UNIVERSITY OF CRAIOVA **Series: Geography**
UNIVERSITATEA DIN CRAIOVA **Seria: Geografie**

Vol. 23 (new series) – 2022
Vol. 23 (serie nouă) – 2022

DESIGN OF GROUNDWATER CATCHMENTS. CASE STUDY: THE WATER SUPPLY OF ADJUD

PROIECTAREA CAPTĂRILOR DE APĂ SUBTERANĂ. STUDIU DE CAZ: ALIMENTAREA CU APĂ POTABILĂ A LOCALITĂȚII ADJUD

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Abstract: The use of groundwater to supply water to citizens is an important component of a country's security strategy, as groundwater is less vulnerable to pollution and can be used even in difficult climatic conditions. Groundwater catchments involve additional investment in research, compared to surface water catchments, because they use an underground source that must be identified through geological and hydrogeological research: the aquifer. From the geological and hydrogeological studies that were carried out in the area, the conclusion is that these aquifers can appear at depths between 15 and 120 m and there is a possibility that they manifest themselves artesian.

Key-words: *aquifer, hydrostatic level, protection zones, water supply*.
Cuvinte cheie: *acvifer, nivel hidrostatic, zone de protecție, alimentare cu apă*.

1. INTRODUCTION

Water supply is one of the most important elements when it comes to resources. Underground water is a source of strategic importance and less susceptible to pollution than surface water because the aquifers are partially protected from the penetration of polluting substances by the covering layers, the flow of groundwater is slow and also the penetration of polluting substances into the underground water is a lasting process. Underground water supply is growing exponentially in European countries in the context of global warming, being the moment when any resource must be exploited to the maximum.

The objectives for designing a groundwater catchment involves:
- Realization of the conceptual model of the aquifer to be captured, model with three components:
  - the spatial model (geological structure of the hydrostructure formations);
  - the parametric model (parameterization of the components of the spatial model: lithology, geomechanical, hydrogeological, hydrogeochemical parameters, etc.);

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- energy / hydrodynamic model (piezometric map of the aquifer in natural regime) (Scrădeanu et al., 2007).

- Mathematical modeling of the fluid flow:
  - groundwater flow;
  - hydrodynamic coupling with surface water;
  - fluid flow associated with groundwater.

- Designing the sustainable operation of the catchment:
  - operating flows;
    - catchment protection zones: severe protection zone, restricted protection zone, hydrogeological protection zone.

The catchment that feeds Adjud locality is made up of 10 boreholes: F2 New, F6 New, F7 New, F8 New, F9 New, F10 New, F11 New, F13, F14, F15 New (Table 1). Some of them are rehabilitated boreholes (F13, F14) and some are rebuilt (F2 New, F6 New, F7 New, F8 New, F9 New, F10 New, F11 New, F15 New).

Table 1 Elevation and piezometric level of boreholes

Borehole	Elevation [m]	Elevation of piezometric level [m]	Depth of piezometric level [m]
F2	105	90.0	15.0
F6	104	84.0	20.0
F7	103	85.5	17.5
F8	104	83.0	21.0
F9	104	82.5	21.5
F10	104	83.5	20.5
F11	103	82.5	20.5
F13	105	85.0	20.0
F14	105	85.0	20.0
F15	109	93.0	16.0

(Data source: Water supply borehole rehabilitation report of Adjud, Vrancea county)

2. DATA AND METHODS

2.1 Study area

Adjud catchment front is located in Vrancea County (Fig. 1), being positioned at approximately 500 m north of Adjud, on the right bank of the upper course of the Siret River, in the immediate vicinity of the national road DN11A that connects Onești and Adjud. Adjud is located in the north of Vrancea county, at the confluence of the Trotuș and the Siret rivers. The topographic area of Adjud is generally flat. The town is bordered by the Sub-Carpathian hills with heights of up to 400 m. The average general altitude of the municipality is about 100 m above sea level.

Based on the data coming mostly from drilling both in the researched area and in its surroundings, two types of aquifers were delimited: one groundwater, surface, and one of medium depth. The groundwater aquifer in the catchment area is intercepted at a shallow depth of up to 10 m, in meadows, terraces, at the base of floodplains and is confined to Holocene deposits of silt, sand, gravel and boulders.

From the hydrogeological and geological analysis, the medium depth aquifer is found at depths between 15 and 120 m. It can also be found in the form of a multilayer type, interspersed with layers of clay. The intercepted deposits are of Upper Pleistocene age (qp3) represented by alternations of medium clays and sands, sometimes coarse, with rolled gravels. Deep aquifer feeding is mainly done by rivers.

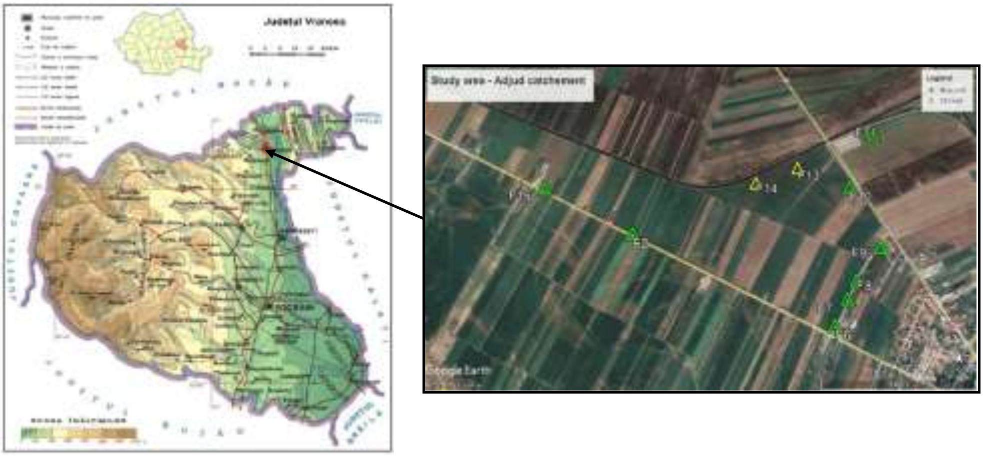

Fig. 1 Location of the study area
(Source: CJ Vrancea, Google Earth)

According to the geological and hydrogeological studies that were carried out within the area (Water supply borehole rehabilitation report - NEW F2 BOREHOLE, catchment front: Adjud, agglomeration: Adjud, Vrancea county- Drills F2 New, F6 New, F7 New, F8 New, F9 New, F10 New, F11 New, F13, F14, F15 New), these aquifers can appear at depths between 15 and 120 m and there is a possibility that they manifest themselves artesian. This complex can form multilayer aquifers fed mainly by rivers. The share of the underground supply of the rivers from the annual runoff in the studied area is on average between 15% and 25% (Ujvari, 1970).

Some of the boreholes intercept two aquifer systems: F7 New, F8 New, F9 New, F10 New, F11 New, F15 New, and some an aquifer system: F2 New, F6 New, F13, F14.

The oldest Quaternary deposits are represented by the Cândești strata in the region of the Siret valley (Mutihac et. al, 2004). Alternations of sands, gravels and rarely clays can be found at thicknesses of up to several hundred meters in some places. Nearby, between the Bârlad and the Prut valleys, the Cândesti strata are arranged laterally with a thickness of 8-10 m of gravel. These gravels are found under the name of Bălăbăneşti gravels and, within most of the region, they do not preserve the individuality of a lithological horizon due to the fact that a flow is carried out on the slopes in the coverage area (Ghenea et. al., 1963).

The Middle Pleistocene consists of the deposits of the old terrace and the loessoid deposits belonging to the high field. In case of the first deposits, on the right bank of the Siret, there is an old terrace made up of deposits of sand, gravel and boulders that are between 5 and 20 m. Taking into account the geological relationships found in the middle and lower basin of the Siret, the deposits of the old terrace are attributed to the upper part of the Middle Pleistocene (Ghenea et. al., 1963).

From a geotectonic point of view, Adjud locality is found at the border of three major structural units: the Scythian Platform, the Moldavides and the North-Dobrogean Orogen (Săndulescu,1984).

2.2 Data

The correct analysis and identification of the multi-layer aquifer was performed based on three components of the conceptual model: spatial modeling of the hydrostructure, its parametric modeling and hydrodynamic modeling. The conceptual model of the aquifer was developed using the data rebdered in Table 2.

Table 2 Data used for the conceptual model

Data used	Additional explanation
Lithology	Determined based on data obtained from drilling (10 boreholes)
Stratigraphy	Corresponding to each borehole, made according to the intercepted aquifer systems
Depth of boreholes and their equipment	Opening of filters
Piezometric level	Groundwater measurements
Drilling coordinates and dimensions	Elevation and depth in each borehole

2.3 Methods

Based on these data, it was possible to achieve the spatial schematization that has a role in observing the geometry of space and implicitly, the captured aquifer (Scrădeanu & Gheorghe, 2007), parametric modeling by evaluating the spatial distribution of parameters that characterize the hydrophysical elements of land and hydrodynamic schematization determining the energy context of the flow.

In order to protect the hydrostructure, but also the boreholes, optimal operating flows are determined for each borehole. Optimal flow is an important factor in the sizing of any type of groundwater catchment. This is the flow rate at which a borehole can extract water from an underground source without the pump entraining sand particles, which would lead to the sanding of the catchment borehole. The estimation of the optimal operating flow was performed by a grapho-analytical method. The calculation of the interference in steady state mode was solved using Dupuit Model.

The work steps involve calculating the coordinates of the points on the circumference of the area of influence in each borehole, calculating the elevation and piezometric load in the affected regime. In order to calculate the unevenness by the analytical method, a network of points was built covering the surface of the site and its surroundings. The influence of each borehole at each point in the network was calculated based on the network.

The determination of the sanitary protection zones was made in the context in which the roof of the multi-layer aquifer is a semi-permeable one composed mainly of sandy clays; there is, therefore, the possibility of pollution by infiltrations. The sizing of the protection areas was done in order to ensure protection against microbiological and chemical contamination. This dimensioning takes into account the hydrogeological characteristics, the type of aquifer, in this case, under pressure, and the morphology of the area. The protection zones are established by calculating the transit time of a possibly polluted molecule of water from its penetration into the soil to the catchment drilling. In this way, the time in which this molecule loses its polluting potential through the self-cleaning effect is followed (Scrădeanu & Gheorghe, 2007).

Spatial schematization has an important role in observing the geometry of the space and implicitly, of the captured aquifer (Scrădeanu, 1996). The resulting model helps to simplify the shape of some separation surfaces: the delimitation of the aquifer, the bed and the roof (Fig. 2) with the help of the data from the exploitation boreholes (F2 New, F6 New, F7 New, F8 New, F9 New, F10 New, F11 New, F13, F14, F15 New) (Scrădeanu, 1997).

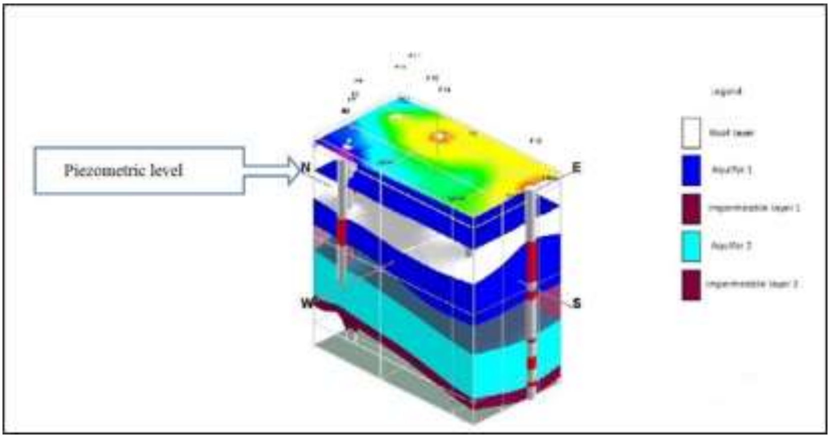

Fig. 2 Piezometric level distribution – 3D model made in the Rockworks program

3. RESULTS AND DISCUSSIONS

The location of the boreholes has a low slope of the topographic surface, which favors infiltrations. Both the amount of precipitation and the temperature values play an important role in the process of refueling the aquifer through infiltrations. The calculation of infiltrations is based on average precipitation and evapotranspiration. In arid plains, most of the water that reaches the surface of the soil in the form of precipitation returns to the atmosphere in the form of vapors.

The chance of rainwater reaching the aquifers is favored by the low slope of the topographic surface, the high permeability of the cover formations, the low air temperature (Scrădeanu & Gheorghe, 2007). Based on the average monthly temperatures and the average monthly precipitation amount in the area and the subsequent calculations, a value of 452.65 mm / year of the actual evapotranspiration was obtained.

The severe health protection zone is the zone corresponding to the time t = 20 days and represents the time that ensures the protection against human activities.

The restricted sanitary protection zone represents the zone corresponding to the time t = 50 days, representing the time that ensures the natural diminution of some possible microbiological contaminants or of some easily degradable substances.

The isochrons of t = 20 days and t = 50 days, corresponding to the limits of the sanitary protection zones and respectively with restriction regime, are determined on the basis of:

- hydrodynamic spectrum of flow in the area of influence;
- transit times for protection zones: T = 20 days for the severe health protection area; T = 50 days for the restricted health protection area.

The severe sanitary protection zone is represented graphically by a contour established on the basis of the distances from the wells calculated for t = 20 days, on current lines that converge towards each well in the N-S, W-E, NW-SE, NE-SW directions. The same procedure is followed for the restricted sanitary protection area, the only difference being the distances from the wells, which are calculated for t = 50 days. In the case of both sanitary protection areas, strict rules are implemented to ensure the protection and proper functioning of the catchment front. Representation of isochrons of t = 20 days and t = 50 days are found in Figs. 3 and 4.

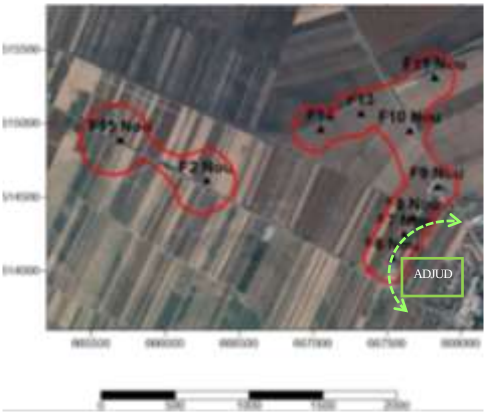

Fig. 3 20-day isochron - the delimitation of the protection zone for the 10 boreholes

Fig. 4 50-day isochron - the delimitation of the protection zone for the 10 boreholes

The restricted health protection area will be marked with visible signs. It is forbidden in this perimeter:

- use of fertilizers;
- location of greenhouses and related activities that may directly or indirectly affect capture (execution of constructions for industrial and agricultural activities);

- location of leak-proof pools for wastewater;
- location of homes, hospitals, airports, military units, if they do not have a sewerage system to transport wastewater.

In addition to the aforementioned restrictions, the following shall be prohibited in these areas: location of buildings of any kind; storage of materials. Only activities that are directly related to the operation of the water resource and the facilities required for these activities are permitted.

4. CONCLUSIONS

The research carried out on the surface of the site led to the shaping of a multi-layer type hydrostructure that satisfies the drinking water needs for Adjud locality and the neighboring communes. The level of groundwater recovery is high, given that the average annual rainfall (731 mm / year) is higher than the actual annual evapotranspiration values (452.65 mm / year), which leads to the restoration of the moisture reserve in the aeration area followed by feeding the area aquifers. Moreover, the deep aquifer is fed mainly from rivers, the catchment front being spatially between the Trotuș and the Siret rivers. The hydrogeological parameters of the aquifer were determined, based on the existing in situ pumping tests. According to these values, the time required for a molecule of water possibly polluted from its penetration into the soil to the capture drilling to lose its polluting potential through the self-purification effect was subsequently calculated, analytically and by numerical modeling.

The Jacob stationary model was used for hydrodynamic testing, where both the hydrogeological parameters of the aquifer (k [m / day], T [m2 / day], a [m2 / day], Se) and the drilling parameters were calculated (R [m], Δs [m]).

The assessment of the extension of the catchment protection areas:

1. T = 20 days for the sanitary protection zone with severe regime that will be fenced and will be marked so that the access of the population, animals and equipment of any kind will be stopped.

2. T = 50 days for the sanitary protection zone with restriction regime, which will be marked by visible signs.

The restrictions will be applied in accordance with Decision no. 930 of 11 August, 2005 for the approval of the Special Norms regarding the character and size of the sanitary and hydrogeological protection areas for Romania.

ACKNOWLEDGEMENTS

The author is grateful to Professor eng. Daniel Scrădeanu, PhD (Doctoral School of Geology, University of Bucharest) for scientific coordination, as well as to S.C. Lafor Service S.R.L. for their support and contributions.

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