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# FLUVIAL ARCHITECTURE OF THE SEDIMENTARY AQUIFER COMPLEX IN THE AREA OF SANITARY LANDFILL PLOVDIV

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ABSTRACT
Aim of the study is to development a lithofacial and fluvial-architectural model of the deposits from the area of the sanitary landfill Plovdiv, which to allow the compilation of a reliable mathematical model for estimation and prognoses of the range and the scale of ground water contamination as result of the landfill exploitation. The developed sedimentological and stratigraphical models are based on field, borehole and geophysical data. Based of field studies and the available subsurface data in the area fluvial lithofacial types were defined and detail lithofacial profiles were developed. This allowed the revealing of the channel, the near-channel and the overbank fines deposits, the characterization of their architecture and determination of four elementary fluvial cycles (EFC). From the obtained 2-D lithofacial data and the information about the direction of the fluvial paleotransport 3-D architectural elements are defined, which further are differentiated according to their hydraulic properties.
Three basic units for the hydrogeological model are defined and identified - high-permeable and low-permeable water-bearing bodies and impermeable bodies (aquitards), and are localized zones of direct hydraulic connection between the high-permeable beds from different EFC.

## INTRODUCTION

The Neogen-Quaternary aquifer complex in the area of the sanitary landfill Plovdiv is formed in fluvial gravels, sands and mud. The summary thickness of these sediments not exceed 40-50 m (Мерачев и др., 1982). The bedrock is from Upper Cretaceous granodiorite porphyrites which build up the lower aquiclude of this aquifer structure.

The wide spectrum of lithological and facial variety of the sediments where the aquifer complex is formed predetermines the wide heterogeneity of conditions that control the pollutant migration. That is why, it is more appropriate to apply the sedimentological approach in describing the spatial parameters of 3D bodies from the complex with homogeneous hydraulic characteristics (aquifers and aquitard), rather than the standard model of “multiple aquifer complex”.

## MATERIAL AND METHODS

For achievement of relevant of the fluvial architecture model, sequences of outcrops, situated transversally and longitudinally to the dominating directions of sedimentary paleotransport were studied and were carefully correlated. The collected field lithofacial data and the data from all drilled in the area the sanitary landfill exploration boreholes (Fig. 1) allowed the definition of 14 fluvial lithofacieses. For revealing the spatial distribution and interrelations of the determinated lithofacieses, a set of lithofacial profiles embraces the area of the sanitary landfill is developed. Based of the spatial interrelations and the genetic interpretation of the established lithofacieses, the systematic measurement of all type indicators of the direction of the sedimentary paleotransport and after the detailed study of the morphology and the orientation of the bounding surfaces of the established lithofacial units, three fluvial architectural-element elements were distinguished. The lithofacial and architectural-element schemes, as well as the nomenclature of the bounding surfaces order proposed by Miall (1996) were accepted. Because of the nature of the existing lithological data, some modifications in the architectural-element nomenclature are made.

The spatial distribution and interrelations of the architectural-element units define several *elementary fluvial cycles* (EFC) situated one above other. The base of every separate EFC is $5^{-th}$ order erosion surface. They correspond to the connotation of the described by Janev (Янев, 1982, p. 70) elementary sedimentary cycles. As a complex of genetically connected and regularly replaced lithofacieses EFC correspond to the first order cycles (elementary cycles) described by Logvinenko (Логвиненко и др., 1976, p. 123).

The proposed by Folk et al. (1970) criteria for definition of the gravel lithofacial units are accepted. According to them, the presence of 30% or more gravel clasts (coarser than 2 mm) is accepted as lower limiting value of this group. Matrix-supported and grain-supported gravel lithofacies varieties are distinguish.

The lithofacial units (as well as for the constructed by them architectural elements) are defined according to their hydraulic properties on the base of grain size data (using φ-scale) received from studies of representative samples.

The proposed by Friedman (in Friedman et al.,1992, p. 36) seven-step scale for estimation of the degree of sorting of the sediments is applied. The results are presented as I(σ)/Ski (standard deviation/skewness) diagram (Fig. 2).

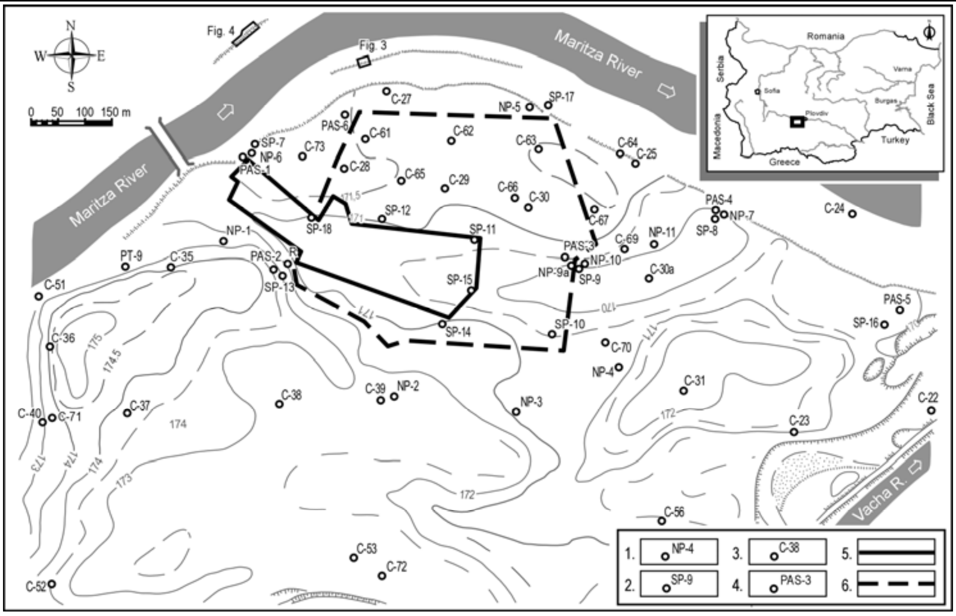


*Figure 1. The area of sanitary landfill Plovdiv with the location of the studied boreholes: (1-2) – monitoring wells; (3-4) – exploration borehole; (5) – the area of sanitary landfill in year 1992; (6) – the area of sanitary landfill in year 2002.*

## LITHOFACIAL AND ARCHITECTURAL-ELEMENT STRUCTURE OF THE SEDIMENTS FROM THE AREA OF SANITARY LANDFILL PLOVDIV

The character of the outcropping and the available subsurface lithological data allowed the correct definition of three architectural elements: (1) *channels deposits* (element CH); *near-channel deposits* – element ND, which units elements LV (levee) and CS (crevasse-splay) in the Miall's scheme (Miall, 1996); and (3) *overbank fines* (element OF). The presented in the sedimentary section architectural elements inside and around the sanitary landfill area form four situated one over other EFC, which we numerated according to the sequence of their formation. Each one EFC represents independent complex of channels, near-channel and overbank deposits, restricted by the 5$^{-th}$ order bounding surface. The thickness of the determined EFC is in the range of 8-13 m and varies in the area.

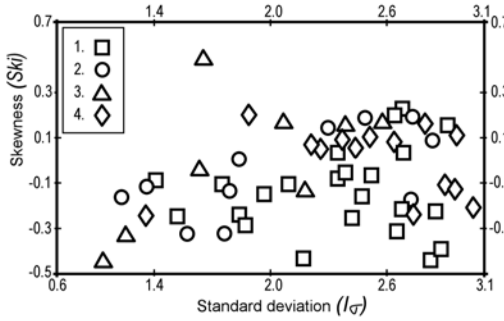


*Figure 2. Grain-size characteristic of the established lithofacial types: (1) gravels; (2) coarse- to medium-grained sands; (3) fain-grained sands; (4) fine-grained clastic sediments.*

According to their grain-size characteristics the distinguished in the area of the study lithofacial units are subdivided in three groups: (1) *gravely*, (2) *sandy* and (3) *fain-grained clastic* lithofacieses.

The matrix-supported and clast-supported gravels (lithofacies Gms and Gm) belong to the first group, as well as trough- and planar-cross-bedded gravels (lithofacieses Gtr and Gp). They build up about the half of the volume of the studied architectural element CH. Lithofacieses Gtr and Gp are most often presented in the lower and middle parts of the channel deposits (Fig. 3a) and represent in-channel gravely bars and banks.

Lithofacies Gm is observed under the guise of uneven, thin, ribbon-like (on the bottom of architectural element CH) or sheet-like (in the middle part and on the top of the channel deposits) bodies and is interpenetrated as lag, relatively washed, mainly channel deposit.

Lithofacies Gms is represent as ribbons and wedge-like bodies with several meters thickness, and very often build up significant part of the deposits of the corresponding EFC. More rarely this lithofacies is represented by small, isolated, lens-like bodies, developed out of scope of the channel deposits. Predominantly these sediments are very poorly sorted ($I(\sigma)>2.0$). Despite this fact, the units build up by lithofacies Gms display relatively high-hydraulic properties.

The generation of lithofacies Gms is connected with the results of single catastrophic flooding events, during which simultaneously is realized channels forming and their filling with poorly sorted or unsorted coarse materials (Бакалова и Айданлийски, 2003). Only the upper most parts of similar deposits undergo consequent stream treatment, while their main mass remains very poorly sorted or unsorted.

The sandy lithofacieses display the extreme diversity. The trough- and planar-cross-bedded, mainly medium to coarse grained sands of lithofacieses Str and Sp (Fig. 3b-c, 4) are widely distributed. They are presented by solitary and grouped sets (cosets), developed in all levels of the architectural element CH. In some cases they build up completely the channel deposits. The thickness of the single sets vary from 15-20 cm to over 80 cm, while that of the cosets reach up to 2 m. Moderately to poorly sorted varieties ($I(\sigma)=0.7\text{-}2.0$) prevail. Often, especially in the lower part of the channel deposits, on the laminas and on the base of the sets, plant detritus and/or intraformational muddy pebble to coble clasts are observed (Fig. 3b and 4).

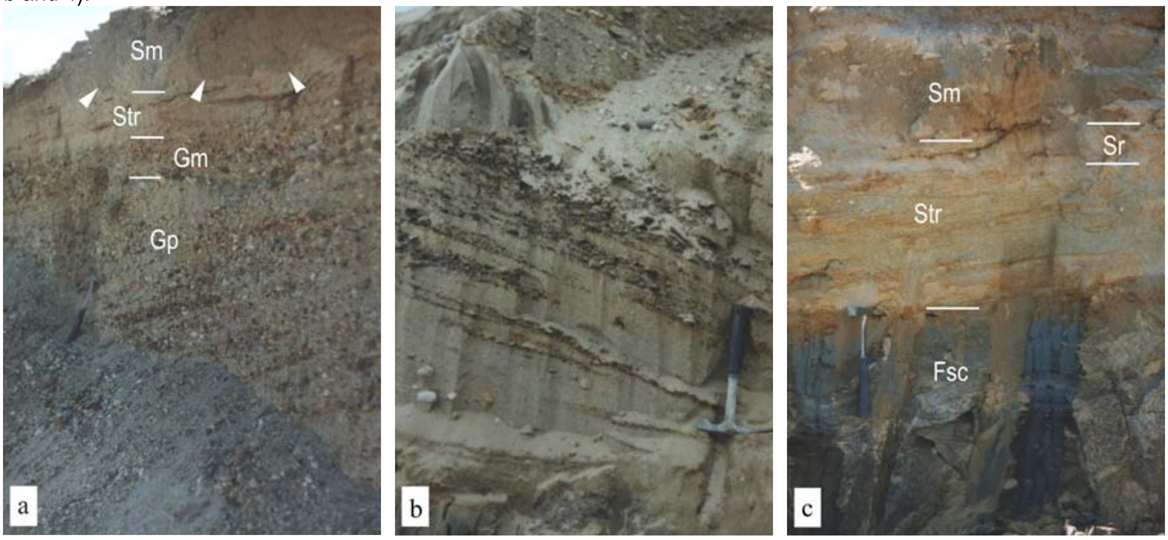


*Figure 3. Lithofacial types: (a) lithofacies Gp from the lower part of channel deposits (architectural element CH), overlied by lithofacieses Str, Sr and Sm. The arrows mark load cast structure; (b) solitary, large scale, heterolithic (with plant detritus - black), plannar-cross-bedded sandy series (lithofacies Sp) from the IV-th EFC (a detail from Fig. 4); (c) lithofacies Fsc from the upper part of architectural element OF (lower part of the picture) overlaid by ripple and meso-scale cross-bedded coarse- and medium grained sands, that build up the periphery of the channel deposits of the IV-th EFC. Abbreviations – see in the text.*

The creation of lithofacieses Str and Sp is a result of the processes of generation and migration of different in shape in-channel sandy mesoforms – transverse and longitudinal bars as well as point bars. In rare occasions they are produced by out of channel processes as well.

Ripple cross-bedded sands from lithofacies Sr are developed mainly on the top or in peripheral parts of the channel deposits. Together with lithofacieses Sl and Sh (low-angle-cross-bedded and horizontal laminated sands), lithofacies Sr takes parts in the structure of the architectural element ND as well. It is represent by fine- to coarse-grained, moderately to poorly (especially in the presence of flaser bedding) sorted sands. Lithofacies Sr builds up thin bodies, which overlie the horizontal laminated and meso-scale cross-bedded units (Fig. 3a and 4).

Lithofacieses Sl and Sh are presented by sheet-like or low-relief cones (architectural element ND), developed in the periphery of the channel deposits and rarely occur as isolated thin bodies among the overbank deposits of element OF. Only in one case when they occur within the typical channel deposits (Fig. 4). Poorly to very poorly sorted, medium- to fine-grained sands prevail.

The massive, poorly sorted ($I(\sigma)>2.0$) sands (lithofacies Sm) have most restricted development. They build up lens- and sheet-like bodies. Like lithofacies Gms, their generation is connected mainly with the results of flooding events. In the cases of significant thickness, they generate load cast structure (Fig. 3a).

The fine-grained clastic deposits are presented by three lithofacieses: laminated (lithofacies Fl) and massive (lithofacies Fm) sandy silts, sandy and silty muds and hyposediments, and laminated and massive clays (lithofacies Fsc). The sediments of lithofacieses Fl and Fm are very poorly sorted, while those of lithofacies Fsc are poorly to moderately sorted. The described fine-grained clastic lithofacieses build up composite, sheet-like, more rarely lens-like bodies. They are the main building unit of the architectural element OF.

In isolated areas of architectural element OF (that between boreholes C-51 and C-28 in III-rd EFC as well as between boreholes C-51, C-71 and C-38 in IV-th EFC) development of paleosols (lithofacies P) is established. The paleosols are characterized by the presence of small limy-rusty spots in the overbank deposits. The presence of lithofacies P leads to decreasing permeability of the sediments.

The morphology and the size of the determined architectural elements are rather variable inside the separate EFC and in the section as a whole. Architectural element CH is presented by solitary and composite channel deposits. Its width vary from several decameters to hundred of meters. In the solitary elements the w/d (wide/depth) ratio is in the range of 20.6-39.1, while in some areas of the composite elements it exceeds 80. As a rule the lower bounding surface is erosional and with complex 3D geometry. The upper surface of the element is subhorizontal to weakly concave. In the composite units the thickness of the architectural element CH reaches 8-9 m.

The study of the spatial development of architectural element CH from separate EFC reveals areas with erosional contacts between the channels deposits of adjacent EFC (Fig. 5).

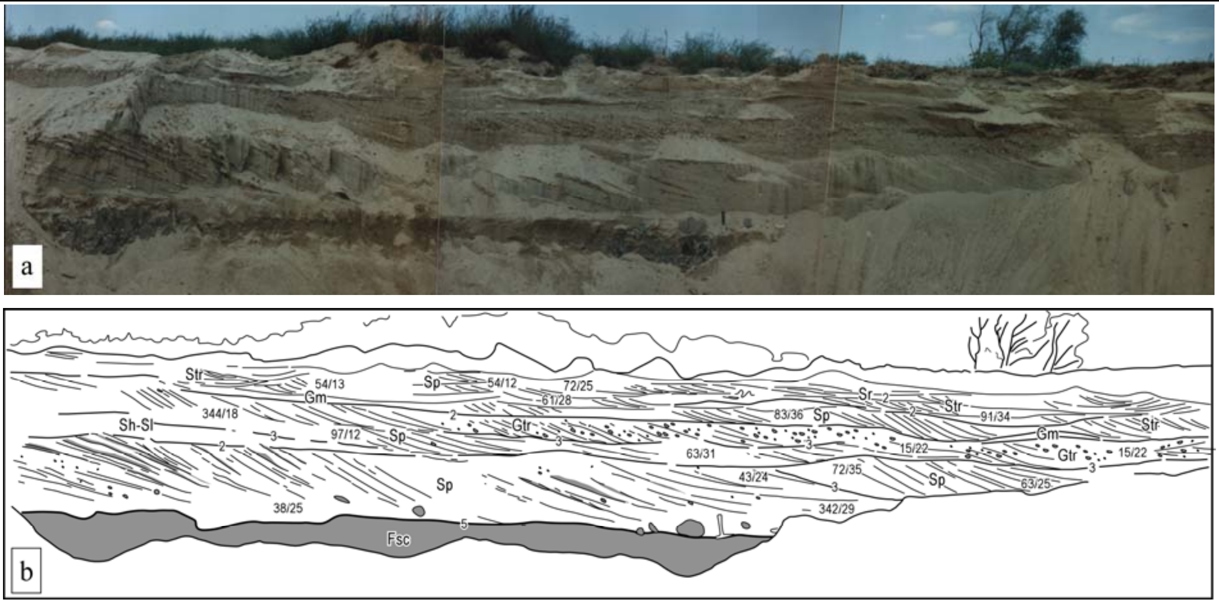


*Figura 4. Photomosaic (a) and diagram (b) illustrating the lithofacial geometry of part of architectural element CH from IV-th EFC. The lower part of the outcrop is build up by lithofacies Fsc, representing the uppermost part of architectural element OF from III-th EFC. On the diagram are presented the order of the bounding surfaces and the orientation (strike/dip) of the cross-bedding. Azimuth of outcrop - 47º. Abbreviations – see in the text.*

The boundary between architectural elements CH and ND could not always be traced precisely through the whole area of development of the channel deposit in the particular EFC. Often it represents a gradual lithological transition with complex geometry. In the detached EFC the thickness of the near-channel deposits do not exceeds 2.7 m. As a rule it varies in the range of 1.1-1.9 m. Laterally with the receding from the channel complex, the thickness of element ND decrease.

Architectural element OF has predominantly sheet-like form. Its average thickness is in diapason of 2.5-3.0 m. Element OF laterally replaces and vertically overlies the sediments of architectural elements CH and ND.

On Fig. 5 the spatial distribution of the described architectural elements in every particular EFC is demonstrated by hypsometrical maps of characteristic bounding surfaces. Because of the limited number of the boreholes that cross the I-st EFC, similar map for this cycle is not developed.

According to Stoyanov and Ajdanlijsky (Стоянов и Айданлийски 2002, Fig. 1) the sediments with prevailing medium-grained sand or coarser fraction are permeable to highly permeable media. Finer-grained deposits should be considered as low-permeable to practically impermeable media. According to the data obtained during the present investigation the group of permeable sediments includes all gravely and part of the sandy lithofacieses (Sp, Str, Sr and partially by Sh and Sl). To the group of aquitards belong mainly the fain-grained clastic and poorly and very poorly sorted sandy lithofacieses.

From hydrogeological point of view, according to the grain-size characteristics and the related hydraulic properties of the water-bearing media the determined above channel deposits are identified as *high-permeable water-bearing bodies*, near-channel deposits – as *low-permeable water-bearing bodies*, and the overbank fines – as *impermeable bodies (aquitards)*. The high-permeable water-bearing bodies are with rather complex geometry, uneven lateral development and complicate vertical communications between them. The other bodies are with plate-like shape, predominantly with even lateral development and with or without vertical connections between them.

The defined above low-rank hydrogeological units are relatively homogenous regarding to their hydraulic properties and migration parameters and their values in the different points and direction vary in narrow range.

## DISCUSSION

In the Quaternary deposits from the area Plovdiv lowland Dragomanov et al. (Драгоманов и др., 1989) determines four to five fluvial cycles, which are integrated in two macrocycles. The restricted area of the investigation not allowed comparison between these cycles and the established here EFC.

The high-permeable water-bearing bodies have geometry similar to the fluvial channel set. As a whole their orientation, in spite of some variations in each EFC, coincides with the contemporary fluvial pattern in the area.

As a result of the paleo-fluvial activity the channel deposits of every EFC partially truncate erosionally the deposits form the lied below EFC. These interruptions in the impermeable and low-permeable bodies (so called “hydraulic windows”) determine possibilities for direct hydraulic connection between the high-permeable bodies from the different EFC.

The high-permeable water-bearing bodies in the sediments of IV-th and III-rd EFC have direct contact almost in the whole area of their occurrence (part of the area bounded by the contour line 160 on Fig. 5a). The formed in this unit groundwater flow is unconfined, because the measured in it groundwater level is in the range of levels 165-167 m. The water levels in

Maritza River and Vacha River varies in the same diapason. This fact, as well the position of the contemporaneous fluvial channels compared to the top of this hydrogeological unit, presumes the existence of direct hydraulic connection between the groudwaters in this unit and the both rivers.

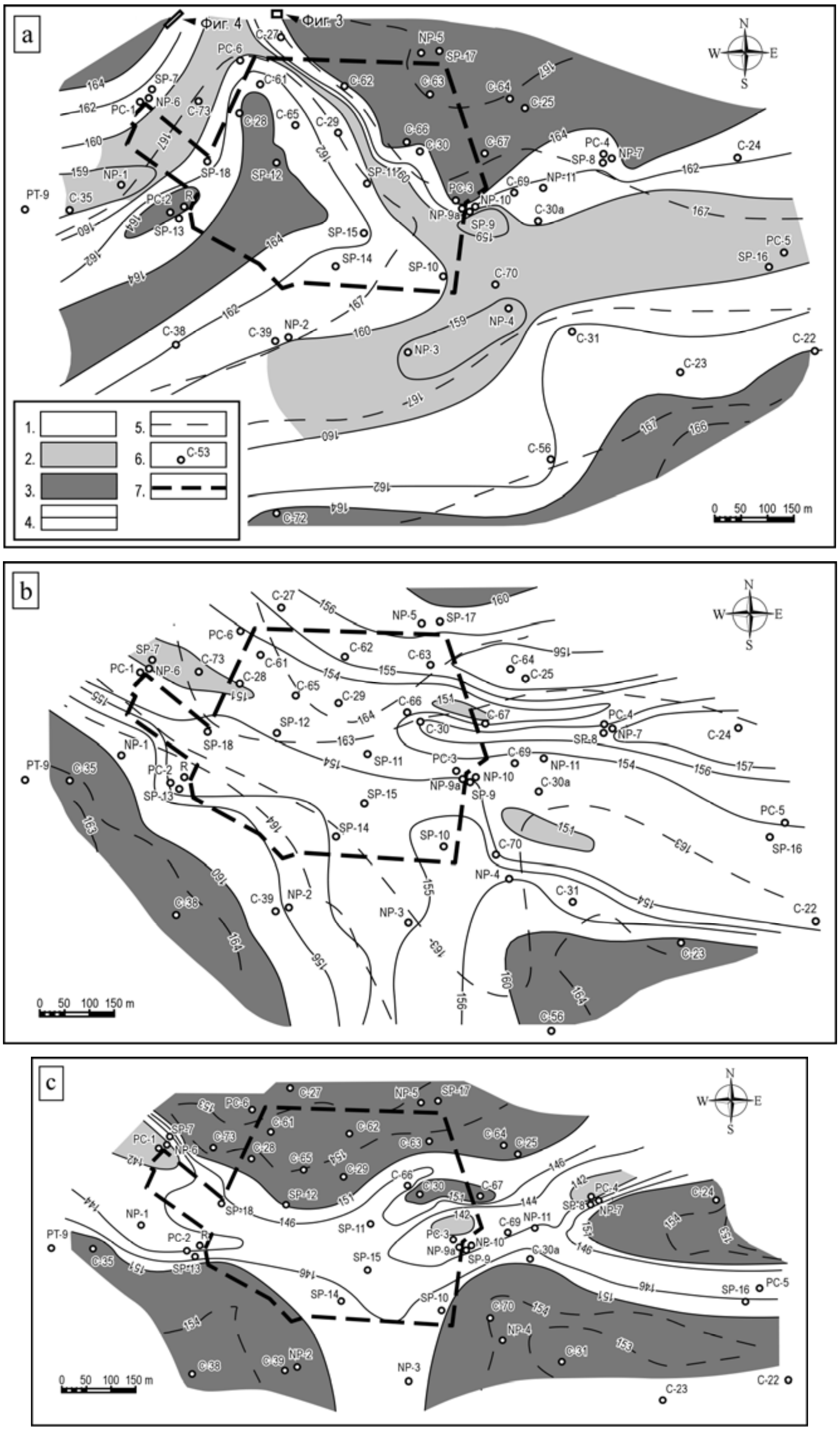

*Figure 5. Hypsometrical maps of characteristic surfaces for the distinguished architectural element in (a) IV-th, (b) III-rd and (c) II-nd elementary fluvial cycle (EFC): (1) area of distribution of architectural element CH; (2) areas of direct contact between channel deposits from vertically adjacent EFC (hydraulic windows); (3) area of distribution of overbank fines (architectural element OF) from the underlying EFC, over which are not developed channel deposits from the displayed EFC; (4) contour lines of the lower bounding surface of architectural element CH; (5) contour lines of the top of the architectural element ND; (6) studied borehole; (7) – area of sanitary landfill  in 2002 year. Abbreviations – same as in Fig. 1.*

The interruptions of the impermeable and low-permeable layers from I-st and II-nd EFC are rather more limited as area and relatively small in size (Fig. 5b,c). This is the reason the ground waters, accumulated in the high-permeable bodies of these two EFC, to be semiconfined. The piezometric water level established in them is with about 10-15 cm higher than the groundwater level in the common for of IV-th and III-th EFC water-bearing body.

The differences in the hydraulic connections between the high-permeable water-bearing bodies give reason in the frame of the aquifer complex two hydrogeological units of higher-order to be defined:

- upper aquifer;
- lower aquifer.

The upper aquifer is formed in the sediments of the IV-th and III-rd EFC, and the lower – in the sediment of II-nd and I-st EFC.

The both aquifers are connected hydraulically. The water exchange between them is realized either directly through the several "hydraulic windows", either indirectly through the low-permeable unit of the II-nd EFC in the zone of partial interruption of the aquitard of the same EFC (Fig. 5b). These are the possible ways for depth infiltration of contaminants leaking from the bottom of the sanitary landfill.

Essentially, the divided in the EFC hydrogeological units are low-rank technical stratigraphical unites.

## CONCLUSIONS

The applied in the study of the fluvial successions architectural-element approach significantly makes easier the identification and the spatial description of low-rank hydrogeological units in the Neogene-Quaternary aquifer complex. The obtained results are good base for more consistent geometric identification of the possible ways and conditions for pollutants migration in the developed 3D mathematical model for ground water contamination in the area of the sanitary landfill Plovdiv. As a base elements in this model should be used high-permeable, low-permeable and impermeable units, defined in the present study.

## REFERENCES

Folk, R., Andrews, P, Lewis, D.1970. Detrital sedimentary rock classification and nomenclature for use in New Zealand. – *N. Z. Geol. Geophys., 13*, 937-968.

Friedman, G., Sanders, S., Kopaska-Merkel, D. 1992. Principles of sedimentary deposits. Stratigraphy and sedimentology. – *Macmillan, New York*, 717.

Miall, A. 1996. The Geology of Fluvial Deposits. Sedimentary Facies, Basin Analysis and Petroleum Geology. - *Springer-Verlag, Berlin-Heidelberg*, 582.

Бакалова, Г., Айданлийски, Г. 2003. Модел на алувиална следпроломна акумулация. – *Годишник на Минно-геоложки университет, 46, св. I,* (под печат).

Драгоманов, Л., Ненов, Т., Ангелова, Д. 1989. Кватернерните наслаги в Пловдивското понижение. - *Сп. Бълг. геол. д-во, 50, 2,* 66-74.

Логвиненко, В., Айнемер, А., Ритенберг, М., Сергеева, Э., Шванов, В.1976. Периодические процесы в геологии. – *Недра*, *Л.*, 263.

Мерачев, Тр., Орешков, К. 1982. Водоснабдяване на гр. Пловдив при с.Кадиево и с. Оризаре. - *Докл. на ИПП "*Водпроект", С.,

Стоянов, Н., Айданлийски, Г. 2002. Мултидисциплинарен подход за симулиране на 3D средата при математическо моделиране на замърсяването на подземните води. - *Годишник на Минно-геоложки университет, 45, св. I,* 105-108.

Янев, С. 1982. Фации и цикличност в добруджанском карбоне. – *Палеонт., стратигр. и литол., 17*, 66-77.

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