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To: John Stolzenberg and Rachel Letzing
Legeslative Council

From: H. J. “Bud” Harris – Citizen member
Subject: Observations and comments on sustainability,cumulative impacts and Section I 4(4b) of draft compact 0058/p1

Two concerns expressed during our first two meetings bring the issue of “Threshold” to the table. The first concern was raised by Senator Cowles when he asked, “what level of withdrawal or diversion is sustainable and how do we know”? The second issue was raised by Mr. Wilusz with regard to the adverse impact requirement and the requirement to assess cumulative adverse impacts. Related issues are contained in Section I4(b) of the draft compact.

These concerns can not logically be addressed without a means of accounting for all forms of withdrawal or diversion of water from a given lake basin (or the total basin) relative to the amount returned. In other words we need to be able to estimate (measure) the flux of water returned to the lake thus knowing the balance. We also need to assess the threats related to either a positive or negative balance. What is needed for rational decisions is a numerical hydrologic model that can be coupled to climatic and economic models useful in assessing potential future conditions (scenarios).

Because I am not a hydrologist with insight about the “state of the science” on this issue I turned to the published literature to see how I might be informed. Serendipitously a colleague presented me with a recent review paper in Science (Oki and Kanae, 2006) titled “Global Hydrological Cycles and World Water Resources.” The authors assert in this paper that to assess the available water resources for human society, the flow (flux) of water should be the primary focus in water assessment. The paper further identifies the usefulness of a water scarcity index to reveal large geographic regions under “water stress” (see attached paper). While this paper addresses hydrologic cycles on a global scale such an approach would appear useful if scaled to the regional level.

My continued search revealed, somewhat to my surprise, that such exercises had already been initiated in the Great Lakes Basin some twenty years ago. For example Laucks and Joeres 1985 described the use of a modified version of the

Great Lakes Regulation Model (U.S. Corps of Army Engineers) to assess the hydrologic and economic impact of large scale diversion from Lake Superior and Lake Michigan. David *et al.* (1988) used the same model to assess diversions and consumptive use on Lake Michigan, Superior and Erie lake levels. The mathematical representation employed in the model for each individual lake is based on the hydrologic budget. The general form used is given by: $dS/d_t=N_t+I_t-O_t-U_t$.

This may be read: The instantaneous change in S (volume of water stored in lake) over the change in time is equal to the $N_t$ (net basin supply to lake at time $_t$)+ $I_t$ (main channel in flow) minus $O_t$ (out flow from channel) minus $U_t$ (all unreturned withdrawals removed from the lake for human uses). In effect this is a simple mass balance equation much like a checking account where the lake level is the "balance available" and responds to deposits and withdrawals.

The question becomes how good are the estimates of inputs and outputs and forces driving these variables. Again two papers written over a decade ago reveal significant insight into understanding the hydrologic flux of the Lakes. Brinkmann (1985) examined "The association between summer temperatures and precipitation patterns over the Great Lakes Region and water supplies to the Great Lakes." Because evaporation and precipitation are major drivers of the water budget an understanding of these variables is important as climate change advances. At the other end Cherkauer and McKereghan (1991) examined the groundwater discharge to Lake Michigan and Green Bay with a focus on embayment's.

These early works have led to further refinements of the models. Much of the recent work has been conducted by investigators at the NOAA/Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan. Their efforts center around the development of "A model for simulation of the climate and hydrology of the Great Lakes basin", (Lofgren, 2004). The use of existing climate models and the current hydrologic model reveals that climate change by 2090 may cause a drop in Lake Michigan lake levels up to a maximum of 1.38 m or possibly a rise of 0.35 m (Lofgren, *et al.* 2002). The differences in outcomes are due to different predictions of basin supplies by different climate models. So the existing modeling capability suggests uncertainty, but does it provide more insight than uncertainty?

I believe the answer to that is yes, because it helps us understand the relationship of potential future withdrawals or diversions to the existing annual water budget of a given lake basin or of the total basin. A relevant question addressed by the research asked what are the effects of present diversion from the Great Lakes relative to potential change in lake level due to climate change? The answer is they have an insignificant effect. For example, the Chicago diversion of 90m$^3$/sec (approx. 2.1 bgd) lowers lake Michigan by 7cm (approx. 2.8 in). Essentially a drop in Lake Michigan of 7 cm is immeasurable against the natural background variation in water levels. Short term variation due to Seiche activity may be as much as two feet, annual variation is a foot or more and 20-30 year variation is 6 feet (approx. 2 meters).

It appears that it would take very large withdrawals from Lake Michigan during any given water year to have a measurable effect. The models may however be useful in informing management by examining the change in a "scarcity index" similar to that used by Oki and Kanae (2006). Such an index could include a water quality term which would account for water that is unavailable due to degraded quality. The index could be defined as renewable water resources, Rws = (W+Pu) /NBS where W is the withdrawal and diversion of all sources, Pu is that portion of run off water unavailable because of pollution and NBS is the net basin supply. The scarcity index increases where the (W+Pu) term becomes larger relative to NBS. Oki and Kanae consider a region highly water stressed if Rws is higher than 0.4. It is considered to be a reasonable although not definitive threshold value because not all the Renewable Freshwater Resource can be used by human society.

The utility of the model lies in the fact that it can simulate various scenarios where combinations of management practices overlaid by changing climatic conditions can be examined and evaluated. Such an approach could possibly be done for separate lake basins or for the Great Lake Basin as a whole. For purposes of illustration allow use of available data from the Lake Michigan Basin and also assume a scarcity index of 0.4 to be the "tipping point" (non-sustainable). Now Senator Cowl's question becomes "how far are we at present from the Tipping Point?" We may also assess cumulative impacts over time by considering the combination of impaired waters (degraded) and withdrawal and diversions (W+Pu). Using the relationship Rws=(W+Pu)/NBS and substituting current estimated values we have: Rws=surface water withdrawal from Lake Michigan (212.5 m$^3$/sec or 4850 mgd)[a], plus diversion out of Lake Michigan (90.7m$^3$/sec or 2070 mgd)[a] plus (113.3m$^3$/sec or 2586 mgd) degraded and unusable water from the Lower Fox River = 416.5m$^3$/sec 0r 9506 mgd divided by the NBS (416.5m$^3$ sec//3159.6m$^3$/sec)[b] = 0.132 Scarcity Index. The Scarcity Index value reveals that we might increase our total withdrawal plus our diversions plus our polluted water volume by three times before we reach the "Tipping Point", a 0.4 scarcity index for the Lake Michigan Basin; a considerable freeboard it would appear.

However, there are several caveats. First, the uncertainty of the Net Basin Supply (NBS) to Lake Michigan has been estimated between 15 and 35 percent ( Neff and Nichols, 2004). Considering the deficit end this allows we could presently be at a 0.2 Scarcity Index rather than 0.13. Second, there is no consideration of future climate change which introduces another level of uncertainty and third, these estimates of impact consider the Lake Michigan Basin only, no downstream effects.

The above scenario is a paper exercise to be sure, but it is useful in gaining perspective on several relevant issues. First, we are reminded that there are limits to the alteration of the hydrologic cycle before we approach risk levels associated with unpredictable adverse future events. For example, the former Soviet Unions debacle with the Aral Sea, the Yellow River of China and the Colorado River stand as testimony to the reality of "Tipping Points" and unpredictable change. This is as much to say, "CONSERVATION FIRST" . Second, while the present state of the science has attendant uncertainties, the existing models are still useful in estimating orders of magnitude change and providing an accounting tool without which we can only "wave our hands." Third, the exercise, in my mind, underscores the need to manage the Great Lakes water resource on an ecosystem and regional basis and further the development of a scientifically defensible management capability.

Regarding the last point such a monitoring and management capability system is well underway in the form of the Great Lakes Observing System (GLOS) which is a regional node of U.S. national Integrated Ocean Observing System (IOOS). The attached pamphlet describes the purpose and capabilities of the developing system. It appears that the GLOS is just what is needed to help address the inventory requirements of the compact and to provide the basis of a management system grounded in science. Taking advantage of this unprecedented cooperative effort should be a matter of interest to Wisconsin and the Special Legislative Committee on the Great Lakes Compact.

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