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GROUNDWATER OF AZERBAIJAN

Groundwater basins

The *Greater Caucasus Mountains*, the *Lesser Caucasus Mountains* and *Kura-Araz Lowland,* which divides the latter two ranges of mountains, are noted for their geostructural characteristics spread along the territory of the Republic of Azerbaijan. Although the area called *Mountainous Talysh* is separated from the *Lesser Caucasus* by *Araz River* in the southeast, it is considered to be a part of the *Lesser Caucasus* Mountain Ranges due to its geostructural zoning. Eighteen hydrogeological basins with porous-stratal, porous-fractured and fractured water resources exist in this area (Table 1).

Table 1

Hydrogeological basins

Geostructural regions	**Hydrogeological basins**
A. Fold Mountains Area of the Greater Caucasus	1. Porous-fractured water basin of the Greater Caucasus; 2. Shamakhy-Gobustan porous-stratal and fractured water basin; 3. Porous-stratal water basin in Absheron Peninsula; 4. Samur-Gusarchay porous-stratal water basin;
B Fold Mountains Area of the Lesser Caucasus	1. Porous-fractured water basin of the Lesser Caucasus; 2. Nakhchivan porous-fractured water basin; 3. Talysh porous-fractured water basin;
C. Kur-Araz Lowland	1.Sheki-Zagatala porous-stratal water basin; 2.Gyanja-Gazakh porous-stratal water basin; 3.Garabagh porous-stratal water basin; 4. Mil porous-stratal water basin; 5. Jabrail porous-stratal water basin; 6. Nakhchivan porous-stratal water basin; 7.Shirvan porous- stratal water basin; 8. Mugan-Salyan porous- stratal water basin; 9. Lenkoran porous- stratal water basin; 10.Porous-stratal water basin in Neogenic foothills of Jeiranchel; 11. Porous-stratal water basin in Neogenic foothills of Ajinour .

Main stock of potable and low-mineralized groundwater in Azerbaijan is found in porous-stratal basins of submontane plains in Kura-Araz lowland and porous-stratal basin of Samur-Gusarchay valley (Fig 1).

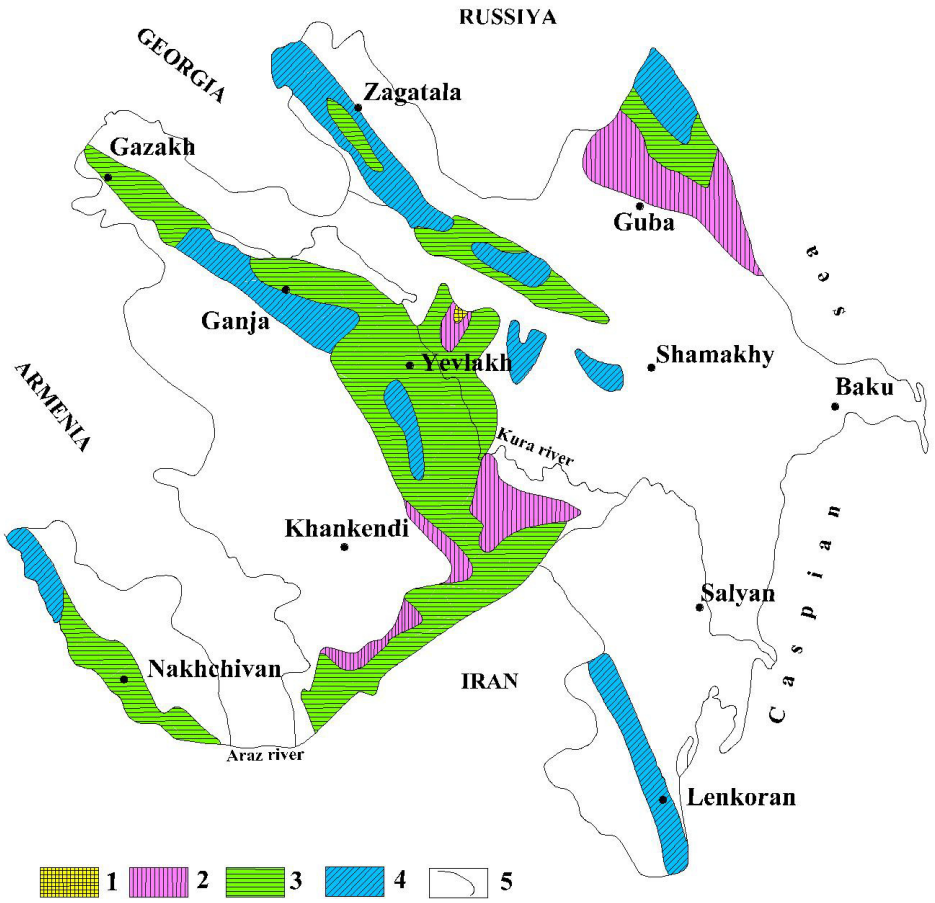

Fig 1. Groundwater in piedmont troughs, fresh and low-mineralized

Legend: Unit rates of usable groundwater reserves, l/s.km^2; 1 - up to 0.1; 2 – 0.1-1.0; 3 – 1.0-10; 4 – over 10; 5 – borders of areas with different groundwater reserve rates

Out of these eighteen basins, the following ones have direct borders with neighbouring countries:

With Georgia - Gyanja-Gazakh, Sheki-Zagatala, Jeiranchel, Ajinour porous-stratal water basins and the Greater Caucasus porous- fractured water basin (partly);

With Armenia – Nakhchivan porous-stratal water basin; porous-stratal water basin of the Lesser Caucasus; and Nakhchivan porous-fractured water basins;

With Iran – Nakhchivan, Jabrail, Mil, Mugan-Salyan, and partly Lenkoran porous- stratal water basins; porous- stratal water basins of the Lesser Caucasus and porous-fractured water basins of Mountainous Talysh.

With Russia – Porous-fractured basin of the Greater Caucasus and Samur-Gusarchay porous-stratal water basin.

Aquifers

Mountainous Structures in the territory of Azerbaijan (the Greater Caucasus, Lesser Caucasus, Nakhchivan, and Mountain Talysh) are composed of Meso-Cainozoic formations. Their main characteristics include: dissected relief, thick zone of weathering, fissured, mostly thin dealluvial loam coverings, valleys, and small intermountain depressions formed by alluvial and fluvioglacial sediments. In the mountainous areas groundwater mainly occurs in the zones of weathering and tectonic disruptions. Groundwater flows out to ground surface at the foothills and on the edges of gorges and valleys in the form of springs with the flow rate of 5-10 l/s. The springs with high discharge rates (60-100 l/s) are mostly encountered in the areas Karst limestone formations. Groundwater resources found in alluvial formations forming the floodplains and the layers beneath riverbeds have a great economic importance. Greatest underground flow rates reach 40-60 thousand m3/day.

Foothill and intermountain plains (Samur-Gusarchay, Gyanja-Gazakh, Sheki-Zagatala, Shirvan, Mill-Garabagh, Jabrail, Lenkoran and Nakhchivan porous-stratal groundwater basins) are rich in fresh and low-mineralized groundwater. They are formed by confluent fans of Upper Pliocene-Quaternary ages, alluvial quaternary and alluvial-dealluvial strata, which are basically rather thick (up to 300-500 m, seldom 1000-1500 m) and are composed of boulders, shingle, gravel, sand, clay and loam.

On the tops of debris cones groundwater forms a single unconfined aquifer, while in the central and peripheral parts, where clay and mud fill emerge, the unconfined aquifer splits into one unconfined and several confined aquifers. Almost all of the abovementioned basins contain one unconfined and several confined aquifers. Thus, the alluvial sediments of Gyanja-Gazakh foothills (explored till the depth of 350-400 m) comprise one unconfined and five confined aquifers; Garabagh and Mil - one unconfined and six confined; Sheki-Zagatala – one unconfined and one whole confined aquifer; Jabrail and Nakhchivan each contain one unconfined aquifer and one confined aquifer.

Main average geological parameters of the aquifers are given in Table 2.

Table 2

Characteristics of aquifers along porous- stratal groundwater basins of foothill planes

№	Hydro-geological region	Aquifer	Occurrence depth of aquifer, m	Static (piezometric) level in relation to ground surface, m	Thickness of aquiferous rocks, m	Well output rate, l/s	Specific yield l/s, m	Permeability of aquiferous rocks, m/d
1	2	3	4	5	6	7	8	9
1	Samur-Gusarchay	Unconfined	-	0 - 35	15-80	1,4-166,6	0,35-22,9	2,7-150,0
		Unconfined	-	0,2-150	Up to 100	5,2-18,0	0,25-1,25	1,1-13,4
		Confined	40 - 80	+18,5–19,0	50-115	7,2-66,8	1-12,2	5,7-246,0

		Confined	68 - 305	+3,0-+6	10-200	6-55,8	1,0-5,0	4,0-55,0
		Confined	62 - 236	+22,5– 25,0	6-60	3,4-54,1	0,3-13,6	3,2-86,6
		Confined	132 - 420	+12,2 – 5,0	5-228	4,5-82	0,1-3,4	0,4-38,1
2	Sheki-Zagatala	Unconfined	-	Up to 89,0	10,0-328,0	0,06-27,2	Up to 13,6	0,02-35,5
		Confined	10,0-70,0	+50,0-7,8	Up to 100,0	0,2-98,0	0,03-2,2	0,03-73,0
3	Gyanja-Gazakh	Unconfined	-	0,2-97,8	5,5-185,2	0,04-32,7	0,01-10,8	0,006-49,9
		Confined	19,3-218,0	+32,0-80,0	2,6-97,3	0,04-57,0	0,02-8,7	0,04-105,9
		Confined	68,5-192,0	+13,7-80,7	3,0-129,5	0,28-25,0	0,04-3,13	0,5-55,6
		Confined	120,0-283,0	+2,0-23,9	14,5-44,5	0,47-12,0	0,06-1,85	0,3-16,2
		Confined	36,0-284,0	+24,2-32,2	5,0-87,0	0,48-36,8	0,04-3,06	0,9-36,7
4	Garabagh	Unconfined	-	0,7-31,0	5,0-50,0	0,06-20,0	0,04-8,65	0,2-93,2
		Confined	20,0-100,0	+2,4-56,0	4,0-109,5	0,07-11,7	0,05-4,2	0,9-38,7
		Confined	70,0-270,0	+15,1-22,0	5,0-104,0	0,0,16-13,8	0,06-2,1	0,1-10,2
		Confined	115,0-290,0	+15,0-7,5	Up to 51,0	0,1-10,3	0,08-0,9	0,5-11,6
		Confined	135,0-400,0	+15,0-7,8	20,0-40,0	0,6-23,2	0,1-0,9	0,9-18,8
		Confined	200,0-380,0	+3,0-11,1	3,0-43,0	0,16-1,2	0,1-0,24	1,6-4,5
5	Mil Plain	Unconfined	-	1,0-80,0	2,0-45,0	Up to 20,0	0,04-8,0	0,8-51,5
		Confined	16,0-110,0	+8,2-37,0	3,0-59,0	Up to 13,7	0,01-3,9	0,02-97,0
		Confined	85,0-185,0	+7,5-3,7	3,0-75,0	Up to 9,0	0,02-2,3	0,2-15,5
		Confined	78,0-242,0	+17,7-0,6	7,0-77,0	Up to 24,3	0,02-2,2	2,4-14,9
		Confined	90,0-300,0	+13,1-16,6	3,0-76,0	Up to 43,0	0,1-1,64	0,3-42,2
		Confined	100,0-300,0	+35,5-45,0	4,0-140,0	Up to 22,3	0,02-1,5	0,1-19,8
6	Shirvan	Unconfined	-	0,4-73,3	3,5-178,6	0,05-11,8	0,02-5,4	0,1-64,1
		Confined	13,0-128,0	+8,2-20,8	3,0-170,7	0,06-13,3	0,02-4,2	0,2-27,9
		Confined	75,0-274,0	+19,1-14,5	3,6-73,8	0,04-8,3	0,01-2,7	0,1-35,3
		Confined	62,0-316,0	+9,0-43,2	4,5-86,4	0,04-4,1	0,01-3,8	0,1-17,9
7	Jabrail	Unconfined	-	0,7-30,0	10,8-119,0	0,13-9,1	0,01-3,0	3,0-24,2
		Unconfined	-	20,0-81,0	23,0-210,0	0,07-18,0	0,01-1,8	0,01-6,8
		Confined	200,0-300,0	+17,1-81,0	15,0-57,0	0,2-5,7	0,003-0,9	0,01-5,5
	Lenkoran	Unconfined	-	0-26,0	1,4-67,0	0,23-16,0	0,03-2,9	0,5-40,0
		Confined	20,0-60,0	+6,3-11,0	1,5-64,7	0,36-15,0	0,03-3,3	1,0-43,0

		Confined	42,0-237,0	+5,0-13,0	6,0-60,0	0,2-9,0	0,2-1,9	1,3-14,8
8	Nakhchivan	Unconfined	-	0,9-34,0	6,0-181,0	0,1-55,5	0,01-27,3	0,01-60,6
		Confined	19,0-120,0	+3,6-+0,1	6,5-95,6	1,6-38,0	0,8-7,2	0,8-57,6

Unconfined aquifers are found throughout the foothill plains. At downgrading terrains, unconfined groundwater table decreases from 60-80 m on the tops of the alluvial fans reaching even to several centimetres at the fringe and natural outflow zones of the beds. Occurrence depth unconfined aquifer is much greater in the apical parts of Sheki-Zagatala (up to 89m), Shirvan (up to 73m), Gyanja-Gazakh (up to 97m), and Mil (up to 80m). Thickness of aquiferous layers vary from 3-4 (Gyanja-Gazakh, Mill-Garabagh, Shirvan plains) to 178-185m (Gyanja-Gazakh, Shirvan, Nakhchivan plains). Maximum output of non-confined wells is 25-30 l/s; majority of wells have yields ranging from 3-5 l/s to 15-20 l/s. A number of springs with flow rates of 0.2-0.3 l/s and 15-20 l/s occur at the fringe and natural outflow zones, and springs with the flow rates of 280-300 l/s are encountered in Sheki-Zagatala plain.

Permeability of aquiferous layers varies from 0.1-0.5 m/day (on the edges of alluvial fan) to 25-48 m/day (on the tops and central parts of alluvial fan).

Confined aquifers lying at a distance of several kilometres below the contact zone of parent rocks and coarse-grained alluvial sediments cover less area than unconfined aquifers. Tops of these confined aquifers were penetrated by wells drilled to depths of 10-70 m in Sheki-Zagatala, 20-171m in Gyanja-Gazakh, 13-128 m in Shirvan, 16-110 m in Mil-Garabagh, 200-300 m in Jabrail and 19-120m in Nakhchivan. Almost each aquiferous layer contains sublayers composed of clay, loamy soil or clay fillers. Confined aquifers are also interlaid by these sediments, which are thicker (from 5-10m to 25-50m) and have greater spreading zone. Piezometric levels of pressurized waters are established below (from 0-3m to 70-80m) and above (from +1+3m to +20+50m) the ground surface. Pressurized waters of Sheki-Zagatala have the highest pressure rates. In most cases piezometric levels of underlying confined aquifers are set higher than those of the overlying. Output of wells drilled into confined aquifers (pumping-out) amounts to: 0.1-57l/s in Gyanja-Gazakh; 0.2-98 l/s in Sheki-Zagatala; 0.1-11 l/s in Shirvan; 0.1-24 l/s in Mill-Garabagh; 0.2-6 l/s in Jabrail; 0.1-38l/s in Nakhchivan. Output of wells drilled into confined aquifers (self-discharge amounts up to 75-98 l/s in Sheki-Zagatala and up to 20-25 l/s in Gyanja-Gazakh. Permeability of the aquifer ranges between 0.1-0.4m/day to 10-46m/day.

Neogenic foothill plains are represented by the Jeiranchel and Ajinour porous-stratal water basins, where groundwater does not have the regional and local spreading as in the cases of abovementioned plains.

Distinguished for their adverse hydrogeological conditions, the Ajinour (mostly in the west) and Jeiranchel porous-stratal water basins are predominantly composed of Palaeogenic and Neogenic clay rocks with sub-constituents such as shingle, sand, sandstone and limestone. Confined and unconfined aquifers with hydrogeological parameters similar to above were penetrated by exploratory wells drilled in the eastern part of Ajinohur, where continental river sediments prevail. Unconfined waters lie in the river valleys and troughs at the depth of 12-91m; Yields of the wells range between 2 and 12 l/s.

Confined waters mostly occur at depth intervals of 60-300m; piezometric levels are 15-80 m below and rarely +1+2m above the ground surface. Well output – 2-11l/s.

In Jeiranchel groundwater is found in local closed basins. Exploratory wells drilled here penetrate unconfined and confiners aquifers at depths varying between 5-8 m to 300-320 m. Flow rates of the wells are mainly between 0,5 and 5-9 l/s. Aquiferous layers comprising the subsoil in both plains are characterized with low permeability in the range of 0,02-1,0 m/d.

Compared with porous-stratal water basin of Jeyranchel and Ajinour, hydrogeological conditions within Shamakhy-Gubustan basin of porous-stratal and fractured water are more favourable. Geological setting of the territory includes limestone, sandstone, sand, sandy clay, clay, loamy soil, argillites and marl of Cretaceous, Paleogenic, Neogenic and Quaternary periods. In general, aquiferous rocks comprise minority. Yields of confined aquifers penetrated by exploratory wells drilled into synclinal depressions and river valleys vary from 0,2-0,5 l/s to 7-8 l/s. Permeability ranges between 0,5-14,0 m/day.

Piezometric levels of pressurized water resources are both below (50-70m) and above (+1 - +2 m) the ground surface.

Being considered as the eastern continuation of the Greater Caucasus mountainous and fold zone, the Absheron Peninsula is characterized with complex hydrogeological conditions. Lack of surface waters, scarceness of atmospheric precipitations, high evaporability and dominance of clay deposits in geological profiles, low permeability of water-containing deposits and salinity of rocks do not enable formation of considerable groundwater useful for consumption. Under natural conditions, the sporadic groundwater occurrence is peculiar to peninsula. Over the last 30-35 years, the area of sporadic groundwater occurrence decreased sharply. Waterless rocks turned into aquiferous ones and previously waterless territories are now exposed to threat of underflooding. Within the area of the Peninsula, pressurized and non-pressurized groundwater is found in layers, which are represented till the depth of productive strata by limestone, sandstone, sand and clayey sand sediments of Quaternary Age. There is a considerable difference between hydrogeological conditions of Western Absheron and those of Eastern Absheron. Occurrence depth of non-artesian aquifers varies from several centimeters to 25-30 meters. Yield of exploratory wells fluctuates between 0,2-0,4 l/s and 3-4 l/s. Permeability varies in the range of 0,1-0,2 and 5-7 m/day. Yield of exploratory wells drilled in confined aquifers is approx. 0,5-1,0 l/s and permeability changes from 0,2 till 13,6 m/day.

The lowlands of Azerbaijan, mainly the Mugan-Salyan, part of Shirvan, Mill and Lenkoran porous-stratal water basins are also distinguished for their adverse hydrogeological conditions. Continental sediments comprise minority in geological composition of these plains and are mainly composed of Upper Pliocene Quaternary and Quaternary continental marine sediments and merely marine sediments. Non-pressurized and pressurized groundwater is found in the peninsula. Level of non-pressurized groundwater varies from 1-3 m to 10-15 m. Non-pressurized groundwater is very close to day surface in the vast majority of the peninsula. Tested yield and permeability of exploratory wells drilled in the peninsula vary between 0,1-0,5 and 4-5 l/s, and 0,05-20,0m/day respectively. Yields observed in exploratory wells drilled in confined aquifers were 1-2 l/s during testing and 1-2 l/s by gravity. Permeability of aquiferous layers is between – 0,31-6,32 m/d.

Conditions of groundwater formation, transit and discharge

Both unconfined and confined waters originate from the single unconfined aquifer on the tops of alluvial fans, where precipitation and runoff are absorbed most intensively. The comb structure of Upper Pliocene–Quaternary and Quaternary coarse deposits directs groundwater flowing through the valley as isolated unconfined and confined aquifers towards the regional discharge zone. The centres of debris cones form the zone of groundwater transit and redistribution of its discharge

among concrete aquifers. The unconfined aquifer that reaches the maximum thickness in the zone of formation rapidly thins and pinches out in the discharge zone. The confined aquifer gains thickness downstream the transit zone and thins in the discharge zone

The Kur is the regional discharge zone for groundwater of Gyanja-Gazakh, Mill-Garabagh, and Shirvan plains, while the Araz is the regional discharge zone for groundwater of Nakhchivan and Jabrail plains. The situation is quite different in the Sheki-Zagatala plain where groundwater flow originating in the Greater Caucasus foothills meets a thick watertight stratum along the edge of the Neogene foothills, and being barred by such regional discharge zones as the Kur and the Araz, increases pressure and partially returns to the Greater Caucasus foothills where it was formed.

Groundwater recharge sources

Precipitation, water from melted snow and small glaciers are the main groundwater feeding sources in the mountains, while precipitation, rivers, and groundwater inflow from the mountains are the main feeding sources in the foothill plains.

Mean annual rainfall in the Greater Caucasus and Lesser Caucasus (above 2700 meters) is 700-1400mm; at the height of 1500-2700 m – over 900 mm, at 1000-2000m – 500-800mm, at the height of 1000-3000m in Nakhchivan 150-500mm. In the foothill plains mean annual rainfall amounts to: 200-400mm in Gyanja-Gazakh; 600-1100mm in Sheki-Zagatala and Alazan-Agrichai; 350-510mm in Shirvan; 250-460mm in Mill-Garabagh; 285-595mm in Jabrail; 700-1300mm in Lenkoran; and 210-310mm in Nakhchivan.

Precipitation exceeds evaporation in the mountains, foothills and uplands and the considerable humidity helps to form surface, and in favourable conditions of foothill plains, groundwater runoffs. In the lowland, evaporation sometimes exceeds the mean annual rainfall several times, which prevents runoff formation and causes intensive evaporation of surface water and groundwater.

The river network of Azerbaijan is characterized by unequal distribution. The rivers streaming down the southwest slopes of the Greater Caucasus and northeast and eastern slopes of the Lesser Caucasus flow into the River Kur. The rivers streaming down the southwest and southeast slopes of the Lesser Caucasus flow into the River Araz; while those streaming down the north-east slopes of the Greater Caucasus and Talysh fall into the Caspian Sea. The river network is developed best in the mountains at the height of 1000-2500m and above and below this zone the network is less developed. The highest river network density (0.84km/km^2) is found in Talysh, the lowest density (0.20 km/km^2) is observed in Gobustan. Average density of the river network of Azerbaijan is 0.39km/km^2.

River water is the main feeding source of groundwater in Sheki-Zagatala and Alazan-Agrichai plains and an important source in Gyanja-Gazakh, Garabagh and Lenkoran plains, but it has no importance in groundwater forming in Jeiranchel, Gobustan and western part of Ajinour plains.

The regime of groundwater recharge with river water has changed considerably since the second half of the last century. The construction of water reservoirs and irrigation canals and expansion of irrigated areas have intensified groundwater feeding through increasing volumes and area of surface water infiltration.

Another factor changing the surface/ground water balance is the influx of groundwater from confined aquifers into unconfined aquifers in the course of well drilling. This process continues and gathers strength.

Groundwater runoff from the mountains has great importance for the Sheki-Zagatala, Alazan-Agrichai, Gyanja-Gazakh, Garabagh and Lenkoran plains.

Forests and meadows with their moisture-retaining capacity greatly contribute to formation of water resources and above all groundwater resources.

Wetlands have no considerable importance in water resource forming in Azerbaijan. They also cannot prevent the sudden floods that are usual downstream the Kur. Wetlands have an adverse impact on forming of water resources suitable for various needs.

Wetlands are located in depressions of the Kur-Araz Lowland and are distinguished for low precipitation, high evaporation, prevalence of argillaceous deposits, low water permeability, high salinity and hindered natural drainage.

Water leaking from irrigation channels infiltrates into soil and increases groundwater table which results in flooding, swamping and irrigation of arid areas and salinization of irrigated areas. The collector-drainage system is clogged and unable to fully cope with infiltration of irrigation water. This causes migration of polluters and components of mineral and organic fertilizers into groundwater.

The rise of the Caspian Sea level that began in 1976-77 has resulted in flooding of the foreland, beaches and roads. Stabilization of the sea level and reduction of flooding rate have been observed since 1998.

The rise of groundwater table and flooding lead to a change of microclimate, growth of indoors air moisture, deterioration of sanitary conditions, growth of populations of mosquitoes and other insects and spreading of diseases. Flooding results in stoppage of industrial enterprises, salinization of arable lands, devastation of gardens and recreation zones.

There is no utilizable groundwater in the wetlands of Azerbaijan. Natural hydrogeological factors have conditioned the forming of thick aquifers with high salinization.

Flooding and swamping in these areas increase groundwater salinization and cause resalinization of argillaceous deposits, rise groundwater table, and aggravate bacteriological condition of surface water and groundwater.

Geostructural and lithofacies features of foothill porous- stratal groundwater basins and the common feeding sources condition the tight *hydrodynamic connection* between unconfined and confined aquifers: unconfined groundwater feeds confined groundwater on the tops and in the centres of debris cones, while confined water feeds unconfined water on the edges of the debris cones.

The situation in the porous-fractured groundwater basins is absolutely different. Thus in the Lesser Caucasus groundwater occurring in fractures associated with intrusions feeds local porous waters. In the Greater Caucasus basic sediment fractures are fed by precipitation, i.e. porous-fractured waters have common feeding sources. There is no connection between groundwater of different fractures.

Groundwater in isolated structures of Neogene foothills also has a hydrodynamic connection.

The issue of man-caused replenishment of groundwater reserves is not sufficiently explored. Relevant studies were conducted only once in 1970s in the representative basin of the River

Gyanjachai, but were incomplete. Yet almost all foothill plains and tops of debris cones of rivers in Azerbaijan present opportunities for researches.

Groundwater Reserves

The potential usable reserves of fresh and low-mineralized groundwater in Azerbaijan are estimated at 24 mln m^3/day. Out of this, 12 mln m^3/day have been approved by the State Commission on Reserves of Azerbaijan and the Former USSR. It's noteworthy that these reserves were estimated in 1970-1980, and the figures most probably differ from real groundwater reserves of Azerbaijan that have certainly changed because of the changes in water economy as well as qualitative and quantitative changes in groundwater recharge sources. The real reserves of fresh and low-mineralized groundwater are considered to be much bigger than the estimated. Besides the estimated reserves of usable groundwater of hydrogeological regions, groundwater reserves of more than 50 deposits have been estimated and approved allowing the construction of water intake facilities. Estimated mineral water reserves in the Azerbaijani sector of the Kur river basin amount to 20.000 m^3/d; thermal water reserves total 130.000 m^3/d.

Groundwater management

In Azerbaijan groundwater is extracted through wells and kahrizes. There are many capped springs in the foothills. The depth of the large majority of the wells in operation is between 120-200 meters.

Until the 1980s, annual groundwater production in the period of intensive agricultural activity was 2.5-2.9 bln m^3; after 1980's it reduced to 1.3-1.5 bln m^3. Over recent years, however, annual groundwater production has increased again up to 3,0-3,5 billion cubic meters.

Groundwater production of Garabagh, Mill and Gyanja-Gazakh plains exceeds that of all other hydrogeological regions of Azerbaijan. Eight to ten percent of groundwater is used for household water supply; 3-4% is used for industrial needs, and 86-88% is used for irrigation. Meanwhile, a major part of the population has to use water from rivers and channels for household needs because of the unequal distribution of water resources and the lack of water intake facilities.

It's noteworthy that Baku, capital city of Azerbaijan, has always confronted with shortage of water the, and though not located in the Kur river basin, the city receives water from the Kur. The Absheron Peninsula, where Baku is situated, is known for its unfavourable climatic conditions: the lack of rivers, insufficient rainfall, high evaporation, predomination of argillaceous deposits, and high salinity of soils. These conditions prevented the forming of fresh and low- mineralized reserves in the Absheron. This is why such megalopolis as Baku has to use groundwater from the remote Samur-Gusarchai basin and the rivers Kur and Samur. One of the greatest water intake facility in the world has been constructed in the distance of 260 km to the north-west in Oguz field of Azerbaijan with the aim of water supply of the Baku city. The water intake facility consists of 78 water wells with the depth of 150-170m and with the productivity 5m^3/sec. The wells have been installed along 2 lines in parallel way with the length of 18 km with the distance of 1000 m between each one.

Although groundwater reserves have been estimated and approved in more than 50 deposits, water intake facilities have been constructed only in 20 of them.

In 1970s-1980s, fresh and low-mineralized groundwater was intensively used for irrigation needs in Goranboy, Khanlar, Samukh (Gyanja-Gazakh Plain), Barda, Agdam, and Agjabedy regions (Garabagh Plain). In some areas, production rates exceeded the rate of usable groundwater reserves.

Groundwater mismanagement is one of the most crucial problems: unlicensed and unqualified drilling of productions wells by legal and natural entities affects the hydrodynamic and hydrochemical balance and exhausts groundwater reserves, sometimes causing inleakage of mineralized water.

Groundwater quality

Porous-fractured and fractured water basins contain fresh groundwater with calcium hydrocarbonate composition. Groundwater containing specific components is mineralized and is described in a separate chapter.

Fresh and low-mineralized waters are widely spread in *foothill plains* depending on specific features of their geological structure, inflow rate, and discharge of aquifers (presence or lack of springs, runoff, upstream filtration into unconfined aquifer with following evaporation, etc.).

In depressions (mostly peripheral zones of debris cones of Garabagh, Mill, and Shirvan plains) fresh and low-mineralized are shifted by very salty or salty waters depending on the abovementioned features. Fresh groundwater occurs throughout the Sheki-Zagatala plain and almost everywhere in Gyanja-Gazakh, Garabagh and Jabrail plains. Mineralization of unconfined and confined groundwater exceeds 3-5 g/l in the areas of the Gyanja-Gazakh plain, where inter-cone depressions contact with the mountain zone and where bentonitic clay is found. High mineralization is characteristic of confined aquifers of Absheron and Akchagyl deposits in Gyanja-Gazakh, Garabagh, and Mil plains. The Garabagh, Mill, and Shirvan plains are distinguished for their complex hydrochemical composition. Thus, in Garabagh and Mill plains, one unconfined and two confined aquifers contain mineralized water and are interlaid by a confined aquifer containing fresh water. In the Shirvan Plain, groundwater outside the river debris cones is mainly salty.

Certain features of chemical composition of groundwater of foothill plains are described in the table 3 below.

Table 3

Characteristic of chemical composition of fresh and low-mineralized groundwater in porous-stratal basins of foothill plains

Indicators	**Porous-stratal water basin**							
	Sheki-Zagatala	Samur-Gusarchay	Gyanja-Gazakh	Garabagh	Mill	Shirvan	Jabrail	Nakhchivan
Solid residue, g/l	0.2-0.5	0,2-0,7	0.3-3.0	0.3-2.3	0.5-2.6	0.-3.0	0.3-3.0	0.2-2.4
Hardness mg-equiv./l	2.0-6.4	1,7-10,3	1.2-27.3	0.6-16.0	0.4-13.0	2.2-6.1	2.3-24.7	0.9-18.1
PH	6.7-8.2	6,9-8,2	6.5-8.2	7.4-8.4	7.1-8.3	7.5-7.7	7.0-8.1	6.6-8.3
Chlorides, mg/l	4-110	4-980	4-1900	10-1040	46-1440	7-200	4-480	3-540
Sulphates,	14-132	12-206	4-1400	9-810	4-506	4-133	10-886	18-1270

mg/l								
Nitrates, mcg/l	Up to 9000	Up to 10000	Up to 9170	Up to 1000	Up to 3000	Up to 5000	Up to 0940	Up to 10000
Fluorine, mg/l	Up to 680	Up to 1500	Up to 1520	Up to 800	Up to 1500	Up to 750	Up to 1080	Up to 1200
Manganese, mcg/l	Up to 30	-	Trace	Up to 90	Trace	No	Trace	Trace
Iron, mcg/l	Up to 10	Up to 30	Up to 125	UP to 70	Up to 130	Up to 50	Up to 100	Up to 25
Copper, mcg/l	Up to 60	Up to 750	Up to 200	Up to 200	Up to 35	Up to 5000	Up to 34	Up to 100
Zinc mcg/l	Up to 50	Up to 4000	Up to 400	Up to 400	Up to 42	Up to 12	Up to 160	Up to 4200
Strontium, mcg/l	300-1700	Up to 1400	Up to 2000	Up to 1950	Up to 1800	250-1300	85-2000	Up to 2000
Lead, mcg/l	No	Up to 100	Up to 90	5-80	Up to 50	Up to 80	Up to 100	Up to 50

Fresh and low-mineralized waters seldom occur in the Neogene Jeiranchel and Ajinour plains, while low-mineralized and salt waters are to be found often here. In these plains, mineralization of pressure water containing sulphate chloride and sodium magnesium sometimes reaches 50-70 g/l. In some areas mineralization of pressure water and unconfined water amounts to 0.3-2.5 g/l and 0.4-1.9 g/l respectively.

Groundwater of the Mugan-Salyan plain and certain parts of the Mill and Shirvan plains are is salt, often very salty with solid residue amounting to 100-200g/l.

Only fresh and low-mineralized groundwater can be used for household, industrial and agricultural needs. Salt water has no practical usage and may contain the whole range of chemical elements and compounds.

Groundwater pollution

Groundwater pollution depends on rate of pollution of its main feed source – surface water, and pollution of the aeration zone.

The basins of the two main rivers of Azerbaijan, the Kur and the Araz, include vast areas on the territories of Georgia and Armenia.

Annual wastewater discharge into the Kur and its tributaries on the territory of Georgia amounts to 330 mln m^3. The water of the Akstafachay River, Kur's right tributary flowing through Armenia, contains chemical dye, oil products, phenol, ammonia nitrogen and other polluters that get into the river together with sewage (over 1mln m^3/year) discharged in Injevan, Dilizhan and other Armenian cities. The rivers Alazan and Iori, Kur's left tributaries, also carry polluted waters from Georgia to Azerbaijan. The Kur, polluted on the territory of Georgia, has BOD 5 – 3.71 mg/l when it crosses

the Azerbaijani border and contains oil products (0.15 mg/l), phenols (0.03 mg/l), and other polluters.

In Azerbaijan the Kur receives agricultural polluters and industrial wastewater both directly and through its tributaries. In some parts of the river BOD 5 reaches 4.1 mg/l, oil products – 0.24-0.30 mg/l, phenol amounts to 0.04-0.08 mg/l, etc.

The Araz, Azerbaijan's second biggest river in terms of its length and flow, receives dangerous polluters (nitrite nitrogen, ammonia nitrogen, heavy metals and other polluters exceeding the sanitary norms dozens of times) from Armenia through its left tributaries Razdan, Arpachai, Okhchuchai and others. Annual wastewater discharge into the Araz on the territory of Armenia exceeds 350 mln m^3. The Kajaran ore mining and processing enterprise and the Kafan copper-ore enterprise annually discharge over 150 mln m^3 of wastewater into the Okhchuchai River turning it into a red-brown, almost black silt flow in the moments of discharge. The red-brown liquid contains high concentration of aluminium, zinc, manganese, titanium, bismuth and other components. The main reason of the catastrophic condition of the rivers is the lack of effective drainage system and purification plants in Georgia, Armenia and Azerbaijan. In most part of communities, domestic wastes are discharged into the Kur and Araz or their tributaries.

On a large part of the lowland soil and zone of aeration are subjected to natural pollution - salinization (sodium chloride, sulphate sodium chloride, sulphate chloride sodium magnesium types of salinization). Salinization rises sharply in poorly drained and drainless areas below the zero contour. Salinization rate in irrigated areas ranges from 0.25% to 1-2%.

Local pollution of soil and zone of aeration with organic and mineral fertilizers can be observed in irrigated areas and around fertilizer storages. Soil and aeration zones around oil-fields and oil processing facilities are polluted with oil products, and on the territory of industrial enterprises soil contains chemical polluters.

In certain parts of irrigated areas of the Garabagh plain concentration of nitrates and nitrites in the zone of aeration in different years exceeded their concentration in groundwater more than 10 times. There is a high concentration of nitrates, nitrites, phosphates, sulphates, chlorine, iron and aluminium around the sludge pit at the Gyanja alumina enterprise.

There is no region-scale groundwater pollution in Azerbaijan; local pollution is of domestic, industrial and agricultural characters.

The main factor causing domestic pollution is the lack of effective drainage system and purification facilities in most of communities. Domestic wastes are discharged into rivers, the sea, natural or manmade pits. Groundwater pollution is caused by infiltration of contaminated river water or migration of pollutants via the zone of aeration.

Aluminium (0.08-3.5 mg/l), iron (3.5-50 mg/l), phenol (0.008-0.004 mg/l), high concentrations of nitrites, nitrates, ammonia and sulphates were encountered in groundwater in the area of the sludge pit of the Gyanja alumina enterprise.

No severe groundwater pollution has been observed in the area despite the concentration of industrial enterprises in the cities of Gyanja, Shirvan, Mingechevir, and Nakhchivan.

Though high, concentration of nitrites and nitrates in groundwater in irrigated areas does not exceed the MCL, while around cattle farms it sometimes reaches 10-10 mg/l and 12-145 mg/l correspondingly.

Concentration of nitrites and nitrates in kahriz waters in the Nakchivan Autonomous Republic is 0.1-1.3 mg/l and 2-75 mg/l respectively.

Bacteriological pollution of groundwater has been registered in irrigated areas, in cities, cattle farms and near sewage-purification facilities.

No pollution of pressure water has been observed, but ammonia of yet unknown origin was found in groundwater of the Gyanja-Gazakh plain.

Institutional issues

All water courses (groundwater basins, aquifers and complexes) on the territory of Azerbaijan are owned by the State. All physical and juridical persons have the right to use groundwater.

The organizations responsible for water management after the water sector reform are:

- The Ministry of Ecology and Natural Resources - carries out groundwater exploration and monitoring and coordinates its use.

- OJSC Azersu - household water supply countrywide and industrial water supply to some enterprises;

- OJSC Melioration and Water Economy – agricultural water supply.

- The State Water Resources Agency of the Ministry of Emergency Situations - deals with protection of strategic water bodies, floods, monitoring and other issues;

- Ministry of Public Health - control the quality of the drinkable water.

A range of industrial and agrarian enterprises have their own water supply systems.

For groundwater exploration and use applications should be submitted to relevant bodies, but this requirement is not always met.

The above mentioned organizations, and first of all the Ministry of Ecology and Natural Resources dispose of information on groundwater of Azerbaijan.

Published books, monographs and maps also contain comprehensive reliable data on this topic.

Information on groundwater reserves is handed upon submission of written application.

Groundwater monitoring

Groundwater monitoring is conducted by the Ministry of Ecology and Natural Resources of Azerbaijan.

The monitoring of groundwater level, flow quality and temperature in the Azerbaijani sector of the Kur-Araz river basin has been conducted since the 40^{th}-50^{th} years of the 20^{th} century. The

monitoring system covers almost all hydrogeological regions associated with foothill plains and depressions and embraces about 800 wells, springs and kahrizes.

The monitoring involves:

- Groundwater level, output and temperature – 3 times per months;
- Groundwater quality – 1-2 times per year.

Same monitoring sites are used to assess groundwater quality, level, yield and temperature.

In case of detection of local pollution frequency of monitoring is increased up to daily.

Beside the Ministry of Ecology and Natural Resources of Azerbaijan, JSC Melioration and Water Economy also holds monitoring in irrigated areas.

No monitoring is held in groundwater intake areas.

After the land reform, some of the monitoring sites turned to be located in private lands creating problems with their maintenance and monitoring. Many observation wells have become unfit for further researches.

Several geo-ecological issues

1. Unconfined groundwater is sensitive to seasonal climatic changes. Annual fluctuation of groundwater level ranges from 0.3-0.5m to 4.5m depending on depth of occurrence, lithologic composition of sediments, rainfall, evaporation and other factors. The peak values are associated with apical and central parts of debris cones. Mineralization and chemical composition of unconfined water in some parts of Garabagh, Mill, and Shirvan plains and throughout the Mugano-Salyan plain are also changeable. Mineralization and chemical composition of pressure water are stable, while their level and yield changes are smoother.

No changes are observed at the regional level.

2. Level and intensiveness of underflooding of lands has great significance to geoecological conditions in the Kur-Araz Lowland. Water leaking from irrigation canals infiltrates into soil and increases groundwater table causing flooding, swamping and irrigation of arid areas and salinization of irrigated areas. The collector-drainage system is clogged and unable to fully cope with infiltration of irrigation water. This causes migration of polluters and components of mineral and organic fertilizers into groundwater.

The rise of the Caspian Sea level that began in 1976-77 has resulted in flooding of the foreland, beaches and roads. Stabilization of the sea level and reduction of flooding rate have been observed since 1998.

The rise of groundwater level and flooding lead to a change of microclimate, growth of indoors air moisture, deterioration of sanitary conditions, growth of populations of mosquitoes and other insects and spreading of diseases. Flooding results in stoppage of industrial enterprises, salinization of arable lands, devastation of gardens and recreation zones.

However, the recently constructed Main Mill-Mugano Collector drains low-mineralized and polluted groundwater on vast areas of the Kur-Araz Lowland, enables reclamation of wetland and prevents their resalinization.

3. The Caspian Sea, one of the main components of the ecosystem of Azerbaijan, is an integral natural geosystem influenced by geological, climatic, hydrological, and space factors. The rise of the sea level leads to deterioration of complex hydrodynamic and hydrochemical conditions of the littoral zone:

- on the one hand, the emergence of the two-meter high barrier across the groundwater flow led to reduction of groundwater discharge into the sea and a rise of groundwater level in certain areas;

- on the other hand, areas earlier occupied by groundwater, were submerged after the rise of the sea level and this resulted in a rise of groundwater level in the littoral zone;

- in the areas of occurrence of low-mineralized groundwater migrating chemical elements and compounds of seawater change chemical composition of groundwater that differs from chemical composition and mineralization of seawater;

- seawaters invading the littoral zone formed by rocks with high condensing capacity have deteriorated conditions of accumulation of fresh and low-mineralized groundwater.

4. The impact of polluted waters of the Kur and the Araz (containing various chemical elements and compounds of agricultural, industrial, and domestic origin) on human health is unknown. Interaction of chemical elements and compounds in the waters of the two rivers is also unstudied. Adverse impact of polluted river water and associated groundwater on the ecosystems of the Caspian Sea and riverside areas is obvious.

Modelling and forecasting

The state of hydrogeological modelling is unsatisfactory and groundwater forecasting models do not exist in Azerbaijan. Hydrogeological modelling has been held only several times for estimation of groundwater reserves and during irrigation and drainage researches. However, for the first time in Azerbaijan, researches have been held for application of artificial intellect systems in forecasting and management of hydrogeological processes.

The available data allow creating hydrogeological models and forecasting. Printed hydrogeological data have been recently transferred into electronic form. There is an urgent need for data gathering, analysis and systematization.

Main groundwater problems

1. Local pollution sources have been registered and regional pollution of groundwater is possible in the areas associated with the rivers Kur and Araz and their tributaries, such as Okhchuchai, Akstafachai. Karkarchai, Arpachai, and Terterchai.

2. Information on condition of groundwater in the regions occupied by Armenia is unavailable. Groundwater pollution in these regions is beyond question taking into account that wastewater of such city as Khankendi is discharged directly into the Karkarchai.

3. An overall research of feeding conditions, hydrochemical and bacteriological composition of groundwater under the influence of rivers is indispensable.

4. The construction of water reservoirs on rivers has resulted in redistribution of water resources and change of correlation between surface water and groundwater necessitating an in-depth research of feeding conditions, hydrochemical and bacteriological composition of groundwater. It is first of all necessary to study influence of three big reservoirs located in the 110-120 km section on the Kur on groundwater of the Gyanja-Gazakh porous-stratal water basin.

5. The lack of an integrated water use scheme hinders rational use of water (including groundwater) resources in condition of their unequal distribution.

6. An appropriate legal base and an effective mechanism to control groundwater use and well drilling are yet to be developed.

7. The exposed trunk channels crossing almost the entire territory of Azerbaijan, which have negatively changed hydrogeological conditions in the Kur-Araz Lowland, should be studied and hydrogeological guidelines for their operation should be developed.

8. The large-scale agricultural activities have led to flooding of vast regions, irrigation of arid areas, and forming of man-made groundwater aquifers. There is a need to hold qualitative and quantitative analysis of all factors that would help to forecast, prevent and manage the process through the establishment of stationary hydrogeological models.

9. It is necessary to re-estimate usable groundwater resources.

10. Influence of depth fluids on groundwater in active water exchange zones is studied insufficiently.

11. Equipment used in hydrogeological researches fails to comply with modern requirements.