RT&A, Special Issue № 4 (70)
Volume 17, November 2022

HYDROGEOLOGICAL CONDITIONS OF THE SHIRVAN STEPPE OF AZERBAIJAN

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Abstract

According to the results of the author`s research on the long-term average level of groundwater, the degree of mineralization, salinization of soils and changes in groundwater regime during 1977-2020, as well as the collection of materials in this direction during 1930-2020, the hydrogeological conditions of the Shirvan plain were studied. Based on the analysis of the results the regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. Five genetic types have been identified according to the factors forming the regime and the synchrony of changes in groundwater levels. Under the influence of natural and anthropogenic factors, the level of groundwater, the degree of mineralization, the chemical composition, the chemical composition and salinity of the soils have changed. During the period from 1958 to 2020, the level of groundwater in the area increased by more than 4.1 m due to irrigated agriculture, and their mineralization degree decreased by 16.2 g/l due to filtration of the surface water and removal of mineralized water through drainage. As a result of the analysis regime types of groundwater were separated and a correlative dependence was found between regime types and factors forming the regime. According to the factors forming the regime and the synchrony of changes in groundwater levels, the genetic types of the regime-climate, hydrological, irrigation, irrigation-drainage, irrigation were separated and their areas of distribution were determined. The climate type regime is characterized by a high correlation between the rise and fall of groundwater level and the seasonal and perennial periodicity of atmospheric precipitation, the hydrological type is characterized by a similar dependence on the surface flow, the irrigation-drainage type is characterized by a similar dependence between irrigation water and surface water basins.

Keywords: groundwater, pressure water, mineralization, chemical composition, groundwater level, salinity, regime, regime-forming factors.

I. Introduction

The water and land resources of Azerbaijan are in a limited state and are constantly exposed to man-made effects from year to year. On the other hand, 71% of the surface waters of the republic come across the border of neighboring states in a certain degree of pollution. The total underground water resources of Azerbaijan are 8.5÷9.5 billion. m^3, and surface waters 28÷32 billion m^3 depending on the water level of the year [1]. The total population of the republic is more than 10 million people. In low-income years, water shortage is 4÷5 billion m^3. The use of water and the demand for it in the republic increases from year to year at a great pace. In this regard, it is necessary to rationally and economically use existing water resources and look for new sources.

One of such sources is underground water. When extracting and protecting groundwater to protect against pollution and depletion, it is necessary to study in detail the hydrogeological conditions and the impact of natural and man-made processes on them and take preliminary preventive measures.

In the territories where groundwater is extracted and used, pollution and depletion of groundwater occurs, pressure underground horizons fail, due to the infiltration of irrigation and other waters, the level of groundwater rises, there is waterlogging of land, physical, chemical, bacteriological, sometimes even radioactive pollution, changes in the structure and tension of soil in the geological environment, activation of exogenous geodynamic processes, re-salination of soil, changes in the composition of groundwater, sometimes disturbance of relief and landscape.

In recent years, scientifically unsubstantiated displacement of internal and surface parts of the Earth: merciless exploitation of underground fossils, including underground water, construction of hydrotechnical structures, large-scale construction of irrigation and reclamation systems, random cutting of forests, destruction of landscapes, etc. lead to changes in the geological and hydrogeological conditions of the territory. On the other hand, global climate change - temperature increase, drought, uneven temperature distribution, increase in intensity of natural cataclysms and other natural processes seriously influence the formation of hydrogeological processes. In such conditions, study changes in hydrogeological conditions under the influence of anthropogenic factors and take proactive measures that are extremely important. [2].

II. Methods

The territory of the Shirvan Steppe covers the left bank of the Kura River from the Mingechaur reservoir in the north-west to the Hajigabul district in the south-east. Within the borders of the steppe landscape are the territories of Yevlakh, Agdash, Goychay, Ismailli, Ujar, Zardab, Kurdamir, Agsu, Shamakhi and Hajigabul administrative districts. The total area of the Shirvan steppe is 680 thousand. га, из них 450 thousand. The area is suitable for irrigation, but due to the lack of water, only 225 thousand. Irrigation is carried out on the square.

Soil salinity in the southern part of the steppe massif is higher than in the north. In addition, the southern part is the discharge of groundwater, and the northern part is the zone of formation and transportation of groundwater. In the north, the soils are relatively light, the filtration coefficient in the thickness of 0-2 and 2-5 m is 3÷10 m/day, in the southern part - 0.1÷0.2 m/day. Territories with a filtration coefficient of 0.1÷0.2 m/day make up more than 80% of the total area. In a thickness of 2-5 m, the filtration coefficient is 3-5 times greater than in a thickness of 0-2 m. This difference causes a change in the flow rate and salt reserves [3-7].

The total length of irrigation systems is 74,000 km, and the specific length is 10.9 m/ha, the water surface area is 5.31 thousand km2 [2, 4]. The supply of ground water through trunk collectors for one linear meter of length is 2.4 m^3/ha.

Drainage waters flowing into the Kuru River and flowing into the sea (m3/sec) are indicated in Table 1.

Table 2 shows the participation of average long-term pressure, ground and irrigated waters in the drainage runoff of the Shirvan steppe, in m^3/sec (Table 2).

In the 30s of the last century, irrigation and reclamation works in Azerbaijan were poorly developed and irrigation canals and collector-drainage networks were located very densely in the irrigated territories. During these years, the depth of groundwater in the Kura-Araks lowland of the Republic, including the Shirvan steppe, was 5.0-10.0 m or more. In irrigated areas, the groundwater level began to systematically rise. In 1951 in all irrigated areas, the occupied area with a groundwater depth of 5.0-10.0 and deeper than 10.0 m decreased from 33% to 20% (i.e. 1.5

times), at the same time, the occupied area with the depth groundwater occurrence deeper than 3.0 m decreased by 2.6 times (Table 3).

Table 1: *Mean annual drainage water discharge in Shirvan steppe (m³/sec) [1, 7].*

Months	Drainage water flowing into the Kura River	Drainage water flowing into the sea	Total
I	0,54	36,58	37,12
II	0,42	33,02	33,44
III	0,73	35,76	36,49
IV	0,96	41,73	42,69
V	1,01	46,18	47,19
VI	0,87	40,17	41,04
VII	0,70	36,37	37,07
VIII	0,55	33,75	34,30
IX	0,47	28,69	29,16
X	0,31	24,42	24,73
XI	0,36	27,73	28,09
XII	0,43	30,95	31,38

Table 2: *Participation of pressurized, groundwater and irrigated water in drainage flow of the Shirvan steppe [7]*

Geographical location of the area	Participation of different waters in drainage runoff		
	Pressurized water	Groundwater	Irrigated waters
Bozdag-Alijancay	11-20	47-62	44-18
Alijanchai-Turyanchai	13-37	35-42	42-21
Turianchai-Geokchai	25-38	33-45	42-17
Geokchai-Akhsu-Girdimanchai	14-32	43-52	43-16
Limit of change	11-29	46-50	43-21

Table 3: *Location of the area by depth of groundwater occurrence (1951), in the steppes of the Kura-Araks lowland, in % of the total area [4, 7]*

Steppes	Area, km²	Depth of groundwater occurrence, m					
		0 - 1	1 – 2	2 – 3	3 - 5	5 – 10	> 10
Shirvan	6917	0,1	10,6	16,6	31,5	36,4	4,8
Southeast Shirvan	1563	18,3	25,5	28,8	18,3	14,0	-
Karabakh	2054	6,5	20,47	14,8	29,53	16,9	11,8
Mil	2907	8,8	20,6	34,8	28,6	7,2	-
Mugan	4658	8,5	36,6	40,4	14,5	-	-
Salyan	727	20,0	30,0	32,9	17,1	-	-
Total for the Kura-Araks lowland	18826	6,36	22,04	26,15	24,92	17,43	3,10

Since 1950, a new stage in the development of land irrigation has begun in Azerbaijan. In 1952, the Varvara reservoir was built and put into operation, and in 1953 the Mingachevir reservoir, which has no analogues in the republic and in the world, in terms of multifunctionality (energy, irrigation, fish farming, tourism, sports, and other purposes). Along with the construction of these unique hydraulic structures, in order to provide the land of the KAN with irrigated water, the Upper Karabakh Canal was built in 1955, the Upper Shirvan Canal was built in 1958, and in 1960 the main canals - the Main Mugan and the Sabir Canal [4, 7].

In 1962, the occupied area of groundwater, lying at a depth of more than 10.0 m, can be said to have not been on the map at all. Groundwater, occurring at a depth of 0 - 5.0 m, occupied more than 84% of the territory of the Shirvan steppe (Table 4).

Table 4: *Location of the area by depth of groundwater occurrence (1962), in the steppes of the Kura-Araks lowland, as a percentage of the total area [7, 8]*

Steppes	Area, km²	Depth of groundwater occurrence, m					
		0 - 1	1 – 2	2 - 3	3 - 5	5 - 10	> 10
Shirvan	6917	18,06	24,20	22,15	19,79	13,80	19,0
Southeast Shirvan	1563	25,3	32,10	20,10	15,30	7,20	-
Karabakh	2054	14,5	51,9	20,45	7,69	5,8	-
Mil	2907	12,8	50,19	24,03	8,42	5,18	-
Mugan	4658	16,6	62,4	20,40	0,6	-	-
Salyan	727	56,4	14,5	6,60	12,5	-	-
Total for the Kura-Araks lowland	18826	18,44	40,95	21,45	11,33	7,10	0,73

Observations show that the level regime of groundwater to a lesser extent depends on precipitation. In various periods of the year, mainly autumn-winter periods, the groundwater level is relatively deep. Starting from April, the groundwater level gradually rises and in July-August the maximum amplitude is observed. From October to January, there is a decrease in the level of groundwater. In the territory where the depth of the groundwater level is up to 3.0 m, their fall and rise to a large extent does not occur. In rare cases, these changes occur in the range of 0.3-0.6 m. However, in irrigated areas located closer to the canals, the amplitude of changes in the groundwater level is 0.3-0.6 m, sometimes more. In 1989, on the territory of the Shirvan steppe, the depth of the groundwater level was up to 1.0 m, 1.0 - 1.5 m, 1.5 - 2.0, 2.0 - 3.0, 3.0 - 5.0 , and more than 5.0 m, respectively, accounted for 4.3%, 18.0%, 28.5%, 36.8%, 10.2% and 2.2% of the total irrigated area, and in 2016, respectively, were 6.3%, 14.8%, 23.0%, 41.7%, 14.5% and 1.8%. As can be seen from V.R. Volobuev, in 1989, on irrigated areas, the area where the depth of occurrence is above the critical level is 22.2%, and in 2016 it was 21.1%. This is due to the fact that there is more drainage flow in the territory [7–8].

In 1989, if irrigated areas with groundwater salinity below 1.0 g/l, 1.0, 3.0 and above 3.0 g/l respectively accounted for 14.8%, 32.2% and 53% of the total area, 0%, then in 2016 they were 26.6%, 33.1% and 40.3%. In the Shirvan irrigated massif in 1989, saline, slightly, strongly and very strongly saline territories respectively amounted to 37.6%, 38.4%, 14.9% and 9.1%, and in 2016 - 44.7% , 29.0%, 18.1% and 8.2%.

Groundwater is common in river fans and the Kura belt throughout the Shirvan steppe and their depth varies from 1.0 to 7.0 m. More than 5.0 m and deeper groundwater is mainly observed in the upper part of the river fan . In the south, in the Kura zone, groundwater occurs at a depth of 3-5 m (Table 5). The filtration coefficient of the rocks of the aquifer varies in the range of 0.1 ÷ 22.0 m/day, the highest value is the upper part of the alluvial fans. When pumping water from wells, the flow rate was 0.06 ÷ 6.0 l/s. In the upper part of the alluvial fans and in the Kura strip, groundwater mineralization is up to 1 g/l, and water hardness is 3.43 ÷ 11.54 mg. equiv/l [1, 4]. The first confined aquifer was discovered in wells in three areas that are separated from each other, Alicanchay-Turyanchay, Goychay and Girdimanchay-Agsuchay alluvial fans of Khivalin age sediments at a depth of 31-182 m. They are separated from groundwater by clays 5-85 m thick. horizons in the upper part of the Agsucay alluvial fan are represented by gravel, and in the rest of the area - by sand and sandy loam. The thickness of the aquifer varies in the range of 15 - 77 m, the piezometric water level before the operation of the Upper Shirvan Canal throughout the territory was below the surface of the earth, and at present - in places 0.9 ÷ 16.5 m below the surface of the earth, in the north it is + 0.64 ÷ + 4.6 m, and in the south, on the left bank of the Kura River, 1.3 ÷ 4.3 m below the ground. In the Goychay section, the piezometric water level is both below the ground (-20.8 m) and higher (+7.2 m), and in the Girdimanchay-Agsuchay section - above the ground (+0.4 ÷ + 8.2 m) along the absolute elevation of the relief varies from 76.3 to 0 m, the slope of the terrain is 0.02 ÷ 0.007. The filtration coefficient of aquifers varies in the range of 0.3 ÷ 25.5 m/day. When pumping water from wells, the flow rate was: 13.3 l/s in the Alijanchay-Turyanchay area, 9.2 l/s in the Goyvhay area, and 1.4 l/s in the Girdimanchay-Agsuchay area. In the upper and central parts of alluvial fans, groundwater mineralization is up to 1.0 g/l, and in the lower part it is more than 3.0 g/l [1, 4].

The second pressure aquifer was opened by wells in the rocks of the Khazar age at a depth of 75 - 274 m, and in the Kura zone at a depth of 150 - 235 m (Table 6). This horizon is found everywhere, except for the Alijanchay alluvial fan. The second aquifer is separated from the first by clayey sands 10–160 m thick, and in some places 70–110 m thick. Their thickness varies within 10 - 40 m (77 m in places) [1, 4]. The filtration coefficient of aquifers is 0.3÷35.3 m/day. The piezometric level on the Girdimanchay-Agsuchay site is set above the ground - 2.1 ÷ 2.7 m, on the Goychay site and below the ground and above, and on the Alijanchay-Turyanchay site below the surface, in the Kura strip above the ground - 1.3÷4.3 m. Flow slope 0.02÷0.0004. When pumping water from wells, the flow rate varies within 0.18 ÷ 6.7 l/s. The total hardness of water is 1.6 ÷ 5.2 mg equiv/l.

The third confined aquifer was opened by wells in the Alijanchay-Turianchay and Girdymanchay areas with sediments of Baku age in the river fans at depths of 62-333.4 m. The third confined aquifer is not found in the Goyvhay area. The third confined aquifer is separated from the second aquifer by clay layers 7–165 m thick, and in many places 10–80 m thick. The thickness of these soils is 4.5 - 86.4 m, mostly 20-70 m. Their filtration coefficient is 0.1÷17.9 m/day, mostly 9 m/day. The piezometric water level is uniquely located above the earth's surface - +7.5 ÷ + 23.0 m. When pumping water, the flow rate of the well changes in the range of 3.01 ÷ 8.5 l/s.

Groundwater suitable for use (mineralization 1…3 g/l) is distributed in the upper and middle parts of the river fans. The total mineralization of groundwater increases towards their movement; in the middle part of the alluvial fans, the mineralization rises to more than 3 g/l and is unsuitable for use. With an increase in mineralization, a change in the chemical composition of groundwater occurs. Fresh and low-mineralized waters have a hydrocarbonate-sulfate, sulfate-hydrocarbonate anionic composition and a mixed composition of cations. Where salinity is of great importance, water types undergo metamorphism to the sodium chloride type. In general, there is a limited amount of groundwater in most of the Shirvan steppe. And in the direction of the axis of the alluvial fans of the rivers Goychay, Turyanchay and Agsuchay, the areas are considered favorable.

After 1975, with the removal of groundwater by collector-drainage systems, in the 0-2 m thickness, the salinity of soils decreased - 0.19%, and in the thickness of 2-5 m - 0.21%. In irrigated canals and irrigated areas, there are chloride-sulfate-magnesium-sulfate-sodium types of water (0.3 ÷ 1.0% salinity), and sometimes sodium-potassium type of salinity (1.0 ÷ 1.5%) [1,8] .

The groundwater regime of the Shirvan steppe was studied by many researchers - O.P.Savarensky, V.A.Priklonsky, N.V.Rogovskaya, D.M.Kats, G.Yu.Israfilov, F.Sh.Aliev, Ch.J. Gulmammadov and others [2,8]. To date, there are a large number of works that consider this issue in various aspects [7,8].

The climatic type includes regimes with a high correlation between fluctuations in the level of groundwater, seasonal and long-term periodicity of precipitation; the hydrological type is characterized by a similar dependence - on surface runoff, for the irrigation-irrigation-drainage type - on water supply and catchment. The climatic regime is widespread where there is no influence of artificial factors. The hydrological type of regime is distinguished in the zone of influence of the river. Kura, where there is no drainage effect, which is characterized by the synchronism of seasonal and integral curves of the groundwater level and the flow of the river. Hens. The correlation coefficient between the groundwater level and the river flow is 0.75 [7].

Table 5: *Level of occurrence, groundwater salinity and degree of soil salinization in Shirvan irrigation massif (thousand ha) [4,8]*

Districts	Years	Irrigated areas suitable for agriculture	Depth of groundwater occurrence, m					Salinity degree of groundwater, g/l			Degree of soil salinity			
			< 1,0	1,0 - 2,0	2,0 - 3,0	3,0 - 5,0	>5,0	< 1,0	1,0 - 3,0	> 3,0	Unsalted	Lightly salted	Medium saline	Highly saline
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Agdash	1984	37,7	1,7	16,4	16,8	2,8	0	4,5	17,8	15,4	8,2	15,6	8,9	5,0
	1986	39,3	3,6	19,6	13,6	2,4	0	4,4	18,8	16,1	18,4	15	4,6	1,3
	1988	38,1	1,7	14,7	15,8	5,2	0,7	5,9	14,2	18	19,1	12,6	4,6	1,8
	2012	34,5	4,2	15,0	8,4	4,3	2,5	4,02	23,9	6,5	12,1	10,9	8,1	3,4
	2015	34,5	0,27	20,1	11,2	3	-	18,2	12,2	4,1	13,7	10,9	5,8	4,1
	2018	34,5	0,9	20,9	13,0	5,3	-	14,2	16,2	4,1	13,7	11,0	5,7	4,1
Geokcha	1984	25,9	2,8	9,1	11,8	2,2	0	1,2	11,6	13,1	12,1	6	4,3	3,5
	1986	26,1	2,5	11,8	9,4	2,4	0	9,3	9,1	7,7	13,2	6,5	3,8	2,6
	1988	26,2	0,6	11,0	10,8	3,6	0,2	9,9	9,7	6,6	13,1	7,1	3,2	2,8
	2012	26,2	4,1	9,8	5,4	4,4	2,5	9,6	10,9	5,7	14,9	6,1	3,9	1,3
	2015	26,2	0,36	12,0	9,9	3,9	-	14,6	5,2	6,4	15,7	5	4,4	1,1
	2018	26,2	0,7	10,8	9,0	4,8	0,9	13,6	6,2	6,4	15,7	5,0	4,5	1,0
Zardob	1984	30	8,1	9,7	4,8	2,1	5,3	2,5	4,4	23,1	7,3	2,5	3,6	16,6
	1986	30,4	3,4	17,2	8,9	0,9	0	4,6	11,4	14,4	7,9	7,3	3,7	11,5
	1988	30,8	1,5	21,6	6,9	0,8	0	4,2	8,9	17,7	9,6	9,4	4,4	7,4
	2012	32,7	0,79	15,9	10,5	5,6	0,45	2,7	10,2	20,3	13,2	8,1	5,2	6,7
	2015	33,2	0,45	11,8	17,6	3,4	-	5,9	14,6	12,7	9,5	11,3	7,4	5
	2018	33,2	0,5	14,0	13,0	5.7	-	4,9	15,5	12,8	9,5	11,3	7,4	5,0
Ujar	1984	24	3,2	11,9	7,5	1,4	0	0	7,7	16,3	2,5	6	7,3	8,2
	1986	24,6	2,8	13,0	7,8	1	0	0,9	7,2	16,5	4,8	11,5	5,4	2,9
	1988	25,3	2	14,5	7,8	1	0	1,6	6,7	17	4,9	12,5	5	2,9
	2012	24,9	0,58	13,2	9	2,2	-	1,2	4,5	19,2	10,8	5,4	2,8	5,9
	2014	24,9	0,39	9,8	9,4	5,3	-	0,91	8,9	15,1	10,8	4,4	2,8	6,9
	2018	24,9	–	14,1	8,7	2,1	-	2,9	5,8	16,2	9,7	6,8	6,3	2,1
Kuurdamir	1984	52,2	4,5	12,4	15,2	7,7	12,4	0	0	52,2	5,1	6,8	16,8	23,5
	1986	53,8	3,9	28,3	16,8	3	1,8	0,3	11,2	42,3	16	22,9	11,1	3,8
	1988	54,8	3,4	30,9	16	3,4	1,1	1,2	12,3	41,3	16,1	24,7	10,3	3,7
	2012	52,8	2,4	23,6	16,3	5,8	4,7	2,1	11,6	39,1	12,5	23,8	11,1	5,4
	2015	52,8	6,6	16,7	16,7	11,3	1,5	8,6	13,1	31,1	23,4	18,9	7,3	3,2
	2018	52,8	2,0	21,7	16,2	11,6	1,3	5,6	16,1	31,1	23,3	18,9	7,3	3,2
Agsu	1984	34,7	4,2	14,0	12,2	2,1	2,2	0	12,4	22,5	14,3	8,6	7,9	3,9
	1986	34,4	3,4	13,5	13,1	2,2	2,2	0	14,2	20,2	13,9	11,4	6,3	2,8
	1988	34,6	1,8	15,8	12,5	2,5	2	2,3	8,3	24	14	13,7	4,5	2,4
	2012	37	2,2	18,0	11,7	3,8	1,4	3,4	11,9	21,7	12,2	12,2	8,7	3,9
	2015	37	0,2	6,1	24,9	5,8	-	2,9	16,7	17,4	20,5	10,3	4,7	1,5
	2018	37	0,2	9,0	22,0	5,8	-	2,9	16,7	17,4	20,5	10,3	4,7	1,5

The irrigation type of regime is formed under the influence of infiltration waters through canals and irrigated fields. The correlation coefficient between the groundwater level and the canal discharge is 0.91. Irrigation-irrigation-drainage type is identified on the basis of a close correlation dependence on drainage flow with a correlation coefficient of 0.74. Irrigation-irrigation type of groundwater regime has a close correlation with water supply. The influence of waterfalls on the level of groundwater, in addition to feeding them with seepage water, is also exerted by seepage water from irrigated fields.

III. Results

In the Shirvan steppe, hydrogeological conditions - basically the natural level and hydrochemical regime of groundwater under the influence of anthropogenic factors have undergone a serious change. Since 1930, due to the construction of large hydraulic structures and irrigation and reclamation systems, as well as the expansion of irrigated areas and the intensive use of surface irrigation, the level and hydrochemical regime of groundwater has changed dramatically. In 1930, the groundwater level averaged 7.0 m, and in 1970 - 2.4 m. From 1930 to 1950, the groundwater level rose by an average of 5 cm per year, and from 1950 to 1980. by 19 cm, in subsequent years, due to evaporation and the operation of collector-drainage networks, the level stabilized. After the construction of the Upper Shirvan Canal - five years later (built in 1958), the piezometric level of the first pressure aquifer came to the surface of the earth, and then stabilized.

In the study area, the hydrochemical regime of groundwater has seriously changed and more than halved, while the pressure regime has not changed. Mineralization of groundwater from 1950 to 1960 rose, and then gradually decreased. This is due to the flow of irrigated water into groundwater and the operation of collector-drainage networks. It was revealed that ground and pressure waters of the same mineralogical composition differ in chemical composition and type. Groundwater with a mineralization degree of up to 1.0 g/l is mainly of a sulfate-hydrocarbonate composition, and pressure waters are of a hydrocarbonate-sulphate type. And with a degree of mineralization up to 3.0 g/l, they are mainly chloride-sulfate-sodium type and sulfate-chloride-magnesium type.

For 80 years, the groundwater level in the territory of the Shirvan steppe has risen by more than 4.1 m, and their mineralization has decreased by 16.2 g/l. The groundwater regime is mainly formed by land irrigation and drainage.

According to the synchronism of changes in the regime-forming factors and the level of groundwater, genetic types of the regime were distinguished - climatic, hydrological, irrigation, irrigation-irrigation-drainage, irrigation-irrigation, and the areas of their predominant development were determined. The climatic type includes regimes with a high correlation between fluctuations in the level of groundwater, seasonal and long-term periodicity of precipitation; the hydrological type is characterized by a similar dependence - on surface runoff, for the irrigation-irrigation-drainage type - on water supply and catchment.

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