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

August 30, 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:

As requested, RJN Environmental Services, LLC (RJN) has completed additional modeling and model documentation relative to the Waukesha Water Utility investigation in the Troy Bedrock Valley and the western Waukesha County unconfined aquifer. In our letter to you dated February 4, 2013, several items were clarified or addressed, including a discussion of how base flow reductions were calculated for the two models (the Troy Bedrock Model and the United States Geological Survey (USGS) regional model developed for the Southeastern Wisconsin Planning Commission (SEWRPC)), both of which use the MODFLOW code.

This letter addresses the following:

- Simulated drawdowns and base flow reductions in the western unconfined area with pumping rates spread among additional wells, and wells in cells containing surface water features;
- Identification on both maps and tables, of the specific streams and lakes being evaluated;
- Simulated pumping rates;
- Drawdown configuration in the western model; and
- Revising the percent reduction in flow for both the western and Troy bedrock valley models using estimated Q80 data at the point where tributaries enter the Fox River.

Additional Western Simulations

A limited area was identified by Waukesha Water Utilities for well construction, based on technical and economic feasibility. This area is shown on Figure 1. To the extent possible, wells were simulated within that area. Based on the area and the desire to maintain a minimum distance of ½ mile between wells, seven were simulated.

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Figure 2 shows the stream segments that were evaluated. Although other streams and lakes, located farther out from the simulated new wells, incurred a reduction in base flow, the reductions were much lower than the streams shown.

Below, two simulations from the previous submittal are shown, along with a simulation with the additional wells. The simulations conducted include:

- Two wells at a total of 10 million gallons per day (MGD)
- Three wells at a total of 10 MGD
- Seven wells at a total of 10.5 MGD

As with previous simulations, the new municipal wells were simulated in model layers 11 through 16. Wells were simulated at projected needed rates, rather than approved capacities. Figure 3 and 4 show the simulated drawdown for layers 1 and 11, respectively, for the simulation of two wells at a total of 10 MGD. Figures 5 and 6 provide the same plots for a simulation of three wells at a total of 10 MGD, and Figures 7 and 8 provide the plots for a simulation of seven wells at a total of 10.5 MGD.

As the plots for layer 11 show, the model continues to simulate the drawdown centered near the northernmost well. This condition was discussed and evaluated at length with Daniel Feinstein of the USGS. The mass balance was observed for each layer in each model cell, and no significant variations occurred in the results. However, the northernmost well is situated near some cells in which portions of the sandstone aquifer are not present in some layers. Consequently, RJN concludes that the reduced number of saturated cells in the vicinity of this well results in a greater drawdown in that area.

Table 1 summarizes the maximum simulated drawdowns for layers 1 and 11 in the various scenarios. While the drawdown for layer 11 of the seven-well scenario is slightly less than in the other scenarios, the results are all comparable.

The SEWRPC model simulates rivers and lakes using the MODFLOW stream package, which calculates and estimated stream flow in model cells. The approach, therefore, taken for this modeling effort was to identify the farthest downstream cell of the individual river reaches, and report the simulated stream flow in that cell. Table 2 summarizes the base flows and base flow reductions for the selected stream segments. The simulated base flow reductions range from 3 percent to 27 percent, with no apparent benefit resulting from the additional wells.

Model Calibration, Assumptions and Limitations

Both models utilized for this work were constructed and calibrated by other parties. The Troy Bedrock Valley model was constructed by Aquifer Science & Technology, in cooperation with SEWRPC. This model was reviewed, in terms of configuration and calibration, by staff from the Wisconsin Geological and Natural History (WGNHS) and the USGS. The SEWRPC model was constructed by staff from the USGS, and reviewed by other USGS staff as well as WGNHS. Consequently, RJN assumes that the models were rigorously calibrated.

The primary assumption in RJN's efforts in both modeling scenarios is that the wells were simulated in the appropriate model layers. However, the same convention used for municipal wells in the construction of both models was followed by RJN. Consequently, the wells should have been simulated in the suitable layers. Other assumptions are inherent to modeling. These typically relate to variables that are rarely measured or defined in the field. These include variables such as the vertical flow permeability, area-wide recharge values and evapotranspiration rates. However, these parameters are typically identified during the calibration process, and are tested in sensitivity analyses. Other assumptions pertain to variables in surface water simulations. Whether using the stream or river package, parameters such as streambed thickness and streambed permeability are never well-defined, and the modeler's experience is often the guide, as well as limited published data.

Essentially, the assumptions also define the limitations. The accuracy of anything simulated by the model, whether pumping, drought conditions, or other changes to the hydrologic system are a function of the applicability of all parameters that are applied to a model. However, these limitations are minimized by rigorous calibration and sensitivity analyses.

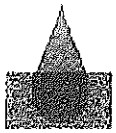
Revised Estimates for the Fox River Basin

The Troy Bedrock Valley model was used for the simulations of the well field scenarios north of the Vernon Marsh. Unlike the SEWRPC model, the Troy Bedrock Model simulates streams using MODFLOW's river package, which simulates changes in groundwater discharge to the streams, but does not estimate stream flow.

Figure 9 shows a typical tributary section. The "Flow Estimation Location" is the position at which the WDNR flow was originally estimated. From that point is an upstream reach and a downstream reach. An assumption was made that the cumulative base flows of the model cells in the upstream reach of the base model (i.e., the model without any new wells – existing wells 11, 12 and 13 were simulated at current pumping rates) resulted in the base flow at the estimated flow location. The cumulative base flows of the model cells in the downstream reach are then added to the stream flow at the estimation location to determine the stream flow entering the Fox River.

For the simulations with the new wells, the following approach was taken. The base flows for the cells of the upstream reach were totaled, and subtracted from the cumulative base flows from the base model. The 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. To calculate the percent stream flow reduction, the Q80 values recently provided by the WDNR at the tributaries' confluence with the Fox River were used. The flow estimation locations are shown on Figure 10.

As with previous submittals, scenarios 1-1, 1-2, 2-1 and 2-2 were simulated. The well locations for these simulations are provided on Figures 11, 12, 13 and 14, respectively.



With respect to the Fox River, the average annual stream flow for the Fox River, as recorded by the USGS gauge in Waukesha was used as the starting point. To that value, the average daily discharge from the Waukesha wastewater treatment plant was added. The cumulative simulated base flows, as well as the input from the tributaries, were added to the flow, to arrive at an estimation of the Fox River discharge into the Vernon Marsh. The estimated flows are provided in Table 3.

This letter should have adequately responded to your requests for additional simulations and clarification. However, if you need anything more, please notify us.

Sincerely,
RJN ENVIRONMENTAL SERVICES, LLC

Robert J. Nauta
Hydrogeologist

Cc: Dan Duchniak – Waukesha Water Utility
Mark Mittag – CH2MHill
Tony Myers – CH2MHill

TABLES

TABLE 1
WAUKESHA WATER UTILITY
WESTERN WELL SIMULATIONS
SIMULATED DRAWDOWN (FEET)

SCENARIO	LAYER 1	LAYER 11
10 MGD - 2 WELLS	1.4	215
10 MGD - 3 WELLS	1.15	175
10.5 MGD - 7 WELLS	1.2	160

TABLE 2
WAUKESHA WATER UTILITY
WESTERN WELL SIMULATIONS
BASE FLOW REDUCTIONS IN STREAMS NEAR SIMULATED WELLS
FLOWS IN GALLONS PER DAY

SCENARIO		MODEL STREAM NUMBER											
		36 Bark River	37 Unnamed[1]	38 Bark River	46 Unnamed[2]	47 Bark River	49 Bark River	52 Battle Cr. & Laura Lake	53 Silver Lake	54 Middle & Lower Genesee	55 Upper Genesee & Duck Lake	57 Golden Lake	229 Irr. Ditch
No pumping	BASE FLOW	8,512,240	334,580	9,731,480	3,710,753	13,725,800	14,316,720	1,353,880	653,453	524,348	292,917	802,604	538,111
10 MGD - 2 WELLS	BASE FLOW	7,801,640	310,270	8,908,680	3,571,700	12,723,480	13,269,520	1,163,140	500,412	435,186	234,573	779,416	493,605
	REDUCTION	710,600	24,310	822,800	139,053	1,002,320	1,047,200	190,740	153,041	89,162	58,344	23,188	44,506
	% REDUCTION	8	7	8	4	7	7	14	23	17	20	3	8
10 MGD - 3 WELLS	BASE FLOW	7,749,280	303,613	8,848,840	3,553,748	12,641,200	13,194,720	1,195,304	517,317	421,049	236,368	780,912	496,148
	REDUCTION	762,960	30,967	882,640	157,005	1,084,600	1,122,000	158,576	136,136	103,299	56,549	21,692	41,963
	% REDUCTION	9	9	9	4	8	8	12	21	20	19	3	8
10.5 MGD - 7 WELLS	BASE FLOW	7,824,080	306,306	8,901,200	3,553,748	12,686,080	13,217,160	1,191,564	474,980	441,769	241,230	767,448	475,279
	REDUCTION	688,160	28,274	830,280	157,005	1,039,720	1,099,560	162,316	178,473	82,579	51,687	35,156	62,832
	% REDUCTION	8	8	9	4	8	8	12	27	16	18	4	12

[1] Tributary to Bark River.

[2] Tributary between Bark River and Union Lake.

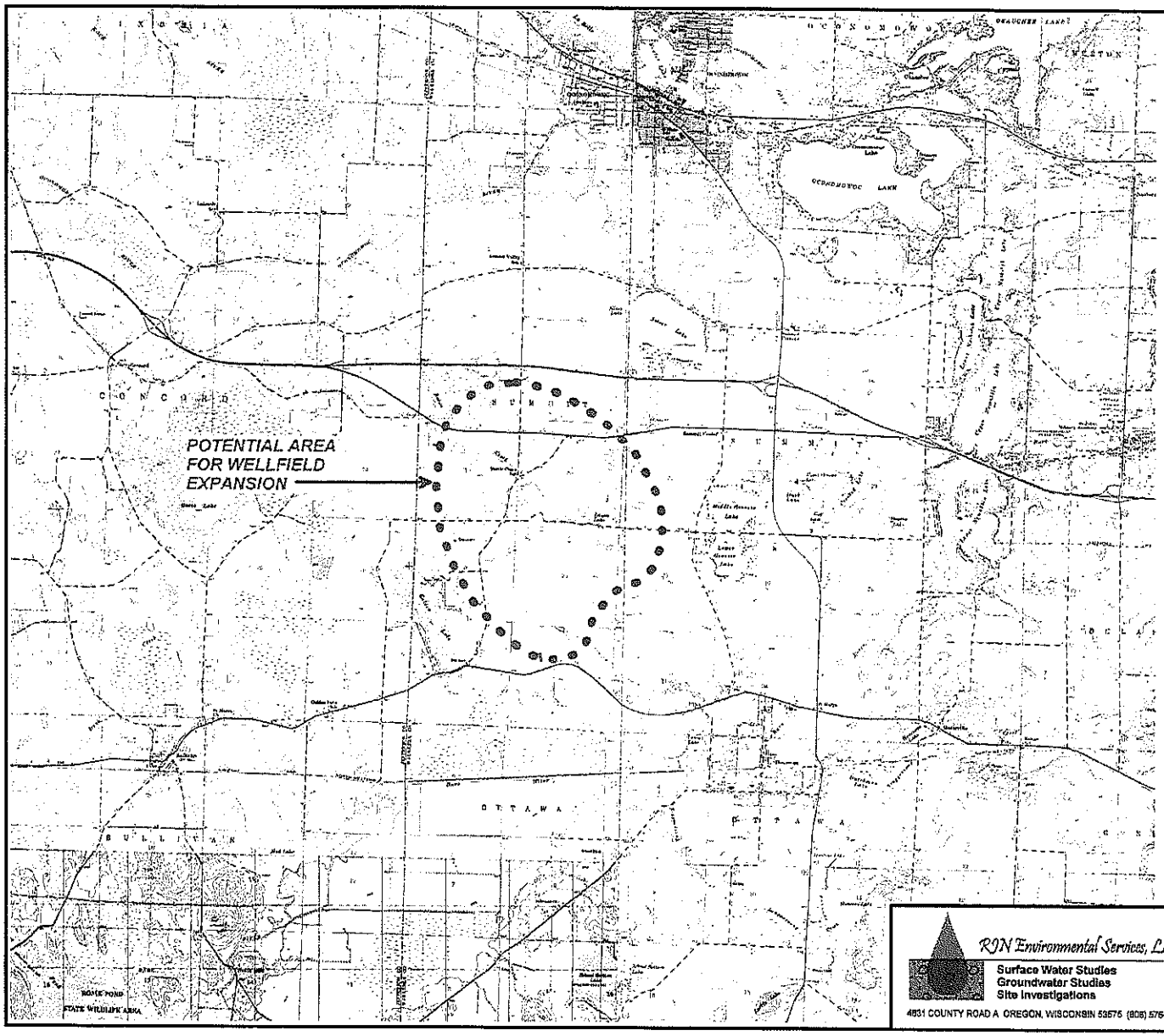
TABLE 3
WAUKESHA WATER UTILITY
ESTIMATED FOX RIVER AND TRIBUTARY FLOWS

Scenario	Fox River[1]		Mill Brook[2] Q80=1.26		Mill Creek[2] Q80=1.18		Pebble Brook[2] Q80=5.44		Pebble Creek[2] Q80=3.41	
	Flow (cfs)	Percent Reduction	Flow (cfs)	Percent Reduction	Flow (cfs)	Percent Reduction	Flow (cfs)	Percent Reduction	Flow (cfs)	Percent Reduction
Base	83.45		1.73		3.73		5.00		3.53	
Run 1-1	81.08	2.8	1.49	19.0	3.71	1.7	4.55	8.3	3.49	1.2
Run 1-2	79.94	4.2	0.66	84.9	3.34	33.1	3.15	34.0	3.55	0.0
Run 2-1	75.98	8.9	0.76	77.0	3.42	26.3	3.14	34.2	3.09	12.9
Run 2-2	78.42	6.0	Dry		3.21	44.1	2.54	45.2	3.55	0.0

[1] Q80 not used for flow for Fox River. It is estimated where it enters Vernon Marsh utilizing the model and average flows recorded at the USGS gauge in Waukesha.

[2] Flow for the tributaries is estimated where they discharge into the Fox River.

FIGURES



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WAUKESHA WATER UTILITY
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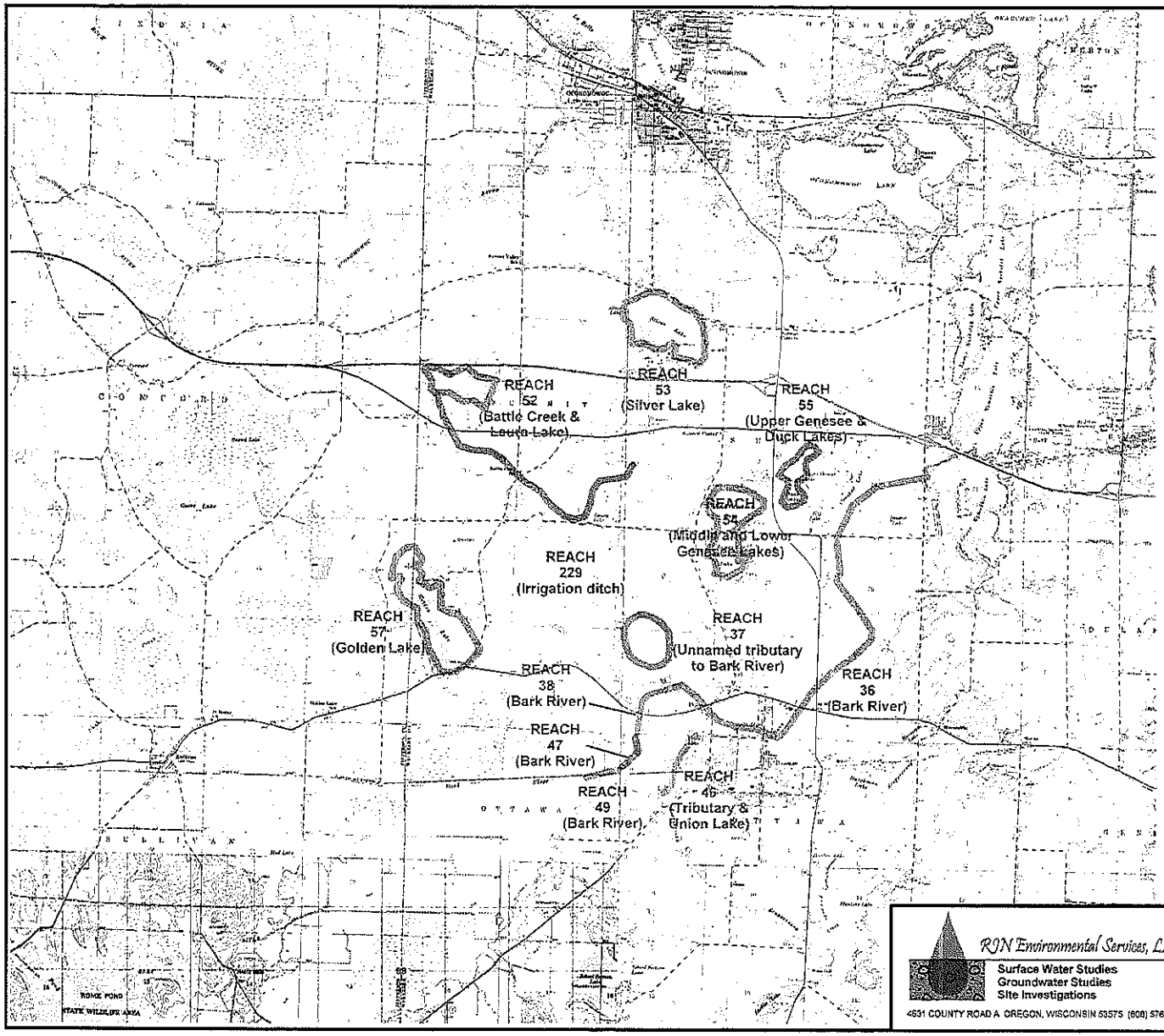
POTENTIAL AREA FOR EXPANSION

FIGURE 1

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	05 FEB 13	EXPANSION



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WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN
WESTERN MODEL STREAM SEGMENTS

FIGURE 2

DRAWN BY	PROJ. No.	DATE	FILE
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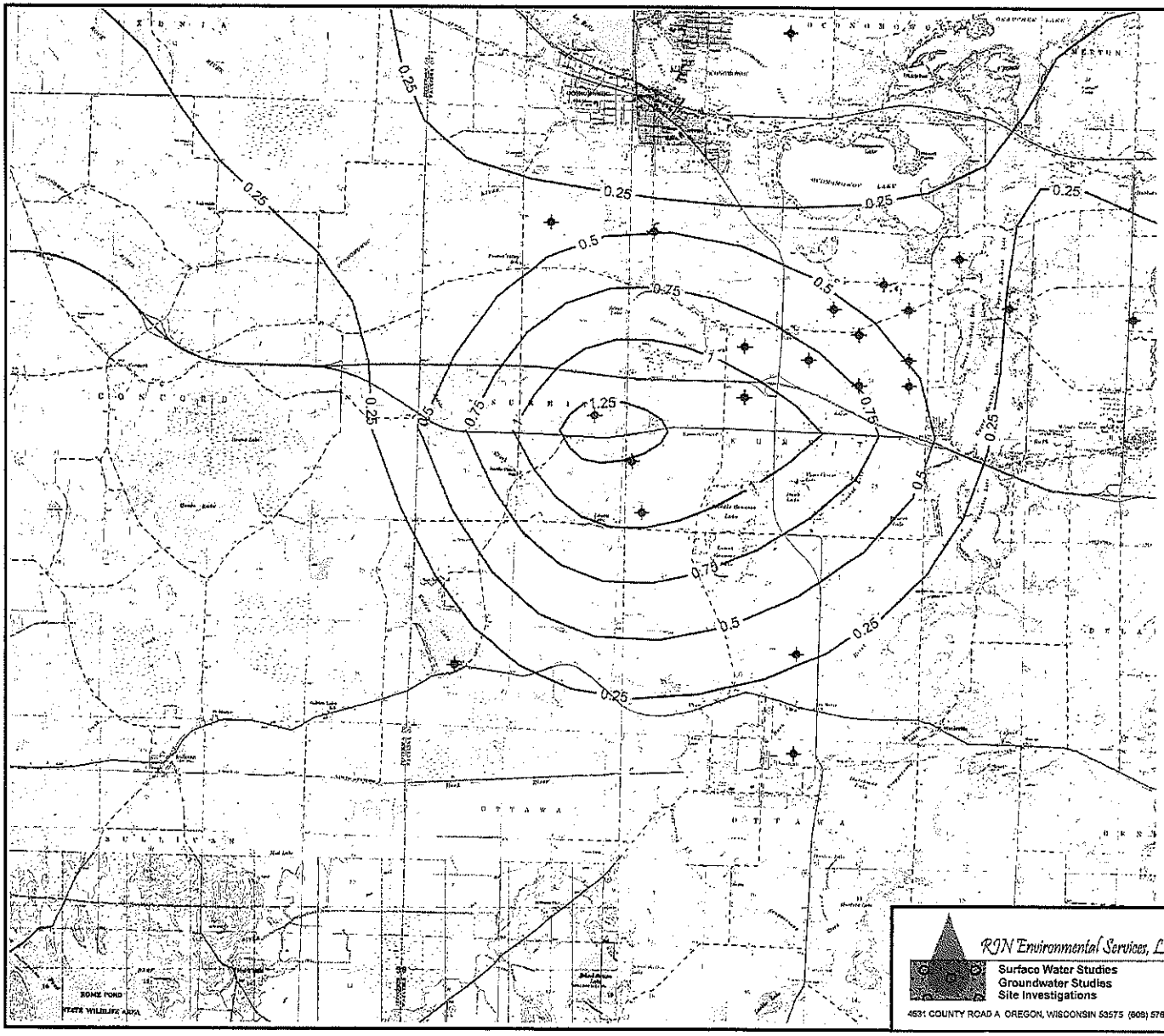

0.2 — SIMULATED DRAWDOWN IN FEET

EXISTING SHALLOW HIGH CAPACITY WELL

SIMULATED NEW WELL

NORTH

SCALE IN MILES

0 0.5 1 1.5 2

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WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 2 WELLS AT 10 MGD
LAYER 1

FIGURE 3

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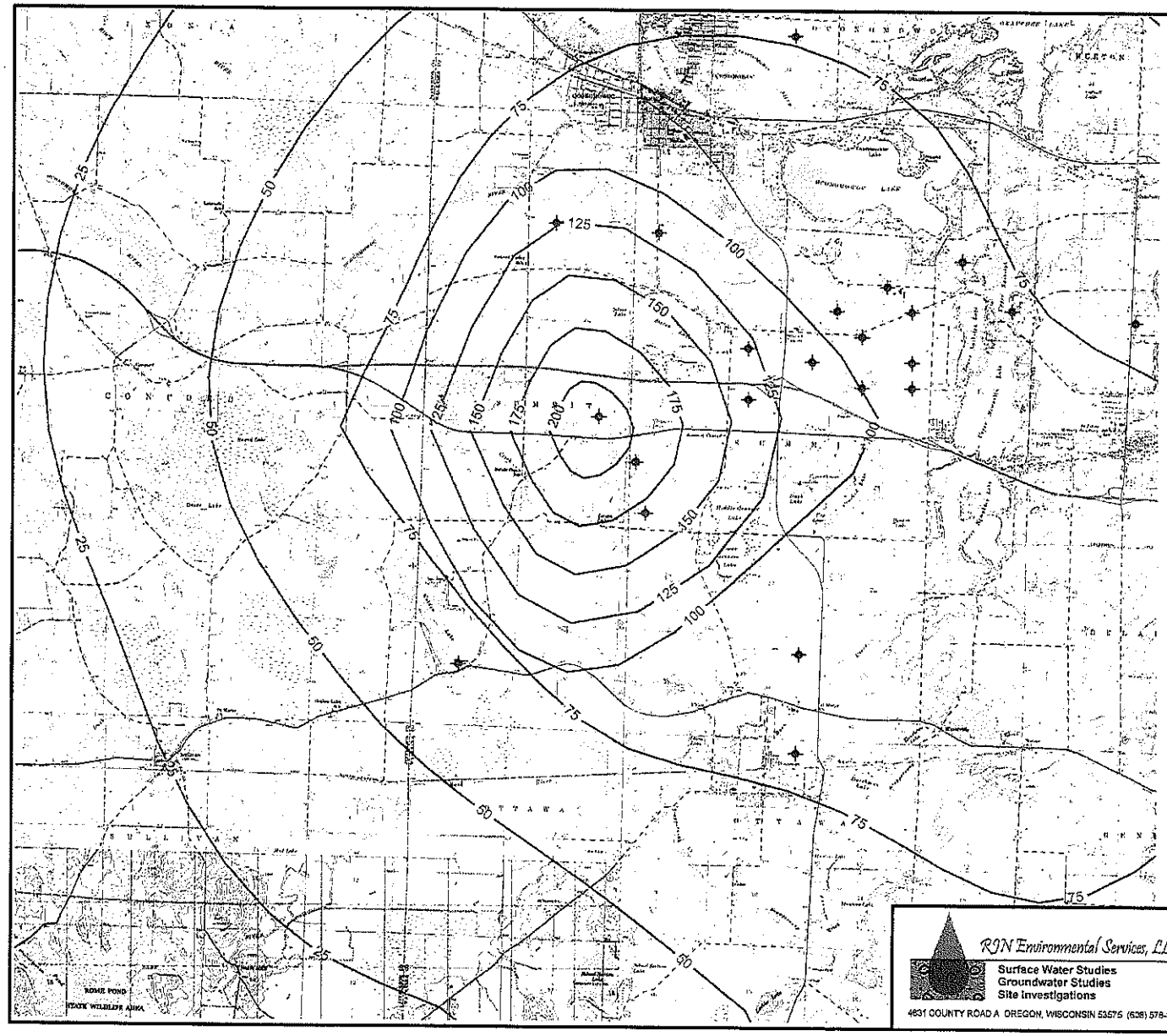
RN	10-201	25 JUN 13	10MGDA DDN L1



25 — SIMULATED DRAWDOWN IN FEET

EXISTING SHALLOW HIGH CAPACITY WELL

SIMULATED NEW WELL

NORTH

SCALE IN MILES

0 0.5 1 1.5 2

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WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 2 WELLS AT 10 MGD
LAYER 11

FIGURE 4

DRAWN BY	PROJ. No.	DATE	FILE
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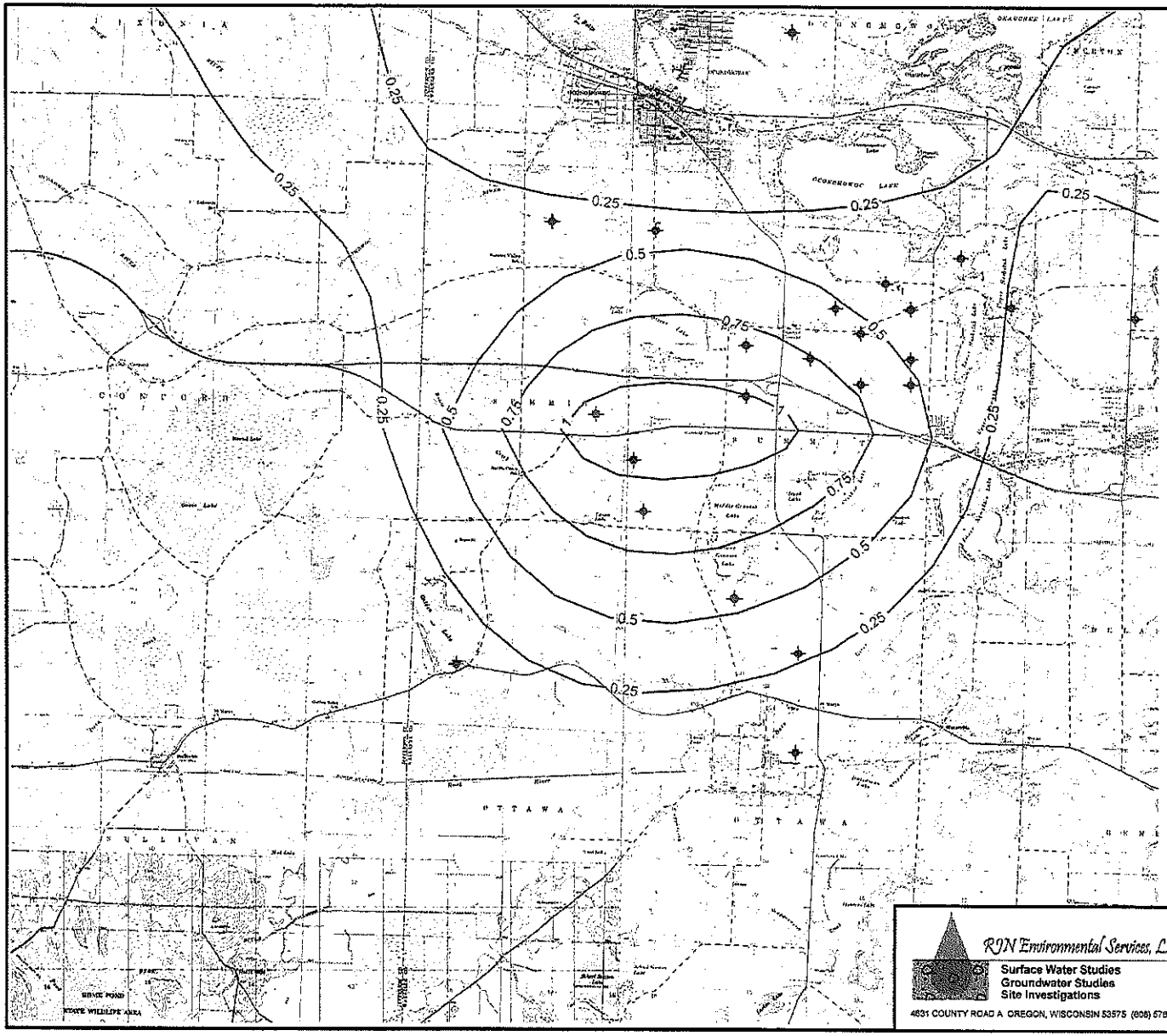

0.2 SIMULATED DRAWDOWN IN FEET

EXISTING SHALLOW HIGH CAPACITY WELL

SIMULATED NEW WELL

NORTH

SCALE IN MILES

0 0.5 1 1.5 2

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WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 3 WELLS AT 10 MGD
LAYER 1

FIGURE 5

DRAWN BY	PROJ. No.	DATE	FILE
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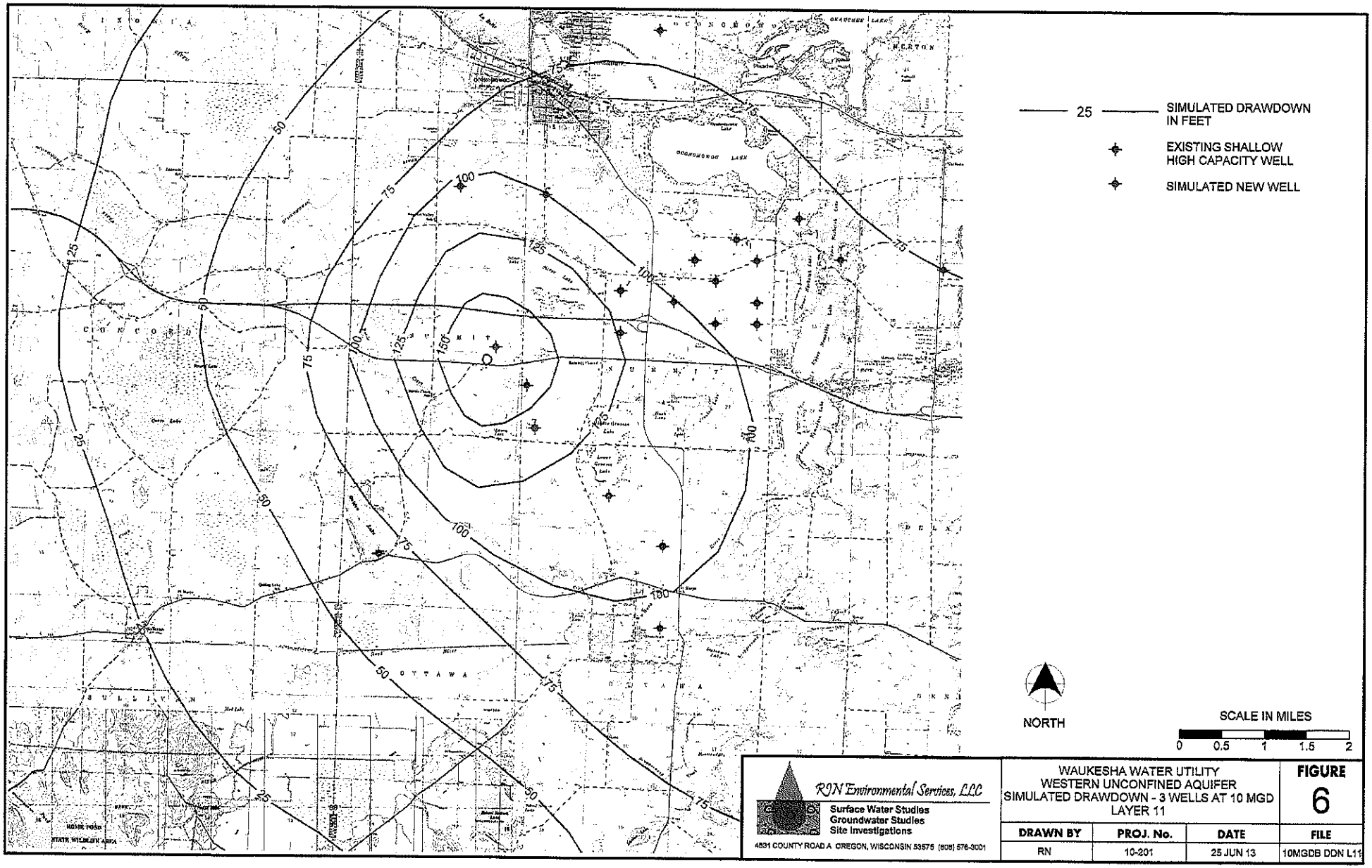

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WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 3 WELLS AT 10 MGD
LAYER 11

FIGURE 6

DRAWN BY	PROJ. No.	DATE	FILE
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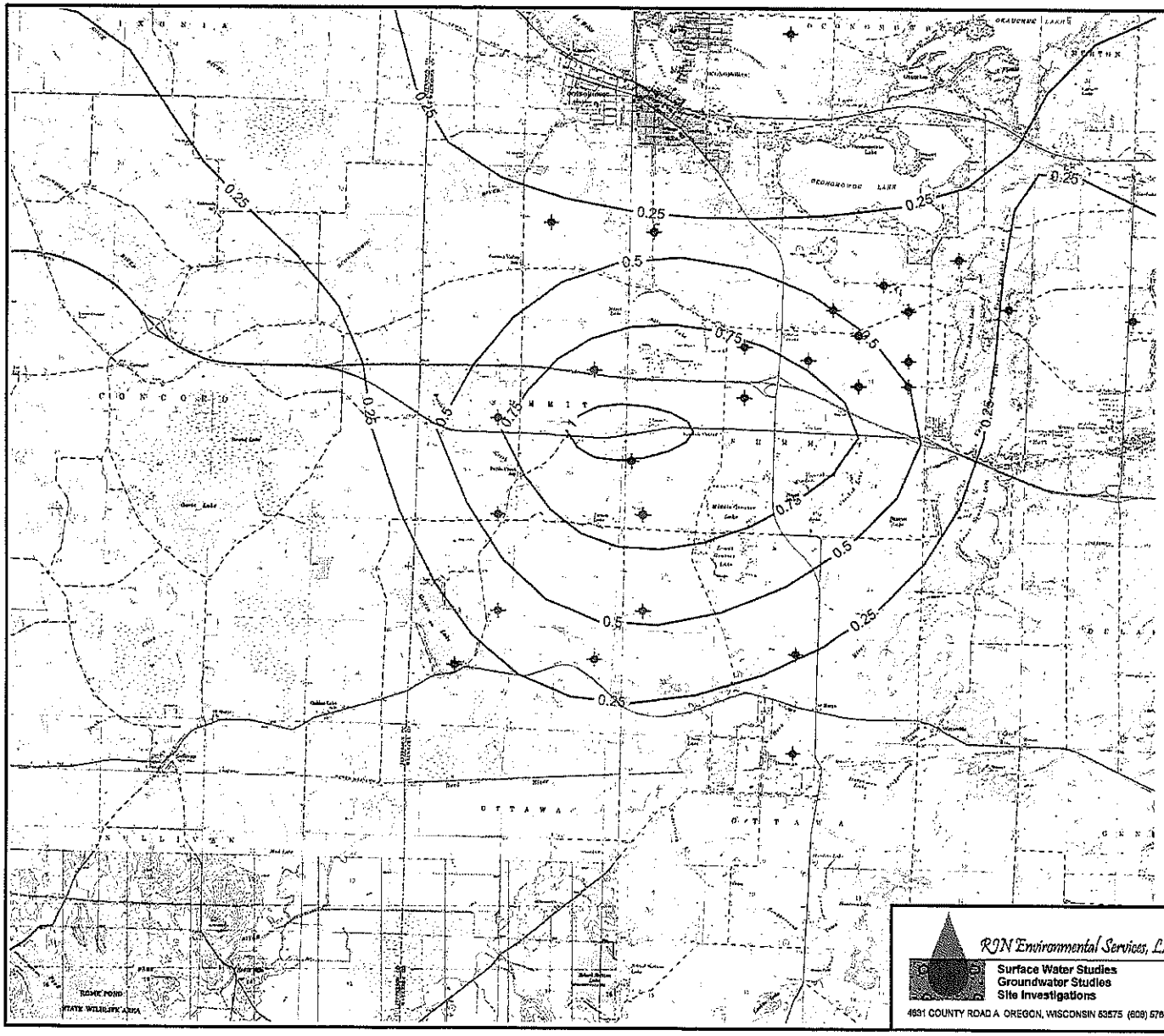

0.2 SIMULATED DRAWDOWN IN FEET

EXISTING SHALLOW HIGH CAPACITY WELL

SIMULATED NEW WELL

NORTH

SCALE IN MILES

0 0.5 1 1.5 2

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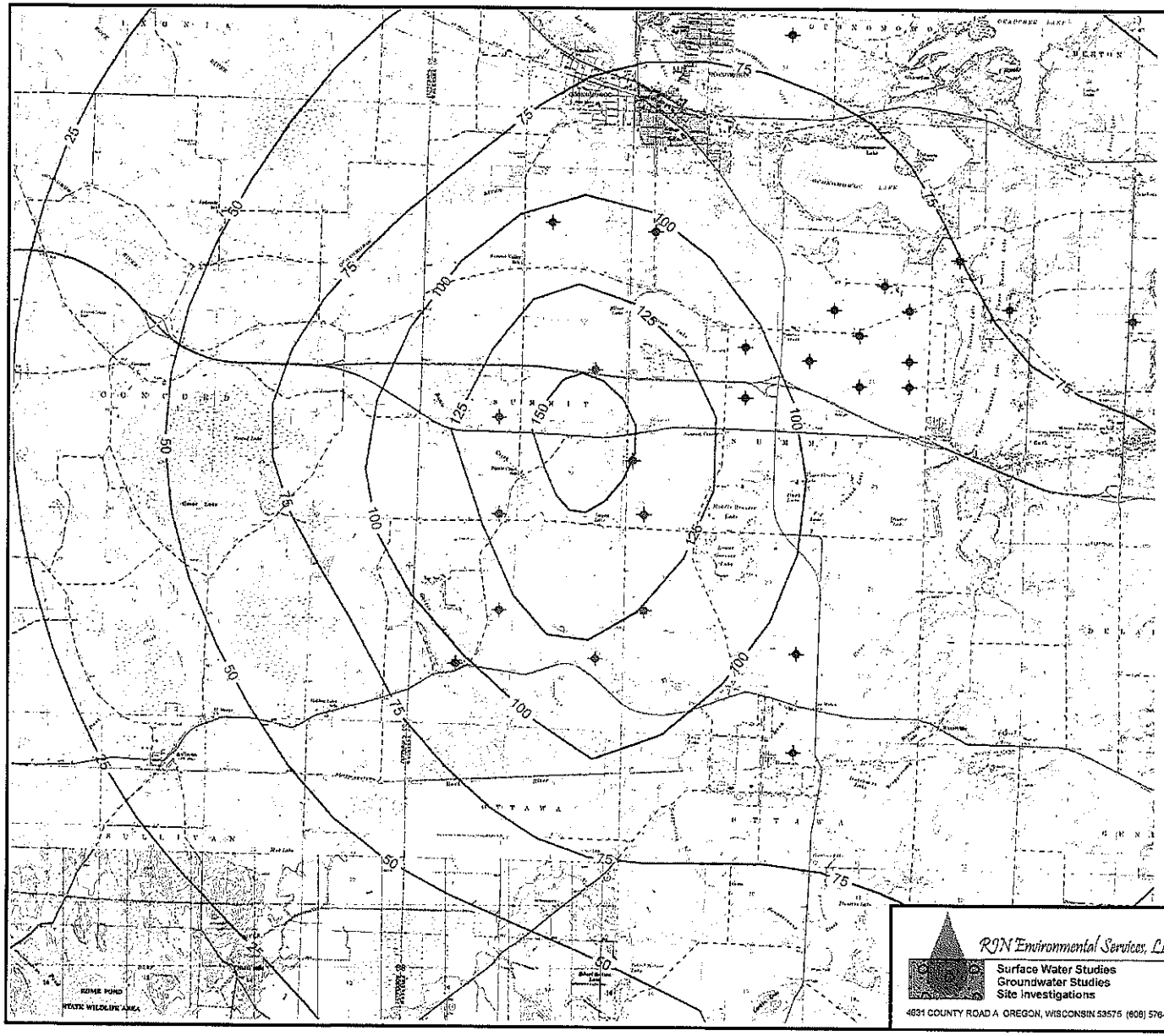
WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 7 WELLS AT 10.5 MGD
LAYER 1

FIGURE 7

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	25 JUN 13	10.5MGD DDN L1



25 — SIMULATED DRAWDOWN IN FEET

EXISTING SHALLOW HIGH CAPACITY WELL

SIMULATED NEW WELL

NORTH

SCALE IN MILES

0 0.5 1 1.5 2

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WAUKESHA WATER UTILITY
WESTERN UNCONFINED AQUIFER
SIMULATED DRAWDOWN - 7 WELLS AT 10.5 MGD
LAYER 11

FIGURE 8

DRAWN BY	PROJ. No.	DATE	FILE
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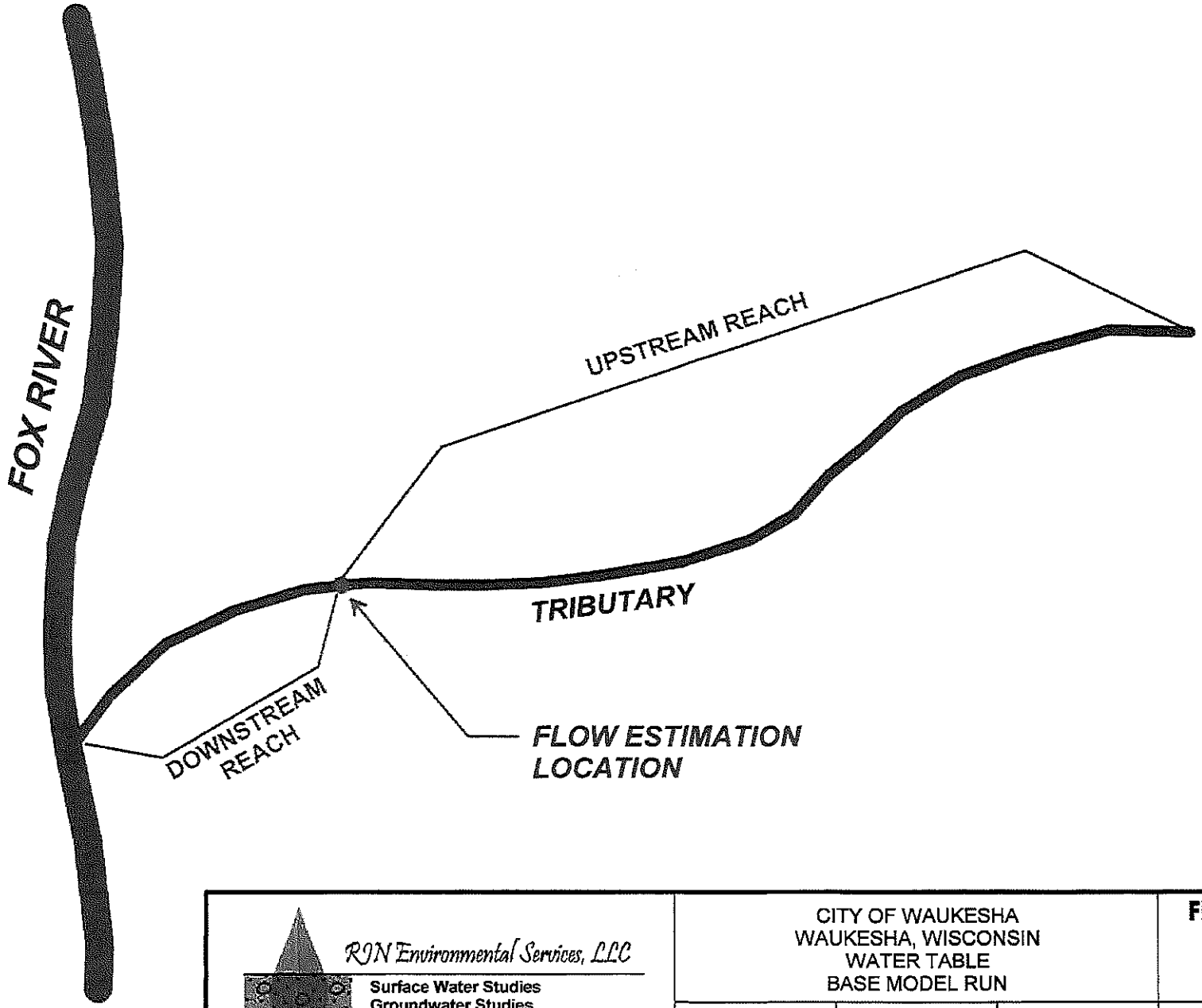

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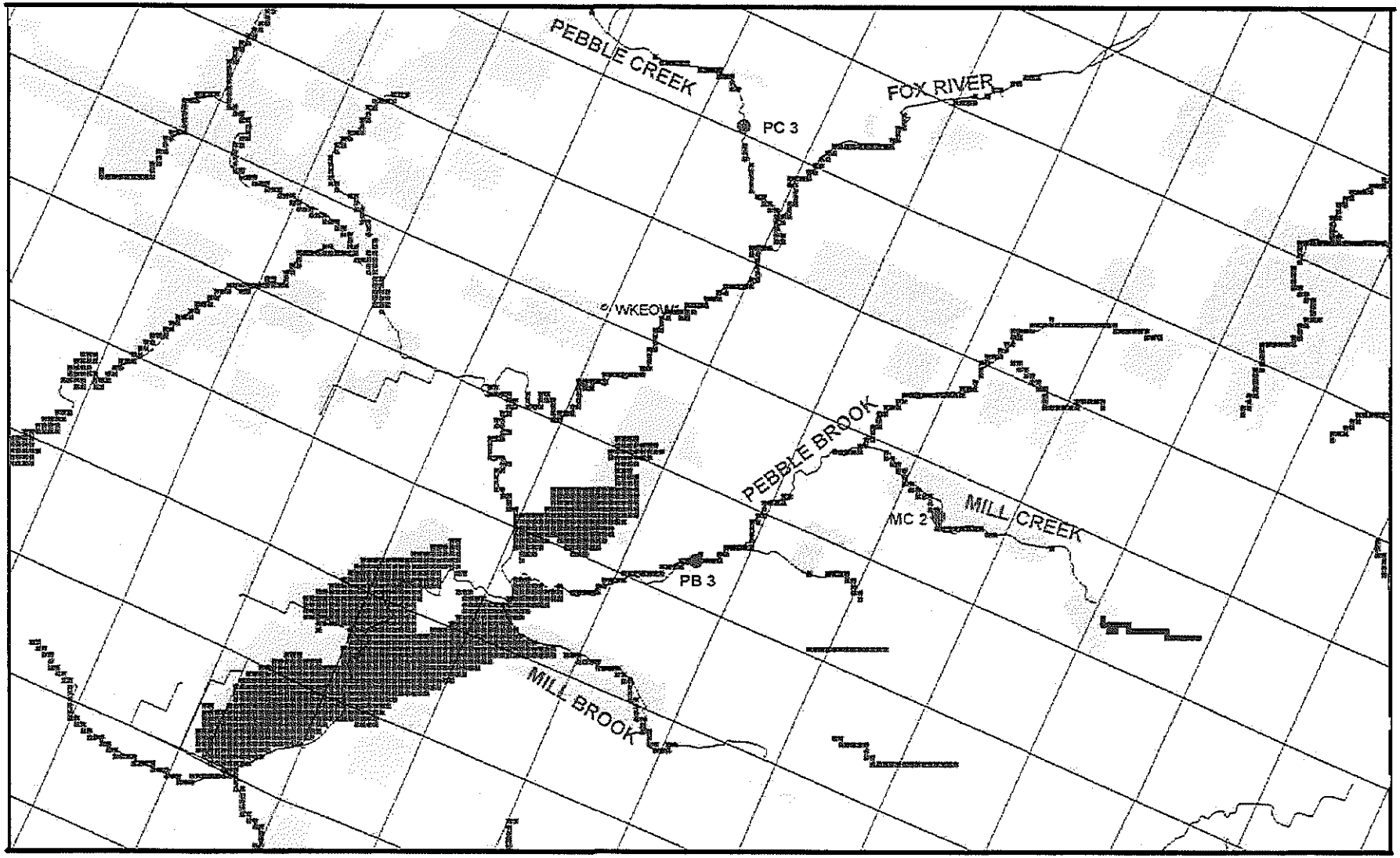
WATER TABLE
BASE MODEL RUN

FIGURE 9

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



NORTH

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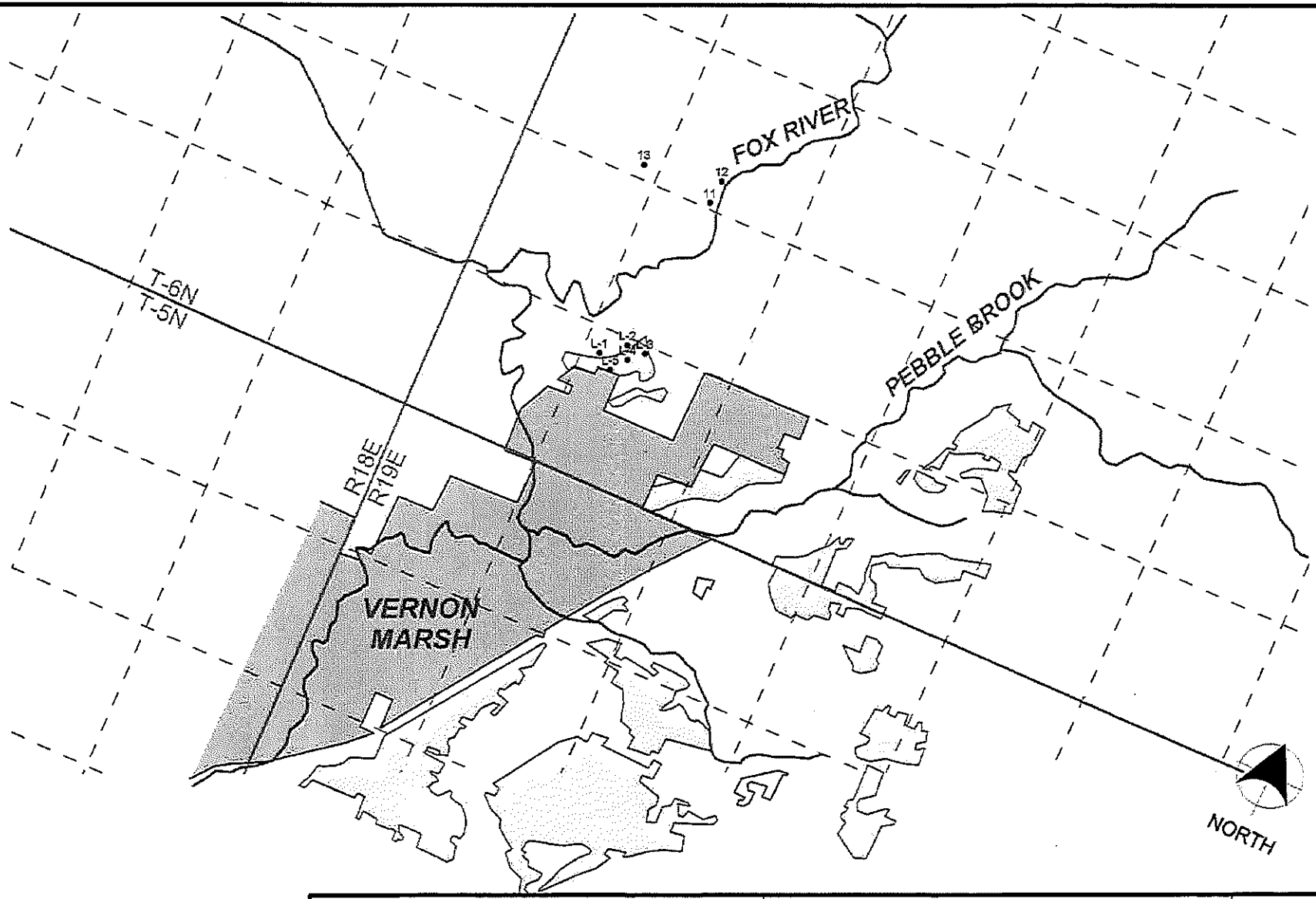
WAUKESHA WATER UTILITY
WAUKESHA, WISCONSIN
STREAM FLOW ESTIMATION POINTS

FIGURE 10

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



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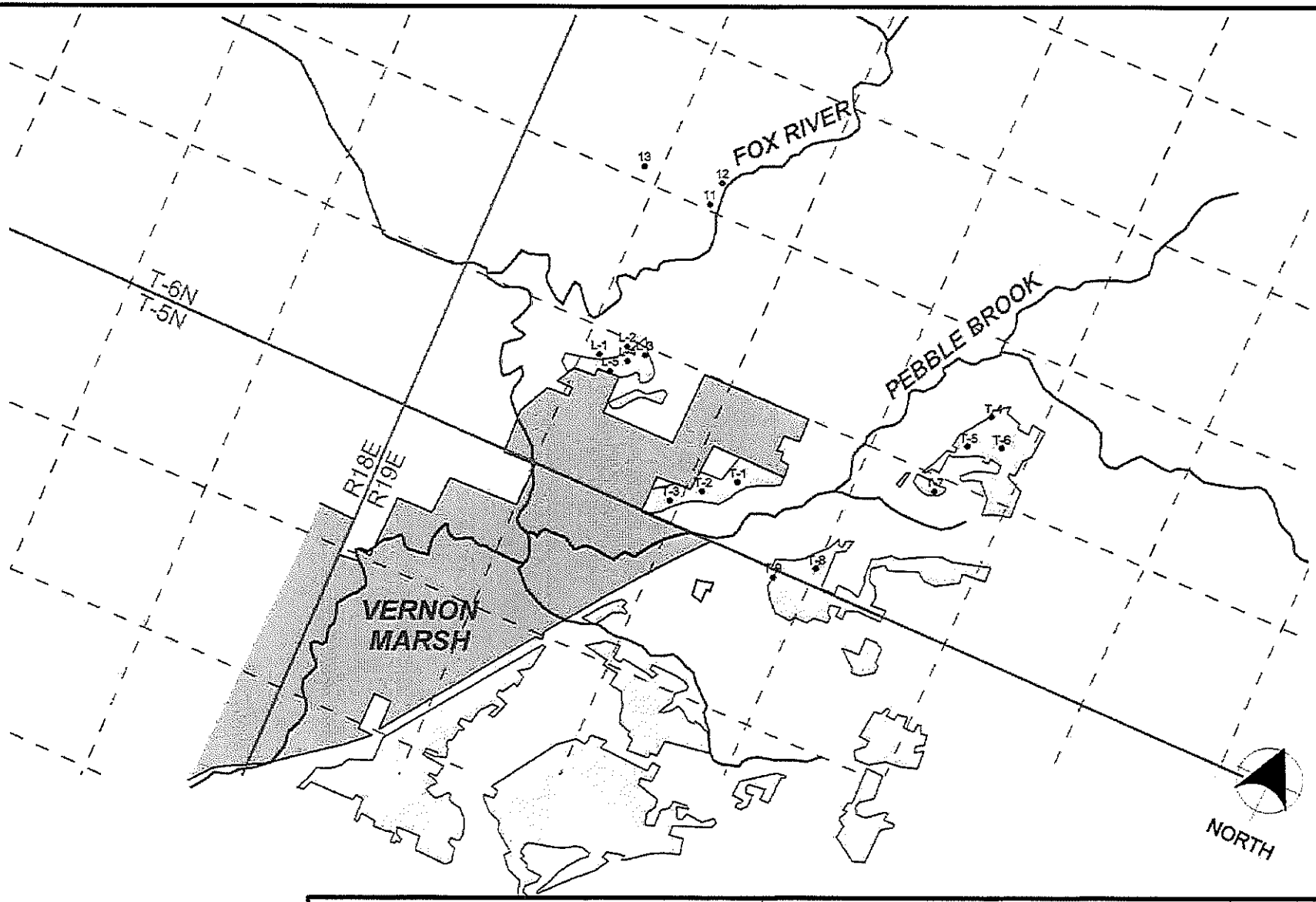
WELL LOCATIONS - SCENARIO 1-1

FIGURE 11

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	03 FEB 13	RUN 1-1



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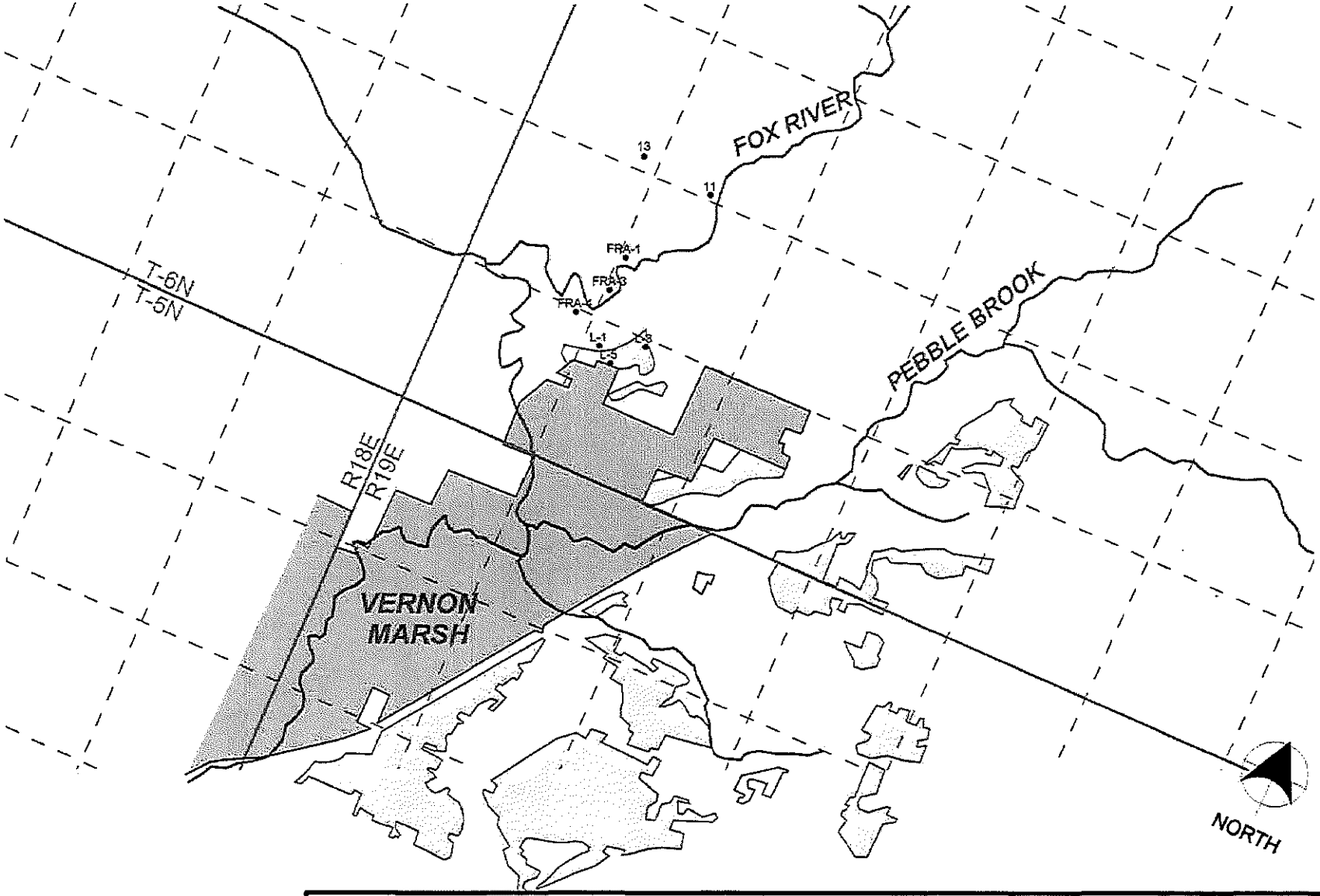
WELL LOCATIONS - SCENARIO 1-2

FIGURE 12

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	03 FEB 13	RUN 1-2



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WAUKESHA WATER UTILITY
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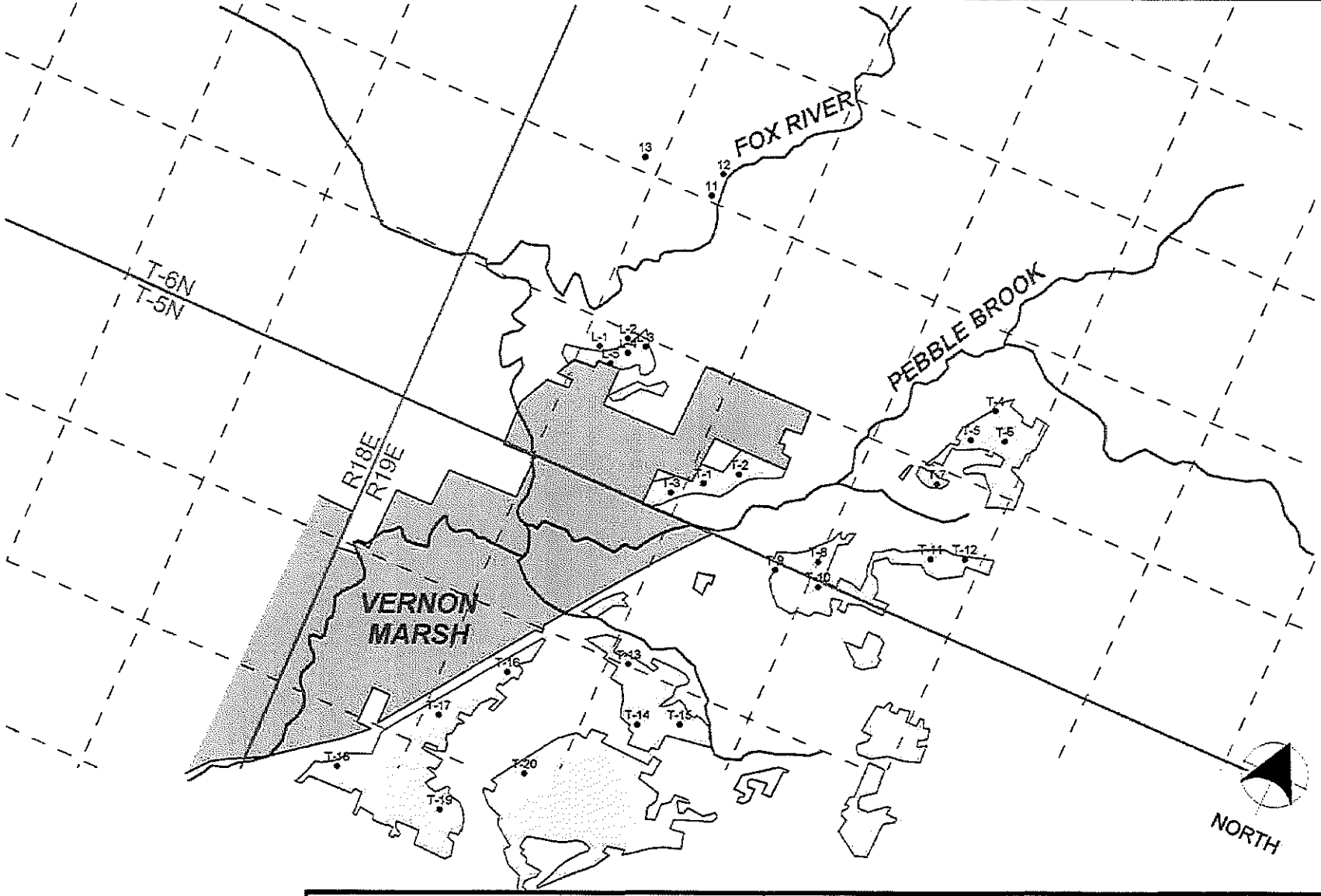
WELL LOCATIONS - SCENARIO 2-1

FIGURE 13

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	03 FEB 13	RUN 2-1



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WELL LOCATIONS - SCENARIO 2-2

FIGURE 14

DRAWN BY	PROJ. No.	DATE	FILE
RN	10-201	03 FEB 13	RUN 2-2