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Managed aquifer recharge and extraction effects on groundwater level and quality dynamics in a typical temperate semi-arid fissured karst system: a multi-method quantitative study

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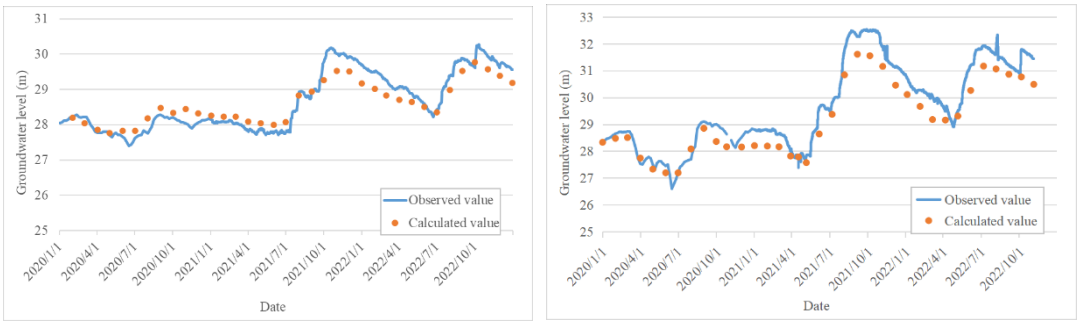
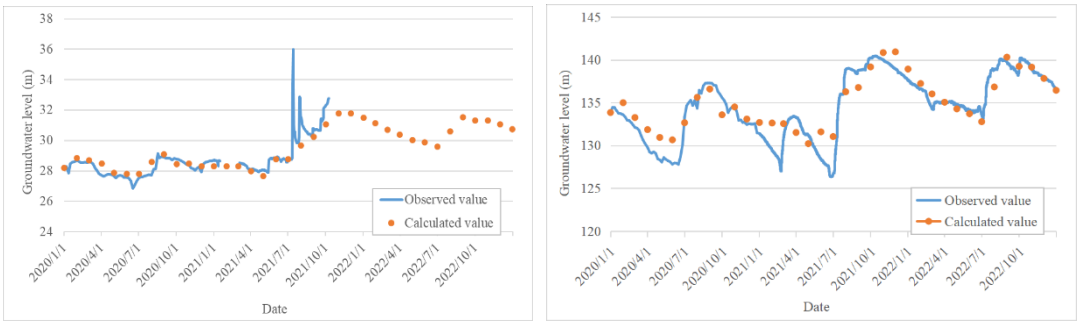
Table S1. Effective porosity at the calculation points

Name	Flow velocity (m/d)	Permeability (m/d)	Hydraulic gradient	Effective porosity
#1-1	233.6	10	4.23E-03	1.81E-04
#1-2	240.3	1	3.85E-03	1.60E-05
#1-3	266.9	2	1.70E-03	1.28E-05
#1-4	295.2	4	1.16E-03	1.58E-05
#1-5	225.5	20	1.20E-03	1.07E-04
#1-6	148.3	20	3.85E-04	5.19E-05
#1-7	82.4	120	3.01E-04	4.39E-04
#1-8	52.4	10	3.07E-04	5.85E-05
#2-1	449.6	10	2.46E-03	5.47E-05
#2-2	293.2	22	1.03E-03	7.70E-05
#2-3	193.5	80	1.67E-04	6.89E-05
#2-4	356.3	80	2.78E-04	6.24E-05
#2-5	307	50	4.42E-04	7.21E-05
#3-1	63	0.3	1.07E-02	5.09E-05
#3-2	96.8	0.3	1.26E-02	3.90E-05
#3-3	165.1	1	1.29E-02	7.83E-05
#3-4	287.7	20	2.08E-03	1.45E-04
#3-5	275.7	120	9.88E-04	4.30E-04
#3-6	71.8	8	8.65E-04	9.64E-05
Max	449.6	/	/	4.39E-04
Min	52.4	/	/	1.28E-05
Average	216	/	/	1.08E-04



(a) Baotu Spring water level

(b) Qiaozili water level

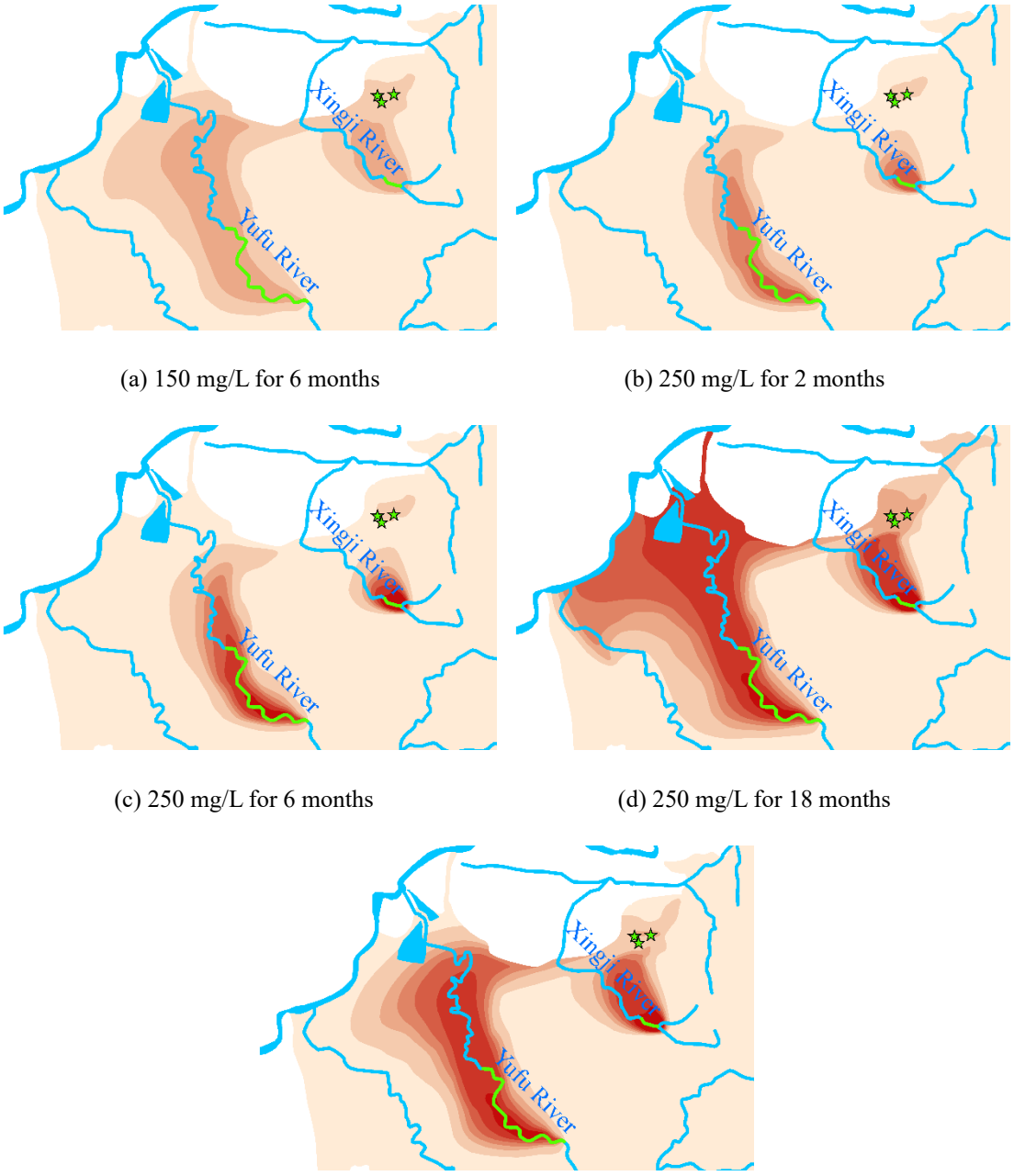


(c) M82 water level

(d) A2-30 water level

Figure S1. Identification and verification result of the groundwater flow model

Figures S1(a)–(d) present the water-level fitting results of monitoring wells in the groundwater flow numerical model of the study area. Among them, Baotu Spring (Fig. S1(a)) and Qiaozili (Fig. S1(b)) are located in the discharge zone, while M82 (Fig. S1(c)) and A2-30 (Fig. S1(d)) are situated in the recharge zone. The numerical model successfully replicates the observed hydraulic head dynamics. The maximum discrepancies between simulated and observed water levels are (1) 0.539 m for Baotu Spring, (2) 0.975 m for Qiaozili, (3) 0.883 m for M82 (after excluding abnormal fluctuations in observed data), and (4) 4.460 m for A2-30. The larger discrepancy at A2-30 is attributed to its location in a mountainous area with high and highly fluctuating groundwater levels. For all other monitoring wells, the differences remain below 1 m, indicating that the numerical model reliably simulates groundwater dynamics and is suitable for managed aquifer recharge (MAR) studies.



(a) 150 mg/L for 6 months

(b) 250 mg/L for 2 months

(c) 250 mg/L for 6 months

(d) 250 mg/L for 18 months

(e) 350 mg/L for 6 months

Figure S2. Evolution of sulphate concentration in karst groundwater under MAR