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MEMORANDUM

To: Sen. Neal Kedzie, Chair, Wisconsin Legislative Council Special Committee on the Great Lakes Water Resources Compact and John Stolzenberg, Chief of Research Services, Wisconsin Legislative Council

From: Daniel Feinstein, US Geological Survey, Wisconsin Water Science Center, and Ken Bradbury, University of Wisconsin-Extension, Wisconsin Geological and Natural History Survey

Subject: Clarification of results of model simulations conducted by USGS and WGNHS, in context of statements made by GeoSyntec Consultants in a report dated March 23, 2006 submitted to City of Waukesha

This Memorandum is a response to a discussion that occurred at the October 4, 2006 meeting of the Wisconsin Legislative Council Special Committee on the Great Lakes Water Resources Compact. At that meeting Mr. Dan Duchniak of the Waukesha Water Utility introduced a letter from Godfrey and Khan Attorneys dated March 28, 2006. The Godfrey and Kahn letter presents a legal argument for Waukesha's use of water from Lake Michigan, and, to support the legal argument, cites a technical report from GeoSyntec Consultants dated March 23, 2006, which was included as an attachment to the letter. Following Mr. Duchniak's presentation of the letter, Ken Bradbury commented that he did not agree with all the technical statements in the GeoSyntec report, which was based on work carried out by Dr. Bradbury, Mr. Daniel Feinstein, and others in the U.S. Geological Survey (USGS) and Wisconsin Geological and Natural History Survey (WGNHS). Dr. Bradbury offered to submit written comments to the Legislative Council for the record. This memorandum contains those comments.

One question that arose at the meeting involved review of the GeoSyntec report by the USGS. The report was never formally reviewed or endorsed by either the USGS or the WGNHS. Mr. Feinstein saw the report in June and provided some informal comments on the telephone to Mr.

Duchniak. The draft version of the report released to the Special Committee apparently does not incorporate these comments. We would like to take the opportunity of these legislative council meetings on the Great Lakes Compact to provide written clarification of the results of the model simulations for southeast Wisconsin conducted by the USGS and the WGNHS in the context of the GeoSyntec report. The GeoSyntec report accurately reflects many aspects of our work. We have drawn attention only to passages that we found unclear or misleading. We want to stress that we have distilled and sharpened the discussion of some of our findings over the last several months in response to many questions from state agencies and the public on ground-water issues in southeastern Wisconsin. GeoSyntec did not have the benefit of this distillation process in March of 2006 when preparing their report. We also want to emphasize that neither the WGNHS nor the USGS takes positions on policy matters, but feel we have an obligation to clarify the scientific import of our work.

Before commenting on particular passages in the GeoSyntec report, we present some key findings of our own work on the hydrogeology of southeast Wisconsin. These findings were presented to the Council by Dr. Bradbury on October 4.

Pumping from the deep sandstone aquifer below southeastern Wisconsin began around 1864. Before that time water that moved from the land surface to the deep sandstone aquifer flowed toward Lake Michigan from a boundary (called the "deep ground-water divide") that was located in western Waukesha County, west of the City of Waukesha. Based on model simulations, the total amount of ground-water flow below southeastern Wisconsin (that is, below Ozaukee, Washington, Milwaukee, Waukesha, Racine, Kenosha and Walworth counties) moving toward Lake Michigan through the deep sandstone aquifer amounted to about 3 million gallons per day.

Beginning about 1864, gradually-increasing pumping from deep wells has significantly altered the natural ground-water flow system in the deep sandstone aquifer. Today, well withdrawals from the deep aquifer below southeastern Wisconsin amount to 33 million gallons per day, which means that the deep sandstone aquifer is now transmitting more than 10 times its natural flow rate. The direction of flow has also changed. Deep ground water no longer moves eastward toward Lake Michigan but now moves toward pumping centers, the most important of which are currently in Waukesha County. Ground water converges on these pumping centers from all directions, including from areas to the west in Jefferson County and from areas to the east extending under Lake Michigan. From a scientific point of view, the deep ground-water flow system is no longer flowing toward Lake Michigan; it is flowing toward pumping centers. Using the southeastern Wisconsin ground-water flow model, it is possible to simulate where the 33 million gallons per day originate. Owing to the particular geology below southeastern Wisconsin, the deep wells derive most of their water from west of the pumping centers. Specifically, some ground water that once flowed toward streams in the Mississippi River Basin is now flowing downward toward the deep wells. This source accounts for about 70% of the well withdrawals. The remaining 30% of the well withdrawals originates from inside the Lake Michigan Basin (including a small amount derived from the Lake itself).

The question is asked: are communities like the City of Waukesha pumping water that was flowing toward Lake Michigan? In fact, the water coming out of the deep wells was flowing toward Lake Michigan before pumping started. The wells are capturing old water that had been

flowing to the east at a relatively slow pace for hundreds if not thousands of years; now much of it is curling back and flowing westward toward the pumping centers. However, it is also important to recognize the effect of pumping on new water. Deep pumping has caused water that is currently entering the ground-water system to move downward toward the deep part of the flow system instead of following its natural course to streams at the land surface. The volume of this replenishing water is much larger than the volume of the pre-1864 flow toward Lake Michigan. Most of this replenishing water is being diverted from streams in the Mississippi River Basin. It will not arrive at the pumping wells for hundreds or thousands of years.

We can summarize our findings as follows: 1) pumping from deep wells has caused more than 10 times the water that once flowed east toward Lake Michigan through the deep aquifer below southeastern Wisconsin to now converge from all directions to inland pumping centers, 2) the deep wells are discharging old water that was once flowing toward Lake Michigan, 3) the wells are mostly replenished by new water that in the absence of deep pumping would have flowed to streams, and 4) about 70% of the replenishing water is diverted from streams in the Mississippi River Basin, the remainder from different parts of the Lake Michigan Basin.

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Below are comments on cited passages from the GeoSyntec March 23, 2006 report. Some of our comments relate to key findings, but many are minor in importance and are only included for completeness.

Title:

THE REGIONAL GROUND WATER FLOW SYSTEM IN SOUTHEASTERN WISCONSIN

BASED ON THE FINDINGS OF THE UNITED STATES GEOLOGICAL SURVEY: GROUND WATER IN THE GREAT LAKES BASIN: THE CASE OF SOUTHEASTERN WISCONSIN

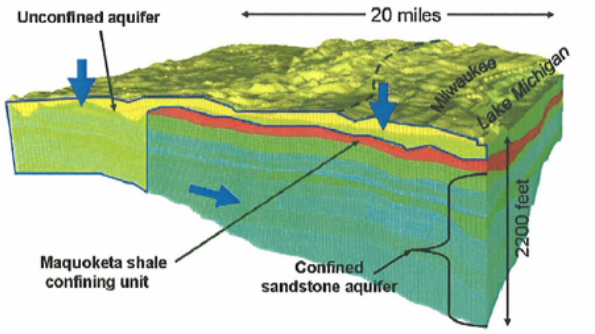
Comment: The GeoSyntec report draws material from the website titled "*Ground Water in the Great Lakes Basin: The Case of Southeastern Wisconsin*" and located at http://wi.water.usgs.gov/glpf/. This website was developed from work performed jointly by the USGS and the WGNHS.

Statement, p.1 of the report:

The USGS has determined that Waukesha draws its water supply from the portion of the St. Peter sandstone aquifer that flows toward Lake Michigan (See Figure 1). An analysis performed by the USGS based on a MODFLOW groundwater model shows that:

Comment: The USGS/WGNHS website does not refer to the "St. Peter sandstone aquifer", but to the "deep sandstone aquifer". The St. Peter sandstone is one geological unit near the top of this aquifer. Second and more important, the first part of this statement is GeoSyntec's *interpretation* of the findings on the USGS/WGNHS website, not a conclusion stated on the site.

Graphic, p. 1 of the report:



Comment: The USGS/WGNHS did not prepare the unconfined aquifer boundary lines shown on this graphic. We do not agree with the sharp boundary imposed between the confined part of the sandstone aquifer below the Maquoketa shale (the red unit) and area labeled as unconfined aquifer to the west. The boundary is, in fact, more transitional. However, it is true that ground water to the west of the boundary tends to flow in local flow systems that discharge to streams and the ground water to the east flows in a single regional system that was flowing toward Lake Michigan before pumping and is now flowing toward wells.

Statement, p. 1 of the report:

> While the City of Waukesha is located outside of the surface water divide, which defines the locations of streams flowing to Lake Michigan and the Mississippi River, Waukesha has always been located over a portion of the St. Peter sandstone aquifer that flows toward Lake Michigan. Thus, Waukesha is within the Lake Michigan groundwatershed and uses tributary groundwater.

Comment: This statement is again an interpretation of USGS/WGNHS work, not a conclusion set forth by the USGS/WGNHS. And, as noted above, the focus of this work is the "deep sandstone aquifer"; no reference is made to the "St Peter sandstone aquifer". But our most important comment on this statement relates to the tense of the last three lines because the historical situation described in those lines no longer applies. The last three lines should be corrected to read "…located over a portion of the *deep sandstone aquifer* in which ground water *flowed* toward Lake Michigan. Thus, Waukesha *was* within the Lake Michigan *deep* ground watershed." Our point is that ground water beneath Waukesha is no longer flowing toward Lake Michigan, and hasn't been for many years. It is flowing toward the deep wells.

Statement, p. 3 of the report:

> Currently, the USGS model indicates that approximately "71% of the water that replenishes discharge from deep wells in southeastern Wisconsin is ground water that flows from surface water streams (captured base flow) within the Mississippi River (surface water) Basin"[5] where the shale layer ends. As this surface water infiltrates, some of it remains in shallow aquifers located in the Mississippi River basin, but the remainder percolates further through the soil to the St. Peter sandstone aquifer. Once settling in the deep aquifer, the direction of flow of this water is easterly toward Lake Michigan, meaning that it becomes Lake Michigan tributary groundwater.

Comment: In our judgment, this statement is scientifically misleading because it implies that the water that replenishes deep wells would someday reach Lake Michigan. This is simply wrong. The water flows toward the wells, not toward the lake. Moreover, all of this water replenishing the wells is "new" to the deep part of the flow system. Before pumping, about 3 mgd flowed through the deep sandstone aquifer toward Lake Michigan. Currently about 33 mgd flows through the deep sandstone aquifer toward pumping centers. The natural flow system has been completely changed; almost all the water flowing into the deep sandstone aquifer is flowing that way in response to pumping. And most of the water currently flowing toward deep wells originates in the Mississippi River Basin.

Statement, p.5 of the report:

> The source of water for the Waukesha Water Utility is, and has always been, drawn from a portion of the St. Peter sandstone aquifer that the USGS has identified as tributary to Lake Michigan, not the Mississippi River basin. The flow of water from the aquifer under both pre--pumping and pumping conditions has always been eastward toward Lake Michigan. Like the surface waters of Lake Superior, it may take hundreds of years for the groundwater in the aquifer to move to southern Lake Michigan, but its ultimate destination is Lake Michigan.

Comment: The last statement is untrue – although under prepumping conditions, deep ground water all moved east toward Lake Michigan, under current pumping conditions deep ground water converges on pumping centers and no longer moves east toward Lake Michigan.

The reference to Lake Superior is obscure. Perhaps the report is comparing the residence time of water in Lake Superior (the average time it spends in Lake Superior before moving to Lake Michigan/Huron or evaporating) to the time necessary for ground water to flow through the deep sandstone aquifer to Lake Michigan itself. The former is about 200 years, the latter before pumping was on the order of thousands or, more likely, tens of thousands, of years. In fact it is possible that some of the water initially entered the ground-water system before Lake Michigan was formed.

Statement, p. 5 of report:

> Defining the deep groundwater divide as being the same as the surface water divide is contrary to scientific evidence. The surface water divide is defined by the surface topography of the area. In contrast, the groundwater divide in southeastern Wisconsin has historically been defined by the western extent of the layer of Maquoketa shale, although it has been affected by pumping from the aquifer over the last 100 years.

Comment: The location of the western edge of the Maquoketa shale strongly influenced the pre-pumping deep divide, but its location was not identical to edge of the shale. Under the influence of pumping, the deep divide has moved about 10 miles farther to the west.

Thank you for the opportunity to provide these comments. Please feel free to contact us or our respective agencies (USGS, WGNHS) if the Council seeks additional information to further their understanding of the complex dynamics of ground-water flow in southeastern Wisconsin.