MIPUG - KM 1 **Risk Tolerance**

Preamble: On page 6 Drs Kubursi and Magee state "...the real issue is for the regulators to align the risk exposure and tolerance of MH to match that of the citizens on behalf of whom the government and/or the Public Utility Board typically act."

(a) Please discuss if in Drs Kubursi and Magee's view there are potential costs to Manitoba's ratepayers of MH becoming too risk averse e.g. targeting too high a level of retained earnings which must be accumulated and maintained through higher electricity rates..

Answer:

a) There are two sides to this misalignment between the two parties' risk tolerance. A too conservative risk tolerance attitude could result in missing opportunities and returns that risk taking could generate. Alternatively, a high risk tolerance could result in losses that the under-estimation of risks and expected values may result in.

**MIPUG - KM 2** **Chapter 1 Summary of Findings**

(a) Please confirm Drs Kubursi and Magee agree Manitoba Hydro's approach to calculating dependable energy is reasonable. If this cannot be confirmed please elaborate.

(b) Please provide additional information (including calculations) to support the statement on page 17 that "...the financial losses of a severe drought are massive and these can deplete accumulated retained earnings of MH in less than three years".

(c) With respect to the statement on page 17 that MH's models "...need to be reviewed and authenticated by external subject matter experts" please discuss if Drs Kubursi and Magee reviewed any of the previous reviews of models undertaken by MH. If so, please elaborate on what additional reviews Drs Kubursi and Magee recommend.

(d) With respect to the statement that long-term contracts need to be staggered over time and diversified over a larger group of counterparties (page 18) please discuss:

i. In Drs Kubursi and Magee's view are there any technical or infrastructure related constraints involved in MH developing long-term export contracts with additional counterparties? If so please discuss.

ii. What in Drs Kubursi and Magee's view would be a reasonable approach for MH to staggering long-term export contracts in terms of volume and time periods?

(e) With respect to the statement on page 19 that "..system expansion is necessary and massive capital will be needed sooner or later to meet the expanding load in Manitoba. The timing and scale should be flexible and appropriately phased, however, in order to allow MH to undertake these expansions in times when material, labour and other costs are low and complementary transmission capacities are firmly in place" please discuss:

i. Are Drs Kubursi and Magee referring primarily to generation resources? Please discuss.

ii. If in Drs Kubursi and Magee's view system expansion is being driven by expanding load in Manitoba (rather than export opportunities) please discuss how in Drs Kubursi and Magee's view MH can target to undertake these expansions at times when material and labour costs are low?

iii. Given the long lead times required for planning, licensing and constructing hydro-electric resources please discuss how MH can plan to undertake these expansions in times when material, labour and other costs are low?

Answers:

a) KM estimated the probability that a randomly chosen five-year period's average water flow is less than the average water flow observed during 1987-1991 is .013833 (one in 72). Furthermore, KM estimated the probability that a randomly chosen five-year period's average water flow is less than the average water flow observed during 1937-1941 is .008466 (one in 118). As well the probability that a randomly chosen seven-year period's average water flow is less than the average water flow observed during 1937-1941 is .012840 (one in 78).

Given these low probability estimates of a more severe drought than the historical record, KM believe that the dependable energy estimates of MH are reasonable. KM had one concern and that relates to the inclusion of wind because it cannot be dispatched. But wind is a small fraction whose inclusion or exclusion is not a serious matter.

b) KM estimated the cost of a 5 year drought at $3,342.7 million and a 7 year drought at $4,548.3 million.

c) KM have reviewed earlier reviews of MH's models and noted that MH presented these models in several experts' forums. KM believe that a special and dedicated review is still needed by experts working in the field with special knowledge in modeling power systems. HERMES and SPLASH are house-developed models, and this external audit and review can be to the advantage of MH and its modeling community.

d-i) Staggering contracts over time is a risk mitigation strategy that allows MH to avoid concentrating lumpy investments in a few periods. This flexibility allows MH to synchronize its investment in capacity expansion with increases in domestic and foreign demand. Many counter parties diversify the portfolio of clients and increase options and bargaining power of MH with its clients.

d-ii) KM are not in a position to draw the time profile of the intended investments other than to note that they should be phased and that this phasing should correspond in some sense or another to anticipated firm demands.

e-i) KM are focusing on both generation and transmission. One without the other is not feasible.

e-ii) KM understanding is that these expansions are ultimately needed to meet the expanding domestic load but are moved ahead of time to generate export revenues to partially cover the costs of the program.

e-iii) KM suggested that given the current slack in the economy it would be advantageous to consider taking advantage of the existing economic situation wherever possible. The expected recovery, when it finally comes, will raise expectations and can easily trigger escalation in costs. MH should exploit the suitable environment of low material and labour costs for as long as they are available and feasible.

**Comparability of MH Models to Other Canadian Utilities**

(a) Please provide the references or describe the research relied on to support the statement on page 57 that "It seems that both Quebec and BC have adopted more advanced systems than MH's Hydro Electric Reservoir Management Evaluation System (HERMES) or Simulation Program for Long Term Analysis of System Hydraulics (SPLASH), but these are still in the same general class of optimizing models of power operations and planning".

(b) On page 57 Drs Kubursi and Magee state "The advantage of Quebec's and BC's is in the stochastic nature of their systems, which makes them more complex and perhaps more useful tools for risk management. But admittedly they are both difficult to manage and present results that are more difficult to interpret. They also fail to include all the complexities that HERMES encompasses". Based on this analysis, do Drs Kubursi and Magee conclude that MH's suite of models, as a package, are generally consistent with Canadian utility standards, or not?

Answers:

a) Please find below a short list of references to these models at BC and Hydro Quebec.

1) Shawwash, Z.K. et. al. BC Hydro Short Term Scheduling and Optimization Model.< http://sciencestage.com/d/3955597/the-bc-hydro-short-term-hydro-scheduling-optimization-model.html>.
2) Vallee Allain and Louis Lafond. Production Scheduling Model for Hydro Quebec.http://cedb.asce.org/cgi/WWWdisplay.cgi?62165.
3) Halliburton, T. Hydro Optimization. http://houston.chapter.informs.org/3
4) The MTGP model. www.iaee.org/documents/Mexico/NUIAEEM.
5) Valette, A. Huang, J.A. Guillon, S. Loud, L. Vanier, G. Levesque, F. Riverin, L. Rizzi, J.-C. Guillemette, F. An integrated approach for optimizing dynamic transfer limits at Hydro-Quebec.2008.
http://ieeexplore.ieee.org/Xplore/login.jsp?url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F4584435%2F4595968%2F04596079.pdf%3Farnumber%3D4596079&authDecision=-203.

b) KM reviewed MH's models and found them on the whole adequate and necessary. KM also felt that these models can be integrated, authenticated and expanded to include nonlinear structures, dynamic formulations and stochastic variables.

**MIPUG - KM 4** **Conclusions and Recommendations with Respect to MH's Models**

Preamble: On pages 122 to 130 Drs Kubursi and Magee provide a series of recommendations related to improving the Manitoba Hydro models they evaluated.

(a) For each of the models reviewed by Drs Kubursi and Magee (MOST; HERMES; SPLASH; PRISM; Load Forecast; and Economic Outlook) please indicate which recommendations Drs Kubursi and Magee believe should be prioritized by MH considering the following criteria:

i. Potential benefit to MH and ratepayers;

ii. Cost required to implement;
iii. Time required to implement; and
iv. Other relevant factors.

KM made a number of recommendations for improving MH models. These are summarized again below and comments are added as to the potential benefits, cost required, time required to implement and other relevant factors.

**MOST**

First, KM would like to see the MOST model cast in a stochastic framework given the many uncertainties that are embedded in the system. It is possible to re-solve the Linear Programming Problem (LP) several times under different specifications of the parameters to take into account possible variations in these variables, but this is not necessary if other systems at MH (for example, PRISM) can be used to generate distributions of the exogenous forecasts.

Second, it is clear that a few price forecasts are embedded in the MOST system; it would make more sense to represent these as probability densities using @RISK in PRISM or any other probability generating system.

Third, KM would also like to see more than one or two skilled persons responsible for the model. It would make more sense to train a designated group of the staff to work on any given model: this will guarantee that a pool of skilled staff is always available to support the model.

Fourth, KM recommended that the system be continuously subjected to validation and verification to improve its forecasting accuracy. Stressing the system (stress tests of the model) should be a regular and routine operation and reports about these tests should be funnelled to the Risk Management Committee.

Fifth, KM believe that it will be useful to formalise the integration of Vista with other models and bring together those supporting and maintaining the system as part of a formal Modelling Committee at MH that meets regularly with a sufficient budget and that is entrusted with the task of internal oversight, review, upgrading, documenting and internalizing the ownership of the models.

Sixth, internal audits are necessary but not sufficient. This function should also be augmented by arms length verification, review and evaluation by an external Model Audit Committee comprised of experts from outside MH with no commercial connections to any of the models. These experts will be involved on a needs basis and granted consulting assignments.

Seventh, KM would like to see that every effort is made to establish full ownership of the model systems within MH and that MOST is not seen or perceived as being a "black box" that was developed generically outside the full control and mandate of the Organization.

Eighth, KM would like to formulate the objective function wherever possible to minimize cost of generation and delivery rather than maximizing net revenues.

The top priority in KM's opinion is to integrate the models on a common platform separating the time periods to reflect the different uses of these. Another priority is to make them stochastic by introducing elements of @RISK into them. The third priority is to verify by the Model Audit Committee. KM are aware that all of this would require additional resources, but these resources are modest and the rewards are high in terms of sophistication, authenticity and results.

**HERMES**

The following specific recommendations have been tendered for HERMES:

First, being an internally developed and maintained system it has advantages and disadvantages. Among the advantages is the ease and flexibility of changing and upgrading the system. This seems to be a continuous process at MH. But being a home grown product it is not documented sufficiently or regularly. KM have not seen a User Manual or a Technical Manual which are typical products of commercially developed systems. Home grown products are also protected and defended with zeal by their developers. It makes sense to subject the system to an external audit by an External Committee of Experts in a similar way to what was suggested above. The need for this validation and audit is doubly important when it is home grown.

Second, the deterministic nature of the model calls for more thorough adjustment and upgrades. It makes sense to move to a stochastic system or at least add a few stochastic modules. The system is flexible enough to accept new modules. This feature can be exploited here to add the stochastic framework.

Third, the same goes for some non-linear modules in the system. Since the underlying structure is nonlinear and new solvers (GAMS or AIMMS) can easily solve large nonlinear and stochastic systems, it is worth considering these upgrades. Successive optimization may reduce this need, but in our opinion this will be a poor substitute.

Fourth, the availability of PRISM and its subordinate @RISK at MH should facilitate using stochastic forecasts instead of the arbitrary optimistic and pessimistic variants.

Fifth, HERMES is one of many systems within the general class of LP system. It is for a short to a medium term horizon. It sits between MOST and SPLASH. We would like to urge the model builders and users to fine-tune their models' integration and collectively work on synchronizing their work and improving their communication with one another.

Sixth, KM note with satisfaction that HERMES incorporates temperature variables. This is a crucial advantage given the sensitivity of load to this variable and the extent to which it is expected to vary in the future.

There are economies of scale to the recommendations as they apply to all models. The priorities here are for integration with other models, validations through an expert group, and documentation. Again the rewards are large. They include using model resources within a community of modellers' structure, more confidence in the model and a more realistic framework.

**SPLASH**

SPLASH is a critical component of the model family at MH. It plays a crucial role in simulating future alternatives and is dependent upon to plan the system requirements for expansion in the future. Given this critical role any weakness or gap can have serious implications for decisions based upon it, or alternatively any improvement and upgrades can yield high returns.

A number of recommendations are noted below that need to be addressed before this system can deliver on its promises.

First, the system relies heavily on linear approximations to deal with a basically nonlinear underlying structure. There are grounds to ask whether a nonlinear specification might now be necessary to deal directly with this problem. Given the major advances in computer languages in the optimization field, this consideration is not far fetched.

Second, the model is fully deterministic, uncertainty is recognized but not dealt with directly. There are a number of areas where the simple introduction of some elements of PRISM can be relied upon to broaden the probabilistic base of the model. This will also increase and improve on the integration of the models at MH and add value to both models. We see a number of areas where SPLASH can use PRISM or simply @RISK

particularly to represent a probabilistic structure for export and import prices, water flows and reservoir elevation levels.

Third, SPLASH is an extension of HERMES and the two could sit on the same platform. At the moment they are not fully integrated. There is more room for linking more explicitly the two systems to benefit from their commonalities.

Fourth, SPLASH is an in-house developed system which can benefit from both internal and external audits.

Fifth, KM have seen some good documentation covering the components of the system but have seen nothing formal. Again, KM would like to suggest careful and formal documentation of the system in User and Technical manuals.

Sixth, although the staff supporting the system are qualified this group should be formalized and expanded to be an identifiable group that is continuously trained and integrated in the overall model community at MH.

Again the priority is to integration on a common platform for all models, the infusion of dynamics, nonlinearities and stochasticity. The costs would be reasonable when all the systems are aggregated together.

**PRISM**

The following recommendations and comments about PRISM were tendered:

First, more staff should be involved with PRISM by including a statistician to make informed selections and representations of the underlying probability distributions available in PRISM and @RISK.

Second, some of the concerns we have about PRISM are in fact associated with the adoption by PRISM of results and vectors from other systems. The concern is that problems or errors in one system may be propagated through the entire family of models.

Third, while @RISK is a standard industry tool for dealing with uncertainty, it is a coarse system that requires customization and sophisticated knowledge of statistics and other related skills to become more flexible and produce genuine and useful results. There are other systems in the field and there is no substitute for detailed and painstaking analyses of the individual risks and the use of standard Value at Risk calculations (VaR). The two systems when used judiciously can be complementary to one another.
Sixth, a few minor but important issues for improving PRISM would include freeing it from the seasonal and annual structure and allowing it to deal with intra-year issues. Also a richer and a better statistical anchor could be used to model water variability than the SPLASH characterization. More than a 5 year time horizon can be adopted to highlight results. Furthermore, as it stands now PRISM is only an energy model; it may be worth considering augmenting it so that it can become as well an energy capacity model. Price

volatility modeling can be enhanced. The simple inert acceptance of external forecasts may be supported by a firmer probabilistic approach. There is also a need to contrast and compare @RISK calculations with other quantitative risk calculations. Greater integration and harmonization of the PRISM model with other MH models should be initiated quickly. Documenting the system explicitly in User and Technical manuals on a regular basis is essential. Equally relevant is subjecting the system to external audit and verification. Finally, adding statisticians/econometricians to the model support team is a critical necessity.

Change is costly but these costs are worth it when PRISM is integrated into the workings of other models and where risk identification and quantification becomes a routine function at MH.

**Load Forecast Model (LFM)**

The following is a short list of our comments on and recommendations for improving the LFM system:

First, the forecasting accuracy of the load forecasts is deemed reasonable for the 5 year term and the move to integrate probabilistic forecasts is encouraging.

Second, the structure of some of the regression equations can be strengthened. The use of one dependent variable may not suffice for future forecasts. Since the main objective is to forecast future values with accuracy, some experimentation with other variables and specifications should be encouraged.

Third, the use of standard deviations of the explanatory variables is a good step but more sophisticated integration of probabilistic structures is advisable. Some of the advanced uses of econometric models for risk analysis combine the use of the standard errors of the coefficients with different probability distributions for the independent variables and then a final Monte Carlo simulation to define the probabilistic range of the key variables of the system. MH could easily develop a similar framework to the one suggested above given that all of the pieces are available in-house for such an analysis.

Fourth, it will make sense that those responsible for the load forecast become official members of the model community group at MH and that integration of their model with the rest of the models at MH be made seamless and interactive.

These recommendations will make LFM more relevant and can support a more nuanced overall MH operations.

**The Economic Outlook**

A number of recommendations are made with regard to the preparation and use of the Economic Outlook beginning with adding both human and financial resources to the EAD and ending with expanding the mandate of the Department and changing some of

its operating procedure. The centrality and pervasive uses of the EO necessitates elevating this function from a purely eclectic assembly of others' forecasts to a more nuanced and effective function.

First, the Department can benefit from the addition of economists and econometricians with quantitative skills and experience in forecasting to its staff.

Second, there is a serious need to revisit the forecasting role of the Department. At this time the eclectic selection of forecasts and forecasters is simplistic and driven by the commercial availability of the forecasts, while untested assumptions about their relevance and accuracy are accepted. Far more productive procedures would include in-house development of a forecasting model and/or cooperation with a Manitoba university department of economics for the development of selection criteria based on track record of forecasting accuracy.

Third, the forecasts adopted should abstract from the arbitrary specification of low (pessimistic) and high (optimistic) forecasts and move to generate probabilistic forecasts from standard risk tools available at MH.

Fourth, it is important that the EO group become part of the modeling family at MH and that their procedures be scrutinized and jointly developed with those who use their forecasts in their respective models.

Fifth, the terms of reference of this group should be expanded to involve serious contributions and evaluations of all economic matters at MH.

Manitoba Hydro supports and uses a number of models beside those discussed above, including PROMOD and others. The focus on the subset above is justified given its centrality and wide use. The improvement of these models and their upgrades and integration would require resources but any investment in them would bear fruit.

**MIPUG - KM 5** **Quantification of MH's Risks**

(a) Do Drs Kubursi and Magee intend the analysis discussed on pages 228-229 to be predictive in absolute terms of the dollar values of potential risks to Manitoba Hydro or is the analysis instead intended to indicate the relative risk exposure for different conditions (without attempting to specifically quantify the risk exposure) please discuss.

(b) Please provide more details on the analysis described on page 228. In particular please explain:

i. Which 15 variables were used to assess impacts on MH's net revenue.

ii. How were the estimated risk exposures and probability distributions for these variables developed? Please provide the estimated risk exposures and probability distributions used in the analysis.

iii. Please explain why the period 2001-2007 (a period including the 2003/04 drought) was selected as a base case? Is this period intended to reflect an "average" operating risk scenario for MH? Please discuss.

iv. With respect to Figure 6.2 on page 230, please explain how the curtailment of exports (reduced by 29%) was arrived at? Why did Drs Kubursi and Magee choose to reduce exports by this percentage for a curtailment scenario?

v. Please discuss how the figures on pages 247 through page 260 were derived and how they relate to this analysis.

Answers:

a) The quantification of risks is both illustrative and given the data in Table 6.1 is anchored on real data and can be used to parameterize and compare risk exposure.

b) i-The variables included in the calculation of net income include: Generation, firm and non firm exports to the US and to other provinces, domestic load, imports (firm and non firm) from other provinces and from the US, prices (domestic rates, firm exports (contract prices), opportunity prices), operating costs include:

Wages and salaries
Cost of fuel used
Cost of materials used
Cost of purchased services
Cost of repairs and maintenance
Royalty expenses
Indirect taxes
Electricity purchased
Other expenses
Depreciation

Interest on debt
Foreign exchange rate

ii- The exact density functions for the stochastic variables are given Chapter 6 in graphs 6.18 to 6.44. The choice of the distribution was made on the basis of their Chi-Square score, mean and variance concordance with the actual series.

iii- This data is produced by Statistics Canada and is part of the public record. The period includes both low flow and high flow years.

iv- This is the 2/7 (the weekend curtailment provision) in most of the term sheets. This is equal to 29%, but we used a lower number to reflect the actual share of the curtailment in total generation.

v- This is discussed in subsection ii above.

**MIPUG - KM 6** **Risk Mitigation Strategies for MH**

(a) With respect to the statement on page 245 that "Droughts will diminish earnings from net exports, and can end up in losses if import prices were to exceed export prices" in Drs Kubursi and Magee's view how likely is Hydro to find itself in such a situation?

(b) With respect to the statement that "MH should think of keeping a storage level each year as a hedge against a major drought" please describe and discuss:

i. Hydro's ability to effect this recommendation given environmental licensing constraints; and
ii. Potential costs associated with this recommendation.

(c) Please confirm that Drs Kubursi and Magee are recommending that MH target an equity level of "...at least a high percentage of the full cost of a seven year drought with high import prices, high interest rates, and an appreciated Canadian dollar." (as stated on pages 18 and 19). If this is confirmed please describe:

i. How likely is such a situation to arrive?
ii. Please quantify (both in dollar terms and a percentage of total capital structure) the level of equity required to achieve this target.
iii. Over what time period should MH target such a level of equity?
iv. How does this compare to the debt:equity targets of other regulated Canadian utilities?

(d) With respect to the recommendation on page 245 that MH should establish a specially created fund to be used in the event of a drastic drought, please discuss:

i. How should such a fund be administered? Under what circumstances should MH be able to draw down the fund? Would approvals from the PUB be required?
ii. Please explain why in Drs Kubursi and Magee's view the fund would require a special rider? Could the fund also be built up using an annual appropriation from general consumer rates approved by the PUB or when export revenues exceed a certain threshold? Please discuss.

Answers:

a) Droughts would eliminate first opportunity exports and any revenue from this source would dry up. It may necessitate imports to meet firm commitments domestically and outside. If these imports involve higher prices than fixed export prices, they will bring down net earnings. The probability of being in such a situation is not high but still positive. All of the probabilities of one year, five year and seven year droughts have been calculated and can be seen in KM answer to PUB-KM 44. Fortunately, the joint probabilities of a severe drought, high import prices and low export prices are quite low.

b) This has to be targeted within the parameters of licenses and regulations. Effectively MH is doing so now but may be willing to raise this amount as a hedge against droughts' impacts. This is not free unless water is destined to be spilled.

c) While operational norms would target average behaviour, risk mitigation would consider adequate reserves and assets for the worst possible case weighted by its probability. The fraction KM recommend is sensitive to the expected value of loss from a severe 7 year drought with adverse economic and price conditions. KM recommend that accumulated retained earnings should not be used in their entirety or alone for drought risk mitigation. ICR and Debt/Equity ratios should be targeted and the three aspects taken simultaneously into consideration. KM believe that the weights defined in the eclectic equation for risk mitigation should be determined by MH and PUB.

d) This fund would include elements from retained earnings, the additional rider on rates that is designated as an insurance premium and other assets (water in storage). The amounts and rules for drawing from it should be worked out by MH and its regulatory and supervisory institutions.