Regional Groundwater Flow Modeling of Yarkant Basin in West China

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Abstract: West china is very arid especially around the Tarim basin. As scarce precipitation and intense evaporation causes water resource shortage in this area, the ground water deeply depends on the conversion of surface water such as rivers, reservoirs, manual channels, and the farms irrigation. Rainfall is not effective to groundwater. Based on the remote sense, the GPS measure, field investigation, geophysical exploration and probe drillings, the total supply of groundwater and the rational pumping yield of the Yarkant basin was determined combining qualitative analysis. The temporal and spatial variation of the groundwater level and the flow fields was forecasted after the new well field was put into use with Visual Modflow. Using Monte-Carlo stochastic method, the recharge was simulated and predicted. The results showed that the yield in the Yarkant valley was about 10.09×10^8 m^3/a.

Keywords: groundwater modeling, groundwater recharge, Visual Modflow, Yarkant Basin

1 Introduction

Yarkant basin is the ultimate oasis in China located at the Takelamagan desert and the Buguli desert and Tuolulake Desert. The total area is 10.81×10^4 km^2 including the mountainous area 6.08×10^4 km^2 and plain 4.73×10^4 km^2. The population is 175×10^4. Scarce precipitation and intense evaporation make this area short of water resources.

The total water resource is $76.49\times10^8 m^3/a$ including the fluvial resource and the natural groundwater replenishment. The ground water is deeply depend on the conversion of surface water such as rivers, reservoirs, manual channels, and the farms irrigation. The translation of surface water supply to groundwater and the natural groundwater replenishment is $42.72\times10^8 m^3/a$.

2 Foundation of groundwater resource simulation model

2.1 Extension of simulation

The model scope of the Yarkant basin plain include the gravel incline bajada in front of mountain and the alluvial and lake plain. The breadth of model is 50~60 km and the extent is 330 km. the model height is between 800 to 2400 m.

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2.2 The spatial variance and boundary generalized

The model was divided into 330*164 elements with the X-axis 330000 m and the Y-axis 164000 m, and 7 layers considering the physical prospecting and hydro-geological characteristics. The confining stratum and aquifer layer were: clay—mild-clay—mild sand-clay and coarse sand—fine sand and the bedrock. The total height ranges from 800 to 2400m. Thus each layer was divided into 54120 elements and whole model has 378840 elements.

For the seasonal character of river stream, precipitation, evaporation, the carry water across field, and the exploration of groundwater, the model divided into 7 stress period and 365 time steps in order to simulate the conversion between the river stream and groundwater exactly.

Boundary conditions: there are mountains at the south, plain in northern and desert in the else direction, so the south is an inflow boundary, and northern, eastern, western are the general inflow-outflow boundary; the reservoirs are the fixed level boundary; the river, streams and channels are the change water level boundary **(Fig 1)**.

2.3 Parameters

The parameters used in modeling including the hydraulic

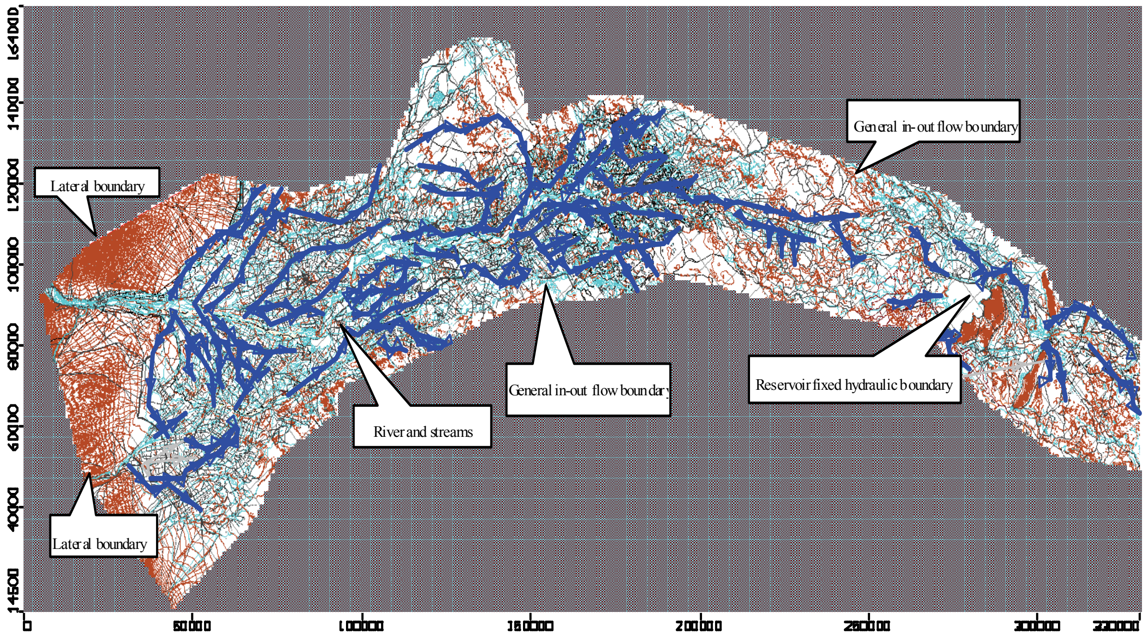

Fig 1 The boundary of model for Yarkant basin

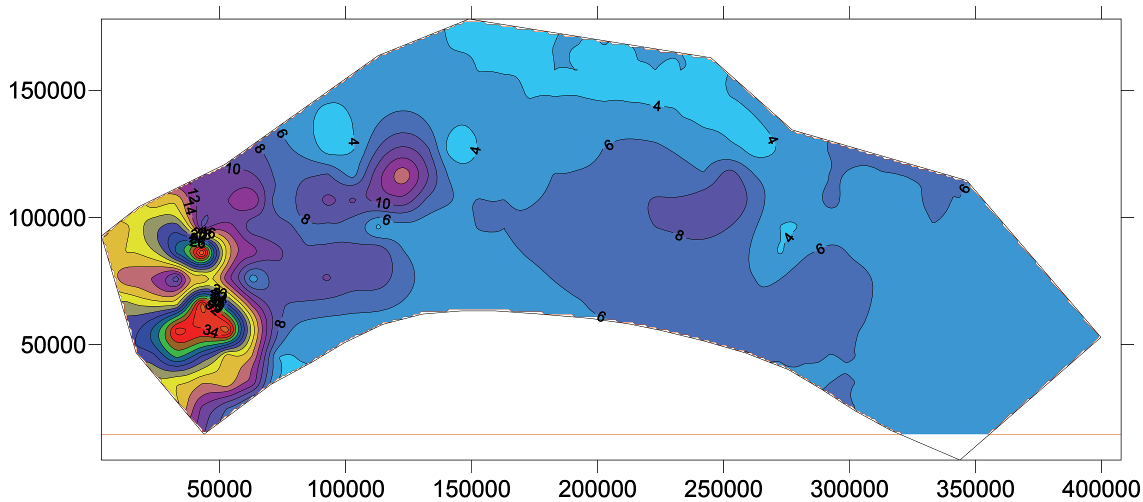

Fig 2 Hydraulic conductivity contour of Yarkant basin

conductivity(*K*), precipitation and seepage coefficient, evaporation, the effective porosity and specific yield of aquifer. The water levels of the river, streams channels, the reservoirs.

Based on the data from pumping field test and field test, though analyze, filtration and re-computation obtained hydraulic conductivity and constructed the hydraulic conductivity contour of Yarkant basin(Fig.2).

Precipitation in Yarkant basin was scarce. Based on the data of five weather stations in this area, the average rainfall from 1953 to 2002 is 53.14 mm/a. And the rain concentrated on May、Jun、Jul、and Aug, the maximum is 9.3mm in Aug. Contrast with precipitation, the evaporation is 2380 mm/a and the maximum value is from Apr to Sep.

3 Simulation scheme and verification

3.1 modeling schemes

The model have three schemes: (1) verification model. (2) systematic cycle model, simulated the groundwater flow according to field condition and exploration and evaluated the quantity of groundwater. (3)forecast model, considering the water-saving measures in the future, the hydro-geological conditions would change greatly, simulated the groundwater flow and evaluated the quantity of groundwater.(Table 1)

3.2 simulation verification

After established the space physical model, using the initial seepage field to adjust the initial water level and other parameters. There are three methods to define the initial groundwater level: 1. based on the monitoring data of wells and boreholes, construct the water level by trend analysis or interpolation; 2. using the hydraulic

Table 1 Three model schemes

schemes	operating	Flow pattern	time	Stress period	steps	Purpose of model
I	normal	Unsteady fluid flow	1 year	7	72	Verification
II (normal)	II	Unsteady fluid flow	1 year	7	72	simulate the groundwater flow and evaluate the quantity of groundwater now
III (program)	III1	Unsteady fluid flow	1 year	7	72	simulate the groundwater flow and evaluate the quantity of groundwater using program
	III2	Unsteady fluid flow	1 year	7	365	simulate the potential exploration using program.

gradient, then calculate the bury depth; 3. using the steady flow model and take the results as the initial seepage level.

In this paper, the first and third methods were used. Based on the data from 952 drills, though the trend analysis gained the water levels of each element as the steady flow level, then run the model and consider the results as the initial water level of unsteady flow.

Fig 3 is steady flow field in contrast. Compare the monitoring contour of water level (red line) with the steady flow field(green line), it can be seen that the flow field influenced by the landform, the water level degraded gradually from the upper to lower area of the Yarkant river. The level accord with the drills level preferably, indicates that the simulating results correspond with the actual. The contour line zigzag obviously near the river, streams or the reservoirs. Fig 4 selected four monitoring spots in order to contrast the water level with simulate results.

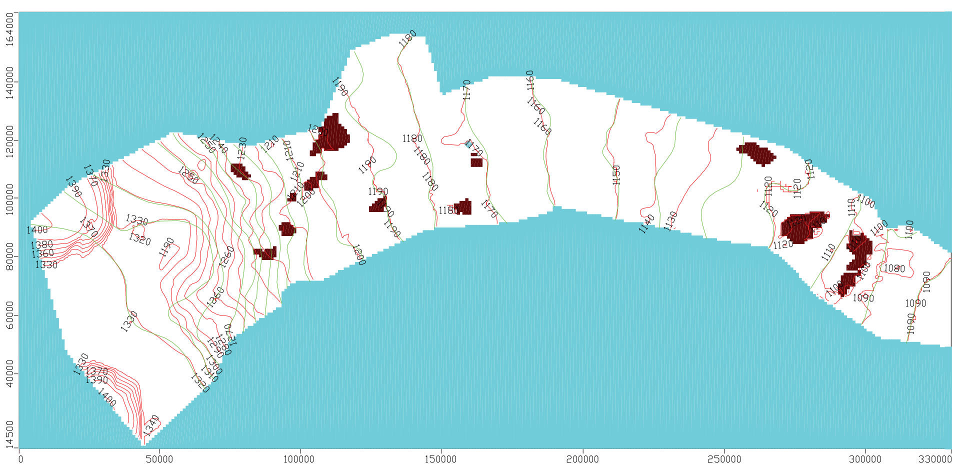

Fig 3 The groundwater flow field

(green line is monitoring level, red line is fitting level)

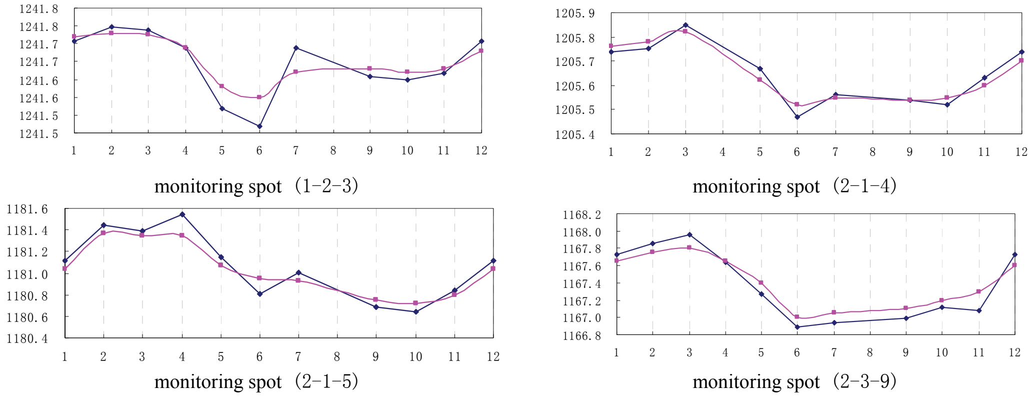

Fig 4 contrast by the part of monitoring spots and fitting element

4 Groundwater resource analysis

The model of Yarkant basin involve the inflow include seepage from the mountain, river seepage, channel seepage, reservoir seepage, precipitation and the irrigation seepage, the outflow include the groundwater evaporation, drainage to the channels, exploration, and the under groundwater outflow.

With the simulating parameters and the subprograms such as RIV, STR, REV, RCH, WELL and so on, run the model to compute the inflow and the outflow of groundwater resource in Yarkant Basin oasis plain, the result lists in Table 2.

Table 2 The inflow and the outflow of groundwater resource in Yarkant Basin oasis plain

inflow	quantity ($10^8m^3/a$)	percentage	outflow	quantity ($10^8m^3/a$)	percentage
seepage from the mountain	0.53	1.21%	Lateral seepage	0.77	1.76%
channel seepage	25.48	58.27%	groundwater evaporation	24.96	57.14%
precipitation and irrigation seepage	4.55	10.40%	Exploration	5.37	12.29%
reservoir seepage	4.37	9.99%	drainage to the channels	12.58	28.80%
river seepage	8.80	18.84%			
sum	43.74	100.00%	Sum	43.68	100.00%
Difference value	0.12		Difference percent	0.25%	

At present, the supply of groundwater is $43.74\times10^8m^3$ per year in Yarkant basin. The seepage from mountain is $0.53\times10^8m^3/a$, while the river seepage, channel seepage, reservoir seepage, precipitation and the irrigation seepage totally $43.21\times10^8m^3/a$. For the rainfall is scarce, it can be take into the irrigation seepage. The data show that the conversion of surface water into groundwater is superior among the inflows of groundwater resource, occupied 98.79％ of total inflows.

Among the outflows, the exploration of groundwater is only $5.37\times10^8m^3/a$ while the total outflow is $43.68\times10^8m^3/a$. And that the inefficacy evaporation of groundwater is $24.96\times10^8m^3/a$ occupied 57.14% of total outflow. Thus it can be seen that it is potential to degrade the inefficacy evaporation to increase the exploration at the Yarkant basin plain.

Furthermore, based on the normal exploration status, simulated the potential of exploration under the condition that the water-saving measures will be put on in the future. As a result, the potential exploration is $4.73\times10^8m^3/a$ in the oasis plain by reduce the evaporation and outflow of the river and streams.

5 Conclusions

The simulation result come to the conclusion that supply and distributing of groundwater restricted by the weather and surface water in western china. The groundwater of Yarkant basin related to the surface water with large

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quantity. The exploration is not enough to met the demand of irrigation for the seasonal lack of water in the spring and autumn, so the potential of increase the exploration not only fit the economy demand but also accord with the hydro-geology status.

Based on the data of survey and test, analysis the supply, flow and excretion of groundwater, and evaluated the water resource using modeling. On contrast to the balance analysis, the modeling results fit with the balance analysis well.

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