Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. IX, 2020
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

INTERACTION OF WATERWAYS LOCATED IN KARST FISSURE AREAS AND GROUNDWATER

Matei MOLDOVEANU, Ioan BICA

Technical University of Civil Engineering Bucharest, 122-124 Lacul Tei Blvd., District 2, Bucharest, Romania

Corresponding author email: moldoveanumatei@yahoo.com

Abstract

The paper aims to present the impact of the waterways Dunare - Marea Neagra, respectively Poarta Alba - Midia, Navodari on both the groundwater and the groundwater catchments located in the vicinity of the waterways and currently in operation for water supply of the cities. Arranged waterways dug in the aquifer store rock, without sealing meassuries, can have both quantitative and qualitative impact on the adjacent groundwater. In order to determine the quantitative changes caused by the waterways on the aquifer layers besides the monitoring of this process, mathematical models can be used adopting different scenarios of water flow, depending on the existing hydrogeological conditions, as well as the possible changes created by the anthropic activities. Groundwater pollution is characterized by low rates of contaminants propagation. In the case of surface water, the impact of a pollutant source on the ecosystem is fast, and once the pollutant source is removed, the ecosystem returns to its original state. In the case of groundwater, due to both the low propagation speeds and the specific remediation mechanisms, the return to the initial state after the removal of the contaminants involves special, long-lasting and costly measures. This study takes into account the geological structure of this area, and the karst-fissure aquifer, as well as the existence of numerous groundwater catchments used to meet the water requirements of the localities in the area.

***Key words**: groundwater, groundwater catchments, karst-fissure aquifer, Romania, waterways.*

INTRODUCTION

The research area of the present paper is located in the North of Southern Dobrogea, in the region between the Capidava - Ovidiu and Rasova - Costinesti faults, the Danube and the Black Sea (Figure 1).

Provision of water supply in the localities in South Dobrogea, including those in the seaside area and in the city of Constanta, have as a majority water sources fronts for catching with wells drilled. Water catchments exploit two hydrostructures with regional development: a free-level hydrostructure, embedded in calcareous formations of the Sarmatian age, called the upper Sarmatian aquifer and a lower hydrostructure partially free and predominantly under pressure, of medium depth, embedded in calcareous-dolomitic formations of Jurassic-Cretaceous age, called the Jurassic - Cretaceous lower aquifer complex.

The Sarmatian upper aquifer is a free-level, groundwater aquifer for South of Dobrogea, which feeds on rainfall and diffuse water losses from irrigation systems (Moldoveanu, 2018).

The Jurassic-Cretaceous lower aquifer complex represents a unitary aquifer in relation to the entire southern Dobrogea territory. In large proportions, about 60% of the southern Dobrogea territory, the aquifer is under pressure, while in the vicinity of the Danube River and in the South, there is an area where this aquifer is with free-level (Zamfirescu et al., 1994).

In the research area, groundwater circulates through karst-fissure environments, which can be formed from underground channels, with different dimensions. The circulation of water in these environments takes place from the sectors in which the water seeps from the surface of the limestone massif, and flows to the other end, place where the drainage of the groundwater (lakes and the Black Sea) occurs (Moldoveanu, 2018).

With the commissioning of the waterways Dunare - Marea Neagra and Poarta Alba - Midia, Navodari, the flow regime through these aquifers changed and subsequently remained constant. An important cause would be that from a constructive point of view, the two waterways are not watertight in the bottom area, allowing in certain sectors the communication of the surface water with the groundwater (Moldoveanu, 2019).

Interaction of waterways with aquifers

From a geological point of view, the formations of sedimentary blanket (of which the store rocks of the two hydrostructures are part) are discordantly arranged on an old crystalline foundation. They present an uneven spatial distribution, which leads to the idea that their sedimentation took place in an active dynamic zone, of structural blocks with different positions (high or low), in different geological stages.

The geological and structural elements are shown in Figure 2 - Structural map of the investigated area.

The thickness of the lower Jurassic - Cretaceous permeable carbonate formations is higher towards the west, reaching the vicinity of the Danube at 1000 m and decreases in steps to the east (seaside area). Above these formations are deposited, especially in the eastern half, packages of semipermeable rocks of Senonian, Eocene and Badenian age.

In 2018, level measurements were made in the observation wells in the vicinity of the waterways. Based on these measurements, the hydrodynamic map of the Jurassic - Cretaceous lower aquifer was prepared (Figure 3).

In the sector investigated in the present paper, the Sarmatian limestones are generally absent and therefore the upper hydrostructure may rarely appear.

The continuous interaction between surface waters and groundwater embedded in karst-fissure aquifers presents specific elements, especially as they are adjacent to seaside areas:

- The main aquifer supplying areas and, implicitly, the formation of karst-fissure aquifers are determined by the favorable geological situations, where the carbonated rocks meet on the surface of the land (up to date) and allow the infiltration of precipitation directly into the layer or through the thalweg of valleys (Albu, 1981).
- The main aquifer discharge areas (drainage) are located in the marine coastal sectors or in natural lakes located near them.
- The existing interference between surface waters (rivers, valleys, lakes or lake systems bordering seaside areas, irrigation channels, waterways, etc.) and groundwater have produced important changes in the water flow regime. These can be rigorously observed by measurements and by drawing up hydrogeological maps with hydrodynamic spectrums (Moldoveanu, 2018)
- In the situation of the waterways exploitation, they may constitute: artificial supplying areas, for certain sectors where were executed and intersect the upper part of the karst-fissure aquifer or drainage areas, in areas where the waterway level quota is lower than the groundwater level quota (Moldoveanu, 2018).
- With the increase of hydrodynamic resources, given the relatively high flow rates of aquifers, there are high risks of occurrence of pollution phenomena coming from agricultural activities (Technical Archieve National Administration Romanian Waters, 2010-2017).

In general, the water level quota in the waterways imposes the flow regime in the karst-fissure aquifer in the area where it is located and, implicitly, it may create pollution risks if it supplies the aquifer to water.

Modelling of interaction between waterways and aquifers

Groundwater flow and pollutant transport from an aquifer can be described by analytical or numerical integration of the fundamental equations of hydraulic diffusivity and hydrodynamic dispersion (Zamfirescu, 1997).

Initial and subsequent time conditions in the aquifer field are imposed on these equations. They are also imposed boundary conditions (at the limit), given by values of Dirichlet-type functions or of its derivatives (Neuman-type conditions) on the bounderies of hydrostructure development (Fetter, 1994).

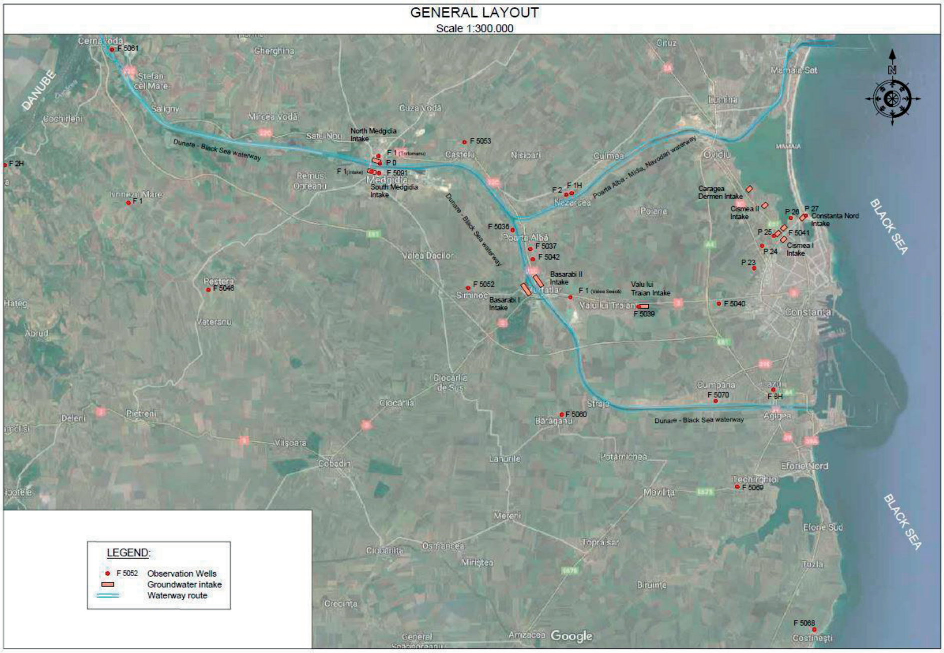

Figure 1. General layout of the investigated area (Moldoveanu, 2019)

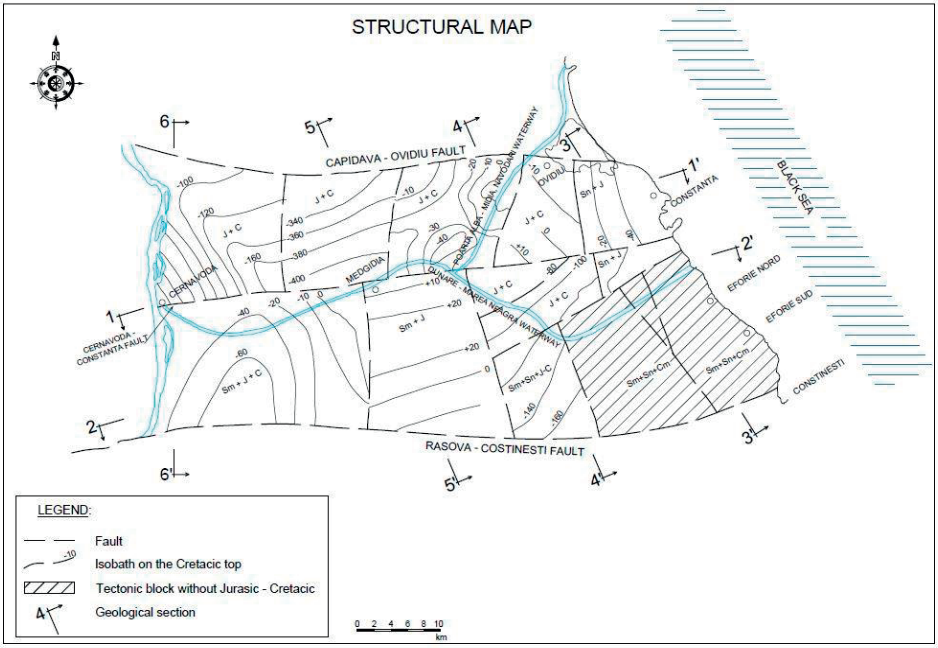

Figure 2. Structural map of the investigated area (Moldoveanu, 2018)

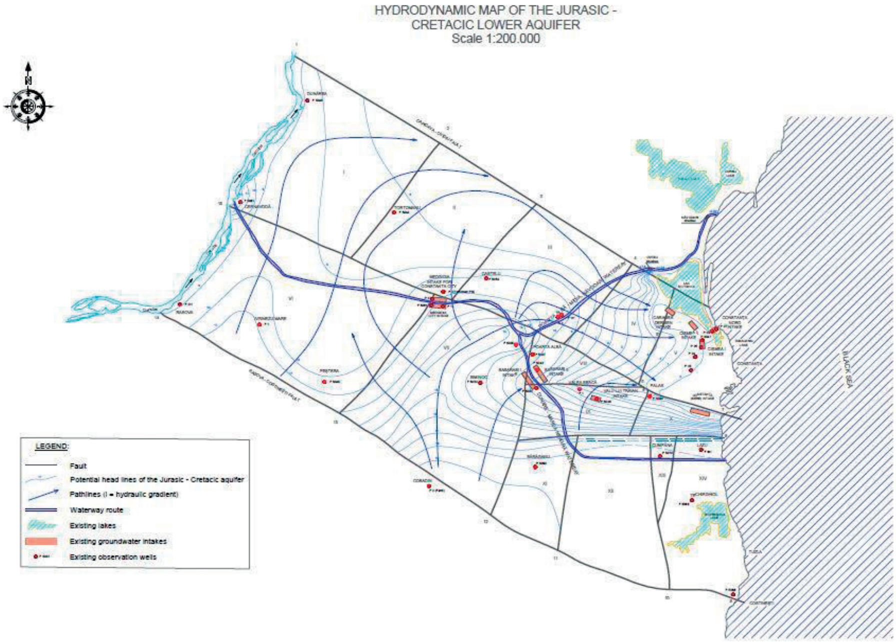

Figure 3. Hydrodynamic map of the Jurassic - Cretaceous lower aquifer

The construction of the flow pattern of the lower aquifer was carried out using the GMS soft.

The studied area covers an area determined by: 68 km - length, respectively 32 km - width, discretized in a network of cells with variable dimensions depending on the areas of interest analysed. Thus, the horizontal dimensions of the discretization cells are generally 1000 m x 1000 m, but they have a finer discretization of 500 m x 500 m in the groundwater catchments areas, for a greater accuracy of the results. The heights of the discretization cells are equal to the thicknesses of the Jurassic - Cretaceous lower aquifer, intercepted in observation wells, and are between 12.80 m and 1205.33 m.

The construction of the Jurassic - Cretaceous lower aquifer flow model was accomplished by introducing lithological data, boundary conditions, observation wells and catchment wells in the calculation program.

The lithology of the Jurassic - Cretaceous lower aquifer was determined by interpolation, using as base data the thickness of the aquifer detected in each observation well.

The boundary conditions imposed for the creation of the hydraulic model were determined by interpolation, based on the hydrodynamic map of the Jurassic - Cretaceous lower aquifer. Also, both the Siutghiol Lake and the section of the waterway the Poarta Alba - Midia, Navodari, which is in direct contact with the Jurassic - Cretaceous lower aquifer (located between the Ovidiu lock, respectively 3 km upstream in the waterway) will benefit from a 1.25 m imposed potential.

The hydrostatic levels from the observation wells were measured in 2018.

The exploited flows values from the groundwater water catchments located in the adjacent areas to the waterways, which supply the Constanta city, Medgidia and Basarabi towns and the Valul lui Traian commune were provided by the water operator Raja Constanta (Technical Archive RAJA, 2018).

The water level quotas in the Dunare - Marea Neagra and Poarta Alba - Midia, Navodari waterways have different values depending on the sections, according to the provisions from the operating and waterways maintenance regulations. On the north-eastern section of the Poarta Alba - Midia, Navodari waterway, in the area where the waterway is in direct relation with the lower aquifer, the water level quota measured after the Ovidiu lock is 1.25 m above Black Sea. The same 1.25 m water level quota height was introduced to Siutghiol Lake (Avadanei, 2012).

RESULTS AND DISCUSSIONS

After the model calibration, the calculated hydrodynamic map of the Jurassic - Cretaceous lower aquifer (Figure 4) was obtained.

The flow directions resulting from the model calibration are mainly oriented South-West - North-East, (Figure 5). Locally, in the area delimited by the Lazu - Cumpana and Cernavoda - Constanta faults, the hydraulic conductivities have low values, and the flow directions are oriented South - North. At North of the Cernavoda - Constanta fault, they return to the South-West - North-East flow directions and have high hydraulic conductivities.

In the area of Ovidiu lock, on the Poarta Alba - Midia, Navodari waterway, a local disturbance was observed, determined by the direct hydraulic connection between the water in the waterway and the aquifer. Also, there were disturbances in the Constanta, Basarabi and Valu lui Traian groundwater catchments areas.

Subsequent to the model calibration procedure, particles were introduced into the cells corresponding to the groundwater catchments, and these generated the supply areas of the wells.

This procedure is called "backward-tracking" and is used to determine the supply areas of the wells. In figure 6, it can be seen that most of the catchment wells are supply from the southern border of the domain, except for the wells from the Constanta Nord, Cismea II and partially Cismea I groundwater catchments, which are supply from the northern border and sometimes from Siutghiol Lake.

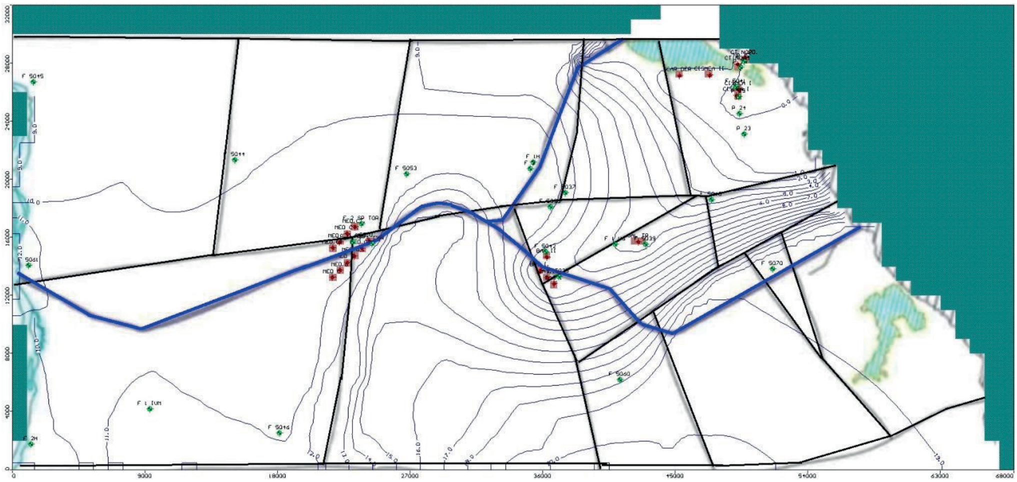

Figure 4. Calculated hydrodynamic map of the calibrated model

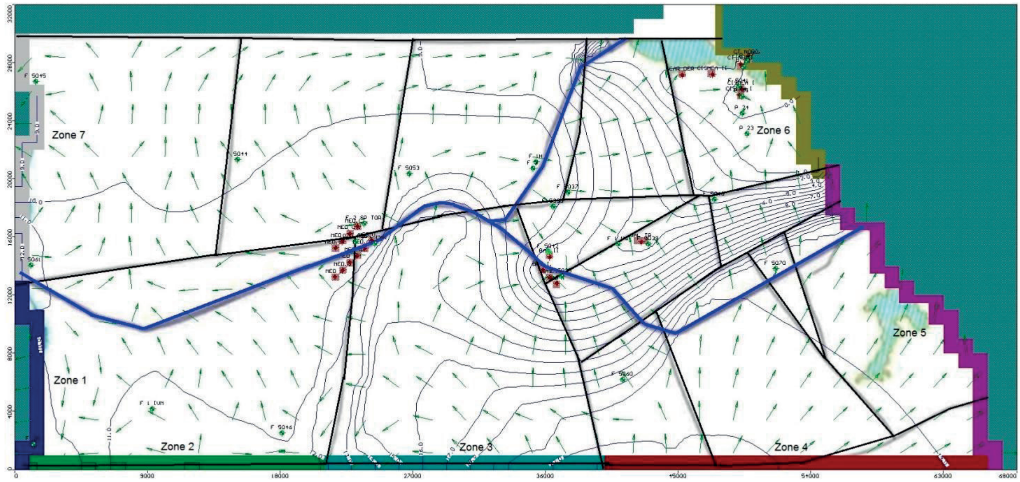

Figure 5. Flow directions through the calibrated model and delimited areas for determining the flow balance sheets

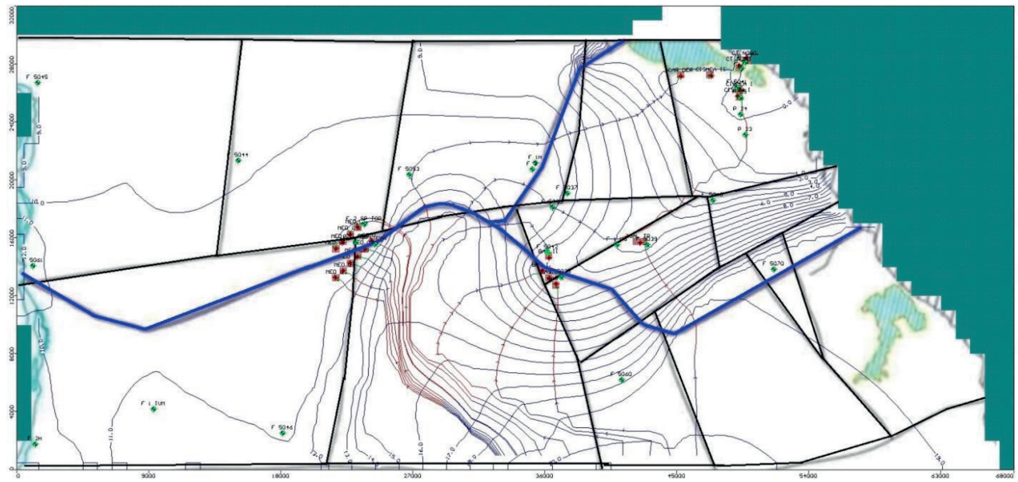

Figure 6. Supplying areas for the catchment wells

As shown in Figure 6, if the hypothesis of an advective pollutant transport is adopted, respectively the pollutant displacement is realized only after its the water flow, the model shows that in present there is no danger of contamination of the catchment wells with water from the Poarta Alba - Midia, Navodari waterway.

Based on the calibrated model, certain areas were drawn on the eastern, southern and western borders to create a balance sheet. Thus, in Table 1, there are shown the inflow and outflow values in the areas with constant level (Siutghiol Lake and section between Ovidiu lock and 3 km upstream), in catchments and in each delimited zone (Figure 5).

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 1. Balance sheet for calibrated model

Crt no.	Border	Inflow mc/day	Outflow mc/day
1	Situghiol lake + section 3 km PAMN waterway	91180	21014
2	Groundwater catchments	0	345550
3	Zone 1	75296	10133
4	Zone 2	39667	53862
5	Zone 3	483650	348500
6	Zone 4	474800	0
7	Zone 5	12840	366340
8	Zone 6	152160	939070
9	Zone 7	287610	353520

CONCLUSIONS

In the researched area in this paper, the North of Southern Dobrogea, more precisely the area between the Capidava - Ovidiu and Rasova - Costinesti faults, is noted the presence of an aquifer with regional extension embedded in Jurassic - Cretaceous limestone rocks called the lower aquifer.

In South of the investigated area there is a free-level aquifer with a phreatic character for South Dobrogea, which feeds on rainfall and diffuse water losses from irrigation systems, called the upper Sarmatian aquifer.

After the commissioning of the Dunare - Marea Neagra and Poarta Alba - Midia, Navodari waterways, the flow regime through these aquifers was abruptly changed, but over time it was balanced. This led to the adoption of the hypothesis of a stationary - conservative flow through the Jurassic - Cretaceous lower aquifer.

After the numerical model was realized and its calibration, the calculated hydrodynamic map of the Jurassic - Cretaceous lower aquifer, the flow directions and the supply areas for the catchment wells were obtained. Also, the model generated a balance sheet of flows in the areas with constant imposed potential (Siutghiol Lake and the section between the Ovidiu lock and 3 km upstream), in the groundwater catchments and on each zone marked in Figure 5.

The supply areas for catchment wells are generally from the southern border with Bulgaria. However, it is noted for the catchment wells from Cosntanta Nord, Cismea II and partially Cismea I source, the supplying areas come and from the northern border and sometimes, when exceeding operating flows and from Siutghiol Lake.

In the waterway Poarta Alba - Midia, Navodari, on the sector between Ovidiu lock and upstream 3 km, the Jurassic - Cretaceous lower aquifer is intercepted by the waterway. This allows direct communication between surface waters, represented by the waterway and rainwater, and the lower aquifer.

The water quality from the catchment wells is influenced in almost all the catchments studied by the waters of the waterway. The only exception is the Medgidia Nord catchment in which the water quality from the wells is not influenced by the waters of the waterway. This is due to the construction of the wells, which have depths between 350 and 400 m, and the definitive columns are perfectly insulated by cementation (about 150 m) against communication with phreatic aquifers.

Corroborating all this information, interference was observed between the waterways and the groundwater in the area of the water catchments, both quantitatively and qualitatively.

ACKNOWLEDGEMENTS

This research work was carried out with the support of the Technical University of Civil Engineering of Bucharest, the Department of Hydraulics Engineering and Environmental Protection, of the National Administration Romanian Waters and also of the RAJA Constanta water operator.

REFERENCES

Albu, M. (1981). *Groundwater mechanics*, Bucharest Technical Publishing House, 59-76.

Avadanei, C. (2012). Regulations for the operation and maintenance of the Dunare - Marea Neagra waterway, updating 2012, Division of Hydrotechnical Works and River Ports, *Contract 8269/3646/II/22, Designer Iptana S.A., client: C.N. Navigable Waterways Administration S.A.* Constanta, 93 p.

Avadanei, C. (2012). Regulations for the operation and maintenance of the Poarta Alba - Midia Navodari waterway, updating 2012, Division of Hydrotechnical Works and River Ports, *Contract 8269/3646/II/23, Designer Iptana S.A., client: C.N. Navigable Waterways Administration S.A.* Constanta, 70 p.

Fetter, C.W. (1994). Applied hydrogeology, Third *Edition, Pretince Hall, Upper Saddle River, New Jersey 07458*, United States of America, 593-602.

Moldoveanu, M. (2018). Underground hydraulics of fissure karst aquifers. Specific elements regarding the interaction of surface water - groundwater. *Research report no. 1 of the Project of the Scientific Research Program*, Bucharest, 64–69.

Moldoveanu, M. (2019). Impact of exploitation of the waterways on the groundwater. *Research report no. 2 of the Project of the Scientific Research Program*, Bucharest, 29–33.

Technical Archive National Administration Romanian Waters (2010-2017). Physical - chemical analyses of Dunare - Marea Neagra, Poarta Alba - Midia, Navodari waterways and of the observation wells located along them.

Technical Archive RAJA Constanta (2018). Exploitation data of water supply systems.

Zamfirescu, F. (1997). *Basic elements in groundwater dynamics*, Didactic and Pedagogical Publishing House, Bucharest, 16–23.

Zamfirescu, F.; Moldoveanu, V.; Dinu, C.; Pitu, N.; Albu, M.; Danchiv, A.; Nash, H. (1994). Vulnerability to pollution of karst aquifer system in southern Dobrogea. *Proceeding of the International Hydrogeological Symposium*, Constanta.