

Attachment E Comparison of Kiffavik Dust Deposition to the EKATI and Meadowbank Mines

Introduction

During the Technical Comment period for the Kiggavik Project's Draft Environmental Impact Statement (DEIS), some concerns were raised with respect to the predictions of dust deposition from Kiggavik and how it compared to other mining assessments, in particular the EKATI Diamond Mine in NWT and the Meadowbank Gold Mine in Nunavut.

SENES Consultants (SENES) has completed a review of both the EKATI and Meadowbank mine modelling assessments in addition to a detailed review of their available air quality monitoring data. This Attachment presents the findings of these reviews and compares them to the Kiggavik dust deposition modelling as presented in Appendix 4B of both the Draft and Final EIS submissions.

Summary of Dustfall at the EKATI and Meadowbank Mines

A detailed review of the EKATI and Meadowbank dispersion modelling reports as well as all available air quality monitoring reports was completed. The documents reviewed include:

Meadowbank Mine

- Meadowbank Gold Project Air Quality Impact Assessment, prepared by Cumberland Resources Ltd in October 2005 (Cumberland Resources Ltd 2005)
- 2012 Air Quality and Dustfall Monitoring Report (Agnico Eagle Mines Limited 2013a)
- 2012 Preliminary evaluation of dustfall along the Meadowbank AWAR (Agnico Eagle Mines Limited 2013b)

EKATI Mine

- o *EKATI Diamond Mine 2005 Air Quality Monitoring Program*, prepared by Rescan in October 2006 (Rescan 2006a)
- EKATI Diamond Mine CALPUFF Air Dispersion Modelling Assessment, prepared by Rescan in October 2006 (Rescan 2006b)
- EKATI Diamond Mine 2008 Air Quality Monitoring Program, prepared by Rescan in January 2010 (Rescan 2010)
- o *EKATI Diamond Mine 2009-2011 Air Quality Monitoring Program*, prepared by Rescan in May 2012 (Rescan 2012)

To begin, a comparison between modelled and monitored dust deposition (i.e., dustfall) is provided in Table E-1 for Meadowbank mine and Table E-2 for EKATI. Note that the averaging period for modelled dustfall is different for each assessment and is indicated in brackets. For each receptor location, a dispersion model will output a deposition rate (e.g., µg/cm²/s) that has been averaged over a specified averaging period (usually monthly or annual). This rate is then converted to a 30-day deposition rate in order to compare the results of each assessment.

It is also important to note that the emission rates presented for EKATI have been estimated based on the information available in the Rescan (2006b) CALPUFF Air Dispersion Modelling Assessment. The original emissions inventory used in the EKATI modelling assessment could not be located. While SENES has made its best attempt to calculate these emissions based on the information at hand, it must be emphasized that there is uncertainty with this estimate.

Table E-1 Comparison of the Modelled and Monitored Dustfall at Meadowbank Mine

			Maximum Modelled Measured Dust Dustfall g/m²/30d			
Mine Site	Model Used	Total TSP, g/s	g/m	² per 30d	Maximum	Mean
Meadowbank	ISCST3	18.2*	26.4	(30 days)	10.5	2.9

NOTES:

n/a - not applicable

As shown in Table E-1, the Meadowbank air quality modelling assessment was completed using the ISCST3 dispersion model. The ISCST3 (Industrial Source Complex Short Term Version 3 model) is a steady-state Gaussian plume dispersion model which has since been replaced by AERMOD as the US EPA regulatory default model. Based on the impact assessment report, dustfall was predicted for a worst-case emissions scenario which only modelled three fugitive dust sources (a tailings area, a waste disposal facility, and a course ore stockpile). The maximum dust deposition value predicted at Meadowbank mine was $26.4 \text{ g/m}^2/30$ days based on a 30-day averaging period. A separate run was carried out to examine the cumulative effects of fugitive dust sources, including road dust, but only PM_{10} and $PM_{2.5}$ concentrations were modelled.

Year-round dustfall monitoring began at Meadowbank in December 2011 at four locations in and around the mine site. Dustfall samples were collected on a monthly basis to establish 30-day dustfall rates. As can be seen in Table E-1, modelled dustfall is roughly 2 times greater than the maximum measured dustfall value (10.5 g/m²/30 days) in 2012. A model is considered to perform well if the predicted value is within a factor of two of a measured value. However, it is expected that this difference would have been even greater had the modelling included all fugitive dust sources (not just the tailings, waste facility and ore stockpile). This indicates that the dispersion modeling was likely overly conservative.

^{*} Emission rate is uncertain.

¹ Averaging period indicated in brackets.

Table E-2 Comparison of the Modelled and Monitored Dustfall at EKATI Mine

Mine	Model	Total TSP ¹ , g/s		TSP from Misery Haul Road ¹ , g/s		Maximum Modelled Dustfall ² g/m ² /30d		Measured Dustfall near Misery Road ³ g/m²/30d		Measured Dustfall near LLCF ⁴ g/m²/30d	
Site	Used	Summer	Winter	Summer	Winter	Ma	aximum	Max	Mean	Max	Mean
FIZATI	CALPUFF	1064.2	110.0	105	18.5	41.7	(Summer)	79.9	19.1	6.5	3.7
EKATI	CALPUFF	1004.2	112.3 185	100	16.5	4.2	(Winter)	n/a	n/a	n/a	n/a

NOTES:

n/a - not applicable

- Emissions estimated based on information available in the EKATI Diamond Mine CALPUFF Air Dispersion Modelling Assessment, prepared by Rescan (October 2006)
- ² Averaging period indicated in brackets.
- Measured values are based on dustfall measurements next to Misery haul road for the period 2006-2012.
- Measured values are based on dustfall measurements next to the Long Lake Containment Facility (LLCF) for the period 2006-2012.

The EKATI assessment was completed using the CALPUFF dispersion model which predicted dustfall for a worst-case summer emissions scenario and a worst-case winter emissions scenario. Winter emissions along the access road were 10% of summer emissions as shown in Table E-2. Correspondence between Rescan and Environment Canada (Appendix D and E of the Rescan 2006 report) also indicates that dispersion modelling was completed for a base case (i.e., without mitigation). However, the monitoring reports indicate that efforts have been made at EKATI to actively reduce dust, including: the application of water to Misery haul road; the application of DL-10 (a chemical dust suppressant) to the Fox and Beartooth haul roads; the application of Envirokleen to the airstrip; and enforcing speed limits. Therefore, any predictions made by the model are expected to be overly conservative compared to actual measurements.

Since 2006, dustfall monitoring has taken place during the summer in and around the EKATI mine. Dustfall jars have been placed at locations in and around the Long Lake Containment Facility (LLCF) and near the airstrip. Groups of monitors have also been placed at varying distances (30 m, 90 m, 300 m and 1 km) downwind and upwind of the Fox and Misery haul roads. Two background monitors have also been located 21 and 36 km from the mine. Dustfall samples are collected on a monthly basis to establish 30-day dustfall rates. The values presented in Table E-2, however, are only based on 2006-2012 Misery haul road dustfall measurements since the maximum modelled dustfall amount was predicted in the vicinity of this road. For comparison, dustfall measurements taken at the LLCF sites are also presented in Table E-2 as these are considered to be more representative of "on-site" dustfall levels. Complete monitoring results are provided at the end of this Attachment.

As shown in Table E-2, the maximum modelled dustfall amount next to Misery road during the summer (41.7 g/m²/30 days) is about 2 times higher than mean measured dustfall (19.1 g/m²/30 days) for the period 2006-2012. This is within the acceptable factor of 2 for dispersion modelling. However, the maximum measured dustfall amount near Misery Road was 79.9 g/m²/30 days. This is about 2 times greater than the modelled dustfall amount and is also much higher than any amount recorded in subsequent years due to high activity levels at the Misery pit. Although this also within the acceptable factor of 2 for dispersion modelling, it is interesting to note that the dispersion model, which excluded mitigation, under-predicted maximum dustfall along a haul road which was reportedly treated with water. Possible reasons for this discrepancy are: 1) the model did not include receptors located close enough (i.e., within 50 m or less) to the road where the maximum measurement was recorded; or 2) the watering regime was not effective.

In addition, Table E-2 shows that dustfall measurements next to the Misery road are about 5-10 times higher than "on-site" measurements taken near the LLCF. This confirms that unpaved roads are a large source of fugitive dust at EKATI as predicted by the dispersion model. As a result, dustfall profiles downwind of haul roads were examined further at EKATI. In addition to on-site monitoring, Meadowbank mine also completed a specialized dustfall study in the summer of 2012 which measured dustfall at increasing distances from the All-Weather Access Road (AWAR) which connects the mine to the Agnico-Eagle dock site in Baker Lake. The results of this study are also examined below.

Haul Road Dustfall Profiles

Figure E-1 shows the downwind profiles of dustfall measurements for the Misery, Fox, and Sable haul roads at the EKATI mine. The profiles are based on mean dustfall recorded downwind of each road over the period 2006-2012. Sable road measurements were taken only in 2007. As can be seen in Figure E-2, dustfall decreases quickly with increasing distance from the road. On average, dustfall values drop by about 75% within 90 m of the haul roads and by 80-90% within 300 m of the haul roads.

Similarly, the dustfall profile for the Meadowbank AWAR study is shown in Figure E-2. At a distance of 100 m, dustfall values had decreased by almost 60% in the vicinity of the AWAR.

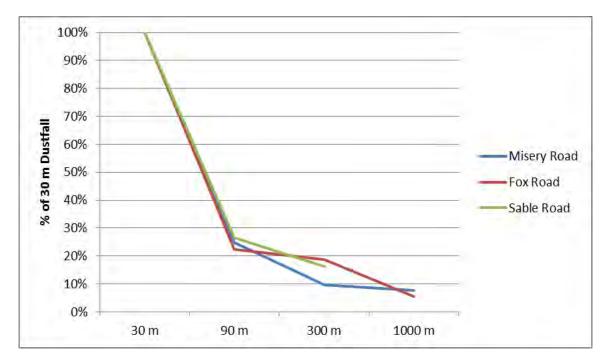


Figure E-1 Average Dustfall Profiles Downwind of EKATI Haul Roads

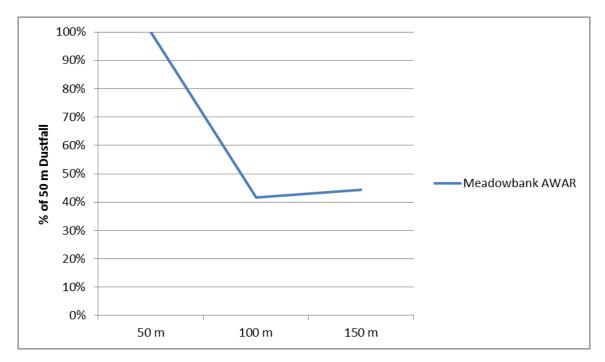


Figure E-2 Average Dustfall Profile Downwind of the Meadowbank AWAR

Comparison of EKATI and Meadowbank to Kiggavik

Since the model used and the emission sources included in the Meadowbank assessment are vastly different from Kiggavik, a direct comparison between the Meadowbank mine dispersion modelling and Kiggavik dispersion modelling is not considered appropriate. However, like EKATI, Kiggavik utilized the CALPUFF dispersion model and had comparable emission sources (e.g., open pits, haul roads, power plant, etc.). Therefore, only a comparison between modelled dustfall at EKATI and Kiggavik will be discussed in detail. However, dustfall measurements from both the EKATI and Meadowbank mines will be compared to the Kiggavik dispersion modelling results.

Table E-3 shows the emission rates and predicted dustfall values for the Kiggavik assessment as outlined in the Draft Environmental Impact Statement (DEIS). Compared to the modelled dustfall values for EKATI (Table E-2), the maximum modelled dustfall value for Kiggavik (outside of the Project Footprint) was more than 20 times lower than the maximum value predicted for EKATI. Additionally, when compared to available monitoring data from Meadowbank and EKATI (Tables E-1 and E-2), it further suggests that the maximum modelled dustfall levels at Kiggavik in the DEIS may have been under-represented. As a result, SENES re-examined its selection of emissions scenario used to predict dust deposition rates. In the DEIS, emissions from Phased Operation Scenario 2 were used to predict dustfall. While this scenario best represented maximum annual emissions at the Kiggavik mine site, it did not represent worst-case emissions along the Kiggavik-Sissons haul road, one of the main sources of dust. As a result, SENES re-modelled dust deposition using the Maximum Operation emissions scenario for the Final EIS. These results are presented in Table E-4 below and are compared again to available dustfall data from EKATI and Meadowbank. Recall that the Maximum Operation scenario provides an upper bound estimate of mining activity air emissions and was used to assess the largest potential short-term (i.e., 1- or 24-hour) effects of mining activities on ambient air quality; therefore, if used to assess long-term (i.e., monthly or annual) effects like dustfall, it is considered to be conservative.

Table E-3 Summary of Modelled Emissions and Dustfall Values for the Kiggavik DEIS Assessment

			Total TSP, g/s		TSP from Sissons H	aul Road,	DEIS Maximum Modelled Monthly Dustfall ¹ , g/m²/30d			
Mine Site	Model Used	Scenario Modelled	Summer	Winter	r Summer Winter		Overall Max	Max near Kiggavik- Sissons Haul Road		
Kiggavik	CALPUFF	Phase 2	69	87	0.7	1.2	1.8	0.11		
Kiggavik	CALPUFF	Phase 2	69	87	0.7	1.2	1.8	0.11		

NOTES:

n/a - not applicable

Table E-4 shows the emission rates and predicted dustfall values for the Kiggavik FEIS modelling assessment. Comparing to the modelled values from EKATI in Table E-2, the maximum modelled dustfall value at Kiggavik (outside of the Project Footprint) is now about 6 times less than the value predicted for EKATI. It has also been identified that the locations of the overall maximum dustfall value are quite different. At EKATI, the maximum value was predicted to occur next the unpaved Misery haul road, whereas at Kiggavik, the maximum was predicted at a receptor in the vicinity of the Main Zone pit.

Table E-4 Summary of Modelled Emissions and Dustfall Values for the Kiggavik FEIS Assessment

			Total TS	SP, g/s	TSP from Kiggavik- Sissons Haul Road, g/s		FEIS Maximum Modelled Monthly Dustfall ¹ , g/m²/30d			
Mine Site	Model Used	Scenario Modelled	Summer	Winter	Summer	Winter	Overall Max	Max near Kiggavik- Sissons Haul Road		
Kiggavik	CALPUFF	Maximum Operation	147.6	200.4	17.9	35.1	7.5	5.4		

NOTES:

n/a – not applicable

Comparing dustfall values predicted along the Kiggavik-Sissons haul road (Table E-4) to the values predicted along EKATI's Misery haul road (Table E-2), the maximum dustfall value in the vicinity of the Kiggavik-Sissons haul road is about 8 times less than the maximum summer dustfall value next to Misery Road in the EKATI assessment. However, the results from the Kiggavik dispersion modelling are of the same order of magnitude as the winter deposition rates predicted from the EKATI Mine. The discrepancy in maximum deposition values between EKATI and Kiggavik can be largely explained by the significant difference in emissions between the haul roads (see Tables E-2 and E-4). Part of the discrepancy can be also be explained by differences in model setup including how the road sources were modelled in addition to differences in the particle size distributions used. All possible differences are discussed in more detail below.

Table E-5 summarizes the assumptions used for modelling the haul roads in the EKATI and Kiggavik assessments. The type of emissions scenario assessed, the traffic volume used, mitigation measures applied, model source type, and particle size distribution are compared.

Table E-5 Modelling Assumptions for the EKATI Misery Haul Road vs. the Kiggavik-Sissons Haul Road

Parameter	EKATI Misery Haul Road	Kiggavik-Sissons Haul Road
Emissions scenario	Worst-case bounding scenario	Worst-case bounding scenario
Traffic volume	Estimated to be 100-200 trips per day	62 trips per day
Mitigation measures	No control in summer90% control was applied in winter	75% control was applied in summer50% control was applied in winter
Metals modelled?	No	Yes. Assumed same composition as Type I waste rock.
Model source type	Area sources	Volume sources
Particle size distribution of TSP	 Mass mean diameter = 10 Geometric standard deviation = 2.5 	 Mass mean diameter = 20 Geometric standard deviation = 1.24

Comparison of emission rates and dispersion modelling results between two different operational sites is a complex endeavor. There are a number of different variables (e.g., trucks weights, silt content, traffic volumes, etc.) and modelling approaches that could contribute to significant differences in dust emission rates from unpaved haul roads. Examining EKATI's CALPUFF modelling report more closely, it was determined that one of the largest contributors to TSP concentrations/deposition values is the Misery Haul Road which connects the main EKATI site to the Misery site. From the modelling files in Appendix F of the Rescan (2006b) report, it was determined that the TSP emission rate for the entire Misery Haul Road was approximately 185 g/s. At roughly 26 km in length, this works out to be about 7 g/s per km suggesting significant traffic volumes (i.e., 100-200 trucks per day round trip, assuming the same road characteristics as those used in the Kiggavik assessment, which may or may not be the case). Along the Kiggavik-Sissons haul road however, emissions were 35.1 g/s (or 1.8 g/s per km) due to lower traffic volumes (about 62 trucks per day round trip). In addition, unlike the EKATI assessment, mitigation measures were assumed for the Kiggavik-Sissons haul road. Specifically, it was assumed that natural mitigation will reduce emissions by 50% in winter and that dust suppression techniques such as watering or calcium chloride application will achieve 75% control during summer. At EKATI, natural mitigation was assumed to control emissions by 90% in winter, but no mitigation was applied during summer which would result in high emission rates.

In addition to contrasting emission rates, different particle size distributions were used in the Kiggavik and EKATI assessments. As noted in the Rescan (2006) report: "There is considerable uncertainty associated with modelling particulate deposition. The primary uncertainty in model results is due to uncertainties in estimates of the particle size distributions, which has a strong influence of settling velocity and dispersion properties." Upon examining the distribution used in the EKATI assessment, there is concern with how the particle sizes were used in the EKATI model. To be more specific,

before inputting the TSP emission rate, the PM_{10} and $PM_{2.5}$ emission rates may need to be subtracted from TSP so that you are representing only the fraction of particulate that is greater than 10 microns. From the information available in the Rescan (2006b) report, there is no evidence to suggest that this was done appropriately and if TSP was input incorrectly (i.e., the TSP fraction was entered as total TSP without subtracting PM_{10} and $PM_{2.5}$), it can lead to an overestimate of deposition rates. However, without the detailed 2003 emissions inventory to cross-reference emission rates with the modelling input file, this error cannot be certain.

Even though the magnitude of the dustfall values predicted for Kiggavik are less than those predicted for EKATI, it is important to note that the predicted patterns of dustfall are similar between the two assessments. In particular, Figure 37 of Appendix 4B of the FEIS showed that annual dust deposition rates are predicted to be in the range of 15 g/m²/year (150 kg/ha/year) in close proximity to the mine sites and the Kiggavik-Sissons haul road. However, deposition rates quickly drop off with distance from the mine site. Specifically, in the vicinity of the Kiggavik-Sissons haul road, the deposition rate drops by 54% between 50 and 800 m from the centre of the road. This is further illustrated in Figure E-3 below which shows the downwind profile of deposition for a cross-section of road located about half-way along the Kiggavik-Sissons haul road. Furthermore, at about 12 km from the Kiggavik Project Footprint, total annual deposition begins to approach background levels. This was demonstrated in Figure 37 of Appendix 4B of the FEIS.

Similarly, the EKATI FEIS also predicted that measurable dust deposition rates (i.e., above baseline) occur within a zone of 14 km from the mine site which is not unlike the predictions made here for the Kiggavik Project. The dustfall pattern predicted in the EKATI FEIS has since been verified through the ongoing dustfall monitoring program discussed above, which has shown that zone of influence at EKATI is between 14 and 20 km. In addition, dustfall measurements within the vicinity of the haul roads at EKATI show that on average, values drop by about 75% within 90 m of the EKATI haul roads and by 80-90% within 300 m of the haul roads (Figure E-1). These results are consistent with the measurements made along the Meadowbank All Weather Access Road, which showed that dustfall values decrease by almost 60% within 100 m of the road (Figure E-2). These measurements imply that dust deposition levels along mine haul roads actually decrease faster than what was predicted by the model along the Kiggavik-Sissons haul road, suggesting that modelled dust deposition beyond about 300 m from the Kiggavik-Sissons haul road are conservative.

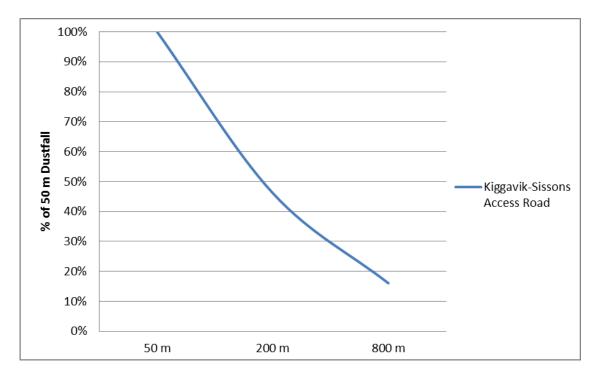


Figure E-3 Modelled Dustfall Profile Downwind of the Kiggavik-Sissons Haul Road

Conclusion

Results of both the EKATI and Meadowbank mine modelling assessments in addition to their available air quality monitoring data was compared modelled dustfall as presented in the Kiggavik DEIS. The findings of this comparison suggested that the emissions scenario used in the DEIS may have under-represented dustfall from the Kiggavik Project, particularly in the vicinity of the Kiggavik-Sissons haul road. As a result, SENES re-modelled dustfall for the FEIS using the Maximum Operation emissions scenario. After re-modelling, dustfall predictions in the Kiggavik FEIS are still less than what has been modelled and observed at EKATI, however, these differences can mostly be explained by differences in emissions and how road sources were parameterized in the CALPUFF model.

Overall, comparison of Kiggavik FEIS dustfall results to EKATI dustfall data has revealed that that the predicted patterns of dustfall are actually quite similar between the two mines. The zone of influence at Kiggavik is predicted to be about 12 km whereas the EKATI zone of influence is about 14 km. In addition, measurements of dustfall along EKATI and Meadowbank roads were found to decrease at a faster rate than what was predicted along the Kiggavik-Sissons haul road, suggesting that modelled dustfall beyond about 300 m from the Kiggavik Sissons haul road is conservative.

Table E-5 EKATI Dustfall Monitoring Data, 2006-2012

	Max Site mg/dn		Mean Site Dustfall, mg/dm2/day		Mean Summer Misery Deposition, mg/dm2/day			Mean Summer Fox Deposition, mg/dm2/day				Mean Summer Sable Deposition, mg/dm2/day				
Year	LLCF-PA-P	LLCF-PB-P	LLCF-PA-P	LLCF-PB-P	30 m	90 m	300 m	1000 m	30 m	90 m	300 m	1000 m	30 m	90 m	300 m	1000 m
2006					6.8	3.1	1.1									
2007					26.6	4.6	1.5		10.1	5.5	12.7		2.6	0.7	0.4	
2008	0.7	1.3	0.5	0.8	0.5	0.3	0.3	0.2	7.9	2.5	1.0	3.1				
2009	0.8	3.4	0.6	2.0	0.8	0.2	0.1	0.3	37.0	5.2	2.3	0.5				
2010	4.0	1.3	2.2	0.9	1.6	0.6	0.4	1.0	24.6	5.5	2.1	0.5				
2011	4.0	2.4	1.8	1.0	1.9	0.7	0.3	0.5	22.7	4.1	1.1	0.3				
Average	2.4	2.1	1.3	1.2	6.4	1.6	0.6	0.5	20.5	4.6	3.8	1.1	2.6	0.7	0.4	

References

Literature Cited

- Agnico Eagle Resources Limited. 2013a. Air Quality and Dustfall Monitoring Report. March.
- Agnico Eagle Resources Limited. 2013b. Technical Memorandum: Preliminary evaluation of dustfall along the Meadowbank AWAR. March.
- Cumberland Resources Ltd. 2005. Meadowbank Gold Project Air Quality Impact Assessment.

 October.
- Rescan Environmental Services Ltd. (Rescan). 2006a. EKATI Diamond Mine 2005 Air Quality Monitoring Program. October. Prepared for BHP Billiton Diamonds Inc. October 2006.
- Rescan Environmental Services Ltd. (Rescan). 2006b. EKATI Diamond Mine CALPUFF Air Dispersion Modelling Assessment. Prepared for BHP Billiton Diamonds Inc. October 2006.
- Rescan Environmental Services Ltd. (Rescan). 2010. EKATI Diamond Mine 2008 Air Quality Monitoring Program. Prepared for BHP Billiton Diamonds Inc. January 2010.
- Rescan Environmental Services Ltd (Rescan).. 2012. EKATI Diamond Mine 2009-2011 Air Quality Monitoring Program. Prepared for BHP Billiton Diamonds Inc. in May 2012.