# RESTORATION PECULIARITIES OF GROUND WATER BASINS IN THE MOUNTAINOUS RELIEF REGIONS

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***Abstract:*** *The goal of the present research is to figure out how to increase the efficiency with which water resources are used in mountainous relief regions on the example of the Ararat Artesian Basin of the Republic of Armenia. The accumulation of significant water runoffs in reservoirs under difficult hydrogeological conditions requires not only large investments in construction, but also in the transportation of water to the consumer, which is fraught with significant water infiltration losses. The paper shows that by the example of artificial recharge of the Ararat Artesian Basin, instead of building a new reservoir to collect 40 million* $m^3$ *of water per year, which requires huge capital investments (5.75-6.25 USD/*$m^3$*), the financial costs can be significantly reduced (0.05-0.075 USD/*$m^3$*) by pumping the same volume of water into the groundwater basin. The obtained results can be used both in different regions of Armenia and in countries with mountainous relief.*

***Keywords:*** *river flow regulation, groundwater basin, artificial recharge, well, environmental and economic justification.*

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## Introduction

Surface water and groundwater resources are considered to be one of the most important material resources necessary for human survival and development. In addition, these resources are key to the sustainability of the natural environment and the evolution of ecosystems [1,2]. The conservation and efficient use of water resources currently face variable and unpredictable global challenges that manifest themselves in various ways [3-5].

The conservation and efficient use of surface and groundwater resources are particularly important in the mountainous regions [6,7]. At present, the issues of regulation and conservation of water resources in mountainous areas are very poorly studied due to their peculiarities [8], and there is an objective need for additional studies, including:

- seasonal fluctuation of river water flows due to spring and autumn floods, as a result of which the efficiency of their use during the growing season is sharply reduced,
- accumulation of water runoff in reservoirs under difficult hydrogeological conditions requires not only large investments in their construction, but also in the transportation of water to the consumer, which, in turn, is fraught with significant water losses due to infiltration and evaporation.

In the present research, taking into account all the aforementioned features, the example of Armenia is considered as a country with a mountainous relief that has similar problems. Such studies are conducted for the first time in the Republic of Armenia.

It is noteworthy that in Armenia the average annual indicator of water resources is 19.70 billion $m^3$ of water, a significant share of which is occupied by evaporation: 11.48 billion $m^3$, and the outflow of the river streams, generated from precipitation, groundwater and boundary waters, is approximately 7.12 billion $m^3$ of water per year. In this regard, there are difficulties in the management and conservation of water resources, which are mainly caused by seasonality and uneven distribution of water sources. In the rivers of Armenia, maximum river water flow is observed in April-May and September-October during active snow melting and heavy rains [9]. As a result, due to the reduced water requirements of plants during the winter season and the scarcity of water in rivers due to light summer rainfall, utilizing these water resources for agricultural crop irrigation becomes challenging. It is worth nothing that approximately 70% of the required total amount of water is not stored in reservoirs and is used inefficiently [10]. In recent years, various ameliorants, as well as, new innovative technologies, have been widely used to improve the efficiency of water use in agriculture [11].

To address the problems of seasonal fluctuations in river flows, 79 reservoirs with a total capacity of 1.40 billion $m^3$ have been built in Armenia, which are used mainly for agricultural soil irrigation to ensure food security within the country and play a significant role in water resource conservation [12]. It should be noted, that many reservoirs in mountainous regions of Armenia constructed in the second half of the 20th century were mostly replenished with outdated pumping equipment and, as a result of long-term operation, may soon cease to function [13].

Notably, significant financial resources are necessary for the reservoir construction (approximately 3-7 USD per $1m^3$ of water, depending on its volume). In mountainous regions with challenging hydrogeological conditions, a substantial portion of the reservoir construction cost pertains to anti-filtering measures for the reservoir's base and walls, along with irrigation canals. This significantly augments the required investment amount. Massive expenditures are also required for measures to ensure the safety of hydraulic structures, most notably dams [14,15].

To address water basin management issues and ensure equitable distribution of water resources in one of RA regions, the construction of the Yeghvard Reservoir was planned. According to the design, the proportion of expenses allocated to anti-filtering measures in the overall construction estimate amounts to 66.8%. Despite the use of expensive anti-filtering materials, calculations reveal notable infiltration losses within the project, amounting to 0.05% per day. Over the course of a year, these losses can accumulate to as much as 18.25% of the collected reservoir water volume. According to calculations, similar losses during water transportation through irrigation canals under the Yeghvard Reservoir project, reach 46%.

Thus, we can conclude that in mountainous areas, the construction of a reservoir for water storage and transportation through canals across plain terrain is inefficient and leads to considerable water losses. International studies in this direction also confirm the difficulty of building in mountainous regions [16,17].

Groundwater, stored in underground basins in mountainous regions, plays a vital role in the formation of water resources [18-20]. For example, in Armenia, 2.40 billion $m^3$ of groundwater runoff is formed per year, out of which 1.19 billion $m^3$ is accumulated in Ararat Artesian Basin (hereinafter referred to as “AAB”), from which artesian wells can provide a stable water flow rate of 5-100 l/s, according to design data. In contrast to surface reservoirs, the groundwater basins are less polluted [21,22], do not require significant operating costs for collection and storage (the cost of pumping them out is relatively low) [23] and are safe from man-made disasters [24]. Therefore, accumulating and pumping water resources from groundwater basins is frequently more effective than building open reservoirs and using water from them for national economic needs. Nevertheless, the intensive and poorly planned exploitation of groundwater basin resources not only results in groundwater depletion, but also leads to deterioration of water qualitative indicators and environmental problems [25-27].

A similar problem arose in AAB between 2007 and 2013, when the growth of numerous spontaneously emerging fish farms was recorded, for the water supply of which a large number of artesian wells were built [28]. As a result, the groundwater basin's water balance has shifted dramatically (Fig.1).

In 1983, the total volume of water used in AAB was 34.6 $m^3/s$ with well fountains accounting for 12.9 $m^3/s$ and deep pumps accounting for 21.7 $m^3/s$, while water from the groundwater basin was not used in fish farming. Despite the increase of total water use which was only 1.8 $m^3/s$ in 2007, the water withdrawal from well fountains increased dramatically, reaching 30 $m^3/s$. In comparison with 1983, the increase was 17.1 $m^3/s$ while deep-well pump water withdrawal dropped dramatically to 6.4 $m^3/s$. Tariffs for electric powerincreased as a result of these measures.12.7 $m^3/s$ of the total water withdrawal was used for fish farming. The reduction of water reserves in AAB reached a peak in 2013, the total withdrawal amounted to 55.5 $m^3/s$ (1.6 times higher than the allowable water withdrawal of 34.6 $m^3/s$), 35.5 $m^3/s$ of which was used for fish farming, which is 22.8 $m^3/s$ higher than the water withdrawal for the same purposes in 2007.

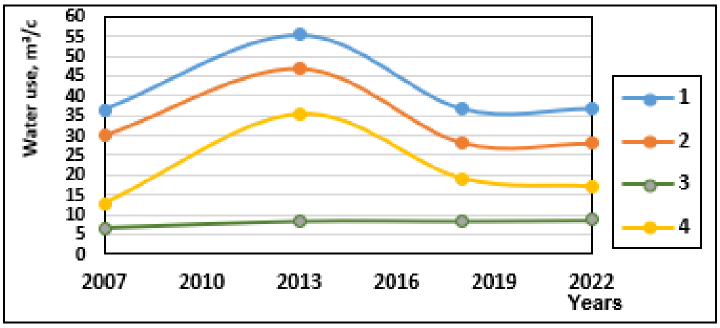


**Fig. 1.** *Dynamics of water use by years in AAB: 1-general water use, 2-from well fountains,3-by deep-water pumps, 4-for the needs of fish farming*

It should be noted that the well fountains contributed to the increase in total water consumption by providing water not only for irrigation but also for drinking and household needs.

It is also noteworthy that as a result of the 2013-2018 measures, total water withdrawal has decreased and has reached 36.6 $m^3/s$ (from 2018 to 2021, there were no significant changes in water use), which stabilized the water balance in AAB, but the negative effects remained. The territory in AAB, which has a positive pressure of groundwater, has decreased threefold (from 32.760 ha in 1983 to 10.706 ha in 2013). Simultaneously, 31 communities were partially or completely cut off from water for irrigation, domestic use and drinking, which they had obtained from well fountains (Sahakyan and Yedoyan, 2020). It should be noted that 122 wells used previously are no longer operational (for this purpose). The flow rate of the Sevjur River water has decreased significantly from 26.1 $m^3/s$ in 1983 to 3.0 $m^3/s$ in 2013. As a result of lowering the groundwater level on 7.0 thousand hectares of irrigated lands, water consumption for crop cultivation increased by 25% (by 14.0 million $m^3$).

The problem emerged in Armenia about the lack of drinking, irrigation and household water in the region requires an immediate solution, including by increasing the water inflow into the groundwater basin.

International experience shows that the best way to solve this problem is artificial groundwater recharge [29-32]. Artificial groundwater recharge (hereinafter referred to as AGR) is not a new concept. Similar hydrogeological activities have been carried out since the mid- 19$^{th}$ century [33]. The United States has wide experience in the use and development of AGR schemes, in particular, systems of infiltration structures and water-absorbing wells have been built in many states [34]. In the Netherlands, since the 1990s, due to the AGR, the annual volume of water resources has exceeded 180 million $m^3$ [35]. In Germany, about 15% of the total drinking water is generated by AGR [36]. Since 1960, artificial recharge of aquifers by preliminarily purified river waters has been carried out in England [37]. In the field of AGR, Israel is one of the world's leading countries, employing the method of water injection (pumping) [38]. AGR is also used in other countries, including Russia, Kazakhstan, India, New Zealand, Argentina, Egypt, etc [39-41].

There are two types of infiltration structures used for AGR: open and closed ones. The first one includes basins, canals, etc, and the second one includes wells, pipelines and water tanks. The open infiltration structures are commonly used to recharge the first groundwater aquifer [42]. These are systems of basins with a sand-covered bottom. The closed infiltration structures are recommended when the ground surface is covered with low- penetrating soils or when the aeration zone has a multilayer structure. The vertical closed infiltration wells are used here, with pumping stations that require significant operational costs [43].

Thus, in mountainous regions river flows are characterized by significant seasonal fluctuations due to spring and autumn floods, as a result of which the efficiency of their use during the growing season is sharply reduced.

The accumulation of river runoffs in reservoirs under difficult hydrogeological conditions requires not only large investments in their construction (3-5 USD/$m^3$), but also in the transportation of water to the consumer, which is fraught with significant infiltration losses from the built structures. Therefore, in many countries it is preferable to use water from groundwater basins, into which, in addition to precipitation, river flows are forcibly directed.

It should also be noted that in mountainous regions, the use of the difference of natural elevations makes it possible to pump water into groundwater basins without the use of expensive high-performance pumping stations. In addition, artificially recharged water must undergo preliminary treatment: settling, filtration, oxygenation, etc. [44], and in some cases chemical treatment methods must be applied that increase the prime cost and reduce the effectiveness of water collection in groundwater basins. At the same time, in contrast to plain areas, in mountainous regions during spring and autumn, rivers are formed due to melting snow, rainfall, underground sources and do not need treatment.

The goal of the present research is to improve the efficiency of water resource use in mountainous regions, for which the following objectives should be set:

- to study the peculiarities of water resource management in mountainous regions,
- to substantiate the strategy of regulation and preservation of water resources,
- to study the possibility of AGR in AAB without the use of pumps,
- to study the hydrogeological conditions and determine the hydrogeological parameters of the Karbian Gorge,
- to perform hydraulic calculations of water flow rate in individual wells, as well as the total water flow rate pumped into the groundwater basin,
- to provide economic and environmental justification for the activities carried out.

The novelty of the presented work is to develop a strategy for the implementation of water regulation, taking into account the characteristics of mountainous regions, which will make it possible to provide significant economic efficiency, without disturbing the ecological balance of the environment.

## Materials and Methods

### The object of research and its formal description

The object of the given research is AGR in mountainous regions. The subject of the research is the Karbian Gorge of the Kasakh River in Aragatsotn Marz of Armenia (Fig.2.), where 12 wells with diameters of 50 cm and depths of 300 m were dug and hydrogeological studies were conducted in 1984-1985.

The average width of the gorge is 0.8 km, its length is 2.0 km, and its depth is 0.1 km. Groundwater depths range from 33 to 38 m. Effluent seepage into the gorge amounts to 165 l/s. In the upper part of the gorge, at an elevation of 1310 m above sea level, the Arzni-Shamiram Canal runs, which takes water at a rate of 13 $m^3$/s from the Hrazdan River and during the growing season (1.05-30.10) provides approximately 40 thousand hectares of irrigated land with irrigation water.


**Fig. 2.** *Drainage basin of the Ararat valley*

Fig. 3 shows the geological section of the canal and a number of wells laid from north to south through the Arzni-Shamiram Canal and 5, 3, 6, 1, 12, 8 wells [1].

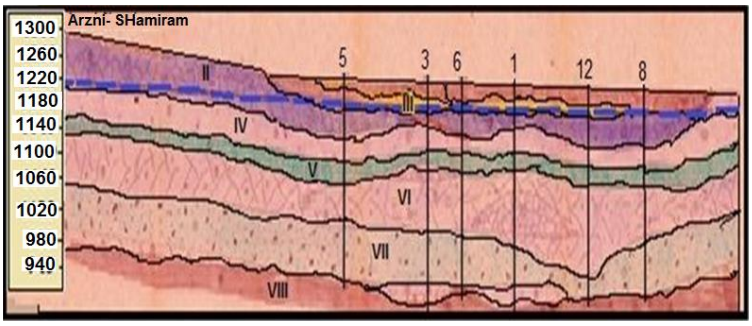


**Fig. 3.** *Hydrogeological section passing through the Arzni-Shamiram Canal and 5, 3, 6, 1, 12, 8 wells: I-hard clay with pebbles and gravel, II-boulder-pebble deposits with gravel and uneven-grained sand, III-tuff, IV-andesites and basalts, fractured, slightly water-bearing, V-pebble-gravel deposits with boulders, water-bearing, VI-andesite-basalts, strongly fractured, porous, VII-boulder-pebble deposits with sandy filler, strongly water-bearing, VIII-andesite-basalts monolithic and massive*

Fig. 4 shows the geological and lithological structure of well № 3, as well as the names of the geological layers, which are identical to the names in Fig. 3.

The section shows that it has three water-permeable layers: the first at a depth of 14-29 m with a thickness of 15 m, the second at a depth of 90-105 m with a thickness of 15 m, and the third at a depth of 200-280 m with a thickness of 80 m,[2] and it is in this layer that water is planned to be pumped to fill the water resources of the Ararat Artesian Basin.

It is envisaged to let water runoffs through the canal and pump it into existing wells, using the natural relief differences in relative height.

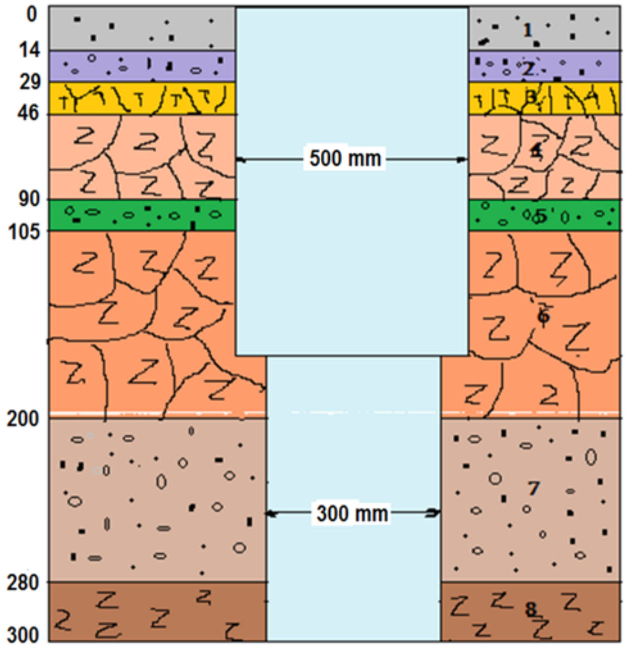


**Fig. 4.** *Geological-Lithological structure of well 3*

### *Research methodology*

According to the proposed idea, it is planned to transfer water to the Karbian Gorge within three spring months by building a pipeline and pumping water into the third aquifer at a pressure of about 100 m through the Arzni-Shamiram Canal of the Hrazdan River. Hydraulic calculations were performed using the hydrogeological parameters of the third aquifer.

The dynamics of the decrease in groundwater level when pumping water from wells, as well as the dynamics of restoring the water level in wells after pumping stopped were used to calculate the soil filtration coefficient. The pumps were placed at a depth of 70-80 m to pump out water. The water flow rate in the wells ranged from 14 to 52 l/s. With group pumping, the total flow rate was 300 l/s. Pumping is carried out from 10 wells, and two wells (10 and 11) are used as observation wells. The pumping process must be carried out until a stationary regime is established (when a further decrease in the groundwater level stops).

Fig. 5 shows data on the maximum decrease in groundwater level after the establishment of a stationary regime. In the main wells, from which groundwater was pumped out, the level of the decrease varied from

[1] Gidrogeologicheskiye usloviya i podschet ekspluatatsionnykh zapasov presnykh podzemnykh vod Karbinskogo mestorozhdeniya paleodaliny reke Kasakh v Ashtarakskom rayone Armyanskoy SSR po sostoyaniyu na 1.01.86 g., Otchet «ARMGIROZEM», Yerevan, 1986, 246 s. (fondovyye materialy, in Russian).

[2] Ibid.

5.81 to 10.65 m. In the observation wells (10 and 11), the decrease in the groundwater level was 1.56 and 1.79 m, respectively.

The soil filtration coefficient is determined in accordance with the restoration of the maximum level of groundwater when the pumping of water stops.

To calculate the filtration coefficient, we used the following formula [3]:

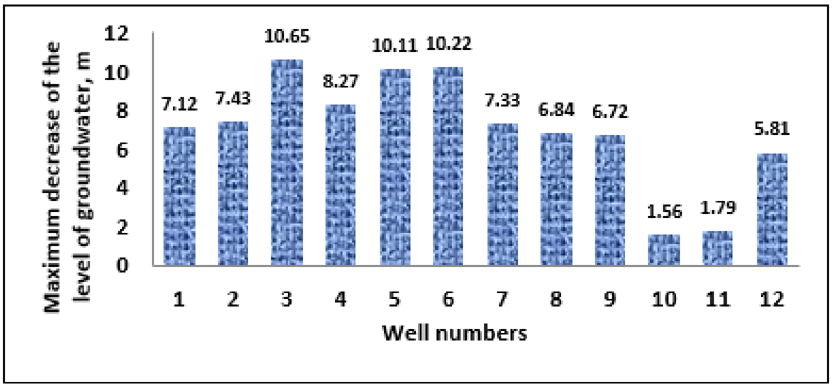


**Fig. 5.** *The maximum decrease of the level of groundwater in wells after the establishment of a stationary regime after 33 days of pumping*

$$S = \frac{0.183Q}{kH\, lg\ ((t_0 + t)/t)}, \tag{1}$$

where $S$ is the lowering of the level of groundwater in the well, m; $Q$ is the water flow rate during pumping out of the well, m$^3$/day; $k$ is the filtration coefficient of the aquifer, m/day; $H$ is the thickness of the aquifer, m; $t_0$ is the duration of pumping until the establishment of a stationary regime, days, $t$ is the current time for the restoration of the groundwater level within days.

The filtration coefficient is determined by the following formula:

$$k = \frac{0.183Q}{HB}, \tag{2}$$

where B is the angular coefficient of a straight line on a graph plotted in the coordinates S and lg((to + t)/t) is determined by:

$$B = \frac{S}{lg\frac{(t_0 + t)}{t}}, \tag{3}$$

In addition, soil filtration coefficients were also calculated using the method of lowering groundwater levels in wells during water pumping, using formulas 4 and 5 [4].

$$k_{n-1} = 0.366Q\frac{(lg\, x_1 - lg\, r)}{H(S_n - S_1)}, \tag{4}$$

$$k_{n-2} = 0.366Q\frac{(lg\, x_2 - lg\, r)}{H(S_n - S_2)}, \tag{5}$$

where $k_{n-1}$ and $k_{n-2}$ are the soil filtration coefficients in the n-$^{th}$ well in relation to the observation wells 1 and 2, m/day, $Q$ is the water flow rate from the n-$^{th}$ well during pumping, m$^3$/day; $x_1$ and $x_2$ are distance between the n-$^{th}$ well from observation wells 1 and 2, m/day; $S_n$, $S_1$ and $S_2$ are the maximum groundwater level drops after steady state conditions in wells $n$ and observation wells 1 and 2, m; $r$ is the radius of the well, m; $H$ is the thickness of the aquifer in m.

## Results and Discussion

### Calculation of the filtration coefficient

Table 1 shows the initial data for calculating the angular coefficient B and the soil filtration coefficient k. Fig. 6 shows the graph for calculating the angular coefficient B.

[3] Rekomendatsii po opredeleniyu gidrogeologicheskikh parametrov gruntov metodom otkachki vody iz skvazhin. Stroyizdat, Moscow, 1986 (in Russian).

[4] Ibid.

Table 2 shows the soil filtration coefficient calculated using the methods described above. Summarizing the indicators of soil filtration coefficients (Table 2), it can be stated that for aquifers of the Karbian Gorge, they vary from 2.45 to 12.43 m/day according to the method of restoring the groundwater level after the cessation of pumping water, and from 1.70 to 12.90 m/day according to the method of reducing the maximum level of groundwater in wells when pumping water.

Despite some differences in the obtained values of the filtration coefficients determined by various methods, they can be considered identical when the complex lithological structure of soils is taken into account.

According to experimental data, boulder-pebble grounds filled with fine-grained sand have a filtration coefficient of 2-10 m/day, which is typical of the aquifers of the Karbian Gorge, confirming the accuracy of the calculations.

**Table 1.** Initial data for calculating the angular coefficient B and filtration coefficient k

| Wells | S, m | $t_o$, day | Q, $m^3$/day | H, m | 0.183 · Q/H |
|---|---|---|---|---|---|
| 1 | 7.12 | 33 | 2592 | 94 | 5.05 |
| 2 | 7.43 | 33 | 4493 | 69 | 11.92 |
| 3 | 10.65 | 33 | 2765 | 110 | 4.60 |
| 4 | 8.27 | 33 | 3586 | 116 | 5.66 |
| 5 | 10.10 | 33 | 2635 | 108 | 4.47 |
| 6 | 10.22 | 33 | 3672 | 112 | 6.00 |
| 7 | 7.33 | 33 | 3568 | 97 | 6.73 |
| 8 | 6.84 | 33 | 3404 | 87 | 7.16 |
| 9 | 6.72 | 33 | 3508 | 95 | 6.76 |
| 12 | 5.80 | 33 | 1210 | 113 | 1.96 |

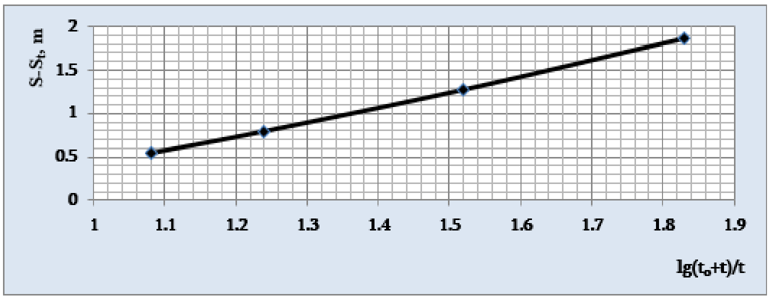


**Fig. 6.** *Dependence of the level of groundwater restoration from relative time*

**Table 2.** Calculation of the soil filtration coefficient, various well performance methods

| Wells | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| According to the dynamics of the restoration of the groundwater level, after the cessation of pumping water | | | | | | | | | | |
| 0.183 · Q/H | 5.05 | 11.92 | 4.60 | 5.66 | 4.47 | 6.00 | 6.73 | 7.16 | 6.76 | 1.96 |
| B | 1.76 | 1.81 | 1.88 | 1.59 | 1.17 | 0.28 | 0.71 | 0.63 | 1.13 | 0.67 |
| k, m/day | 2.87 | 6.57 | 2.45 | 3.57 | 3.81 | 12.43 | 9.53 | 11.43 | 5.96 | 2.94 |
| According to the decrease in the maximum level of groundwater in wells during water pumping | | | | | | | | | | |
| $k_{n-1}$ | 4.20 | 7.00 | 1.90 | 3.30 | 1.90 | 12.90 | 5.80 | 10.80 | 6.10 | 2.20 |
| $k_{n-2}$ | 4.10 | 7.80 | 1.70 | 3.60 | 1.80 | 12.70 | 5.40 | 11.70 | 5.90 | 2.30 |

**Hydraulic calculation of AGR in the AAB**

Fig. 7 shows a plan of the Karbian Gorge, which gives the location of 12 wells in the area, the level of groundwater, the horizontal relief and pipelines feeding wells.

The volume of water pumped into groundwater aquifers is determined by the pipeline water pressure, the filtration properties of the aquifers, the number of wells, the distance between them, etc. The formula (6) [45] determines the water flow rate (Q) under simultaneous group pumping.

$$Q = \frac{2\pi k f h(H_n - H_w)}{\phi \, ln \frac{\sigma_n}{\pi r_w}}, \tag{6}$$

where $k_f$ is the filtration coefficient of the aquifer, in m/day, $h$ is the thickness of the aquifer in m, $H_p$ is the pressure created in the well (the difference between the absolute heights of the Arzni-Shamiram Canal and the groundwater level in the well), m, $H_w$ is the loss pressure in the pipeline, m; φ is the coefficient that takes into account the effect of floating particles in water on the filtration properties of aquifers (φ = 1 when pumping clean water, $r_w$ = 0.25 m - well radius; $\sigma_n$ = 100 m - half the distance between wells). The data obtained by formula (6) were compared with the data obtained by the well-known formula of V.M. Nasberg [5].

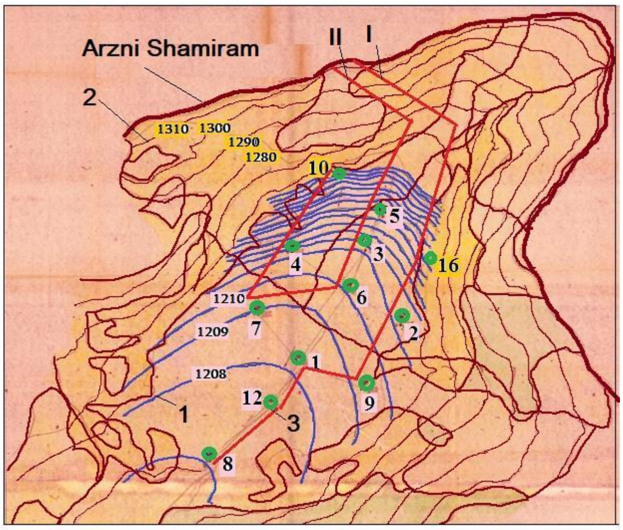


**Fig. 7.** *Scheme of the location of wells and feeding pipelines in the plan of the territory of Karbian Gorge:*
*1 - groundwater level, 2 - relief horizontals, 3 - wells,*
*I and II - pipelines of water supply*

$$Q = \frac{k_{\text{ф}} H^2}{0.423\, lg \dfrac{2H}{r_{\text{ск}}}}, \tag{7}$$

where:

$$H = H_p - H_w\,. \tag{8}$$

Formula (7) does not take into account the influence of the thickness of the aquifer $h$, because $h$ depends on the water flow rate ($Q$) in a straight-line law, in formula (7) it is proposed to introduce a dimensionless correction factor $\alpha$ in the form of formula (10).

$$Q = \frac{\alpha k_f {H_T}^2}{0.423\, lg \dfrac{2H_T}{r_w}}, \tag{9}$$

$$\alpha = \frac{h}{h_{av}}, \tag{10}$$

where $h_{av}$ = 50 m is the average thickness of the aquifer.

To calculate the flow rate of the pumped water, road and local pipeline losses must be determined. The volume of water and flow rates in 12 wells calculated according to formula (6) is 5.287 $m^3/s$, assuming no pressure loss in pipelines. Two pipelines are proposed to supply this amount of water from the Arzni-Shamiram Canal and distribute it to wells. According to terrain calculations, the length of the first line is 1866 m, with 1222 m of the initial part having a diameter of 1220 mm and the last part having a diameter of 820 mm due to a decrease in flow rate along the way. The second line II has a length of 1669 m in the first part 892 m and a diameter of 1220 mm, and the second part: 820 mm. Water from these pipelines is distributed through wells via pipes 500 mm in diameter and 200 m in length. Each line, in accordance with the calculation, the water flow rate will amount to 3.0 $m^3/s$. Based on the initial data, road and local losses were also calculated along the pipeline and in the well pipes.

The initial data, as shown in Table 3, were used to calculate the flow rates of water pumping into the wells.

[5] State Committee of Water Economy Ministry of Energy Infrastructures and Natural Resources The Republic of Armenia, Preparatory survey for Yeghvard irrigation system improvement project, Final report, 2016 (in Armenian).

**Table 3.** Initial design indicators and water flow pumping into wells

| Wells | $H_p$, m | $H_w$, m | $H_p$-$H_n$, m | $k_f$, m/day | h, m | $Q_1$, $m^3/s$ | $Q_2$, $m^3/day$ | α = h/50 | $Q_3 = αQ_2$, $m^3/s$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 102 | 5.67 | 96.33 | 4.2 | 50 | 0.316 | 0.366 | 1.00 | 0.366 |
| 2 | 99 | 3.34 | 95,66 | 8.4 | 20 | 0.251 | 0.725 | 0.40 | 0.290 |
| 3 | 99 | 2.72 | 96.28 | 2.0 | 80 | 0.244 | 0.175 | 1.60 | 0.280 |
| 4 | 99 | 5.36 | 93.64 | 3.5 | 55 | 0.282 | 0.290 | 1.10 | 0.319 |
| 5 | 95 | 2.61 | 92.39 | 3.8 | 53 | 0.290 | 0.308 | 1.06 | 0.327 |
| 6 | 100 | 8.82 | 91.18 | 12.4 | 50 | 0.882 | 0.973 | 1.00 | 0.973 |
| 7 | 101 | 7.72 | 93.28 | 9.5 | 48 | 0.664 | 0.777 | 0.96 | 0.746 |
| 8 | 103 | 11.41 | 91.59 | 11.4 | 52 | 0.847 | 0.896 | 1.04 | 0.932 |
| 9 | 101 | 4.53 | 96.47 | 6.0 | 45 | 0.406 | 0.525 | 0.90 | 0.473 |
| 10 | 88 | 5.15 | 82.85 | 2.5 | 39 | 0.124 | 0.165 | 0.78 | 0.129 |
| 11 | 94 | 3.64 | 90.36 | 6.2 | 47 | 0.437 | 0.481 | 0.94 | 0.452 |
| 12 | 103 | 6.97 | 96.03 | 6.2 | 47 | 0.411 | 0.536 | 0.94 | 0.504 |
| ∑ | | | | | | 5.153 | 6.217 | | 5.789 |

Thus, by pumping 5.153 $m^3/s$ of water through 12 wells into the groundwater basin, the volume of pumped water per day can be 445219 $m^3$, and for three months of operation of the wells, 445219x30x3 40069710 $m^3$ or approximately 40 million $m^3$ of water can be transported to AAB.

**Discussion**

Thus, the obtained data on water flow rate calculated using (7) and (9) formulas produce similar results. This provides reason to believe that these water flow rates calculations can be trusted. It is possible to increase groundwater reserves and solve problems associated with their decrease by artificially recharging the AAB in the amount of 40 million $m^3$/year. The outcomes of methodological approaches can be applied in a variety of mountainous countries.

**Environmental justification of artificial recharge of AAB reserves**

Physical and chemical indicators of water are important for artificial recharge of water reserves in the groundwater basin. We distinguish the temperature and the number of floating particles from the physical indicators of water (Table 4).

**Table 4.** Qualitative indicators for the Hrazdan River water at the Arzni-Shamiram Canal water intake site

| Months | Qualitative indicators | | | | | |
|---|---|---|---|---|---|---|
| | t, C$^o$ | Floating particles, mg/l | pH | Water hardness, meq/l | EC, mS/cm | $HCO_3$, meq/l |
| III | 7.3 | 1.0 | 8.06 | 3.7 | 0.598 | 2.55 |
| IV | 8.3 | 10.1 | 7.95 | 3.3 | 0.677 | 2.35 |
| V | 9.5 | 73.8 | 7.45 | 1.9 | 0.181 | 2.35 |

Water temperature during the water supply period ranges between 7.3 and 9.5$^0$C, which corresponds to the groundwater temperature and cannot cause environmental problems. The content of floating particles, particularly in May, amounts to 73.8 mg/l, which can lead to a decrease in the soil filtration coefficient. However, these particles settle as the water moves along the Arzni-Shamiram Canal.

From March to May, the waters in the Hrazdan River are formed mainly from precipitation, snow melting and underground sources, therefore, have good chemical indicators. The Republic of Armenia standards were used to assess the chemical composition of the water. It can be concluded that the critical indicators (pH, hardness, electrical conductivity and hydrocarbonates) of water do not exceed the maximum permissible concentrations (MPC).

The content of contaminated elements in canal water is shown in Table 5. Sulfates and chlorides, which can seep into domestic water, as well as nitrates, ammonium and phosphates (which get in by washing agricultural fields), do not exceed the MPC. Soils above the Arzni-Shamiram Canal are not cultivated.

The concentrations of a number of microelements in the Hrazdan River at the water intake area of the Arzni-Shamiram Canal are shown in Table 6. The MPC is not exceeded in the concentrations of extremely toxic elements such as cobalt, lead, arsenic, nickel and copper.

**Table 5.** Content of pollutants in the Hrazdan River at the water intake section of the Arzni-Shamiram Canal

| Months | Content of Materials, mg/l | | | | |
|---|---|---|---|---|---|
| | Sulphates MPC = 100 | Chlorides MPC = 300 | Nitrates MPC = 40 | Ammonium MPC = 0.5 | Phosphates MPC = 3.5 |
| III | 72.66 | 55.24 | 13.72 | 0.19 | 0.16 |
| IV | 53.97 | 38.66 | 36.33 | 0 | 0.15 |
| V | 32.47 | 13.81 | 14.74 | 0 | 0.20 |

**Table 6.** Concentrations of a number of microelements in the Hrazdan River at the water intake section

| Months | Concentration, mg/l | | | | | | |
|---|---|---|---|---|---|---|---|
| | As 0.05 | Mo 0.5 | Pb 0.1 | Mn 0.01 | Co 0.01 | Ni 0.01 | Cu 0.001 |
| I | 0.008 | 0.002 | 0.0001 | 0.006 | 0.0001 | 0.001 | 0.001 |
| II | 0.008 | 0.002 | 0.0001 | 0.0032 | 0.0001 | 0.001 | 0.001 |
| III | 0.003 | 0.001 | 0.005 | 0.0035 | 0.0001 | 0.001 | 0.001 |

Pesticide traces were also not found in water analyses. AAB water is primarily used for irrigation and fish farming, and when used for drinking and domestic purposes, it is usually subjected to biological treatment in each community. Consequently, there is no need to construct a special biological water treatment station when water is pumped from the Karbian Gorge.

However, the process of water pumping in the Arzni-Shamiram Canal should be the focus of environmental monitoring services, which should conduct regular monitoring of water quality to exclude the groundwater pollution (Sahakyan and Yedoyan 2020; Sahakyan et al. 2021), and it is also necessary to continue the studies on the effect of artificial recharge of AAB on quantitative (groundwater reserves, groundwater level and pressure) and qualitative (chemical composition) indicators of water quality after operation of the pumping system in the Karbian Gorge.

It should be noted that in the mountainous regions, water, especially in the spring months, is formed from atmospheric precipitation, has fairly good quality indicators and does not require additional purification.

### Economic justification of artificial recharge of AAB reserves

In order to implement AGR technology for AAB of Karbian Gorge it will be necessary to implement construction works on Arzni-Shamiram Canal for the intake of 5-6 $m^3$/s, where 2 water intakes and 2 lines of pipelines with diameter of 1220 mm, water valves, grids for preventing penetration of floating bodies, automatic systems for water flow regulation and closing automatic water entry in case of accidents should be installed (Table 7). Two pipelines with a diameter of 1200 mm and a length of 2114 m, the diameter of which will be reduced to 820 mm and the total length will be 1421 m after the reduction of water flow along the way. Then a pipe with a diameter of 500 mm and a total length of 2400 m will be descended into each well. It is necessary to install 16 water valves of different diameters, which will regulate the flow and distribution of water to the wells.

The economic calculation of the activities of the artificial recharge system of the AAB shows that in order to pump 40 million m$^3$ water, it is necessary to invest about 2 million 26 thousand USD (0.05 million USD for one cubic meter of water) on construction-installation operations, including water intake, pipeline and well treatment. In comparison with the construction, the annual maintenance, and the transportation of the same volume of water to the point of consumption through canals, according to Yeghvard Reservoir project will cost at least 230 million USD (5.5 USD/m$^3$) [6]. It should be noted that the Government of Armenia did not approve of the construction of the Yeghvard Reservoir due to the need for large investments.

**Table 7.** Estimate of measures for artificial recharge of water resources in the AAB

| Wells | Name | Diameter, mm | Length, m | UnitCost, $ US | Quantity, pcs | Total Sum, $ US |
|---|---|---|---|---|---|---|
| 1 | Metal Pipe | 500 | 2400 | 150 | - | 360000 |
| 2 | Metal Pipe | 820 | 1421 | 200 | - | 284200 |
| 3 | Metal Pipe | 1220 | 2114 | 330 | - | 697620 |
| 4 | Water Valve | 500 | | 2000 | 12 | 24000 |
| 5 | Water Valve | 820 | | 2500 | 2 | 5000 |
| 6 | Water Valve | 1220 | | 3800 | 2 | 7600 |
| 7 | Well Treatment | | | 5000 | 12 | 60000 |
| 8 | Construction Work | | | 150000 | 1 | 150000 |
| 9 | Water Intake | | | 100000 | 1 | 100000 |
| 10 | Total | | | | | 1688420 |
| 11 | VAT, 20 % | | | | | 337684 |
| 12 | Total Sum | | | | | 2026104 |

Thus, in mountainous areas, using the difference in relief heights as well as high quality indicators of pumped up water, artificial recharge of groundwater basins can be provided with high economic efficiency.

**Conclusion**

- River flows are extremely seasonal in mountainous regions, with spring and autumn floods reducing the efficiency of their use significantly in the crop growing period. The accumulation of runoff in reservoirs under difficult hydrogeological conditions requires not only a significant initial investment in construction (3-5 USD/m$^3$), but is also accompanied by significant infiltration and evaporation.
- It is mostly efficient to direct river flows into the groundwater basins. In lowland countries, these activities require significant financial outlays for water purification and its pumping into groundwater basins with the help of powerful pumping stations, which significantly increase the prime cost of waterobtained in this way. In mountainous regions, the water is characterized by high quality indicators, and relief differences in relative heights make it possible to pump water without using powerful pumping stations.
- Based on the example of AGR of AAB of Armenia, it is demonstrated that financial costs can be significantly reduced to spending less than 2-3 million USD (0.05-0.075 USD/m$^3$) for construction of a facility to pump 40 million m$^3$ of water per year into the groundwater basin, which includes a water intake, pipeline and well treatment, rather than capital investments for construction of a new reservoir to collect 40 million m$^3$, its annual maintenance and transportation to the point of consumption by canals costs 230-250 million USD or 5.75-6.25 dollars/m$^3$. The artificial recharge of AAB of Armenia in the amount of 40 million m$^3$/year makes it possible to increase the groundwater reserves and to solve the emerged problems due to their decrease as a result of their active use for national economic purposes.

[6] State Committee of Water Economy Ministry of Energy Infrastructures and Natural Resources The Republic of Armenia, Preparatory survey for Yeghvard irrigation system improvement project, Final report, 2016 (in Armenian).

- The findings of the present research, as well as the methodological approaches proposed in it, can be applied not only in the regions of Armenia, but also in a variety of countries with mountainous relief.

**Conflict of interest**

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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**Data availability**

Data will be made available on reasonable request.

**References**

[1]. T. Lv, L. Wang, H. Xie, X. Zhang, Y. Zhang, Evolutionary Overview of Water Resource Management (1990–2019) Based on a Bibliometric Analysis in Web of Science. Ecological Informatics, 61, 2021, 101218. Doi: https://doi.org/10.1016/j.ecoinf.2021.101218

[2]. U. Kumari, K. Swamy, A.Gupta, R.R. Karri, B.C. Meikap, Global Water Challenge and Future Perspective (chapter 8). Green Technologies for the Defluoridation of Water, 2021, 197-212. Doi: https://doi.org/10.1016/B978-0-323-85768-0.00002-6

[3]. K. Makanda, S. Nzama, T. Kanyerere, Assessing the Role of Water Resources Protection Practice for Sustainable Water Resources Management: A Review. Water, 14, 2022, 3153. Doi: https://doi.org/10.3390/w14193153

[4]. D.C. CallejasMoncaleano, S. Pande, L. Rietveld, Water Use Efficiency: A Review of Contextual and Behavioral Factors. Frontiers in Water, 3, 2021, 685650. Doi: https://doi.org/10.3389/frwa.2021.685650

[5]. W.J. Cosgrove, D.P. Loucks, Water Management: Current and Future Challenges and Research Directions, Water Resources Research, 51 (6), 2015, 4823-4839. Doi: https://doi.org/10.1002/2014WR016869

[6]. K. Stefanidis, Current Trends, Gaps, and Future Prospects in E-Flow Science: Allocating Environmental Water Needs Under a Changing World (chapter 5). Environmental Water Requirements in Mountainous Areas, 2021, 201-234. Doi: https://doi.org/10.1016/B978-0-12-819342-6.00008-7

[7]. L. Huber, J. Rüdisser, C. Meisch, R. Stotten, G. Leitinger, U. Tappeiner, Agent-Based Modelling of Water Balance in a Social-Ecological System: A Multidisciplinary Approach for Mountain Catchments. Science of the Total Environment, 755 (1), 2021, 142962. Doi: https://doi.org/10.1016/j.scitotenv.2020.142962

[8]. Y. Liu, Q. Tao, C. Liang, Y. Wu., Research on Water Resources Conservation of Mountain River Based on the Concept of Region Partition. Journal of Mountain Science, 8, 2011, 582–591. Doi: https://doi.org/10.1007/s11629-011-0241-9

[9]. A.Kh. Markosyan, E.V. Avanesyan, E.N. Matevosyan, T.S. Martirosyan, Current Problems of Water Use and Water Productivity Improvement in the Republic of Armenia. Proceedings of X International Scientific and Technical Conference on Modern Problems of Water Management, Environmental Protection, Architecture and Construction, Tbilisi, Georgia, July 25-27, 2021, 129-135.

[10]. S.B. Galstyan, A.A. Vartanyan, V.H. Tokmajyan, N.E. Gorshkova, H.V. Tokmajyan, The Regulation of Water Regime of Field Crops and Decorative Woody Plants in Natural Conditions by Applying Polymer-Mineral Raw Material. Bulletin of High Technology, Shushi, 1 (11), 2020, 11-15.

[11]. V.H. Tokmajyan, A.Kh. Markosyan, A.A. Khalatyan, N.B. Khachatryan, The Perspectives of Providing the Storage of Irrigation Water in the Case of Using Water Collecting Additives in the Ground. Bulletin of High Technology, Shushi, 2 (6), 2018, 9-14.

[12]. V. Tokmajyan, A.Vartanyan, N. Mikayelyan, Construction of reservoirs using polymer-mineral materials N1 and PMM. Construction of Optimized Energy Potential, 10 (2), 2021, 31-38. Doi: https://doi.org/10.17512/bozpe.2021.2.04

[13]. P.H. Baljyan, H.G. Kelejyan, E.V. Avanesyan, V.H. Tokmajyan, Evaluation of the Actual State of the Mataghis Reservoir W-H Characteristic and Forecasting of Future Changes. Bulletin of High Technology, 3 (17), 2021, 14-22.

[14]. C. Petheram, T.A. McMahon, Dams, Dam Costs and Damnable Cost Overruns, Journal of Hydrology X, 3, 2019, 100026. Doi: https://doi.org/10.1016/j.hydroa.2019.100026.

[15]. W. Xin, Y.M. Wang, Research on Influencing Factors of Reservoir Construction Risk Based on Interpretative Structural Modeling. World Journal of Engineering and Technology, 9 (4), 2021, 727-736. Doi: https://doi.org/10.4236/wjet.2021.94049

[16]. J. Zhang, A. Huo, Z. Zhao, L. Yang, J. Peng, Y. Cheng, Z. Wang, Impact of Mountain Reservoir Construction on Groundwater Level in Downstream Loess Areas in Guanzhong Basin, China. Water, 14 (9), 2022, 1470. Doi: https://doi.org/10.3390/w14091470

[17]. J. Li, L. Liao, X. Dai, Economic and Agricultural Impacts of Building a Dam - Evidence from Natural Experience of the Three-Gorges Dam. Agriculture. 12 (9), 2022, 1372. Doi: https://doi.org/10.3390/agriculture12091372

[18]. H. Hasibuan, A.H. Rafsanjani, D.P.E. Putra, S.S. Surjono, Identification of Groundwater Potential Zones in the Southern Mountains, Yogyakarta Special Region. IOP Conference Series: Earth and Environmental Science, 926, 2021, 012086. Doi: https://doi.org/10.1088/1755-1315/926/1/012086

[19]. A. Mukherjee, Overview of the Groundwater of South Asia, in: A. Mukherjee (ed.), Groundwater of South Asia. Springer Hydrogeology, 2018, 3-20. Doi: https://doi.org/10.1007/978-981-10-3889-1_1

[20]. S. Rakhmatullaev, F. Huneau, J. Kazbekov, P.Le Coustumer, J. Jumanov, B.El. Oifi, M. Motelica-Heino, Z. Hrkal, Groundwater Resources Use and Management in the Amu Darya River Basin (Central Asia). Environmental Earth Sciences, 59, 2010, 1183–1193. Doi: https://doi.org/10.1007/s12665-009-0107-4

[21]. K.D. Balke, Y. Zhu, Natural Water Purification and Water Management by Artificial Groundwater Recharge. Journal of Zhejiang University Science B, 9, 2008, 221–226. Doi: https://doi.org/10.1631/jzus.B0710635

[22]. S. Foster, J. Chilton, G.J. Nijsten, A. Richts, Groundwater - A Global Focus on the 'Local Resource'. Current Opinion in Environmental Sustainability, 5 (6), 2013, 685-695. Doi: https://doi.org/10.1016/j.cosust.2013.10.010

[23]. A. Ross, S. Hasnain, Factors Affecting the Cost of Managed Aquifer Recharge (MAR) Schemes. Sustainable Water Resources Management, 4, 2018, 179–190. Doi: https://doi.org/10.1007/s40899-017-0210-8

[24]. D. Perera, V. Smakhtin, S. Williams, T. North, A. Curry, Ageing Water Storage Infrastructure: An Emerging Global Risk. United Nations University Institute for Water, Environment and Health (UNU-INWEH) Report Series, 11, 2021, 7–8.

[25]. S. Samani, Analyzing the Groundwater Resources Sustainability Management Plan in Iran through Comparative Studies. Groundwater for Sustainable Development, 12, 2021, 100521. Doi: https://doi.org/10.1016/j.gsd.2020.100521

[26]. X. Jia, D. O'Connor, D.Hou, Y. Jin, G. Li, C. Zheng, Y.S. Ok, D.C.W. Tsang, J. Luo, Groundwater Depletion and Contamination: Spatial Distribution of Groundwater Resources Sustainability in China. Science of the Total Environment, 672, 2019, 551-562. Doi: https://doi.org/10.1016/j.scitotenv.2019.03.457

[27]. E. Wheida, R. Verhoeven, An Alternative Solution of the Water Shortage Problem in Libya. Water Resources Management, 21, 2007, 961–982. Doi: https://doi.org/10.1007/s11269-006-9067-6

[28]. N. Mirzoyan, N. Avetisyan, H. Mnatsakanyan, L. Tadevosyan, Groundwater Use and Efficiency in Small - and Medium-Sized Aquaculture Farms in Ararat Valley, Armenia. Groundwater for Sustainable Development, 6, 2018, 1-5. Doi: https://doi.org/10.1016/j.gsd.2017.09.001

[29]. I.N. Gale, I. Neumann, R. Calow, M. Moench, The Effectiveness of Artificial Recharge of Groundwater: A Review. Commissioned Report CR/02/108N. British Geological Survey, Keyworth, 2022.

[30]. H. Bouwer, Artificial Recharge of Groundwater: Hydrogeology and Engineering. Hydrogeology Journal, 10, 2002, 121–142. Doi: https://doi.org/10.1007/s10040-001-0182-4

[31]. M. Zammouri, N. Brini, Efficiency of Artificial Groundwater Recharge, Quantification through Conceptual Modelling. Water Resources Management, 34, 2020, 3345–3361. Doi: https://doi.org/10.1007/s11269-020-02617-1

[32]. D. Wadi, W. Wu, I. Malik, A. Fuad, M.M. Thaw. Assessment and Feasibility of the Potential Artificial Groundwater Recharge in Semi-Arid Crystalline Rocks Context, Biteira District, Sudan. Scientific African, 17, 2022, e01298. Doi: https://doi.org/10.1016/j.sciaf.2022.e01298

[33]. J.O. Kimrey, Artificial Recharge of Groundwater and its Role in Water Management. Desalination, 72 (1–2) 1989, 135-147. Doi: https://doi.org/10.1016/0011-9164(89)80031-1

[34]. T. Asano, Artificial Recharge of Groundwater. Butterworth-Heinemann, USA, 1985.

[35]. M.W.M. Tielemans, Artificial Recharge of Groundwater in the Netherlands. Water Practice and Technology, 2 (3), 2007, wpt2007064. Doi: https://doi.org/10.2166/wpt.2007.064

[36]. K. Hellauer, S. Karakurt, A. Sperlich, V. Burke, G. Massmann, U. Hübner, J.E. Drewes, Establishing sequential managed aquifer recharge technology (SMART) for enhanced removal of trace organic chemicals: Experiences from field studies in Berlin, Germany. Journal of Hydrology, 563, 2018, 1161-1168. Doi: https://doi.org/10.1016/j.jhydrol.2017.09.044

[37]. C. Sprenger, N. Hartog, M. Hernández, E. Vilanova, G. Grützmacher, F. Scheibler, S. Hannappel, Inventory of Managed Aquifer Recharge Sites in Europe: Historical Development, Current Situation and Perspectives. Hydrogeology Journal, 25, 2017, 1909–1922. Doi: https://doi.org/10.1007/s10040-017-1554-8

[38]. J. Guttman, I. Negev, G. Rubin, Design and Testing of Recharge Wells in a Coastal Aquifer: Summary of Field Scale Pilot Tests. Water, 9 (53), 2017. Doi: https://doi.org/10.3390/w9010053

[39]. M.A.E. Moneam, Review of Artificial Recharge Prospects for Augmentation of Groundwater in Egypt: A Case Study of El Bustan Extension Area. Ain Shams Engineering Journal, 14 (7), 2023, 101995. Doi: https://doi.org/10.1016/j.asej.2022.101995

[40]. V. Mirlas, V. Antonenko, V. Kulagin, E. Kuldeeva, Assessing Artificial Groundwater Recharge on Irrigated Land Using the MODFLOW Model: A Case Study from Karatal Agricultural Area, Kazakhstan. Earth Science Research, 4 (2), 2015, 16-34. Doi: https://doi.org/10.5539/esr.v4n2p16

[41]. B. Wang, M. Jin, J.R. Nimmo, L. Yang, W. Wang, Estimating Groundwater Recharge in Hebei Plain, China Under Varying Land Use Practices Using Tritium and Bromide Tracers. Journal of Hydrology, 356 (1–2), 2008, 209-222. Doi: https://doi.org/10.1016/j.jhydrol.2008.04.011

[42]. Z. Şen, Practical and Applied Hydrogeology, Chapter 4 - Unconfined Aquifers, 2015, 209-278. Doi: https://doi.org/10.1016/B978-0-12-800075-5.00004-2

[43]. J. Li, X-H. Xia., H. Zhan, M.G. Li, J-J. Chen, Non-Darcian Flow for an Artificial Recharge Well in a Confined Aquifer with Clogging-Related Permeability Reduction. Advances in Water Resources, 147, 2021, 103820. Doi: https://doi.org/10.1016/j.advwatres.2020.103820

[44]. P.J. Stuyfzand, Hydrogeochemical Processes During Riverbank Filtration and Artificial Recharge of Polluted Surface Waters: Zonation, Identification, and Quantification, in: M.Shamrukh (ed.) Riverbank Filtration for Water Security in Desert Countries, 2011, 97-128. Doi: https://doi.org/10.1007/978-94-007-0026-0_7

[45]. V.V. Senkus, Modelirovaniye protsessa nagnetaniya shakhtnykh vod v vodonosnyye plasty. Mining informational and analytical bulletin (scientific and technical journal) 7, 2007, 94-101 (in Russian).

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