Assessing the severity of the Mashhad-Chenaran aquifer crisis using C/RW, GWD, and GDS indices

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Abstract-The ever-increasing growth of population and development in the agricultural and industrial sectors, coupled with drought, has intensified the exploitation of the groundwater resources from the Mashhad-Chenaran Aquifer (MCA), which has caused an extensive drop in the water level and a sharp decrease in groundwater reservoirs. In this paper, a number of indices based on renewable water have been used to evaluate the severity of the MCA crisis. Based on this, the ratio of consumed water to renewable water (C/RW) was estimated to be 1.3 on average for the past 6 years, which is a sign of imbalance according to the standard. And the dependency indices on renewable groundwater (GWD) was more than 80%, and the stress resulting from the increase in groundwater abstraction (GDS) was estimated to be more than 181%. According to these indices, the MCA is in a water deficit condition. In other words, the renewable water cannot meet the water needs and the groundwater of MCA must be managed more carefully. It is necessary to take immediate and appropriate solutions by related organizations and companies.

Key Words: Aquifer crisis, Mashhad-Chenaran, Water quantitative indices

1. INTRODUCTION

In arid and semi-arid areas, we are faced with limitation of surface water resources, so the growth of different sectors of society need sustainable management of existing fresh water, specially groundwater, resources. During the past few decades, many researchers have evaluated and analyzed the vulnerability of water resources using different indices [1, 2, 3]. Therefore, choosing criterions that show more accurate assessment of water status can bring political decisions closer to scientific ones. In this paper, by using three different quantitative indices (including the ratio of consumed water to renewable water (C/RW), the dependency on renewable groundwater (GWD), the stress resulting from the increase in groundwater withdrawal (GDS)), the critical situation of Mashhad-Chenaran aquifer (MCA) has been evaluated.

2. STUDY AREA

The study area, MCA, is located in the Qaraqom catchment area with an area of about 9957 km^2, between 58° 20′ to 60° 8′ east longitude and 35° 40′ to 36° 3′ north latitude "Figure 1". The MCA is the most important alluvial aquifer in terms of size and exploitation rate in Razavi Khorasan province, NE of Iran.

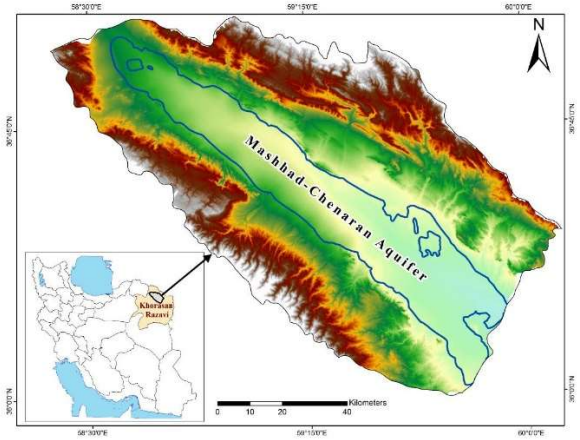

Fig 1- The location of the Mashhad-Chenaran aquifer.

3. MATERIALS AND METHODS

In order to estimate the volume of renewable water, the required information such as the components of the alluvial aquifer balance (includes annual precipitation, runoff

volume, the volume of withdrawal from surface and groundwater resources), and also to investigate the groundwater consumptions in the study area, the data of the recent 6 years (1395-1401) were taken from Khorasan Razavi Regional Water Company. Then, all three quantitative indices of C/RW (which represents the amount of consumption of the agricultural, industrial and drinking fields out of the total renewable water in the area and the sustainability of aquifer), GWD (which define the withdrawal volume of groundwater compared to the total volume of water sources (surface and groundwater)), and GDS (which evaluate the condition of the groundwater balance) were calculated using equations, 1, 2, and 3, respectively [4]. The critical condition, dependency and stress of aquifer for different indices, were given in Table 1.

$$C/RW = \frac{(V_r+V_g) - I_r}{RW} \quad (1)$$

$$GWD = \left(\frac{V_G}{V_S}\right) \times 100 \quad (2)$$

$$GDS = \left(\frac{V_{abstraction}}{V_{recharge}}\right) \times 100 \quad (3)$$

Where: V_r, the withdrawal volume of surface; V_g, groundwater withdrawal volume; I_r, is the volume of back water; R_W, is the volume of renewable water; $V_{abstraction}$, is the total volume of abstraction from the aquifer; and $V_{recharge}$, represents the volume of aquifer recharging. In all items, volume is in million cubic meters (MCM).

Table 1 – Aquifer critical condition, dependency and stress for different indicators.

Indices	Critical, Dependency and Stress Conditions
C/RW	
<0.4	Good
0.4-0.7	Critical
0.7-1	Extreme Critical
>1	Unbalanced Aquifer
GWD	
< 25 %	Low Dependency
25-50 %	Intermediate Dependency
>50 %	High Dependency
GDS	
< 25 %	No stress
25-40 %	Low Stress
>40 %	High Stress

4. RESULTS AND DISCUSSION

The calculated three quantitative indices for MCA is tabulated in Table 2. The results show that along with the development of technology, the use of groundwater from MCA has been greatly intensified. Based on C/RW results (average of 1.3), it can be seen that the amount of consumed water from MCA is more than the amount of renewable water and the MCA is an unbalanced aquifer, which must be taken a standard, long-term development plans to obtain C/RW ratio of 0.4. The calculated values of GWD for MCA, is more than 80%, which confirms the high dependence of the water consumption on groundwater resources rather than on surface water sources. Also, according to the calculated GDS values (average of 181%), as a result of over-abstraction from MCA, the storage of aquifer, the groundwater levels, and the aquifer's yield were decreased dramatically. For this reason, the MCA is a critical aquifer with high stress situation. As a result, the MCA is in a water deficit condition in terms of the investigated indices. In other words, because of the high population in this area, the renewable water cannot meet the water needs. It is necessary to take appropriate solutions by related organizations and companies.

5. AKNOWLEDGENT

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Table 2 Water resources conditions, water balance items and calculated three quantitative indices for the Mashhad-Chenaran aquifer (MCA) for the past six years

Items	Years					
	95-96	96-97	97-98	98-99	99-00	00--01
Water Resources Condition						
Wells	6704	6704	6326	6086	5797	5818
Qantas	1084	1084	1084	1084	1008	1008
Springs	656	656	656	656	668	668
Groundwater withdrawal (MCM)	967	900	903	878	695	747
Surface water withdrawal (MCM)	158	128	143	193	236	226
Drinking water withdrawal (MCM)	274	267	269	292	299	321
Industries water withdrawal (MCM)	149	128	112	108	92	98
Agriculture water withdrawal (MCM)	702	634	665	671	535	549
Water Balance Items						
Elevation of Precipitation (mm per year)	321	189	374	333	125	223
Precipitation (MCM)	3200	1878	3725	3312	1245	2219
Evapotranspiration (MCM)	2318	1288	3009	2472	932	1776
Renewable Water (MCM)	883	590	716	841	313	442
Surface Renewable (Run-off) (MCM)	98	82	148	138	113	146
Underground Renewable (Penetration) (MCM)	785	508	567	703	200	297
Backwater (MCM)	169	328	328	343	322	342
Surface Onput (MCM)	82	68	30	108	90	86
Surface Output (MCM)	21	22	78	44	4	16
Groundwater Onput (MCM)	0	0	53	0	0	0
Groundwater Output (MCM)	12	0	0	4	0	0
Indices						
C/RW	1.1	1.2	1	0.9	1.9	1.4
GWD %	86	88	86	82	75	77
GDS %	127	174	146	127	297	219

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