HYDROGEOLOGY BREAKOUT SESSION
NOVEMBER 26, 2002 (DAY 2, EVENING)
DE BEERS BOARDROOM, 3RD FLOOR SCOTIA CENTRE

Attendees: Greg Oryall (AMEC/DBCMI - Chairperson), Steve Wilbur (Dogrib Treaty 11), Tim Byers (Yellowknives Dene), Doug Halliwell (Environment Canada), Alecandre Desbarats (NRCan), Margo Burgess (NRCan), Dave Osmond (GLL/MVEIRB), Rob Dickin (GLL/MVEIRB), Neil Hutchinson (GLL/MVEIRB), North Douglas (Rae Edzo Metis Local 64), Joao Kupper (Stantec Consulting, NSMA), Don Chorley (Golder/DBCMI), Lee Atkinson (HCI/DBCMI), Ken DeVos (Golder/DBCMI), Tom Higgs (AMEC/DBCMI), Colleen English (DBCMI – Note Recorder)

This is an informal summary of the discussions and is not binding on the participants.

Groundwater Inflow Quantities

Alec, NRCan: re: Appendix IX.3 - how are K values determined from shut in or flaw tests? There are problems with formula itself. Is there an equation?

Lee, HCI: Cooper-Jacob equation.

Alec: Retained shut-in or flow tests for hydraulic conductivity (K) values – could you justify why you used one test versus another?

Lee: Flow tests produced very questionable results, probably due to inaccurate measurements of flow.

Alec: Why were shut-in head values not used in calibration? Was it because you did not feel they represented steady state conditions?

Lee: Yes.

*Discussion on K and heads measured in D-7 with a pressure gauge.

*Discussion on fracture zones.

Steve, Dogrib: Have we done enough work to clarify that we will not see anything unusual?

Alec: Why are head values surprisingly uniform along a single borehole? Alec stated that he is used to seeing changes of 5-20 psi. (Lee acknowledged this.)

Steve: If boreholes are open, is it possible to conduct thermal tests in the fracture zones?

Lee: No, this is not possible as all holes all sealed – the mine is flooded.

Steve: 2300m of borehole data, 8-10 holes. In relation to fractures and discontinuities do you feel you had enough opportunities to intersect the potential flow zones?

Lee: Pre-mine development drifts are planned.

Ken, Golder: A lot of data was compiled given the time that we had and the other programs on the go.

Steve: Do we have hydrogeologic data in the entire area we are permitting?

Greg: We have hit both significant rock types and covered off as much of the mine as we could.

Steve: Can you comment on the fracture joint sets found?

Lee: An order of magnitude or two is associated with flow direction. That was refined with additional data. K tensor is in a vertical plane to the north/south and the second component is east/west. This has shown a preferred orientation.

Alec: When have a gently dipping dyke, I would expect sub-parallel fracture systems.

Lee: I had expected to see a difference between the hanging and footwall, but the data does not reflect this.

Alec: Were there any horizontal fracture zones with high conductivity?

Lee: No.

Alec: To what do you attribute the anisotropy?

Lee: I would guess the exfoliation is glacial unloading, and the orientation in the vertical would have to be tectonic, but I honestly cannot say as I do not know as this is outside my area of expertise. Most of the mine is in granite, with only a small portion of metavolcanic rock.

Doug, EC: Regional structural geology analysis would be required to help explain why the hydraulic conductivity is ten times as large north-south.

Steve: Did you see changes in fracture density with depth?

Lee: Like things tightening up the depth? (Confirmed) No, we didn't. In terms of elevation, the horizons of all the holes are similar. Our goal was to look at the most critical/susceptible rock mass. When modeled, we used a theory more developed in the coal mine areas which assumed much of the area will subside, and you will get beam-like effects. Below the beam will be more fractured, while above would be less, but, when running the model, we did not drop the K above the beam. Vertical hydraulic conductivity in granite is the driving factor of this model.

Steve: How much did you break down the model grid (or cell size) to represent identified heterogeneity?

Alec: In relation to the dips on underground boreholes, is the negative meaning downward? (Yes.)

Alec: How did you assign weighting of K values?

Lee: Totally subjective. In very low K zones, pressure buildup does not reflect formation response. Zero weighting was even used sometimes. It was done on a test-by-test basis.

Alec: OK, but this makes it difficult to audit your method.

*Geometric averaging discussion.

Alec: Not a bad justification that you have used, as it is not an advanced theory.

Lee: There is no way we would simulate fractures on a project like this.

Alec: Assigning individual K values to every element would add more certainty.

Greg (to participants): Are there any concerns you have that the predictions made in the EA would not be sufficient to predict the impacts?

Steve: One approach to modeling is to create an undesirable situation, determine how to change various parameters to create a bad situation and ask how probable it is. You used standard deviations. Would you have considered an approach such as this?

Lee: Have never tested the inverse. The lake is modeled as a constant head, so I don't think that approach would work for this project.

Rob, GLL/EIRB: If a value varies by 1 order of magnitude, how does that vary flows into the mine?

Lee: Would never pull a single parameter out for multi-variable analysis.

Rob: There is some uncertainty in the numbers as there is not much data available for determining lake sediment hydraulic conductivity – ie: one slug test in one borehole. Limited data is a factor, so if you could change that factor, what would be the result?

Lee: Can show you similar outputs, but not the final results as I did not pull out only one parameter.

*Discussion on leakance factors and how they were determined.

Lee: Won't ever really know their true value. It's a factor that should improve with future calibrations of the model because as you raise the leakance factor, the model starts to become insensitive to it above a certain range of values.

*Discussion of alternative formulas for leakance factors.

Alec: I do not discredit this. I am simply trying to probe, test and prove what has been done. I want something to work with, in terms of physical justification for leakance values used, in order to perform an effective audit of the work.

Greg: Will provide you with an example of application of the model. For the advanced exploration program (AEP), we needed to calculate to the day, how much drilling and sampling we could do. We planned for 4 months. Using the model we predicted how much we could get done in those 4 months, and we ended up getting a week and half more drilling done than planned. This helps to show the conservatism. The prediction held up well with what we found when we went down for the AEP.

Tom: Also need to take into the account that we need to ensure the water treatment plant will be able to handle the volumes predicted. Therefore, we need to know if there is a fatal flaw in the model for determining these flows.

Lee: When examining water from Snap Lake, we left out reduction in the K in a subsidence zone above the neutral axis.

Greg: Is there anything critical with regard to the flow determination component that we haven't mentioned?

Doug: The Snap and Krackle faults only conduct groundwater in some zones. Did the granite-metavolcanic contact points contain much water when intersected by underground mine workings? The contact-related fractures are more likely to have more connectivity than the faults and possibly conduct more water.

Lee: The underground mine excavations did not encounter much water at the granite-metavolcanic contact at the two locations.

Dave, GLL/EIRB: (Summarized the model and how it was used.) That seems pretty realistic.

NRCan: This was a good information exchange. I now understand the constraints for the characterization campaign. It is not possible to go back and perform more work due to flooding of the mine and that causes a problem. We would not press forward on some comments to the next written round.

Steve: These additional details were helpful. I am able to take away a good feeling for the limits of the model. Still have some overall questions, but nothing too specific. Unsure if I will carry forward these issues to a technical report at this time. I will have to think it over.

Neil, GLL: Can we take a step forward with satisfaction on these issues?

Steve: Certainly De Beers puts more at stake at this point in terms of numbers and operating and hydraulic constraints. I would tend not to raise the issue because of that.

Alec: It is in De Beers interest to get the inflow calculations right, but that does not necessarily mean that I'll buy into them without proper justification of all steps in the modeling.

Greg: Are there any concerns that the predicted flows for the mine are different than you'd expect, given the rock type and your experience?

Steve: Not in relation to the raw values. Have seen heavy water flow reduce to nothing as Lee describes, but have also seen continuous flow. That is the core of what I'm getting at - do we have enough data to characterize this?

Rob: I have increased confidence in the approach taken now. It is reasonable, and has been calibrated with real data. I think this was a worthwhile information exchange.

Tim, Yellowknives Dene: If the predictions and models are incorrect, the ramifications are greater for De Beers than the environment. Stemming from this, the Yellowknives Dene would ask that if the predictions turned out to be wrong, do any of the experts in the room believe that if there was a massive inflow of minewater, would there be a mine safety issue/hazard for workers in the shaft?

John McConnell, DBCMI: There are procedures in place in terms of advancing the development. Before we go into an area, we will drill ahead and see if there is a need to grout prior to any development. Most of primary development is under the ore body. The kimberlite dike acts as a sort of umbrella and we will also drill holes around the area prior to blasting. With these methods in place, we don't foresee a problem.
Tim: So De Beers does not just use predictive models in relation to mine safety issues, you would actually be performing safety procedures that would protect the workers. That's good.

Regional Groundwater Flow (NRCan not present for this discussion.)

Joao, Stantec/NSMA: *Drew a diagram on the board showing a cross-section of the regional groundwater flow. I feel that the flow does not necessarily well up between the two permafrost zones after leaving Snap Lake. Instead, I think that it would keep going straight.
Greg: If you assume that all flows go to North lakes, how much impact would result from this? We do not necessarily feel the water flows follow this pattern, but we assume this solely to predict the impacts with a high level of conservatism.
Ken: We only looked at the issues in a smaller lake in order to predict the maximum impacts.
Lee: Upwelling in the model was forced for impact predictions related to geochemistry.
John: We are not necessarily concerned if hydrologic model is not 100% correct in this example, as we are focusing on the impact predictions.
Steve: If the lake levels changed, how would that change the predictions?
Lee: It wouldn't really due to anisotropy (N/S gradient).
Steve: I agree with premise of what you are doing to predict the impacts, but I still want the model to be correct.
Don: If you take away the boundary conditions, the change in K tensor can change where the flow ends up.
Steve: Have all the lakes that contribute to the overall system been surveyed for their precise level? If the levels are not known that well, how would this affect the predictions?
Lee: It would change the amount of flow, but not the direction. I agree that some small amount of underflow would occur beneath the permafrost, but the model was configured to facilitate geochemistry predictions.
*Discussion on chloride concentrations and particle tracing in the groundwater, and the result that surface water influence increases with distance from the mine.
Steve: What is the difference between the real versus tweaked models?
Lee: There is some underflow, but there is still a definite discharge from Snap Lake to both the north and the northeast lakes.
Joao: If you extended the model boundary, what would happen?
Lee: Some water will continue to go to the farther lakes.
Ken: Will having a more regional component to the groundwater flow affect the overall environmental impact assessment? No. Does it influence the mine inflow and its environmental influence factor? No. So, you have a point and it should be noted, and it was in Lee's report, but does that point cause any change to impact predictions? No.
Rob: I do not think that the North Lakes report was clear that this was a worst case scenario. Now there are a lot of biologists, etc worked up about the impacts of this. (To Don) You should definitely bring this up in your presentation tomorrow.
Steve: You have stated that the taliks below the lakes are approximately 1/3 the width of that lake – could you please comment on that. There are a lot of other lakes in the Snap area, you have

simplified the permafrost regime to be uniformly thick, which it likely is not, as variability is more than what you are representing. Is this significant in talik determination in intermediate sized lakes?
Don: There are not many of these sized lakes around and they all tend to have a higher elevation than Snap Lake. As far as regional flow, smaller lakes have less influence due to their small size.
Steve: What is the quantitative measure for big versus small lakes and the impacts associated with these? How have you addressed the other lakes?