UNDERTAKING RESPONSE

EA No: 0809-001 **Undertaking No: 2 and 4**

Date Received

Transcript: Day 2, pg. 46; and Day 4, pg. 227

Undertaking:

Undertaking 2:

The Giant Mine Project Team to provide which characteristics of worst-case scenario presented by the IPCC were used and what time frame was considered – i.e. what time span (50, 100, 200, 500 years)?

Include which aspects of climate change were considered – e.g. was it just air temperature or also with respect to precipitation and its effect on water management?

Also indicate whether climate change was incorporated into the event frequencies for various climate related events.

Undertaking 4:

The Giant Mine Project Team to update parties on the thinking of climate change models and what has happened since 2001. Include how it has affected the project design.

Lukas Anderson (Review Board) to also provide any additional climate change and extreme event predictions he has to the design team.

Response:

Please see attached two parts to this Undertaking response:

Attachment #1 – Climate Change (Hydrology)
Attachment #2 – Climate Change Scenarios

Attachment #1 – Climate Change (Hydrology)

Potential climate change effects were not explicitly incorporated into the design basis for the Baker Creek remediation at the Giant Mine, for reasons discussed below. However, the 1:500-year event specified as the current design discharge was increased by approximately 10% (from 22.8 m^3/s to 25.0 m^3/s) from that indicated by the results of a frequency analysis of Baker Creek flood flows. The design also accommodates a 2.0 m accumulation of bedfast ice (approximately 1.0 m depth across the floodplain) as well as an additional 1.0 m of freeboard, the combination of which provides a conservative design to accommodate flows greatly in excess of the design discharge. The capacity of the channel before reaching the lowest spill point is approximately 58 m^3/s when only the ice accumulation is considered, and approximately 183 m^3/s with an ice-free channel that uses the entire freeboard allocation.

Climate models do not provide predictions or forecasts of future conditions. The IPCC Data Distribution Centre (IPCC 2011b) states that *"Although there is increasing confidence among atmospheric scientists that increased atmospheric greenhouse gas concentrations will increase global temperatures, there is much less confidence in estimates of how the climate will change at a regional scale. However, it is precisely at this regional or local level (e.g. at the scale of a farm, a river catchment or even an individual organism) that climate change will be felt. Since no method yet exists of providing confident predictions of climate change at these scales, an alternative approach is to specify a number of plausible future climates. These are termed 'climate scenarios'."*

The following comments must be read with this in mind. Climate scenarios and the resulting model projections are not forecasts or predictions, but "what-if" representations of possible futures with no defined probability of occurring.

Changes to Precipitation

Climate model output for the point corresponding to the Yellowknife Airport (Environment Canada climate station 2204100; 62°27'46" North, 114°26'25" West) were downloaded from the Canadian Climate Change Scenarios Network web site (CCCSN 2011). That site provides output from 24 General Circulation Models (GCMs) that contributed to the IPCC Fourth Assessment Report (AR4) in 2007, and for three ensemble-mean scenarios (A1B, A2 and B1) as described in undertaking #2. Monthly total precipitation values for the two Canadian GCMs (CGCM3T47 and CGCMT63) for the baseline (1971-2000) and future projected (2071-2100) periods are presented in Table 1. Table 1 also includes the published 1971-2000 normals for Yellowknife Airport (EC 2011b).

Table 1: Monthly Total Precipitation for Baseline and Future Projected Periods (mm)

Model:	EC 2011b	CGCM3T47-Mean				CGCM3T63-Run 1			
Period:	1971-2000	1971-2000	2071-2100			1971-2000	2071-2100		
Scenario:	Baseline	Baseline	A1B	A2	B1	Baseline	A1B	A2	B1
January	14.1	20.3	24.7	25.6	23.1	19.5	26.6	29.6	23.4

Model:	EC 2011b	CGCM3T47-Mean				CGCM3T63-Run 1			
February	12.9	17.0	19.0	20.1	20.3	17.4	21.6	23.4	23.4
March	13.4	16.6	18.8	20.5	17.7	17.9	19.1	24.5	20.4
April	10.8	12.3	14.6	15.1	13.7	16.6	19.3	18.4	18.7
May	19.1	17.1	21.4	24.6	20.3	20.1	24.2	25.2	24.3
June	26.9	29.9	34.9	37.3	35.6	33.0	40.3	46.6	42.1
July	35.0	32.8	39.9	42.3	35.2	43.8	47.3	46.1	44.3
August	40.9	24.0	29.6	31.5	28.5	34.9	40.2	40.0	43.5
September	32.9	24.8	30.6	33.7	28.8	41.1	45.1	46.5	46.3
October	35.0	30.9	34.3	36.0	32.4	38.6	47.7	47.4	39.6
November	23.5	23.0	27.5	28.3	26.2	26.9	34.3	36.0	29.4
December	16.3	20.2	24.7	26.2	23.2	22.7	32.2	33.1	29.8
Winter	43.3	57.5	68.0	71.7	66.5	59.4	80.0	85.7	76.4
Spring	43.3	45.9	54.7	60.0	51.6	54.5	62.5	68.0	63.4
Summer	102.8	86.7	104.5	111.1	99.4	111.6	127.7	132.8	129.9
Autumn	91.4	78.5	92.3	97.9	87.4	106.5	126.9	129.7	115.2
Annual	280.7	268.6	319.4	340.5	304.8	331.8	397.1	416.1	384.7

Table 1 shows projected changes in monthly, seasonal and total annual precipitation for the two models. Percent changes corresponding to these values are presented in Table 2. Changes are calculated based on model baseline values, rather than those reported by EC (2011b).

Table 2: Projected Changes in Total Precipitation (%)

Model:	CGCM3T47-Mean			CGCM3T63-Run 1		
Scenario:	**A1B**	**A2**	**B1**	**A1B**	**A2**	**B1**
January	21%	26%	13%	37%	52%	20%
February	12%	18%	19%	24%	35%	35%
March	13%	23%	7%	7%	37%	14%
April	19%	23%	11%	17%	11%	13%
May	25%	44%	19%	21%	26%	21%
June	17%	25%	19%	22%	41%	28%
July	21%	29%	7%	8%	5%	1%
August	24%	31%	19%	15%	15%	25%
September	23%	36%	16%	10%	13%	13%
October	11%	17%	5%	24%	23%	3%

Model:	CGCM3T47-Mean			CGCM3T63-Run 1		
November	20%	23%	14%	27%	34%	9%
December	22%	30%	15%	42%	46%	31%
Winter	18%	25%	16%	35%	44%	29%
Spring	19%	31%	12%	15%	25%	16%
Summer	20%	28%	15%	14%	19%	16%
Autumn	18%	25%	11%	19%	22%	8%
Annual	**19%**	**27%**	**13%**	**20%**	**25%**	**16%**

Projected changes in total precipitation between the 1971-2000 baseline period and the 2071-2100 future projected period are all positive and indicative of warmer conditions, with the atmosphere having a greater capacity to carry moisture. Projected changes in total annual precipitation range from +13% to +27%.

Comment on Precipitation Modeling

Table 1 notably shows that the annual total precipitation for the baseline period is not consistent between the two models or with the published monitoring data. The CGCM3T47 model under-projects annual precipitation by 4% from the Environment Canada published data, while the CGCM3T63 model over-projects annual precipitation by 18%. These discrepancies are on the order of the projected future changes.

The two models also show even greater differences in monthly and seasonal precipitation. The CGCM3T47 model monthly results range from an over-projection of 44% in January to an under-projection of 41% in August. The "wetter" CGCM3T63 model monthly results range from an over-projection of 53% in April to an under-projection of 15% in August. The two are essentially the same model (CGCM3.1) run at two different resolutions. The T47 version has a spatial resolution of 3.75 degrees latitude/longitude and 29 vertical levels, while the T63 version has a spatial resolution of 2.8 degrees latitude/longitude and 31 vertical levels (EC 2011c). This means that the size of a single model grid cell in the Yellowknife area is approximately 196 km by 210 km for the T47 version, and 147 km by 157 km for the T63 version.

The large spatial resolution of the climate models is one major reason for their inability to adequately represent baseline conditions, which should cast doubt on their ability to accurately represent future climates. The factors influencing climate in the Mackenzie River Basin, including the Baker Creek watershed, were examined by Szeto (2008), which stated *"the strong cold bias that affected the region in some climate model results can be attributed to the under-prediction of orographic precipitation and associate[d] latent heating of the cross-barrier flow, and the subsequent weakening of mean subsidence and warming of the basin in the models."* A strong linkage was also identified between conditions in the north Pacific Ocean and the Mackenzie River basin, with the preceding quote related to the movement of air masses over the mountains of western North America.

Szeto (2008) also stated that *"the large recent warming trend observed for the region can be understood as the enhanced response of the basin to the shift in the North Pacific circulation regime during the mid-1970s"*. This shift of the Pacific Decadal Oscillation (PDO), and its associated effects on the hydroclimatology of western Canada, was examined by Whitfield et al. (2010), which included a warning that it is possible that observed changes attributed to climate change could actually be due to natural cycles such as the PDO. The PDO has been observed to alternate between warm and cool phases approximately every 30 years, meaning that the duration of a full cycle could be up to 60 years, meaning that temperature and precipitation trends at even long-term climate stations such as the one at Yellowknife Airport could be influenced by the PDO.

IPCC Lead Author Kevin Trenberth (2007) stated that *"In particular, the state of the oceans, sea ice, and soil moisture has no relationship to the observed state at any recent time in any of the IPCC models. There is neither an El Niño sequence nor any Pacific Decadal Oscillation that replicates the recent past; yet these are critical modes of variability that affect Pacific rim countries and beyond".* Given that the models cannot represent such significant physical phenomena, it casts even more doubt on their ability to adequately represent future changes.

Runoff Projections

Though it has been suggested that climate change has been responsible for observed increases in flooding, IPCC (2007b) clearly stated that *"documented trends in floods show no evidence for a globally widespread change"*. A more recent study (Hirsch and Ryberg 2011) concluded that there was no statistical evidence for flood magnitudes in the United States increasing with global carbon dioxide concentrations, based on long-term (85 to 127 years, thus minimizing PDO effects) stream gauging data. Suggestions of future effects on floods (and droughts) depend on model projections rather than historical observations.

Projections of future runoff must consider not only projections of precipitation magnitude and temporal distribution, but on lake evaporation and evapotranspiration. Projections for specific watersheds must also consider the hydrography of the basin. For example, Spence and Hosler (2007) note that in the Baker Creek watershed, the sequence of lakes, wetlands and channels is such that outflow and evaporative losses may cause lake levels to fall below their outlet elevations, and that by mid-summer in a dry year only the lowest 4% of the basin is hydrologically connected to the outlet of Lower Martin Lake, just upstream of Giant Mine. This effect would be amplified in a scenario where increases in evaporation are greater than those in precipitation.

Late season conditions such as these would create a condition where more winter and spring precipitation is required to cause a waterbody to spill, which would offset the effect of increased precipitation on freshet flows. In addition to this, warmer conditions would be expected to reduce the length of the winter period where snow has a chance to accumulate, potentially reducing the magnitude of snowmelt peaks.

CCCSN (2011) also provides gridded climate data and agroclimatic indices for the periods 1961-1990 (baseline), 2010-2039 and 2040-2069 (projections). For the grid point nearest to Yellowknife, it is projected that potential evapotranspiration would increase by 15% in 50 years and 21% in 80 years. Precipitation deficits (potential evapotranspiration less precipitation) were also projected to increase by even greater amounts (19% in 50 years and 27% in 80 years). These projections are also consistent with warmer conditions, as greater evaporation from waterbodies and evapotranspiration from land would accompany greater precipitation.

Discussion

Projections of future climate change must be distinguished from predictions or forecasts. Climate models are limited by coarse resolution and the inability to adequately represent physical features (e.g., mountainous landscapes) and phenomena (e.g., natural climate cycles such as the PDO). The two Canadian climate models discussed here both fail to accurately represent baseline conditions and yield very different results for future projections, in particular when monthly and seasonal precipitation values are considered.

Runoff projections depend not just on precipitation, but other factors including evaporation, evapotranspiration and watershed hydrography. The Baker Creek watershed is likely to be very sensitive to the balance between precipitation and evaporation, and future projections suggest that evaporation is likely to increase at a greater rate than precipitation. It is entirely possible that a warmer environment could result in lower flows on Baker Creek.

Regardless, the hydrological design basis for Baker Creek provides the following elements of conservatism to accommodate potential future increased runoff:

- The current design discharge was increased by 10% above that indicated by the frequency analysis of site-specific flood data;
- The current design criteria incorporates 2 m of anchor ice accumulation and 1 m of freeboard, which for an ice-free channel would accommodate a discharge of 183 m3/s, compared to the current design discharge of 25 m3/s. The freeboard allocation alone would provide a channel capacity of 58 m3/s; and
- Should there be a confirmed increase in the flood regime of Baker Creek, such that the channel capacity is inadequate, it would also be possible to increase the channel and floodplain capacity by excavating or dyking as appropriate.

References

CCCSN. 2011. Canadian Climate Change Scenarios Network. Web site http://cccsn.ca, data downloaded 7 November 2011.

EC. 2011b. Canadian Climate Normals 1971-2000, Yellowknife A. Environment Canada Climate Station 2204100. Web site http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1706, downloaded 7 November 2011.

EC. 2011c. The Third Generation Coupled Global Climate Model. Canadian Centre for Climate Modelling and Analysis. Web site http://www.ec.gc.ca/ccmac-cccma/default.asp, downloaded 7 November 2011.

Hirsch, R.M. and K.R. Ryberg. 2011. Has the magnitude of floods across the USA changed with global CO2 levels? Hydrological Sciences Journal , DOI:10.1080/02626667.2011.621895.

IPCC. 2007b. Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability. Section 1.3.2.2 Floods and Droughts.

IPCC. 2011b. Climate model output: period-averages. Intergovernmental Panel on Climate Change, Data Distribution Centre. Web site http://www.ipcc-data.org/ddc_climscen.html, downloaded 17 October 2011.

Spence, C. and J. Hosler. 2007. Representation of stores along drainage networks in heterogenous landscapes for runoff modelling. Journal of Hydrology, Volume 347, pp 474-486.

Szeto, K.K. 2008. On the Extreme Variability and Change of Cold-Season Temperatures in Northwest Canada. Journal of Climate, Volume 21, 1 January 2008, pp 94-113.

Trenberth, K.E. 2007. Predictions of Climate. Climate Feedback, The Climate Change Blog, http://blogs.nature.com/climatefeedback/2007/06/predictions_of_climate.html, downloaded 7 November 2011.

Whitfield, P.H., R.D. Moore, S.W. Fleming and A. Zawadski. 2010. Pacific Decadal Oscillation and the Hydroclimatology of Western Canada – Review and Prospects. Canadian Water Resources Journal, Volume 35(1), pp 1-28.

Attachment #2 – Climate Change Scenarios

Introduction

Technical sessions to discuss the Giant Mine Remediation Project Developers Assessment Report were held in Yellowknife in the week of October 17, 2011. This memorandum is to answer questions regarding climate change and the scenarios selected for the information responses.

Previous Work

Climate change predictions from the Intergovernmental Panel on Climate Change (IPCC) have been utilized in the previous modeling of ground freezing. Estimates of climate warming from IPCC 1995 and 2001 were used in the report "Conceptual Engineering for Ground Freezing" (SRK, 2006) that was appended to the Remediation Plan. Scenarios from the IPCC Climate Change 2007 Synthesis Report were utilized in the Developers Assessment Report (DAR) and in responses to the MVEIRB's Information Request 3. The estimated temperature changes utilized in the previous work are summarized in Table 3.

Table 3: Annual, Winter and Summer Mean Temperature Changes in Yellowknife in 2100 utilized in Previous SRK work.

Document	Temperature Change (°C)						Source
	Worst Case			Range			
	Annual	Summer	Winter	Annual	Summer	Winter	
Ground Freezing Report (SRK, 2006)	4.5*			2.5-4.5			IPCC 1995 and 2001
Ground Freezing Report (SRK, 2006)	5.2	2	9.2	3-5.2	1-2	5-9.2	IPCC 1995 and 2001
DAR (SRK, 2010)		2.1	9.6	3.3	1.2-2.1	5.4-9.6	IPCC 2007
Response to Review Boards IR #3	5.8			0.0-7.9			IPCC 2007

Climate Scenarios

The IPCC has produced numerous scenarios of future climate change. The IPCC scenarios are based on varying concentrations of atmospheric greenhouse gases (GHGs) for the best case to worst cases of economic growth, land use and hydrocarbon usage. The IPCC Special Report on Emissions Scenarios (SRES) (2000) breaks the emissions scenarios into four families. The A1 family represents rapid economic growth, more efficient technologies; within the A1 family there are three sub families that describe the alternate energy sources. Of these sub-families A1B represents the balance of all energy sources. The B1 family has the same population as the A1 family but more rapid changes in economic structure. The B2 family has an intermediate population and economic growth. The A2 family has high population growth and slow technology changes and economic development. No likelihood has been attached to any of the SRES scenarios.

Climate change scenarios based on the IPCC climate models are available through various websites. Two Canadian websites that provide this data are the Pacific Climate Impacts Consortium (PCIC) and the Canadian Climate Change Scenarios Network (CCCSN) available at pacificclimate.org and cccsn.ca respectively.

The Pacific Climate Impacts Consortium provides a regional analysis tool to obtain climate prediction values for specific regions along the Pacific coast and the Yukon region of Canada. Regional climate data is available by province, territory or custom regions can be defined by drawing a region on the map. The climate change data available is relative to the 1961-1990 baseline.

The Canadian Climate Change Scenarios Network provides climate change data based on weather station locations. The climate change data is available relative to the 1961-1990 baseline, the 1971-2000 baseline or a custom baseline. Mean temperature predictions which are not dependant on baseline data are also available. Three “ensemble-mean” scenarios which are the average of several A2, A1B and B1 scenarios are also used to predict climate change. The website recommends using the ensemble scenarios as they distinguish climate change from natural system variation better than a single experiment (CCCSM, 2011). The A2 ensemble represents the case of high emissions, the A1B ensemble medium emissions and the B1 ensemble low emissions.

Temperature increases predicted for the Yellowknife area by the three ensemble-mean scenarios from the CCCSN are summarized in Table 2.

Table 4: Annual, Winter and Summer Mean Temperature Change in Yellowknife in 2100 relative to the 1974-2003 Baseline

Ensemble Mean Scenario	Annual			Winter			Summer		
	Worst Case	Best Estimate	Best Case	Worst Case	Best Estimate	Best Case	Worst Case	Best Estimate	Best Case
SR-A2	6.0	4.8	3.6	8.5	6.7	4.9	4.8	3.5	2.2
SR-A1B	5.5	4.3	3.1	7.7	6.1	4.5	4.3	3.0	1.7
SR-B1	3.8	2.9	2.0	5.2	3.9	2.6	2.9	2.0	1.1

Source: CCCSN, 2011

Discussion

The climate change scenarios assumed in the various Giant Mine reports were all intended to represent conditions in the year 2100. The estimates have changed as the IPCC updates and their Canadian interpretations became available.

The most recent work, in the DAR and the responses to Information Requests, has covered a range that is consistent with the range of increases estimated from the most recent IPCC and Canadian climate change sources. For example, the graphs presented in the response to the MVEIRB's Information Request 3 cover a mean annual temperature range from today's values to an increase of 7.9 °C, which exceeds the 3.8 – 6.0 °C range of "worst case" temperature increases predicted by CCCSN's ensemble-mean scenarios.

It should be noted that the ground freezing modeling used only the temperature increases from climate change models. It did not consider other effects, such as changes in precipitation, which would have only minor direct influences on ground freezing.

References

Canadian Climate Change Scenarios Network (CCCSN). 2011. Available at: cccsn.ca (Accessed November 2, 2011)

Intergovernmental Panel on Climate Change (IPCC). 2001. Climate Change 2001: Synthesis Report: Contribution of Working Groups I, II,III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R.T. (ed), Cambridge University Press, 398p.

Pacific Climate Impacts Consortium (PCIC).2011. PCIC Regional Analysis Tool (BETA). University of Victoria, B.C. Available at: http://tools.pacificclimate.org/select (accessed November 1, 2011)

SRK Consulting (Canada) Inc. 2006. Conceptual Engineering for Ground Freezing. Prepared for: Indian and Northern Affairs Canada. January 2006.

SRK Consulting (Canada) Inc. 2011. Giant Mine Remediation Project Developer's Assessment Report. Prepared for: Indian and Northern Affairs Canada. October 2010.