from the mine development and closure landscape.

7. Benga has relied on “average” conditions in many cases and has not sufficiently provided conservative, or “worst-case” scenarios to support the decision-making process.

8. Benga is overly confident that their monitoring will be successful in detecting contaminants originating from the mine and closure landscape, and that mitigation measures will be successful well into the future.

Major conclusions

9. Benga has relied too heavily on “Adaptive Management” to deal with a limited understanding regarding irreversible changes to the water table, water balance, and geochemistry that will permanently impact area ecosystems.
10. Benga’s consistent impact ratings of “not significant” are inconsistent with the removal of a mountain, re-distribution of the waste rock, creation of large Se management areas, and permanent disturbance to the local watersheds.
11. The risk of creating another “Elk Valley” situation, where attempts are still being made to mitigate the impacts, is “significant” and needs to be considered in any decision regarding this Project.

Thank you