RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations

February 4, 2013

Ms. Shaili Pfeiffer
Wisconsin Department of Natural Resources
PO Box 7921
Madison, Wisconsin 53707-7921

RE: Waukesha Water Utility
Groundwater Flow Modeling

Dear Ms. Pfeiffer:

Additional modeling has been completed in both the Vernon Marsh area and the western Waukesha County area. The purpose of this work was to provide estimated reductions in the actual flows of streams under various pumping scenarios.

Troy Bedrock Model

A decision was made to continue to utilize the Troy Bedrock Model, rather than introduce a new model to the project. Despite the fact that this model simulates streams using MODFLOW's River Module, we developed a methodology to estimate flow variations under the various pumping scenarios, utilizing the estimated Q80 flow rates for the tributaries, provided by the Wisconsin Department of Natural Resources ("WDNR").

Figure 1 shows a typical tributary situation. The "flow estimation location" is the position at which the WDNR flow was estimated. From that point is an upstream reach of the stream and a downstream reach. An assumption was made that the cumulative upstream base flows in the base model (i.e., the model with no new wells) resulted in the estimated flow at the flow estimation location. Note that existing wells (11, 12 and 13) were simulated at current rates, provided by the Waukesha Water Utility. The cumulative base flows of the downstream locations are then added to the stream flow at the estimation location to determine the stream flow entering the Fox River from that tributary.

For the simulations with new wells, the following approach was taken. The base flows for the upstream reach were totaled, and subtracted from the cumulative base flows from the base model. This difference was then used to adjust the flow at the flow estimation point. The cumulative base flows for the downstream reach were then added to the revised flow at the flow estimation location to calculate the flow into the Fox River under the pumping scenario.

Flow estimates were conducted for Mill Brook, Mill Creek, Pebble Brook and Pebble Creek (shown on Figure 2). Figures 3, 4, 5 and 6 show the simulated well locations for model scenarios 1-1, 1-2, 2-1 and 2-2, as originally run in 2010.

Table 1 summarizes the flows for the base conditions the scenarios listed above. Although the reductions in flow of the Fox River are minor, significant flow reductions occur in the tributaries. Also, even though a scenario might results in minimal reductions in one or two tributaries, the same scenario results in significant flow reductions in other tributaries. For example, Run 1-1 resulted in a 1.1 percent reduction in flow for Pebble Creek, but a 20.8 percent reduction in Mill Brook.

Western Unconfined Aquifer Model

Additional study was conducted for the western unconfined bedrock model (SEWRPC regional model). In the previous report, the changes in base flows caused by the new wells were tabulated. This re-evaluation presents the simulated change in stream flows. This is possible because the SEWRPC model simulates the streams and lakes in the SEWRPC counties using MODFLOW's stream module, which calculates stream flows. The model was set up with streams and lakes in segments, or reaches. Figure 7 shows the reaches that were studied for this work.

The same five scenarios that were earlier run were re-run for this evaluation. Table 2 summarizes the changes in stream flows for the scenarios. As would be expected, the lowest flow scenario (two wells, each at 2 million gallons per day ("MDG")) resulted in the least change in stream flow, ranging from less than 1 percent reduction to 4.6 percent. However, all other scenarios resulted in stream flow reductions of over 10 percent.

The WDNR has indicated concerns about single wells being used in this model to pump at rates for which multiple wells were used in the Troy Bedrock Model. The SEWRPC model has a much larger cell size than the Troy model. Consequently, a single cell in the SEWRPC comprises as much area as would have held multiple wells in the Troy model. Because MODFLOW simulates all wells in the center of a model cell, the use of multiple wells pumping a total of 5 MGD, for example, would produce the same results as one well simulated at 5 MGD. Therefore, single wells were placed in any given model cell.

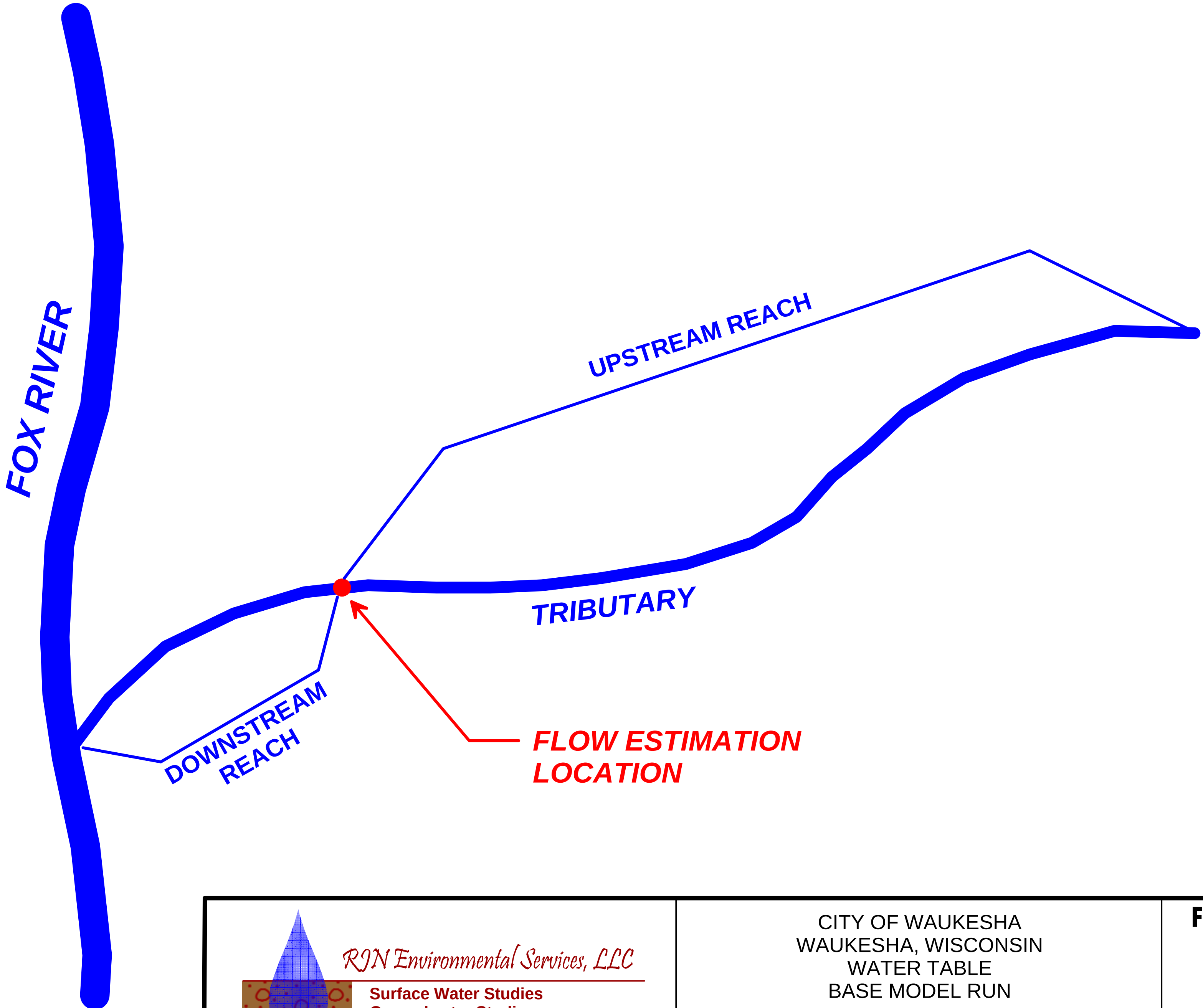
Additional concern was raised with respect to the simulated drawdown in the SEWRPC model. A cone of depression surrounds the northernmost well, whereas the simulated drawdowns in the central and southernmost wells are less evident. RJN has been working on developing an explanation for this, with the help of staff at the US Geological Survey ("USGS") and the Wisconsin Geological and Natural History Survey ("WGNHS"). An initial step was to verify that the model is simulating the wells as directed. This was done by evaluating the mass balance, layer-by-layer for the individual cells containing new wells. This evaluation was completed for the following scenarios: Two wells, each at 5 MGD; three wells, each at 5 MGD; three wells, each at 3.33 MGD.

Table 3 summarizes the simulated rates of groundwater removed by wells for each model cell and layer of the cells containing wells. Wells were simulated in model rows 11 through 16, which is consistent with other wells open to the sandstone aquifer. As this exercise shows, the wells are being properly simulated by the model. However, the aquifer cannot sustain 3 wells at 5 MGD per well. In that scenario, layers 12 and 13 of the center well are pumped dry, likely caused by the combined impact of a stress on either side of that well.

RJN is still working with the USGS and WGNHS to determine the cause of the simulated drawdown configuration. A possibility is the proximity to inactive cells. The northern well (R102, C68) is adjacent to inactive cells in the lower two layers. This causes the well to draw more water from other directions, and could therefore cause additional drawdown. More information will be provided as we explore other aspects of the model.

Sincerely,
RJN ENVIRONMENTAL SERVICES, LLC

Robert J. Nauta
Hydrogeologist

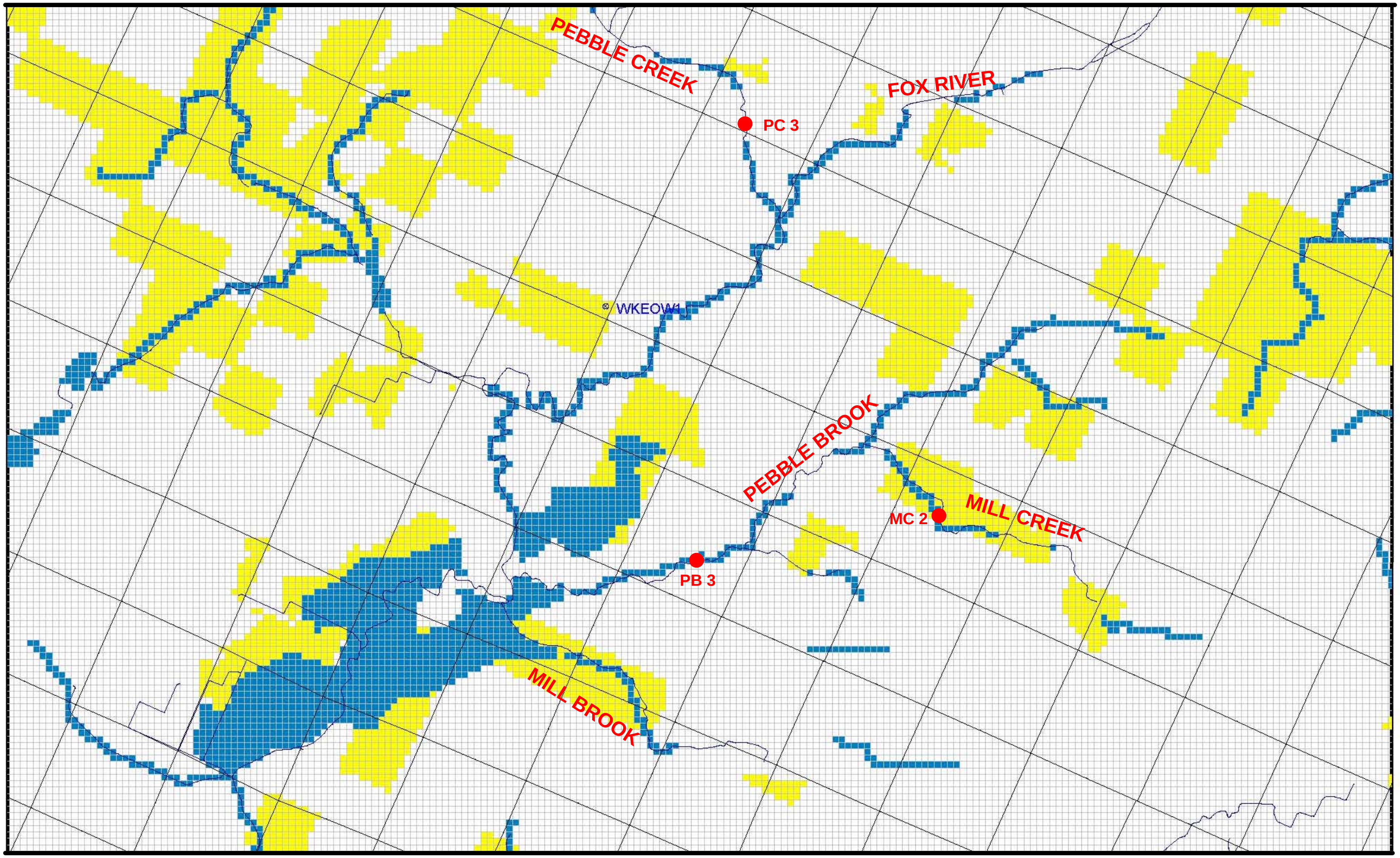


RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations
4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

CITY OF WAUKESHA
WAUKESHA, WISCONSIN
WATER TABLE
BASE MODEL RUN

FIGURE 1

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	31 JAN 13	FLOW EST



RJN Environmental Services, LLC
Surface Water Studies
Groundwater Studies
Site Investigations

4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN
STREAM FLOW ESTIMATION POINTS

FIGURE 2

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	03 FEB 13	FL PTS