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Terry Sargeant
Chairman, Manitoba Clean Environment Commission,
305-155 Carlton Street
Winnipeg MB R3C 3H8

Dear Chairman Sargeant:

Thank-you for contacting me regarding your current review of the licensing of regulation of Lake Winnipeg under The Water Power Act. I am pleased to have entered into an agreement with the Commission to provide consulting services in support of this review. I request that you accept this letter as the report that is required by our agreement.

I note that our agreement specifies that I am to provide a plain language written report on isostatic rebound as it relates to Lake Winnipeg, including a brief plain language explanation of isostatic rebound, which I also call uplift - how it affects Lake Winnipeg, what projections are for the future, what interaction this has with Manitoba Hydro's operation of Lake Winnipeg Regulation, other relevant information, and a review of relevant sections of the Panel's report to ensure technical accuracy.

I also was asked to provide the attached CV, which I can summarize as follows. I was appointed Director of the Minnesota Geological Survey, State Geologist of Minnesota, and Professor in the Department of Earth Sciences at the University of Minnesota on July 1, 2003. In addition, I now fulfil roles such as member of the US National Geospatial Advisory Committee, and Associate Editor of the Journal of Great Lakes Research, while previously I have held positions such as President of the Association of American State Geologists, and President of the Geological Association of Canada. While with the Geological Survey of Canada as a Research Scientist from 1986 until 2003, I was involved in studies of the long-term evolution of Lake Winnipeg, along with work on several other soil- and water-related topics in regions ranging from Alberta to Hudson Bay. I hold a Ph.D. from University of Colorado, an M.Sc. from University of Manitoba, and a Bachelor's degree from University of Winnipeg.

With respect to your requirement for a plain language written report on isostatic rebound as it relates to Lake Winnipeg, I have no doubt that it will be adequate for me to repeat what I wrote in 1998. At that time, I was asked to provide information with a scope similar to your request after meetings related to Lake Winnipeg shoreline erosion. The text that I provided to multiple parties at the time follows:

– *beginning of quote from 1998 -* "The principal conclusion that I took from the meeting was that it will be very important for there to be much greater recognition of the distinction between the natural component of shoreline erosion, and the component that can be attributed to lake level regulation managed by Manitoba Hydro. To my knowledge, it has not yet been demonstrated whether the latter component is positive, negative, variable, or negligible.

I have heard verbal claims that shoreline erosion on Lake Winnipeg is entirely due to regulation. It is this sort of claim that results in a 'History vs. Hydro' debate, implying that the cause is one or the other. I have and will be very quick to side with the 'History' side of any debate structured in this manner, due to our familiarity with the long-term history of Lake Winnipeg basin expansion, and the several natural mechanisms, primarily uplift, that are driving this expansion. The most readily available formal measurement of the natural component of shoreline erosion, that I am aware of, is the Penner and Swedlo study completed in the 1970s, which was based on surveys extending back to the 1870s, vertical aerial photographs, and ground surveys. Their summary of pre-regulation natural shoreline retreat rates, typically 0.5 to 5 m/year in the south basin, was reprinted in 'The Lake Winnipeg Shoreline Handbook'.

I am not aware of a formal assessment of whether regulation has changed shoreline retreat rates, although I am aware that many people have opinions on the matter. I can think of two approaches that could be taken to this question. One would be to measure the rate of shoreline retreat since regulation, and compare this to the pre-regulation rates. This assessment would primarily rely on ground surveys and vertical aerial photographs, with shoreline referenced to cliffs and vegetation limits, rather than the water line that is vulnerable to large short-term fluctuations. Another approach would be for predictions of shoreline retreat rate to be made on the basis of pre- and post-regulation lake level regimes. This would best utilize a detailed model of Lake Winnipeg shoreline processes, which is not yet available. In the absence of a locally-based model, more generic models could be used. You may be interested to note, however, that, in the 1992 SEPM Special Publication No. 48, the leading shoreline erosion authorities Pilkey and Thieler state, "It is doubtful that any existing models can predict shoreline erosion rates with an accuracy useful to coastal communities." This

does not, however, mean that we should back off from doing the research that is required to work toward a useful model, especially one specific to Lake Winnipeg.

There also was discussion regarding current lake level and lake level management operating rules. What impact short term changes to lake level management would have on shoreline erosion rates in the short or long term is a topic we are not in a position to evaluate, although I would think that a deviation of mean lake level, averaged over a few years, from the long term mean, would to some degree influence shoreline retreat rate.

I also noted recognition that issues of lake level regulation are also relevant to topics such as wildlife habitat, although we have no role in the topic.

I was asked at the meeting whether one could predict what lake level would have been without regulation. In my opinion, this analysis could readily be done. For example, one could examine the relationship between lake level and mean monthly inflow from the four major rivers. Pending confirmation of a good correlation, one could use mean monthly river inflow data, with appropriate lags, to estimate what lake level would have been without regulation, whether higher or lower. It might be found, however, that climatic factors that do not manifest themselves in river flow data may be significant. This is not, however, an analysis that is within the mandate of our present work.

On more than one occasion, I have heard the argument that Lake Winnipeg lake level must be artificially high at present, because very old trees are being felled by shoreline erosion. The invalid assumption behind this argument is the notion that the natural state of Lake Winnipeg is stability. These observations can readily be explained by the fact that this lake has been gradually expanding for 8000 years, so you could have a 5000 year old tree that simply will be taken down when the lake finally arrives and that tree's time has come. There is no 'natural' level for Lake Winnipeg that has now been perturbed by human interference. The natural state of this lake is for it to constantly expand, at least for another few thousand more years.

We believe that lake level rise, largely driven by uplift, is the principal driver of shoreline erosion. At the meeting, I was, quite justifiably, challenged to explain how a subtle lake level rise, which we estimate to be 20 cm/century (2 inches in 25 years), in the south basin, could possibly cause the devastation that property owners have witnessed. I agree that this is difficult to fathom, but in this area of low land gradients, a slight vertical displacement leads to a large lateral displacement when the shore profile adjustment is complete.

In order to understand this and every other process at work on Lake Winnipeg, it is essential to have some insight into how the lake works. I believe that this topic can be understood by anyone, not just a geologist, so I will now endeavour to lay out our reasoning.

Lake Winnipeg lies at the interface between granites and related rocks to the east, and sedimentary rocks such as limestones to the west. The granites formed 2 to 3 billion years ago. The limestones formed about a half billion years ago, when central North America was covered by a shallow tropical sea in which debris such as shells and corals accumulated, including the fossils we see in Tyndall Stone. The processes that formed these rocks no longer play a role in the evolution of Lake Winnipeg.

The Ice Age, also known as the Pleistocene, is geologically very recent. During the peak of the most recent glacial cycle, between 10,000 and 20,000 years ago, Canada was covered by a glacier similar to the continental ice sheets that presently cover Greenland and Antarctica. Ice flow radiated from the Hudson Bay region, and this ice flow scoured out the Lake Winnipeg basin as we know it.

As the continental ice sheet was reduced in size by climatic change at the end of the Ice Age, the land that slopes toward Hudson Bay in the Red River Valley filled with water due to the presence of the ice barrier to the north. This formed Lake Agassiz, which was in existence in an ever-evolving form between about 11,000 and 8000 years ago. It was in Lake Agassiz that the clay soils of the Winnipeg region were deposited. When the glacier finally was split into two remnants that both soon melted, by the formation of icebergs in Hudson Bay, Lake Agassiz drained.

The continental ice sheet was about 4 km thick over Hudson Bay. The surface of the earth basically floats on the interior of the earth, so accumulation of this ice mass depressed the surface of the earth by about a km. As the glacier began to wane due to a shift from a positive to a negative balance between snow accumulation and loss due to melting and formation of icebergs, its mass was reduced and eventually removed. Removal of this much weight is like taking a load out of a boat, and the surface of the earth rose. Much of the uplift took place under the glacier, or soon after its withdrawal.

Several observations indicate that the 8000-year period since deglaciation has not been enough time for the earth to adjust to removal of the glacier. Around Hudson Bay, there are many marine shorelines that have been left behind by retreat of the bay due to uplift. The age of these shorelines can be determined by radiocarbon dating of shells found in the gravels of these fossil beaches, and in other deposits. The highest shoreline

around Hudson Bay dates to about 8000 years, but those closer to the bay date to about 1000 years and younger. This indicates that retreat of the bay has continued in recent centuries. The fact that the uplift continues today is indicated by observations such as results from the Churchill tide gauge, where high-quality data collected since 1940 indicates that sea level at that site is retreating at a rate of about 0.7 m/century. Allowing for global sea level rise of about 20 cm/century in recent decades, this allows the uplift rate to be rounded off to about a m per century. The pattern of subtle trends in the strength of gravity across Canada supports these conclusions and indicates, along with information from the Great Lakes, that the general trend in uplift is for rates to diminish inland from Hudson Bay in all directions.

Because the rate of uplift diminishes inland from Hudson Bay, a tilting action results. We know that the Lake Winnipeg region was tilted after the retreat of Lake Agassiz, because the shorelines of Lake Agassiz, which would have been horizontal at the time of their formation, now rise in elevation toward the northeast. Hence for at least much of its history, the Lake Winnipeg basin has been rising, and the north end has been rising more rapidly than the south end.

A clear discussion of the influence of tilting on a large lake requires a review of the natural mechanisms that control lake level. An open container of water such as a lake undergoes fluctuations in its level as water is gained and lost. The volume of a lake does not determine lake level; volume is a result of lake level. Input of water to a lake occurs in the form of river inflow, direct precipitation, and groundwater discharge from underwater springs. Losses include river outflow, evaporation, and groundwater recharge as seepage into the lake bottom. If inflow is greater than losses due to evaporation and groundwater recharge, the lake has a water surplus, and excess water is evacuated by outflow at the outlet(s). If evaporation and groundwater recharge together exceed inflow, the lake has a water deficit, and no outflow will occur.

Hence the water budget of a lake is dictated chiefly by climate, with secondary effects related to groundwater. In the case of a lake with no outflow, a closed basin with a negative water budget, lake level is purely a result of climate. Examples of closed lakes are Great Salt Lake in Utah and Devil's Lake in North Dakota. At present, however, Lake Winnipeg has a large water surplus. Water primarily derived from the Winnipeg and Saskatchewan Rivers is evacuated by the Nelson River at a rate of about 60 cubic km per year, a large flux compared to the small volume stored in the lake, about 300 cubic km. Lake Winnipeg therefore is governed by processes related to a positive water budget. Secondary, short-term effects on lake level are caused by wind setup, and to a lesser extent, barometric pressure.

In the case of an outflowing lake with a positive water budget, lake level is controlled by the combination of climate and outlet geometry. Climate over the drainage basin determines how much excess water there is to be evacuated. Lake level has to reach at least the elevation of the lowest point on the topographic barrier around the lake, hence the bed of the outlet stream. Above this level, an additional depth is required for outflow to be adequate to evacuate the surplus water. A narrow outlet channel requires more depth than a broad outflow to achieve a given flow rate. This is called the stage (water level) vs. discharge (volumetric rate of flow) relationship for the outlet.

Lake Winnipeg has, at least in recent millenia, been an outflowing lake. The mean lake level therefore is constant at the outlet relative to mean climate of the time, given that a certain depth is required to evacuate excess water. Tilting of a lake basin causes mean lake level to pivot at the outlet. Because the outlet of Lake Winnipeg is in the north, uplift of the north end of the lake progressing at a rate more rapid than the basin to the south has meant lake level rise over the entire basin, with the rate increasing southward.

Not all lakes rise and expand due to tilting, however. Lake Nipigon has its outlet in the south, so it is contracting. Lake Superior has its outlet in the middle relative to the pattern of uplift, so it is rising in the south and falling in the north.

We have collected cores from the bottom sediments of Lake Winnipeg that allow us to sample the entire sequence of sediments deposited since Lake Agassiz, including the first layer of Lake Winnipeg sediments that buried the older Lake Agassiz deposits. We have obtained radiocarbon ages from this procedure that indicate that much of the South Basin of Lake Winnipeg was dry land 4000 years ago, while Netley Marsh was dry land about 1500 years ago. We also have radiocarbon dates from rooted tree stumps just below lake level that suggest gradual rise in lake level over recent centuries. These observations indicate that gradual expansion of Lake Winnipeg in response to tilting has been continuous throughout post-Lake Agassiz time.

While we place our emphasis on uplift, which has been the dominant influence, at least in the south, four other process should be mentioned as secondary factors affecting Lake Winnipeg lake level over the long term: climate, river diversions, basin merging, and outlet downcutting.

Our radiocarbon dating of basal Lake Winnipeg sediments in cores indicates that, unlike the gradual inundation of the rest of the lake, the inundation of the central South Basin was not gradual. It seems to have occurred rapidly, as basal ages across this area cluster around 4000 years. This is the time when climate changed rather abruptly from

warmer and drier to cooler and moister, probably raising lake level a few metres. This is the reverse of the trend that we may presently be experiencing due to the emission of greenhouse gases. In fact, the worst case scenario for climate change now and in future decades would be a return to the climate of 5000 years ago, when the prairie region was much drier. Climate of the Lake Winnipeg region has been relatively stable in the past 4000 years, however, so the impact of this climate change would have been applied rapidly, with control of lake level evolution to the present day returning to uplift dominance.

Another factor in Lake Winnipeg lake level history was diversion of the Saskatchewan River, which formerly bypassed Lake Winnipeg in the channel now occupied by the Minago River. Between 4000 and 5000 years ago, uplift caused diversion of the Saskatchewan River to Lake Winnipeg. This would have raised lake level on a one-time basis by about a half metre.

At present, Playgreen Lake and Lake Winnipeg are almost functioning as one lake. Strong northward currents typically flow through Warren Landing, in what could almost be considered a Narrows rather than a river, feeding the Nelson River to the north. When strong north winds blow, however, flow at Warren Landing can be to the south. But for a few millenia after Lake Agassiz, however, what is now Lake Winnipeg was three or more lakes, a South Basin lake draining through a river in the Narrows to a North Basin Lake, which in turn drained to a completely separate Playgreen Lake. All of these lakes expanded in response to tilting, and eventually the North Basin and South Basin lakes merged. Relocation of the outlet for the South Basin Lake to a point farther north, where uplift is more rapid, would have accelerated lake level rise in the south. More recently, perhaps about 2000 years ago, Playgreen Lake merged with Lake Winnipeg, again increasing the rate of lake level rise and lake expansion in the South Basin, once again renewing the otherwise gradually diminishing rate of rise.

Outlet down-cutting is a factor that seems not to be a significant control on Lake Winnipeg. Whereas this was the dominant factor in controlling the early history of Lake Superior, the outlet of Lake Winnipeg at Warren Landing is shallow and broad, and would have been rapidly eroded to resistant bedrock. Therefore while this could have been a compensating factor offsetting the rise due to uplift, it seems not to have played a role.

Maps showing the pattern of present uplift on the world and continental scales may be seen on p. 117 of the March 1997 issue of Scientific American, and on the cover of the 4 December 1997 issue of Nature. General models such as these, based to varying degrees on continent-wide syntheses of radiocarbon-dated marine shorelines, tide gauge trends,

lake gauge trends, and gravity, give a rough estimate for uplift rates of 0.4 m/century at the north end, and 0.2 m/century at the south end of Lake Winnipeg. The difference between these two values implies a 20 cm/century rise in lake level at the south end of Lake Winnipeg.

This prediction can be tested by comparison to available data from Lake Winnipeg. Offshore from Gimli, at our site 122, the pre-Lake Winnipeg surface lies under 10 m of water and 4 m of sediment. We have dated the initiation of Lake Winnipeg sedimentation at this site at about 4000 years. A rise of the lake to its present level over the past 4000 years implies a rate averaging 35 cm/century (1400 cm/40 centuries). This would be an average of higher rates earlier in the period in question, and lower rates at present, perhaps comparable to the current estimate of 20 cm/century. According to Penner and Swedlo, a 40-cm-thick peat bed found 3 m below lake level near Elk Island was dated at 1060 years for the upper part of the bed and 1660 years for the lower part. Interpolating between the upper date and present lake level gives an estimate of 28 cm/century (300 cm/10.6 centuries) for lake level rise over the past millennium. Work by Dr. Erik Nielsen, of the Manitoba Geological Services Branch, on the radiocarbon age of drowned stumps in the Lake Winnipeg shoreface also indicates a submergence rate of about 20 cm/century over the past 300 years. Hence available data are strongly supportive of the lake level rise predicted by uplift models.

Even without this sort of data, the experienced eye can quickly see that water levels are rising on Lake Winnipeg. For example, geologists now agree that barrier islands are a sign of water level rise. The sandy beach that separates the south end of the lake from Netley Marsh is a barrier island. Other good examples can be seen on Lake Manitoba, the east coast of the US, Duluth, Hamilton, and northwestern Europe. The geological model for how barrier islands work is for there to be erosion on the basin side, and accretion on the lagoon side. In other words, the natural behaviour for a barrier island is for it to migrate landward like a conveyor belt. One can also recognize water level rise on Lake Winnipeg in the form of drowned valleys, also known as estuaries, such as lower Netley Creek and lower Icelandic River.

Even if Hudson Bay is still being uplifted and the Great Lakes are still being tilted, and even if there is evidence for Lake Winnipeg having expanded in recent millennia, centuries, and decades, this does not prove that Lake Winnipeg is presently still being tilted. Complexities in the uplift pattern could have formed in recent time. Lake gauge data, however, have provided indications of present-day uplift. This takes the form of a gradual increase in the difference between southern gauges and northern gauges over several decades. We also are investigating this topic with new approaches. In cooperation with NASA, we have installed two new Global Positioning System satellite

receiving stations at Pinawa and Flin Flon, that will, in combination with existing stations in Iowa and Churchill, give us measurements of uplift rates. In cooperation with the US government, we also are doing very sensitive measurements of gravity along a transect of sites from Iowa to Churchill that will give us an independent check on uplift or subsidence rates.

The 1974 Penner and Swedlo report supplemented existing knowledge of shoreline erosion rates with information from surveys done at intervals of one to a few decades from the 1870s to the late 1960s. It was found that the shoreline of the South Basin retreated over this period at rates typically of 0.5 to 5 m per year. An average rate of, for example, 1 m per year could, of course, represent 10 m in one year and no recession for 9 years. Can this steady rate of shoreline erosion be explained by a 20 cm/century rise in lake level? Let's relate the 20 cm/century rise to regional topographic gradients. At Gimli, the land rises about 25 m within 10 km inland, a gradient of 2.5 m/km. In this case, a 20 cm/century lake level rise would translate to a lateral shift of 0.8 m/year, similar to actual shoreline erosion rates reported by Penner and Swedlo. From the centre of the south basin to Netley Creek, the surface under Lake Winnipeg sediments rises to the present land surface at a rate of about 0.3 m/km. A 20 cm/century lake level rise in this case translates to a lateral migration of about 6.7 m/year. This estimate is compatible with our data offshore from Gimli that shows that the south end of the lake has migrated 30 km to its present position in 4000 years, implying an average rate of shoreline retreat of about 7.5 m per year. This agreement is surprisingly good, considering that we have not yet built a more detailed model that takes into account the role of climate in expansion of the lake. Penner and Swedlo reported similar retreat rates over much of the southern shore.

Large increments of basin expansion being driven by a few inches of lake level rise may seem counter-intuitive. A one-metre rise in lake level happens frequently due to wind setup, and the water line only moves a few metres. But according to the above reasoning, a one-metre permanent rise in lake level will drive the shoreline inland 400 metres to the west, and over 3 km to the south. How can this apparent contradiction be reconciled? The key point is that shoreline processes have cut a notch at the water line that has a much higher gradient than the surrounding landscape. Penner and Swedlo indicate that the gradient between the high water and low water line on Lake Winnipeg typically is about 10%, or 100 m/km. It is this slope that takes up the short term fluctuations. The steeper nearshore gradient can also be seen on the hydrographic chart for the south basin. Around Gimli, the offshore gradient is about 3.4 m/km between the shore and ten feet depth, while farther offshore, the gradient is less than 1 m/km. Along the south shore, the gradient to ten feet depth averages 1.2 m/km, while farther offshore it is about 0.25 m/km. Hence short term fluctuations are taken up by the high gradient

slope at the water line, but a permanent rise exposes that slope to a sustained increase in wave power. In the case of a one-step lake level rise, the shoreline would retreat and the shore profile would flatten until wave power delivered to the shore diminishes to a level that allows a stable coastal position. In the case of a steady, ongoing rise, a steady retreat of the shore results. Even if a steady rise were to stop, retreat would continue until equilibrium is reached.

It is useful to compare shoreline erosion on Lake Winnipeg with global trends at sea level, which are probably best documented in the US. In SEPM Special Publication No. 48, Pilkey and Thieler present a summary of erosion rates on the US coast. Values of 0.5 to 4 m/year are typical of the Atlantic and Gulf coasts. There now is consensus that this erosion is driven by the present global (eustatic) sea level rise of about 20 cm/century, which happens to be similar to the rate of lake level rise that we estimate for the south end of Lake Winnipeg.

Shoreline protection engineering is an extremely controversial topic, and it is not within our mandate to make recommendations or to conduct research into design. I can, however, offer a few thoughts. Engineers tend to recommend engineering, whereas geologists tend to recommend that you back off and respect the forces of nature. There is no doubt, however, that a Professional Engineer can design a means to temporarily protect a high value installation that was, through error or necessity, built too close to a retreating shore.

Geologists, on the other hand, are quick to point out the inadequacies of shoreline engineering. While erosion may be halted at the water line, it is essential to recognize that erosion continues underwater to a depth of several metres. Consequently, the shore armour is exposed to progressively greater wave power. Furthermore, sand must be mobile for shoreline systems to be in a state of dynamic equilibrium. According to a standard geomorphology textbook by Bloom, "Extensive reclamation and beach stabilization projects actually endanger barriers, because unless sand is free to move with changing wave conditions, erosion results." In SEPM Special Publication No. 48, Pilkey and Thieler state, "The myriad sea walls, breakwaters, groins, and jetties that line developed shorelines divert offshore, slow down, trap, and otherwise reduce the regional beach sediment supply by longshore currents, and thereby increase erosion rates." This view is summed up on the cover of one edition of the book "The Beaches are Moving", by Kaufman and Pilkey, as follows, "these facts provide a new ability to make informed, intelligent decisions for the coast. This is the first book to explain why the shore must move, and how utterly foolhardy we are to armor our coast against the unbeatable force of nature."

Engineers do, however, recognize the limitations of their solutions. For example, "The Lake Winnipeg Shoreline Handbook", states, "In most cases a careful review of long term erosion rates, the effects of protective structures on beaches, and the cost of protective structures in relation to the cost of land will indicate that the best course of action is to allow natural erosion to continue." – *end of quote from 1998 -*

In relation to more recent research, I can note the following as examples.

Lambert, A., T. S. James, and L. H. Thorleifson. 1998. Combining geomorphological and geodetic data to determine postglacial tilting in Manitoba; Journal of Paleolimnology, v. 19, p. 365-376

Lambert et al. (1998) combined geomorphological data with GPS, absolute gravity, and lake gauge data to better constrain estimates of postglacial rebound in central North America.

Nielsen, E., 1998. Lake Winnipeg coastal submergence over the last three centuries. Journal of Paleolimnology, 19: 335-342.

Nielsen (1998) utilized radiocarbon dating of peat and drowned trees along the barrier beaches at the south end of Lake Winnipeg to indicate that water levels in that area have been rising at a rate of about 20 cm/century over the last three hundred years.

Tackman, G.E., D.R. Currey, B.G. Bills, T.S. James, 1998, Paleoshoreline evidence for postglacial tilting in Southern Manitoba, Journal of Paleolimnology, 19, 343-363.

Tackman et al. (1998) utilized air photo interpretation and field surveys in southern Manitoba to infer that the once level paleoshorelines of Lake Winnipegosis and Dauphin Lake and Lake Agassiz have been tilted up by postglacial rebound.

Lewis, C. F. M., Forbes, D. L., Todd, B. J., Nielsen, E., Thorleifson, L.H ., Henderson, P. J., McMartin, I., Anderson, T. W., Betcher, R. N., Buhay, W. M., Burbidge, S. M., Schröder-Adams, C. J., King, J. W., Moran, K., Gibson, C., Jarrett, C.A., Kling, H. J., Lockhart, W. L., Last, W. M., Matile, G. L. D., Risberg, J., Rodrigues, C. G. Telka, A.M., and Vance, R. 2001. Uplift-driven expansion delayed by middle Holocene desiccation in Lake Winnipeg, Manitoba, Canada. Geology, v. 29, no. 8, p. 743-746.

Lewis et al. (2001) outlined the uplift-driven expansion Lake Winnipeg, while drawing attention to the possibility that climate may have imposed fluctuations on the largely uplift-driven trend.

Lambert, A., N. Courtier, G. Sasagawa, F. Klopping, D. Winester, T. S. James and J. O. Liard, 2001, New constraints on Laurentide postglacial rebound from absolute gravity measurements, , Geophysical Research Letters, v. 28, p. 2109–2112.

Lambert et al. (2001) summarized absolute gravity measurements at six sites along a 3000 km-long, mid-continental, North American profile from the coast of Hudson Bay southward to Iowa.

Lambert, A., James, T. S., Courtier, N., Simon, K., Schmidt, M., Lewis, C. F. M., Mainville, A., 2005, An improved postglacial rebound model with applications to the Nelson River drainage basin; Geological Survey of Canada, Open File 4927, 24 p.

Lambert et al. (2005) produced a new map of vertical crustal movement rate for Manitoba by assimilating available geodetic and geomorphological data to a model of the Earth's response to the surface unloading associated with the melting of the Laurentide ice sheet.

Brooks, G., C. F. M. Lewis, and L. H. Thorleifson. 2005. Influence of loss of gradient from postglacial uplift on Red River flood hazard; The Holocene, v. 15, no. 3, pp. 347-352

Brooks et al. (2005) outlined how the isostatic rebound that is causing expansion of Lake Winnipeg also occurs farther south, thus affecting the Red River, which has lost 60% of its gradient in post-Lake Agassiz time.

van der Wal, W., A. Braun, P. Wu, and M. G. Sideris, 2009, Prediction of decadal slope changes in Canada by glacial isostatic adjustment modelling; Canadian Journal of Earth Sciences, v. 46, p. 587-595.

Van der Wal et al. (2009) described glacial isostatic adjustment as the dominant process causing vertical motion of the land surface in Canada, and went on to outline examples of impacts of isostatic rebound, such as on the Nelson River and Lake Winnipeg.

Lambert, A., Henton, J., Mazzotti, S., Huang, J., James, T. S., Courtier, N., van der Kamp, G. 2013, Postglacial rebound and total water storage variations in the Nelson River drainage basin: a gravity-GPS study; Geological Survey of Canada, Open File 7317, 33 p.

Lambert et al. (2013) combined GPS, absolute gravity and GRACE satellite data to produce an updated map of postglacial rebound.

Your request also indicated a need for an indication of projections for the future. In reply, I can indicate that uplift can be expected to continue at a gradually diminishing rate, as it has done throughout the ten thousand years or so of postglacial time.

In addition, you indicated a need for my perspective on the interaction uplift has with Manitoba Hydro's operation of Lake Winnipeg Regulation. My impression is that there will be no direct link between uplift and operation of regulation in foreseeable time.

You also asked me to provide any other relevant information. I can think of nothing to add.

I also was asked to review relevant sections of the Panel's report draft to ensure technical accuracy. As examples of references to the influence of uplift due to isostatic rebound on Lake Winnipeg shoreline erosion, I note the following:

- On page 70 of the report, for example, a quotation from the Lake Winnipeg Shoreline Erosion Advisory Group (LWSEAG) report is presented as follows – 'The principal finding is that in most instances, erosion, flooding and dynamic beach changes at the shoreline are the result of naturally occurring processes. Man-made alterations to the natural lake systems may affect the extent of the erosion, flooding and dynamic beach changes, but typically to a much lesser degree than the natural processes.'
- On page 71 of the report, it is stated that 'The LWSEAG also reported, based on information from the Geological Survey of Canada, that southward movement of the Lake Winnipeg ridge around the south end of Lake Winnipeg is due to glacial rebound. This is a phenomenon where the Earth's surface in a defined area lifts slowly as it recovers from the weight of the glacial sheets of ice that once rested upon it. The rebound was found to be greater at the north end of the lake, resulting in a tilting action that has shifted the position of the southern ridge by more than 16 miles over the past 4,000 years.' (*I have omitted an error in converting to km from the quote. The 16 mile number perhaps comes from my writing, although the number I indicated, as quoted earlier in this letter, was 30 km, so more than 16 actually should read more than 18 miles if the intention is to cite what I said, although I don't regard this as significant*).

  'Based on the conclusions of shoreline erosion experts, Lake Winnipeg shoreline erosion is driven by natural processes. As discussed in the previous section, Manitoba Hydro studies show that regulation has reduced water levels from where they would have been without LWR. Based on this information, it is Manitoba Hydro's understanding LWR has not increased Lake Winnipeg shoreline erosion rates.'

- On page 74 of the report, the following text is presented: "Glacial Rebound - Among the oldest of factors influencing Lake Winnipeg is post-glacial isostatic rebound. On a time-scale of centuries, its effect on Lake Winnipeg is an upward tilting of the lake bottom at its north end with a corresponding increase in water depth at the lake's south end. With the relatively wide, naturally-occurring gaps in the beach ridge between Lake Winnipeg and Netley-Libau Marsh, post-glacial rebound is a potential contributor to increased levels of inundation in the marsh."
- References also are made to isostatic rebound in the appendices.

I am comfortable with the above cited statements.

I hope that this letter is adequate to fulfil your current requirement. Please let me know if I can be of further assistance.

Sincerely,

Harvey Thorleifson Ph.D., P.Geo., D.Sc.
State Geologist of Minnesota
Director, Minnesota Geological Survey
Professor, University of Minnesota

Attachment: Curriculum vitae

Leonard Harvey Thorleifson Ph.D., P.Geo., D.Sc.; January 2015

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- http://www.geo.umn.edu/people/profs/THORLEIFSON.html
- Date and place of birth: 6 April 1957; Baldur, Manitoba, Canada
- Citizenship & immigration status: Canadian citizen, US Permanent Resident

Education

- Doctor of Philosophy, Geology, University of Colorado, 1989
- Master of Science, Geology, University of Manitoba, 1983
- Bachelor of Arts, Honours, Geography & Biology, University of Winnipeg, 1980
- Bachelor of Science, Geography, University of Winnipeg, 1978

Professional registration

- Professional Geoscientist, Association of Professional Geoscientists of Ontario

Employment

- Director, Minnesota Geological Survey, 2003-present
- Professor, Department of Earth Sciences, University of Minnesota, 2003-present
- Research Scientist, Geological Survey of Canada, 1986 – 2003, including work on:
  - Geological mapping; 3D GIS; drillhole databases
  - Quaternary stratigraphy, sedimentology, & paleoenvironmental analysis
  - Indicator mineral methods in mineral exploration; diamonds, gold
  - Offshore surveys, shoreline erosion, soil chemistry, climate change
  - Long term history and controls on Red River flooding
  - Regional groundwater investigations

Professional Service

- Chair, Society for Mining, Metallurgy, & Exploration, Minnesota Section, 2013-2014
- Past President, Association of American State Geologists, 2013-2014
- President, Association of American State Geologists, 2012-2013
- President Elect, Association of American State Geologists, 2011-2012
- Vice President, Association of American State Geologists, 2010-2011
- Chair, Organizing Committee, Geological Society of America 2011 Annual Meeting
- Management Committee, OneGeology.org, 2006-2008
- Trustee, Geological Society of America Foundation Inc., 2007-2012
- Chair, Minnesota Center for Mineral Resource Education, 2009-2012
- Chair, Society for Mining, Metallurgy, & Exploration, Twin Cities Subsection, 2008-2011
- Associate Editor, *Journal of Great Lakes Research*; 2003-present

- Member of the Board, Geological Society of Minnesota, 2008-2012
- Treasurer, Association of American State Geologists, 2008-2010
- Committee Chair, Association of American State Geologists, 2006-2010
- Program Coordinator, AASG Centennial Conference co-hosted with USGS, 2008
- Statistician, Association of American State Geologists, 2006-2009
- President, Canadian Federation of Earth Sciences; 2004-2006
- Program Chair, Geological Society of America North Central Annual Meeting, 2005
- President, Geological Association of Canada, 2003-2004
- Chair, Canadian Institute of Mining & Metallurgy, Ottawa Branch, 2002-2003
- Councillor, Geological Association of Canada, 1999-2005

Professional Honors

- Association of American State Geologists Presidential Award, 2009, for extraordinary service to the Association; one of two awards presented in 2009
- Honorary Doctor of Science, University of Winnipeg, 2007
- Co-recipient, The Carol Shields Winnipeg Book Award, 2003, Crossroads of the Continent: A History of The Forks of the Red and Assiniboine Rivers, Heartland Associates Inc., Edited by Barbara Huck
- Distinguished Lecturer, Canadian Institute of Mining, Metallurgy and Petroleum, 1998-1999
  Natural Resources Canada Merit Awards; 1996, 1997, 1998, 1999

Congressional Testimony

- Testimony on "Effect of the President's FY 2013 Budget for the U.S. Geological Survey on Private Sector Job Creation, Hazard Protection, Mineral Resources and Deficit Reduction" Subcommittee on Energy and Mineral Resources, Natural Resources Committee, United States House of Representatives, March 22, 2012

Panels

- Member, National Geospatial Advisory Committee, 2014-present
- Member, National Academies, National Research Council, Board on Earth Sciences and Resources, Committee on International Science at the U.S. Geological Survey, 2011-2012
- Member, Midwestern Governors Association Renewable Electricity, Advanced Coal and Carbon Capture Advisory Group, 2008-2009
- Faculty search committee, U of Minnesota Department of Soil, Water, and Climate, 2009
- USGS-AASG Statemap Review Panel – 2006, 2007, 2008
- Provost's Advisory Committee, University of Minnesota Institute on the Environment, 2006
- Member, Head of Earth Science Search Committee, November 2005 – March 2006
- Ex officio member, Minister's National Advisory Board on Earth Sciences, Natural Resources Canada, 2004-2006
- Ex officio member, Geological Survey of Canada Advisory Committee, 2004-2006
- Member, Review Panel, USGS Mineral Resources Grants Program, June 2005
- Member of USGS Eastern Mineral Resources Team 2004 Strategic Review 5-person panel; one-day review, Reston; lead writer of review & recommendations

- Expert Technical Advisory Committee, Ontario Mineral Exploration Technologies Program; 2001-2004
- National Round Table on the Environment and the Economy, Environment and Sustainable Development Indicators Initiative, Land and Soils Cluster Group; 2001
- White House Diamond Conference: Technologies for Identification and Certification; Washington, DC; January 10, 2001 – suppression of the trade in conflict diamonds
- Departmental environmental review panel; Atomic Energy of Canada nuclear fuel waste disposal concept; 1993-1995

Workshop and Short Course Leader/Presenter

- Short Course Leader; 3D Geological Mapping; Denver, October 26, 2013
- Short Course Leader; 3D Geological Mapping; Minneapolis, October 8, 2011
- Short Course Leader; 3D Geological Mapping; Portland, October 17, 2009
- Short course co-leader & lead-off presenter; Indicator Mineral Exploration Technology; May 31st, 2009; 24th International Applied Geochemistry Symposium, Fredericton, Canada
- Application of Heavy Mineral Methods in Stream Sediment and Till to Exploration; Alaska Miner's Association 2007 Annual Convention and Trade Show; Short Course, November 5 – 6, 2007, Anchorage, sole presenter
- Workshop co-chair; 3D Geological Mapping for Groundwater Applications; Denver, Colorado, October 27, 2007
- Short course co-leader & lead-off presenter; Indicator mineral methods in mineral exploration; September, 2007; Exploration 2007, Toronto
- Organizer & keynote speaker, OneGeology Workshop, Brighton, U.K., March 2007
- Workshop co-chair; 3D Geological Mapping for Groundwater Applications; Salt Lake City, Utah, October 15, 2005
- Organizer; Minnesota Minerals Coordinating Committee, Minerals Opportunities Meeting on Minnesota Diamond Potential, February 16, 2005
- Workshop co-chair; 3D Geological Mapping for Groundwater Applications; St. Catharine's, Ontario, May 15, 2004
- Short course co-leader & lead-off presenter; Indicator mineral methods in mineral exploration; March 8, 2003; Prospectors and Developers Association of Canada, Toronto
- Chair; National Surficial Geological Mapping Workshop, Ottawa, 12/13 December 2002
- Workshop co-chair & speaker; 3D Geological Mapping for Groundwater Applications; Denver, Colorado, October 26, 2002
- Workshop co-chair; Federal Water Research Network workshop on coordination of federal water resource research; March 7, 2002, Ottawa
- Short course co-leader; Kimberlite indicator mineral tracing in Canada; principles and methods; Queen's University; May 1999; 2000, 2001, 2002, 2003
- Short course presenter: Kimberlite indicator minerals in glacial sediments. Association of Exploration Geochemists, International Geochemical Symposium, Vancouver, April 10 1999
- Short course presenter: Kimberlite indicator minerals in glacial sediments. Diamond exploration short course, Edmonton, 1992
- Short course presenter: Kimberlite indicator minerals in glacial sediments. Diamond exploration short course, Sudbury, 1992

Coordination

- Organizer & co-chair, Geoscience Summit, Ottawa, October 2004
- Facilitator; Federal/Provincial Consultation on Surficial Geological Mapping, Ottawa, 2002
- Coordinator; science/policy liaison, Natural Resources Canada water-related research – 2001 - 2003, responsible for linking Departmental science and policy initiatives related to water quality, aquatic ecosystems, water resources, and water-related hazards
- Co-coordinator; measurement and modelling of glacial isostatic adjustment initiative - since 1999, facilitator of a working group dealing with the use of absolute gravity and uplift measurements in applications such as geodetic reference systems and lake level change, including a conference session, workshop, and successful proposal development
- Coordinator: Prairie groundwater/climate change project- 1999-2003; coordination of a multi-agency working group of federal staff, provincial staff in three provinces, and university-based researchers, including a workshop and successful proposal development
- Coordinator: Hydrogeology of the Winnipeg/Lake Winnipeg region project – 1996-2003; coordination of a regional multi-agency groundwater project in south-eastern Manitoba
- Co-coordinator; Lake Winnipeg Project –1993-2003; co-coordinator of a multi-agency project on the Lake Winnipeg basin, including arrangement for financial support from Manitoba Hydro in relation to controversy over shoreline erosion
- Co-coordinator; Prairie soil and till sampling program – co-coordinator of a 1992 multi-agency collection of till and soil for indicator mineral and soil chemistry analysis from over 2000 sites across the prairie region
- Co-coordinator; Geology of the Winnipeg region National Geoscience Mapping Program (NATMAP) project; 1991-2003, co-coordinator of a series of projects on the geology of south-eastern Manitoba

Investment Seminar Speaker

– Government of Canada/Financial Industry seminars promote investment in Canadian mining

- Tokyo, Seoul, 2001; Perth, Melbourne, Sydney, 1997; Hong Kong, 1997

Postdoctoral Fellow Supervision

- 2004-2005; Zbigniew S. Malolepszy; 3D mapping

Teaching

- University of Minnesota, Autumn 2014, Autumn 2013, Autumn 2012, Autumn 2011, Autumn 2010, Autumn 2009, Autumn 2008, Autumn 2007, Autumn 2006, Autumn 2005, Autumn 2004, Winter 2004, Freshman Seminar, presented with Survey staff; University of Colorado, 1983-1986, TA/Laboratory Instructor – Introductory Geology, Sedimentology; University of Winnipeg, 1982, Sessional lecturer - Introductory Geology; University of Manitoba, 1981-1983, TA/Laboratory Instructor – Paleontology, Geomorphology; Swimming instructor, 1974-1976

Advocacy

- Association of American State Geologists liaison committee, Washington DC; March and September 2003-present
- Geological Association of Canada representative to the Partnership Group for Science and Engineering (PAGSE) – which speaks on behalf of Canadian science and engineering to the Government of Canada; 1999-2003
- Member, PAGSE Communications Committee – which organizes monthly Parliament Hill 'Bacon and Eggheads' breakfasts at which scientists speak to Members of Parliament and science policy leaders; 1999-2003

Fieldwork

- 2009: soil sampling, west-central Minnesota
- 2008: soil sampling, south-central Minnesota
- 2004: till sampling, soil sampling, north-central Minnesota
- 1997: till sampling by float plane; north-eastern Manitoba
- 1994 & 1996: offshore surveys; Lake Winnipeg
- 1992: drilling; kimberlite property, Saskatchewan
- 1991-1992: till sampling, soil sampling, mapping, stratigraphy, drilling; Prairie region
- 1986-1988: till sampling, mapping, drilling; Beardmore-Geraldton, northern Ontario
- 1987: winter drilling; Timmins, northern Ontario
- 1986 & 1987: offshore surveys; Hudson Bay
- 1984-1986; Ph.D. field work, stratigraphy; Hudson Bay Lowland, northern Ontario
- 1983-1986; leader of undergraduate field trips; Colorado
- 1981: M.Sc. field work, Lake Agassiz outlets; Lake Nipigon region, northern Ontario
- 1980: summer student, mapping, Manitoba Geological Survey; southeastern Manitoba
- 1979: summer student, ecological research; Experimental Lakes Area, near Kenora Ontario

Thesis Supervision

- External examiner, Ph.D., Michelle Trommelen, University of Waterloo, 2013; Ph.D., Kelsey McCormack, McMaster University, 2010; Committee member, External examiner, Ph.D., Aki Artimo, University of Turku, Finland, 2003; Committee member, Ph.D., Nancy Grant, University of Manitoba, Canada, 1997; Committee member, Ph.D., Abigail Burt, University of Waterloo, Canada, 1997; External examiner, M.Sc., Tim Warman, University of Manitoba, Canada, 1991; External examiner, M.Sc., Rick Lemoine, University of Manitoba, Canada, 1988

Software Development

- Design team; Vertical Mapper, Borehole Mapper

Adjunct Professor

- University of Waterloo Adjunct Professor; 1998-2002; 2010-present
- University of Manitoba Adjunct Professor; 1998-2002

Selected Memberships

- Association of American State Geologists
- American Geophysical Union
- American Quaternary Association
- Association of Applied Geochemists
- Geological Association of Canada
- Geological Society of America
- Minnesota Ground Water Association
- Prospectors and Developers Association of Canada
- Society for Mining, Metallurgy, and Exploration

Theses

- Quaternary stratigraphy of the central Hudson Bay Lowland; 1989; University of Colorado at Boulder; Supervisor: Dr. J. T. Andrews
- The eastern outlets of Lake Agassiz; 1983; University of Manitoba; Supervisor: Dr. J. T. Teller

Student Honors

- Geological Society of America Quaternary Geology and Geomorphology J. Hoover Mackin Award, 1985 – in recognition of Ph.D. research
- Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarship; 1982 – 1985 – in support of M.Sc. & Ph.D. research
- University of Manitoba Graduate Fellowship, 1981; Dr. George Brownell Prize in Earth Sciences, 1981 – in recognition of highest academic achievement in geology course work
- University of Winnipeg Gold Medal in Honours Geography, 1980
- The O. T. Anderson Award, to the outstanding graduate for distinguished academic and extra-curricular achievement during undergraduate years, 1980; The Wesley Award, for distinguished service to the University of Winnipeg Student Government, 1980; W.C. Lockhart Award, for devoted service to the students of the University of Winnipeg, 1979 – to recognize achievement, including terms as President and Vice-President of the University of Winnipeg Students Association, four years as student Senator on the university academic governing body, two years as student Board member on the university financial governing body, and service on several university administrative committees and search committees
- University of Winnipeg Alumni Association Entrance Scholarship, 1975

Selected Publications and Reports

Thorleifson, L. H., R. C. Berg, H. A. J. Russell, conveners, 2013, Three-Dimensional Geological Mapping: workshop extended abstracts; Geological Society of America Annual Meeting, Denver, Colorado, October 26, 2013, Minnesota Geological Survey Open File Report OFR-13-2, 84 p.

Thorleifson, L.H., 2011, Potential for implementation of mineral carbonation as a carbon sequestration method in Minnesota: Minnesota Geological Survey Open-File Report 11-2, 26 p.

Lively, R., T. Wahl, and H. Thorleifson. 2011. Minnesota Geological Survey Information Systems. In Soller, D.R., ed., 2011, Digital Mapping Techniques '09—Workshop Proceedings,

Morgantown, West Virginia, May 10–13, 2009: U.S. Geological Survey Open-File Report 2010–1335, 260 p., p. 207-218.

Thorleifson, Harvey, Richard C. Berg, Hazen A.J. Russell, 2010, Geological mapping goes 3-D in response to societal needs, GSA Today, Volume 20, Issue 8 (August 2010), pp. 27-29

Thorleifson, L. H., 2009, Assessment of preservation needs and long-range plan for geologic collections and data in Minnesota; a report prepared in fulfilment of National Geological and Geophysical Data Preservation Program Award Number 07HQGR0126; Minnesota Geological Survey, 31 p.

Thorleifson, L. H., ed., 2008, Potential capacity for geologic carbon sequestration in the Midcontinent Rift System in Minnesota, Minnesota Geological Survey Open File Report OFR-08-01, 138 p.

Thorleifson, L. H., 2008, Understanding Canada's Water, Canadian Water Treatment, January/February 2008, v. 8, no. 1, p. 32-33

Jennings, C.E., J. S. Aber, G. Balco, R. Barendregt, P. R. Bierman, C. W. Rovey III, L. H. Thorleifson, and J. A. Mason. 2007. Mid-Quaternary in North America. In S.A. Elias. Ed., Encyclopaedia of Quaternary Science, p. 1044-1051.

Thorleifson, L. H., K. L. Harris, H. C. Hobbs, C. E. Jennings, A. R. Knaeble, R. S. Lively, B. A. Lusardi, G. N. Meyer. 2007, Till geochemical and indicator mineral reconnaissance of Minnesota. Minnesota Geological Survey Open File Report OFR-07-01, 512 p., 15 pdf digital files, 5 digital images.

Mayer, T., Simpson, S., Thorleifson, L.H, Lockhart, W., Wilkinson, P. 2006. Phosphorus geochemistry of recent sediments in the South Basin of Lake Winnipeg. Aquatic Ecosystem Health & Management, Volume 9, Number 3, July-September 2006, pp. 307-318

Brooks. G, C. F. M. Lewis, and L. H. Thorleifson. 2005. Influence of loss of gradient from postglacial uplift on Red River flood hazard; The Holocene, v. 15, no. 3, pp. 347-352.

Thorleifson, L. H., K. Harris, J. Berg, R. Tipping, Z. Malolepszy, B. Lusardi, D. Setterholm, and F. Anderson; 2005; Geological mapping and 3D model of deposits that host ground-water systems in the Fargo-Moorhead region, Minnesota and North Dakota; Minnesota Geological Survey Report, submitted to the U.S. Department of the Interior, Bureau of Reclamation in fulfilment of Cooperative Agreement No 04FG601925, in support of the Red River Valley Water Supply Project; 155 p., accompanied by 1:200,000 surficial geology map, 1: 400,000 bedrock geology map, drillhole database, and digital files depicting extent, thickness, and elevation of mapped strata

Thorleifson, L. H. 2004. Diamond exploration in Canada; 37th Forum on the Geology of Industrial Minerals, p. 163-166.

Thorleifson, L. H. and Pyne, D. M. 2004. Conversion of lithological data in the Manitoba water well database (GWDrill) to a mappable format; *in* Soller, D.R., editor, 2003, Digital Mapping Techniques '03 -- Workshop Proceedings: U.S. Geological Survey Open-file Report 03-471.

Thorleifson, L. H., G. L. D. Matile, G. R. Keller, and D. M. Pyne. 2003. Construction of a hydrostratigraphic model for southern Manitoba; 4th Joint International Association of Hydrogeologists-Canadian National Chapter/Canadian Geotechnical Society Conference, 5 p.

Simpson, S. L., L. H. Thorleifson, C.F.M. Lewis, and J.W. King. 2003. 1999 Lake Winnipeg Project: cruise report and scientific results; Geological Survey of Canada Open File 4196, 423 p.

Brooks. G.R., St. George, S., Lewis, C.F.M., Medioli, B.E., Nielsen, E., Simpson, S., and Thorleifson, L.H. 2003. Geoscientific insights into Red River flood hazards in Manitoba. Geological Survey of Canada Open File Report 4473, 35 pp.

Thorleifson, L. H. and Berg, R. C. 2002; Three-Dimensional Geological Mapping for Groundwater Applications; Workshop Extended Abstracts; Denver, Colorado, October 26, 2002; Geological Survey of Canada Open File 1449, 87 p.

Lewis, C. F. M., Forbes, D. L., Todd, B. J., Nielsen, E., Thorleifson, L. H., Henderson, P. J., McMartin, I., Anderson, T. W., Betcher, R. N., Buhay, W. M., Burbidge, S. M., Schröder-Adams, C. J., King, J. W., Moran, K., Gibson, C., Jarrett, C.A., Kling, H. J., Lockhart, W. L., Last, W. M., Matile, G. L. D., Risberg, J., Rodrigues, C. G. Telka, A.M., and Vance, R. 2001. Uplift-driven expansion delayed by middle Holocene desiccation in Lake Winnipeg, Manitoba, Canada. Geology, v. 29, no. 8, p. 743-746.

Berg, R. C. and L. H. Thorleifson. 2001; Geological Models for Groundwater Flow Modeling; GSA North-Central Section, Workshop Extended Abstracts. Illinois State Geological Survey Open File Series 2001-1, 62 pp.

Maathuis, H. and Thorleifson, L. H. 2000. Potential impact of climate change on Prairie groundwater supplies: review of current knowledge. Saskatchewan Research Council Publication No. 11304-2E00, 43 p., 28 figures, three appendices.

Thorleifson, L. H. and R. G. Garrett. 2000. Lithology, mineralogy, and geochemistry of glacial sediments overlying kimberlite at Smeaton, Saskatchewan. Geological Survey of Canada Bulletin 551, 40 p.

Todd, B. J., C. F. M. Lewis, E. Nielsen, L. H. Thorleifson, R. K. Bezys, and W. Weber. 1998. Lake Winnipeg: geological setting and sediment seismostratigraphy; Journal of Paleolimnology, v. 19, p. 215-244.

Lambert, A., T. S. James, and L. H. Thorleifson. 1998. Combining geomorphological and geodetic data to determine postglacial tilting in Manitoba; J. Paleolimnology, v. 19, p. 365-376.

Matile, G. L. D., Thorleifson, L. H., Grant, N., Burt, A. and Mann, J. (1998): Geology of the Winnipeg region NATMAP project (NTS 62H/W, 62I and 52L/W); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1998, p. 161-171.

Thorleifson, L. H., Betcher, R., Birks, J., Boyle, D., Cherry, A., Clark, I., Desbarats, A., Edwards, T., Farrell, D., Grasby, S., Hinton, M., Kaszycki, C., Kennedy, P., Leybourne, M., McDougall, W., McRitchie, D., Osadetz, K., Remenda, V., Render, F., Ryan, S. and Woodbury, A. (1998): Hydrogeology and Hydrogeochemistry of the Red River valley/Interlake region of Manitoba (NTS 62H, 62I, 62O, 62P and 63B); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1998, p. 172-185.

Thorleifson, H., Brooks, G., Hanuta, I., Kroker, S., Matile, G., Nielsen, E., Prévost, C., and Rannie, W., 1998: Red River flooding: evolutionary geomorphic trends and evidence for major floods in recent centuries (NTS 62H/W); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1998, p. 186-195.

Thorleifson, H., Anderson, T., Betcher, R., Bezys, R., Buhay, W., Burbidge, S., Cobb, D., Courtier, N., Doering, J., Fisher-Smith, G. Forbes, D., Franzin, W., Friesen, K., Frobel, D., Fuchs, D., Gibson, C., Henderson, P., Jarrett, K., James, T., King, J., Kling, H., Lambert, A., Last, W., Lewis, M., Lockhart, L., Matile, G., McKinnon, T., Moran, K., Nielsen, E., Pullan, S., Rack, F., Risberg, J., Rodrigues, C., Salki, A., Schröder-Adams, C., Stainton, M., Telka, A., Todd, B., Vance, R. and Weber, W. (1998): Status of the Lake Winnipeg Project (NTS 62I, 62P, 63A, 63B, 63G and 63H); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1998, p. 196-209.

McClenaghan, M. B., Thorleifson, L. H., and DiLabio, R. N. W. 1997. Till Geochemical and Indicator Mineral Methods in Mineral Exploration; in Proceedings of Exploration 97: Fourth Decennial International Conference on Mineral Exploration, ed. A. G. Gubins, p. 233–248.

Matile, G. L. D. and L. H. Thorleifson. 1997. Till geochemical and indicator mineral reconnaissance of northeastern Manitoba. Manitoba Energy and Mines. Geological Services. Open File OF 97-3, 174 p, one diskette.

Thorleifson, L. H. and R. G. Garrett. 1997. Kimberlite indicator mineral and geochemical reconnaissance, southern Alberta; in Exploring for minerals in Alberta: Geological Survey of Canada Geoscience Contributions, Canada-Alberta Agreement on Mineral Development (1992-1995); ed. R. W. Macqueen; Geological Survey of Canada Bulletin 500, p. 209-233.

Thorleifson, L. H. 1996. Review of Lake Agassiz History. in Sedimentology, Geomorphology, and History of the central Lake Agassiz Basin, Field Trip B2, Teller, J. T., Thorleifson, L. H., Matile, G., and Brisbin, W. C., eds., Geological Association of Canada Guidebook, p. 55-84.

Garrett, R. G. and Thorleifson, L. H. 1995. Kimberlite indicator mineral and till geochemical reconnaissance, southern Saskatchewan. in D. G. Richardson, ed., Investigations completed by the Saskatchewan Geological Survey and the Geological Survey of Canada under the geoscience program of the Canada-Saskatchewan Partnership Agreement on Mineral Development (1990-

1995), Geological Survey of Canada Open File 3119; Saskatchewan Geological Survey Open File Report 95-3, p. 227-253.

Thorleifson, L. H., P. H. Wyatt and T. A. Warman. 1993. Quaternary stratigraphy of the Severn & Winisk drainage basins, Ontario. Geological Survey of Canada Bulletin 442, 59 p.

Thorleifson, L. H. and F. J. Kristjansson. 1993. Quaternary geology and drift prospecting, Beardmore- Geraldton area, Ontario. Geological Survey of Canada Memoir 435, 146 p.

Thorleifson, L. H., P. H. Wyatt, W. W. Shilts, and E. Nielsen. 1992. Hudson Bay Lowland Quaternary stratigraphy: evidence for early Wisconsinan glaciation centred in Quebec. in P. U. Clark and P. D. Lea, eds., The Last Interglacial-Interglacial Transition in North America. Geological Society of America Special Paper 270, p. 207-221.

Rannie, W. F., L. H. Thorleifson and J. T. Teller. 1989. Holocene evolution of the Assiniboine River paleochannels and Portage la Prairie alluvial fan. Canadian Journal of Earth Science, v. 26, pp. 1834-1841.

Forman, S. L., A. G. Wintle, L. H. Thorleifson and P. H. Wyatt. 1987. Thermoluminescence properties and age estimates for Quaternary raised marine sediments, Hudson Bay lowland, Canada. Canadian Journal of Earth Science, v. 24, pp. 2405-2411.

Teller, J. T. and L. H. Thorleifson. 1987. Catastrophic flooding into the Great Lakes from Lake Agassiz. in Catastrophic Flooding (Binghamton Symposium in Geomorphology; V. 18), edited by L. Mayer and D. Nash, Allen and Unwin, p. 121-138.

Dredge, L. A. and L. H. Thorleifson. 1987. The Middle Wisconsinan history of the Laurentide Ice Sheet. Géographie physique et Quaternaire, v. XLI, no. 2, p. 215-235.

Teller, J. T., L. H. Thorleifson, L. A. Dredge, H. C. Hobbs and B. T. Schreiner. 1983. Maximum extent and major features of Lake Agassiz. in Glacial Lake Agassiz, edited by J. T. Teller and Lee Clayton, Geological Association of Canada, Special Paper 26, p. 43-45.

Teller, J. T. and L. H. Thorleifson. 1983. The Lake Agassiz - Lake Superior Connection. in Glacial Lake Agassiz, edited by J. T. Teller and Lee Clayton, Geological Association of Canada, Special Paper 26, p. 261-290.

Recent Unrefereed Publications

Thorleifson, Harvey, 2009, An Agenda for Development of Vertically Georeferenced, Web-optimized, Subsurface Information; Three-Dimensional Geologic Mapping, Workshop Extended Abstracts, October 17, 2009, 2009 Annual Meeting, Geological Society of America, Portland

Thorleifson, L. H. 2006. President's Report, 2006; Canadian Geoscience Council. 21p.

Thorleifson, L. H. 2004. Mapping; Geotimes annual highlights issue, v. 49, no. 7, p. 32-33.

Thorleifson, L. H. and S. Hanmer. 2005. Conference Report, Geoscience Summit 2004 Ottawa, Ontario 16 - 17 October 2004, v. 32. no. 2, p. 49-63.

Thorleifson, L. H. 2004. Presidential Address: Geoscience for the needs of Canadians, Geoscience Canada, v. 31. no. 3, p. 97-101.

Thorleifson, L. H. 2003. Crossroads of the Continent; a history of the Forks of the Red and Assiniboine Rivers; Chapter 1, The Foundation of the Forks; Chapter 2, Laying down the landscape; Heartland Associates, Winnipeg, p. 14-45.

Thorleifson, L. H. and McClenaghan, M. B. 2003. Indicator Mineral Methods in Mineral Exploration. Prospectors and Developers Association of Canada Short Course, March 8, 2003, 100 p.

Recent & Forthcoming Invited Technical Presentations & Public Lectures

- Charting a path forward for geological mapping in the US; Digital Mapping Techniques, Delaware, May 2014
- Rationale and Methods for Regional 3D Geological Mapping; Digital Mapping Techniques, Delaware, May 2014
- The role of geoscience in society, guest speaker, University of Wisconsin, Eau Claire, December 2013
- Rationale and Methods for Regional 3D Geological Mapping, short course lead-off presentation, Geological Society of America, Denver, October 26, 2013
- The Search for Diamonds in Minnesota, Rush City Historical Society, October 1, 2013
- Presidential Address, Association of American State Geologists, Annual Meeting, Deadwood, South Dakota, June 10 2013
- The role of geoscience in society, Canadian Council of Professional Geoscientists (CCPG), Conference Dinner Speaker, June 1, 2013, Winnipeg
- Integrated, web-accessible public sector geoscience mapping systems, Canadian Society of Petroleum Geologists Luncheon Speaker, March 18, 2013, Calgary
- What's the Rural Minnesota Narrative for the Future? Minnesota's Exceptional Natural Resources Geology and Mineral Potential, McKnight Foundation, March 14, 2013
- Short Course 3. New frontiers for exploration in glaciated terrain, Lead-off speaker: History and status of till geochemical and indicator mineral methods in mineral exploration, Prospectors and Developers Association of Canada, Short Course, March 1, 2013
- Earth science knowledge that the people of Minnesota need, Keynote speaker, Minnesota Earth Science Teachers' Association, Annual Conference, February 8, 2013
- Shared Waters - Shared Responsibility: Working Across Borders to Protect and Restore Lake Winnipeg and the Red River Basin, Humphrey School of Public Affairs, University of Minnesota, Panel 1: Connections: Minnesota, Manitoba, and the Red River Basin, December 13, 2012
- The past, present, and future of the Minnesota Geological Survey, Minnesota Mineral Club, guest speaker, October 21, 2012
- The past, present, and future of the Minnesota Geological Survey, Geological Society of Minnesota, dinner speaker, September 17, 2012
- The role of public geoscience in Society, Alberta Geological Survey strategic planning retreat keynote speaker, Edmonton, April 13
- The Search for Diamonds in North America, Kentucky Geological Survey annual public lecture, Lexington, February 22, 2012
- Methods in 3D geological mapping, Alberta Geological Survey seminar, Edmonton, January 27, 2012
- Geologic Mapping for Environmental Geology. Celebrating Geologic Mapping for Science and Society. Kentucky Geological Survey. December 1, 2011

- Minnesota Geological Survey Programs; SME Twin Cities Subsection Annual Conference; 27 October 2011
- The Role of Geoscience in our Society. GSA Lunchtime Lecture #4. Geological Society of America Annual Meeting, October 12, 2011
- Incorporation of Geologic Data with Soil Survey Information; invited presentation; 2011 National Cooperative Soil Survey National Conference National Conference; "Soil Survey — Interpreting the Inventory in a Digital World"; Asheville, North Carolina; May 22-26, 2011; co-authored with Dave Soller of USGS
- The search for diamonds in North America; Dinner Speaker; Minnesota Academy of Sciences, April 16, 2011
- The search for diamonds in North America; Guest Lecture; University of Wisconsin, River Falls, April 5, 2011
- How do the people of Minnesota know what is under their feet, and why do they need to know?, Minnesota Science Teacher Conference, Mankato, April 1, 2011
- The search for diamonds in North America; Sip of Science; University of Minnesota, Saint Anthony Falls Laboratory, Public Lecture, March 9, 2011
- Status of public geological databases in Minnesota; University of Minnesota Geography Department; Weekly Seminar, February 11, 2011
- The search for diamonds in North America; Association of Women Geoscientists, Minnesota chapter, January 22, 2011
- Status of public geological databases in Minnesota; Guest Speaker; Informal Club, Saint Paul, November 15, 2010
- The search for diamonds in North America; Guest Lecture; Engineers Club of Northern Minnesota, October 6, 2010
- Status of public geological databases in Minnesota; Guest Speaker; Mesabi Range Geological Society, Eveleth, September 15, 2010
- Development of science language based on content analysis; IUGS-CGI OneGeology-Europe; Geoscience Language Workshop; Berlin, August 2010
- A draft structure for Minnesota Geological Survey information systems; Harvey Thorleifson, Richard Lively, and Tim Wahl; Digital Mapping Techniques, Sacramento, May 2010
- Minnesota Geological Survey information systems and their application to regional landscape and geological research topics; St. Anthony Falls Seminar Series Spring Semester 2010; 3 March 2010
- Status of Public Geological Databases in Minnesota; University of Minnesota 58th Annual Geotechnical Engineering Conference; 26 February 2010
- Geoscience Mapping and Web Accessibility Systems of the Future; Canadian Exploration Geophysical Society/British Columbia Geophysical Society; 2010 KEGS/BCGS Roundup Breakfast; January 19th, 2010
- Status of MGS Information Systems; Minnesota Geological Survey Brown Bag Seminar, 14 October 2009
- Water-related issues in the Red River valley and Lake Winnipeg; Minnesota/Dakota/Manitoba Legislators' Forum, Gimli Manitoba, June 25, 2009
- Carbon Sequestration, Nature Conservancy, Minneapolis, June 11, 2009
- Till geochemical and indicator mineral methods in mineral exploration: history and status; session keynote; International Applied Geochemistry Symposium, New Brunswick, May 2009
- Geological mapping, The Engineers' club of Minneapolis, April 10, 2009
- The search for diamonds in North America, Minnesota Mineral Club, Dinner Speaker, January 10, 2009
- The role of earth science in our nation; Creative Retirement, Winnipeg, October 29, 2008

- Natural History of Lake Winnipeg; the Long-Term Perspective; Luncheon Speaker; Conference on Lake Winnipeg Environmental Science, University of Winnipeg, October 28, 2008
- Minnesota's Geology and the History of its Exploration, American Association of University Women, Minneapolis, October 20, 2008
- North American Diamond Production, Society for Mining, Metallurgy, and Exploration, Twin Cities Subsection, October 16, 2008
- Carbon Capture and Storage - climate change strategy options for Minnesota, Minnesota Section of the American Institute of Professional Geologists (AIPG), September 9, 2008
- OneGeology: Making Geological Map Data for the Earth Accessible; co-authors I Jackson and J Broome; 33rd International Geological Congress, Oslo, 6-14 August 2008
- Delivering our science to the intended user: wrap-up of session IEI-01 on general contributions to geoscience information; 33rd International Geological Congress, Oslo, 6-14 August 2008
- The transition to 3D, web-accessible geological mapping; 33rd International Geological Congress, Oslo, 6-14 August 2008
- From 1:1 million geology to high resolution applications for society; 33rd International Geological Congress, Oslo, 6-14 August 2008
- Conference wrap-up speaker; Centennial Conference of the Association of American State Geologists, Shepherdstown, West Virginia, June 2008
- Prospects for Geologic CO2 Sequestration in the Upper Midwest, Iowa Geological Survey, April 4, 2008
- Till geochemical and indicator mineral reconnaissance of Minnesota, University of Iowa, April 4, 2008
- Till geochemical and indicator mineral reconnaissance of Minnesota, Minnesota Earth Science Teachers Association, February 1, 2008
- The search for diamonds in MN, Geological Society of Minnesota, Lecture, January 28, 2008
- Vision for web-accessible 3D geological mapping, Gocad seminar, Vancouver, 25 January 2008
- Prospects for Geologic CO2 Sequestration in the Upper Midwest, Minnesota DNR Staff Meeting, November 29, 2007
- Vision for web-accessible 3D geological mapping, Minnesota Geotechnical Society, Duluth Chapter, November 20, 2007
- Minnesota Geochemical Database; Minnesota Water Resources Conference, October 23, 2007
- Geological Society of America, Hot Topics, Geology – Google Earth-style, lead-off speaker, October 28, 2007
- Keynote Address; GIS Day; Ottawa, October 2007
- Canadian Diamonds, Minnesota Mineral Club, October 20, 2007
- Presentation on characterization activities that have been planned by the Minnesota Geological Survey; Geological Characterization; PCOR Partnership, Grand Forks, October 19, 2007;
- Canada's Water; Public Lecture, University of Winnipeg, September 13, 2007
- Till geochemical and indicator mineral reconnaissance of Minnesota, AIPG Minnesota Chapter Luncheon, September 2, 2007
- Public sector case study: Indicator mineral survey of Minnesota; Short Course; Exploration 2007, Toronto, September 2007
- Introduction to indicator mineral methods in mineral exploration; Short Course; Exploration 2007, Toronto, September 2007
- Indicator mineral methods in mineral exploration – wrap-up talk; Short Course; Geological Association of Canada, Yellowknife, May 22 2007
- Vision for web-accessible subsurface information, Committee on Geological and Geotechnical Engineering, National Research Council, Washington DC, May 17, 2007

- Vision for web-accessible subsurface information, Keynote Address, Pennsylvania GIS Conference, Camp Hill, PA, May16 2007
- Thorleifson, L. H., K. L. Harris, H. C. Hobbs, C. E. Jennings, A. R. Knaeble, R. S. Lively, B. A. Lusardi, G. N. Meyer. 2007, Till geochemical and indicator mineral reconnaissance of Minnesota. Institute on Lake Superior Geology, poster
- Till geochemical and indicator mineral reconnaissance of Minnesota, Mesabi Geological Society, Lecture, April 18, 2007
- Introduction to the Geological Specification, Lecture, OneGeology Workshop, Brighton UK, March 2007
- Future Aspirations, Lecture, OneGeology Workshop, Brighton UK, March 2007
- Vision for web-accessible subsurface information, Agriculture and Agri-food Canada, Ottawa, January 9, 2007
- Geoscience for the Needs of Society; Keynote Address; Western Inter-University Geoscience Conference, Winnipeg, January, 2007
- The Future of Geological Mapping; Geological Survey of Canada Logan Club, Ottawa, November 24, 2006
- The Future of Geological Mapping; USGS Reston, November 21, 2006
- The role of the Minnesota Geological Survey in groundwater management, Minnesota Ground Water Association, November 14, 2006
- Vision for web-accessible 3D Geological Mapping, Geological Society of America, Philadelphia, October 22, 2006
- Geoscience for the Needs of Society; Keynote Address; American Institute of Professional Geologists National Meeting, St. Paul, September 26, 2006
- Vision for web-accessible 3D Geological Mapping, Digital Mapping Techniques, Columbus Ohio, June 2006
- Canadians need web accessible 3D geological mapping ASAP; May 2006, Geological Association of Canada, Montreal, session keynote address
- 3D geological mapping, Iowa State University, 21 April 2006
- The Search for Diamonds in North America, Geological Society of Minnesota, 17 April 2006
- The role of geological mapping in supporting production agriculture; West Central Spring Agronomy Seminar, Owatonna, 22 February 2006
- 3D Geological Mapping in support of groundwater inventory in the Fargo-Moorhead region, North Dakota and Minnesota; 16 February 2006; Detroit Lakes Public Library
- 3D Geological Mapping in support of groundwater inventory in the Fargo-Moorhead region, North Dakota and Minnesota; 16 February 2006; City of Moorhead Public Service Commission
- 3D Geological Mapping in support of groundwater inventory in the Fargo-Moorhead region, North Dakota and Minnesota; 15 February 2006; North Dakota State University
- 3D Geological Mapping in support of groundwater inventory in the Fargo-Moorhead region, North Dakota and Minnesota; 15 February 2006; University of North Dakota
- Geology of the Red River Basin and Lake Winnipeg; January 2006. Red River Basin Commission. Winnipeg. Lead-off technical speaker
- The Search for Diamonds in North America, St. Cloud State University, St. Cloud, Minnesota, October 28, 2005
- The Search for Diamonds in North America, University of Wisconsin, Oshkosh, Wisconsin, October 13, 2005
- Information Systems Required to Ensure Sustainable Groundwater Supply, invited lecture, Prairie Water Policy Symposium, Winnipeg, 22 September 2005

- Diamonds, guest speaker, 29 June 2005, University of St. Thomas
- Indicator mineral methods in mineral exploration, guest speaker, Wisconsin Geological Survey, Madison, 1 June 2005
- Harris, K. L., Berg, J. A., Lusardi, B. A., Setterholm, D. R., Tipping, R. G., Malolepszy, Z., Anderson, F. J., Thompson, D. L., Arntson, A. D., Reppe, T. H. C., and Thorleifson, L. H. 2005. Geological mapping and 3D model of the Fargo-Moorhead region, Minnesota and North Dakota, and a review of published information on ground water availability assessment of surficial aquifers of the Red River of the North basin, Minnesota; Geological Society of America North-Central Section, 2005 Abstracts with Programs, v. 37, no. 5, p. 94.
- Canada's Water; Geological Association of Canada, Halifax, May 2005
- Development of digital, interactive, and 3D geological mapping systems for groundwater applications; Soil, Water, and Climate Seminar, University of Minnesota, 11 April, 2005
- Development of digital, interactive, and 3D geological mapping systems, Digital Mapping Techniques, Baton Rouge, April 2005
- Indicator mineral methods in mineral exploration, and their application to Minnesota geology, Luncheon speaker, American Institute of Professional Geologists Minnesota Chapter, 5 April 2004
- Geology of Lake Winnipeg, Geological Society of Minnesota, 21 February 2005
- Indicator mineral methods in mineral exploration, and their application to the discovery of diamonds in Canada, guest speaker, University of Wisconsin, Eau Claire, 18 February 2005
- Overview of the world diamond market, Minnesota Minerals Coordinating Committee, Minerals Opportunities Meeting on Minnesota Diamond Potential, February 16, 2005
- Indicator mineral methods in diamond exploration, Minnesota Minerals Coordinating Committee, Minerals Opportunities Meeting on Minnesota Diamond Potential, February 16, 2005
- Groundwater Mapping, Red River Basin Commission International Summit Conference, Fargo, 13 January 2005
- Development of digital, interactive, and 3D geological mapping systems, Minnesota soil mapping liaison meeting, 11 January 2005
- Development of digital, interactive, and 3D geological mapping systems, Ontario Mineral Exploration Technologies Program, 3D mapping symposium, Toronto 16 December 2004
- Development of digital, interactive, and 3D geological mapping systems, Minnesota Association of Professional Soil Scientists Fall Meeting, 3 December 2004
- Indicator mineral methods in mineral exploration, Manitoba Geological Survey Open House, Winnipeg, 20 November
- The Search for Diamonds in Canada, McAlester College, 18 November 2004
- Indicator mineral methods in mineral exploration, Keynote address, Quebec Exploration 2004, Quebec City, November 2004
- Development of digital, interactive, and 3D geological mapping systems, Geological Society of America Annual Meeting, Denver, November 2004
- Development of digital, interactive, and 3D geological mapping systems, International Geological Congress, Florence Italy, August 2004
- Drinking Water Protection and 3D Mapping, Minnesota Department of Health, Drinking Water Protection Staff Meeting, Nisswa 27 October 2004
- Overview of geoscience in Canada, Geoscience Summit, Ottawa, 16 October 2004
- The Search for Diamonds in Canada, University of Minnesota, Department of Geology and Geophysics, Department Seminar, 30 September 2004
- New frontiers in geological mapping, Guest Speaker, Geological Society of Minnesota Annual Banquet, September 20 2004

- Sustainable development of Groundwater Resources, Sustainable Water Resources Roundtable, St. Paul, 13 September
- Geoscience for the needs of society, Wrap-up speaker, International Conference on Developments and Prospects of Professional Geology in the World: a new relationship between geology and society; Florence, Italy, August 27, 2004
- Geoscience for the Needs of Canadians; Presidential Address; Geological Association of Canada, St. Catharines Ontario, 12 May 2004
- Developments in geological mapping, North Dakota Geological Survey, Bismarck, 27 April 2004
- The role of 3D Geological Mapping in Groundwater Management, Guest Speaker, North Dakota State University, Faculty of Engineering, Fargo, 26 April 2004
- 3D mapping of Red River Valley groundwater resources; Moorhead City Council, Moorhead, 26 April 2004
- New methods in geological mapping; Dinner speaker, Minnesota Geotechnical Society, 14 April 2004
- New frontiers in geological mapping; Society for Mining, Metallurgy, and Exploration, Minnesota Section, Duluth, 13 April 2004
- The Search for Diamonds in Canada, Luncheon speaker, American Institute of Professional Geologists Minnesota Chapter, 6 April 2004
- The role of glaciology in diamond exploration, Luncheon speaker, Midwest Glaciology Conference, Minneapolis, 25 March 2004
- The role of 3D Geological Mapping in Groundwater Management, Plenary Speaker, Minnesota Water 2004, 23 March 2004
- The role of geological mapping in groundwater management; Dinner speaker; Minnesota Department of Natural Resources Division of Waters Staff meeting; 16 March 2004
- The role of geological mapping in supporting agriculture; West Central Spring Agronomy Update, Owatonna, 24 February 2004
- The role of geological mapping in groundwater management; Minnesota Pollution Control Agency, Rochester, 18 February 2004
- The role of geological mapping in groundwater management; Board of Water and Soil Resources, St. Paul, 27 January 2004
- Developments in geological mapping, Iowa Geological Survey, Iowa City, January 2004
- The role of geological mapping in groundwater management; Minnesota Pollution Control Agency, St. Paul, 22 January 2004
- New methods in geological mapping; Minnesota Department of Natural Resources Division of Land and Minerals Staff meeting; St. Cloud, 20 January 2004
- 3D mapping of Red River Valley groundwater resources; Red River Basin Commission annual conference, Moorhead, 14 January 2004
- Geological map of the future; digital, interactive, 3D. American Geophysical Union Fall Meeting, San Francisco, December 2003
- The role of geological mapping in groundwater management; Minnesota Department of Agriculture, St. Paul, 15 December 2003
- Indicator mineral methods in mineral exploration, University of Minnesota, Duluth, 20 November 2003
- Geological map of the future; digital, interactive, 3D. NATO Advanced Research Workshop, Poland, November 2003
- The role of geological mapping in groundwater management; Minnesota Ground Water Association annual conference, 10 November 2003
- Construction of a groundwater model for the Winnipeg region, United States Geological Survey, Mounds View, 6 November 2003

- Geological map of the future; digital, interactive, 3D. Earthtech, Minneapolis, 29 October 2003
- The Search for Diamonds in Canada; Dinner speaker; Mesabi Range Geological Society, Eveleth, 22 October 2003
- Development of methods for 3D geological mapping, University of Turku, Finland, 8 October 2003
- Developments in North American geological mapping, Geological Survey of Finland, 7 October 2003
- 3D geological mapping for groundwater applications, University of Helsinki Geology Department, Finland, 6 October 2003
- Natural history of Lake Winnipeg, Dinner speaker, Canadian Association of Geographers, Prairie Chapter, Gimli, Manitoba, 27 September 2003
- Last millennium sedimentation in Lake Winnipeg: a record of recurring Red River floods; University of Minnesota Quaternary paleoenvironments seminar, 24 September 2003
- The role of geological mapping in addressing water-related issues, Water Resources Science Seminar, St. Paul Campus, University of Minnesota, 22 September 2003
- Thorleifson, L. H., G. L. D. Matile, G. R. Keller, and D. M. Pyne, 2003, Construction of a hydrostratigraphic model for southern Manitoba; 4th Joint International Association of Hydrogeologists-Canadian National Chapter, Winnipeg, September 2003
- The role of geoscience in addressing water-related issues in Canada; Geological Association of Canada; Vancouver, May 2003, invited talk
- Diamond exploration in Canada; Canadian Institute of Mining, Metallurgy and Petroleum Annual Meeting, Montreal; May 2003; session leadoff speaker
- The role of geological mapping in addressing water-related issues, Luncheon speaker, Geological Survey of Canada Alumni, April 2003
- The Search for Diamonds in Canada; Geological Association of Canada Newfoundland Section, February 2003
- Developments in Canadian geological mapping; Minnesota Geological Survey, February 2003
- Last millennium sedimentation in Lake Winnipeg: a record of recurring Red River floods; University of Minnesota, February 2003
- Groundwater monitoring in Canada; stream gauging coordination meeting, St. John's, Newfoundland, October 2002
- The search for diamonds in Canada; Institute for Lake Superior Geology; Kenora; May 2002
- The search for diamonds in Canada; YMCA Luncheon Discussion Club; Ottawa; February 2002; Luncheon speaker
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum Ottawa Branch, Ottawa; December 2001; Dinner speaker
- Diamond exploration in Canada; Carleton University, Ottawa; May 2001; Invited lecture
- Diamond exploration in Canada; 37th International Forum on the Geology of Industrial Minerals; Victoria, British Columbia. May 2001; Session keynote
- Diamond exploration in Canada; Federal-Provincial Committee on Mineral Statistics; Ottawa. May 2001; invited lecture
- Diamond exploration in Canada; Canadian Institute of Mining, Metallurgy and Petroleum Annual Meeting, Québec City; April 2001; session keynote
- Diamonds in Canada; Manitoba Mining and Minerals Convention 2000; November 18 2000; Keynote address
- The search for diamonds in Canada; Carleton University, Ottawa; May 2000; Invited lecture
- The search for diamonds in Canada; Martin Collegiate, Regina; March 2000; Invited lectures
- The search for diamonds in Canada; Sheldon Williams Collegiate, Regina; March 2000
- The search for diamonds in Canada; Royal Saskatchewan Museum, Regina; March 2000

- The search for diamonds in Canada; Miller Comprehensive High School, Regina; March 2000; Invited lectures
- Exploration Sedimentology; Mining Millennium/Prospectors and Developers Association of Canada. March 2000. Invited lecture
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum Ottawa Branch Luncheon, Ottawa; February 2000; Luncheon speaker
- Careers in geology; University of Ottawa, Ottawa; January 2000; Invited lecture
- Geology of the Red River/Lake Winnipeg System; The International Coalition for Land and Water Stewardship in the Red River Basin, Winnipeg; January 2000; Keynote session lecture
- The search for diamonds in Canada; Sudbury Geological Discussion Group Annual Dinner, Sudbury; December 1999; Luncheon speaker
- The search for diamonds in Canada; Science and Technology Week, Ottawa; October 1999
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Sudbury; April 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Trail; April 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Kimberley; April 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Calgary; April 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Chicoutimi; April 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Red Lake; March 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Association of Professional Engineers and Geoscientists of Saskatchewan, Prince Albert; March 1999; Dinner speaker
- The search for diamonds in Canada; Association of Professional Engineers and Geoscientists of Saskatchewan, Yorkton; March 1999; Dinner speaker
- The search for diamonds in Canada; Association of Professional Engineers and Geoscientists of Saskatchewan, Swift Current; March 1999; Dinner speaker
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Leaf Rapids; March 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Thompson; March 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Montréal; March 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Montréal; March 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Flin Flon; February 1999; CIM Distinguished Lecturer presentation
- The search for diamonds in Canada; Canadian Institute of Mining, Metallurgy and Petroleum, Labrador City; January 1999; CIM Distinguished Lecturer presentation