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PROBLEM AND PROGNOSIS OF EXCESS WATER INUNDATION BASED ON AGROGEOLOGICAL FACTORS

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Abstract: Excess water inundation can be regarded as a typical geological event in lowland areas when the surface is seasonably but persistently inundated in a considerably large area. Excess water inundation brings about serious damage essentially in agricultural regions, so one of the tasks of agrogeology is the prediction of excess water inundation upon geological conditions. From the geological factors of excess water inundation the two decisive are the permeability of surface and near-surface geological formations and the hydrostatic level of groundwater below the surface. The first one prevents or delays the infiltration of precipitation, whereas the second one is back damming infiltrating precipitation withholding thus precipitation on the surface. The excess water inundation as a phenomenon is evaluated differently area by area, so the definition was made clear first. Then after the research of the geological factors of excess water inundation, the determination of the possible occurrence of this problem is shown through a small region as an example in the northeast of the Great Hungarian Plain by the compilation of different thematic maps. Finally it can be stated that areas of high risk of excess water inundation due to geological factors are more extensive than those influenced solely by relief and other geomorphological characteristics, therefore deliberate land use is necessary.

Keyword: Environmental geology, Hydrogeology, Excess water, Permeability, Barcău, Criş

1. INTRODUCTION

Excess water inundation can be regarded as a typical geological event in lowland areas when the surface is seasonably but persistently inundated in a considerably large area (*Pálfai,* 2001). More than 45 % of Hungary's total area, which is a typically lowland country, now is endangered by excess water inundation. Moreover this phenomenon occurs extensively in other countries bearing large lowland areas like Russia, Romania, China and India. However, the definition of the event – as we can see later in the paper – is considerably different. Excess water inundation brings about serious damage essentially in agricultural regions but it can cause a lot of problems within settlements as well when buildings are established in the flattest spots ignoring the laws of nature.

One of the tasks of agrogeology is the prediction of excess water inundation upon geological conditions. This task can be performed considerably properly through the recognition of events and settings generating and causing excess water inundation and through their appropriate target-oriented interpretation. Instead of excess water present in the area these prediction maps demonstrate its probable occurrences. They give answer to the question if there is a possibility of inundation or there is not. The two decisive geological factors of excess water inundation are the permeability of surface and near-surface geological formations and the hydrostatic level of groundwater below the surface (*Kerék* et al., 2001; *Kuti et al.*, 2005). The first one prevents or delays the infiltration of precipitation, whereas the second one is back damming infiltrating precipitation withholding thus precipitation on the surface.

2. THE DEFINITION OF EXCESS WATER INUNDATION IN THE INTERNATIONAL SCENE

The event of excess water inundation occurs extensively all over the world especially in lowland areas but it can also be encountered in flat regions of hilly lands as well as in wider valleys with gentle slopes in lower mountain ranges. Nevertheless, "the phenomenon is not much dealt with in other countries, e.g. the saturation of bottomlands with water is assigned to floods" (*Nagy*, 1999).

Reporting on the international status of the investigation of excess water inundation was largely affected by failing to find an appropriate standard English expression. Different dictionaries and professionals suggested various expressions like inner water, inland waters, inland inundation, waterlog, waterlogging, none of which describing however the investigated event properly. Discussing the problem with an expert interpreter, a water management expert and with a section chairman in the Second General Assembly of the EGU (April 25-29, 2005.) we decided to use the expression of "excess water inundation".

The expression of "waterlogging" is also closely associated with the related notion, for it refers to the water saturation of the root zone (=excess water in the root zone, *Belford* and *McFarlane*, 1993). However, in our case excess water appears on the surface as well, therefore it is more appropriate to use the expression of "inundation" (=surface ponding, *Belford* and *McFarlane*, 1993).

Excess saturation of surface sediments with water affects essentially agricultural lands, especially when groundwater is rich in salts and there is also a risk of salinisation. This unfavourable situation occurs in quite a number of countries in the world, especially where poorly designed irrigation systems are operating in large areas, like in India, Pakistan, Egypt, the region around the Aral Sea – (*Goldsmith*, 1998), and in China – (*Goldsmith* and *Hildyard*, 1984). Owing to extensive salinisation mounting groundwater level is also a serious problem in Australia. It is predicted that some 17 million acre land will be affected by the risk of salinisation within fifty years unless the process can be stopped (*Stone*, 2004).

Water saturation of the root zone is of concern already before groundwater reaches the surface for the vegetation is already affected. Leaves turning yellow due to the lack of oxygen in the root zone and resulting deficient nutrient intake are the first warning signs of this process. Water saturation of the root zone according to the grown plants was investigated by the Australian authors referenced above. They compared different species and genera according to their sensitivity to excess water saturation (*Belford* and *McFarlane*, 1993).

3. INVESTIGATED AREA AND METHODS

The Bihar Plain is situated on the eastern part of the Great Hungarian Plain, between the Berettyó and Sebes-Körös Rivers. The elevation of the surface is 87-103 meters above the see level, gently dipping to the south-west. The relative relief-energy is low, approximately 2 m/km^2. The whole area is plain only some abandoned river channels variegate the morphology.

The geological mapping of the Great Hungarian Plain had been completed between 1964 and 1985 in 1:100.000 scale. Map sheets were explored with ten meters deep shallow boreholes. These boreholes were drilled at 1500 meters far from each other, which means 320-480 boreholes per map sheet. After a short field description the solid material and groundwater samples taken from the boreholes were examined in details at the laboratory. The yielded database was used to compile the geological map of the Great Hungarian Plain, and further environmental-geological and agrogeological maps also based on these data. This database also gives the basement of this paper.

Our agrogeological and environmental-geological maps shows the possible vulnerability and risk factors of a given area derived from the geological conditions. These maps could be used essentially in the planning of prevention. According to these sheets we can outline the vulnerable areas, and could suggest the most optimal land use and agriculture.

4. GEOLOGICAL FACTORS OF EXCESS WATER INUNDATION

Excess water inundation can occur in valleys, as well as flatland and lowland areas if:

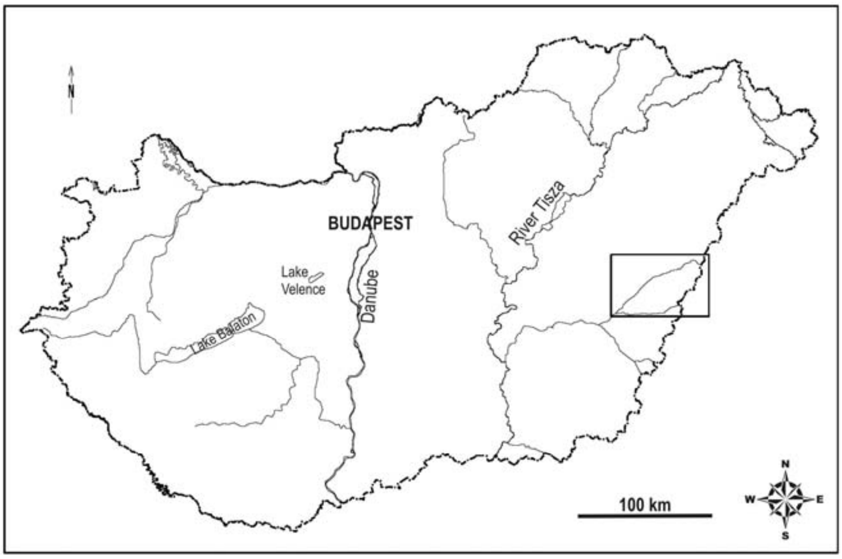
- the soil is frozen preventing infiltration,
- groundwater mounts to or over the surface,
- the area is without an outlet and water accumulating in deeper parts cannot filtrate in the soil.

Of the listed events the third one is unambiguously due to geological factors for it really matters if the surface is permeable or impermeable. Geological conditions are also prominent in the second event. The rise of groundwater above the surface can be the result of the following factors acting separately or jointly to different extent:

1. Hydrostatic groundwater level below the surface.
2. Groundwater flow.
3. Permeability of the surface – near-surface geological formations.
4. Presence of impermeable formations relatively close to the surface.

The closer to the surface groundwater is, the higher the risk of excess water inundation will be. The risk of excess water inundation mounts especially if groundwater level reaches or exceeds 1 m throughout or in most part of the year. The capillary zones of the upper soil horizon are then saturated with water almost up to the surface. In this case, with sufficient precipitation, groundwater rises inevitably above the surface when snow melts. At the same time, groundwater more than 2 m below the surface can grow the risk of excess water inundation only when coupled with other factors (*Kuti et al*., 1989).

Permeability of near-surface horizons has a serious impact on the infiltration of precipitation. Low permeability impedes the vertical movement of precipitation and the lateral one of the groundwater. On the one hand these formations provoke sustainably high groundwater level, on the other hand they delay the infiltration of precipitation in the related aquifer which in turn facilitates excess water inundation. Depending on its thickness the occurrence of a poorly permeable horizon within a geological formation can grow the risk of excess water inundation at a rate similar to that of the presence of an impermeable layer on the surface. When calculate the average of permeability for a formation it is therefore quite important to weigh with thickness. Since filtration conditions in a formation are defined by the least permeable layer, embedded impermeable layers should be considered instead of or beside the average permeability value in strongly inhomogeneous formations.



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ig. 1
Location of the searched area in Hungary

When assessing the rate of excess water inundation, the presence of impermeable horizons on the surface are of utmost importance, for a strongly impermeable surface layer e.g. salt-affected strata or calcareous mud prevents the infiltration of precipitation and stimulates the formation of puddles and patches of excess water inundation.

Different thematic maps should be compiled to assess the risk of excess water inundation in an area (e.g. surface geology, lithological setting of the near-surface 10 m assemblage of the profile). By means of these maps and processing key borehole data the map of the risk of excess water inundation can be compiled then. In this paper it is represented on the example of a small region in the northeast of the Great Hungarian Plain, the Bihari-plain (Fig. 1).

4.1. Surface formations

In the eastern part of the Great Hungarian Plain the surface and near-surface geological formations of the investigated area appointed between rivers Berettyó and Sebes-Kőrös are represented by fluvial, young, Upper-Pleistocene and Holocene deposits.

Finer sediments, like clay and silt or their combinations are predominant on the surface. Of coarser sediments sand occurs solely in greater and smaller patches on the surface. This surface – near-surface sand is often considerably silty.

The mentioned sand patches on the surface are presumably the remnants of point bars of ancient rivers, especially that of the Kőrös.

Thickness of sand on the surface attains 10 m in a small area but it generally alternates between 2 and 6 m.

Downward the 10 m profile the sediments offer a considerably more versatile picture than on the surface. Beside the afore-mentioned ones gravel occurs in the northern, north-eastern part of the area in various thicknesses below the surface clay.

In compliance with its fluvial nature the lithological setting of the area is rather complicated. It can be described by frequent alternation of finer and coarser beds.

Clayey and silty horizons occurring on the surface became affected by salt in extensive areas as a result of geochemical and pedological processes during the Holocene. These salt-affected regions on the surface have definitively been considered impermeable with regard to excess water inundation.

4.2. Lithology of the surface – near-surface formations

To characterise the agrogeological problems of an area it is insufficient to know the surface features. Additionally (fig. 2), it is necessary to be familiar with the uppermost 10 m sequence or at least with the beds above groundwater level, with the superimposed sequences of differently grained sediments i.e. with the lithology of surface and near-surface formations. The occurrence of a thick impermeable bed below the permeable ones on the surface, the thickness of the impermeable layer on the surface, the sediments occurring below it and the homogeneity or the inhomogeneous densely stratified character of the near-surface sequences are all important aspects (*Kuti et al*., 2005).

According to the experience gained in Hungary the lithology of the uppermost 10 m of the profile was considered, since this sediment assemblage represents generally appropriately the soil – parent rock setting of different areas.

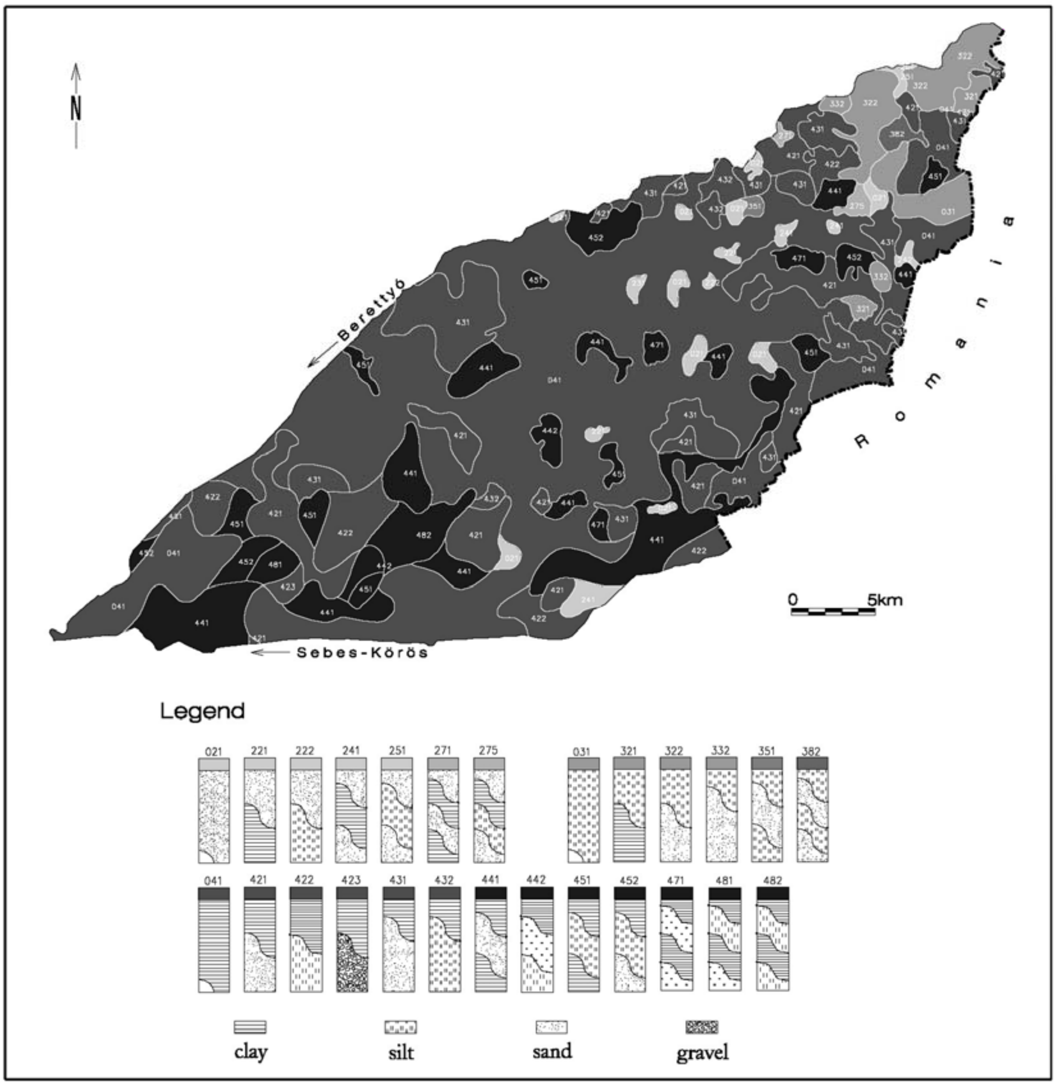

Fig. 2 Lithological setting of the surface – near-surface 10 m assemblage of the profile

In order to define typical lithological assemblages loose sediments have initially been classified in the following four groups according to their granulometric features:

gravel with grain size of more than 2 mm,

sand with grain size between 0.06 and 2 mm,

coarse silt with grain size between 0.02 and 0.06 mm, clay and fine silt[1] combined with grain size of less than 0.02 mm.

They are represented on the map depending on which one on the surface occurs and if it is considerably thick (8-10 m) or it alternates with other beds. This method always enables us to know the type and stratification pattern of the sedimentary assemblage occurring below the surface deposits.

Using this method some 172 lithological types have been distinguished. These types are characteristic of the given region and they can easily be represented on the map. While setting them up only the granulometric composition of different sediments were considered, whereas age characteristics and genetics were ignored.

Different lithological types are identified on the map and in the legend by 3-digit code numbers.

If the code starts with zero, sediments occurring on the surface have considerable thickness (more than 8-10 m). Codes 011, 021, 031, and 041 refer thus to thick gravel, thick sand, thick coarse silt and thick clay – fine silt assemblage, respectively. Within this group one single lithological type can be assigned to each sediment type resulting in four lithological types in total.

In other cases, the first digit (1=gravel, 2=sand, 3=silt, 4=clay–fine silt) refers to the formation on the surface, whereas the second and third ones do not provide direct information on the given lithological type. In this case the three digits bear combined information.

Of the further three main groups, the first one refers to a considerably thick (4-6 m) surface formation in the uppermost 10 m sequence overlying one of the other three sediment types of similar thickness (e.g. 221). Some 3-3, i.e. a total of 12 lithological types can be assigned to this group.

In the following group, below the uppermost thinner (2-4 m) sediment one of the other three, 6-8 m thick sediment types occur (e.g. 231). Similarly, 3-3, i.e. a total of 12 lithological types can be assigned to this group.

The third group represents the situation when a 2-3 m thick surface deposit overlies a sequence made up of the alternation of similarly thick sediment horizons. Some 36-36 i.e. a total of 144 lithological types can be assigned to this group (e.g. 482).

4.3. Hydrostatic level of groundwater below the surface

Taking a look on the groundwater level map of the area it can be observed that groundwater level considerably varies below the surface. From less than 1 m up to more than 9 m all depth intervals occur in greater and smaller patches (Fig. 3).

Average groundwater level in the area alternates between 1 and 4 m below the surface. In the eastern part it is closer to the surface. It alternates between 1 and 2 m there in extensive areas, whereas it is higher than 1 m in greater and smaller patches. In the middle and southern parts it alternates between 2 and 4 m, whereas in the west and north along River Berettyó it is lower than 4 m below the surface.

[1] In the following, this group is simply referred to as clay, but it includes the clay – fine silt assemblage so the fraction with grain size of less than 0.02 mm.

While predicting the possibility of excess water inundation the 1 and 2 m depth values are considered. In these areas it is not necessary to count with considerable vertical groundwater movements not even in the distant future. According to our observations maximal groundwater fluctuation does not exceed 1 decimetre in areas where groundwater level is higher than 2 m below the surface.

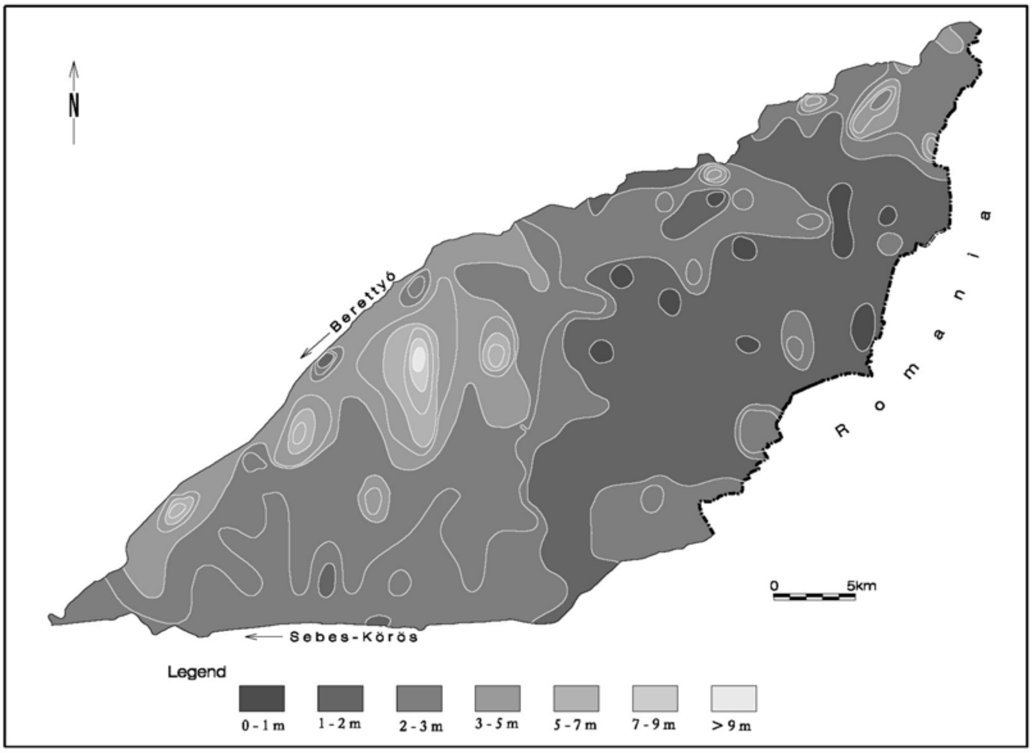

Fig. 3 Hydrostatic level of groundwater below the surface

5. CATEGORIES OF EXCESS WATER INUNDATION RISK ACCORDING TO THE CLASSIFICATION OF GEOLOGICAL FACTORS

The first step to determine the risk of excess water inundation of an area should be the relief-based evaluation of the region, for the risk exists only in valleys, as well as flatland and lowland areas. Our investigated area is essentially lowland without considerable uplifted terrains.

The next step after the exclusion of higher terrains potentially devoid of the risk of excess water inundation should be the determination of the risk for the rest of the area through evaluating its lithological setting by means of the map “Lithological setting of the surface – near-surface 10 m assemblage of the profile” and of the table attached (Table 1). Risk categories upon the lithological setting can be described as follows (Table 2):

Table 1. Lithological types of formations in Bihari-plain

Code	Name	Description
021	thick sand	sediment assemblage of high permeability
221	thick clay below thick sand	clay impedes vertical movement of groundwater
222	thick silt below thick sand	sediment assemblage of high permeability
241	sand-clay-sand	permeability is determined by the clay layer
251	sand-silt-sand	permeability is only slightly affected by the silt layer of high water-retaining capacity in the middle
271	sand-clay-sand-clay	permeability is determined by the clay layers of low permeability
275	sand-clay-silt-sand	permeability is determined by the clay layer of low permeability
031	thick silt	sediment assemblage of intermediate permeability and high water-retention capacity
321	thick clay below thick silt	permeability is fundamentally determined by the clay layer of low permeability
322	thick sand below thick silt	sediment assemblage of intermediate permeability
332	thick sand below thin silt	sediment assemblage of comparatively high permeability
351	silt-sand-silt	permeability is only slightly influenced by the surface silt layer of high water-retaining capacity
382	silt-sand-silt-sand	permeability is only slightly influenced by the layers of high water-retaining capacity
041	thick clay	sediment assemblage of low permeability, impervious sediment assemblage
421	thick sand below thick clay	permeability is fundamentally determined by the surface clay layer of low permeability
422	silt below thick clay	sediment assemblage of low permeability
423	thick gravel below thick clay	permeability is determined by thickness of the surface clay layer of low permeability
431	thick sand below thin clay	permeability is determined by thickness of the surface clay layer of low permeability
432	thick silt below thin clay	permeability is determined by thickness of the surface clay layer of low permeability
441	clay-sand-clay	permeability is determined by thickness of the surface clay layer of low permeability
451	clay-silt-clay	permeability is determined by thickness of the surface clay layer of low permeability
452	clay-silt-sand	permeability is determined by thickness of the essentially impervious clay layer
471	clay-sand-clay-sand	permeability is determined by the clay layers of low permeability
482	clay-silt-clay-silt	permeability is determined by the clay layers of low permeability

Table 2. Classification of the rock development types based on the sensitivity to inland water

Risk category		Rock development types
A	**A1**	011, 121, 122, 123, 132, 151, 152, 153, 181, 182, 183, 184, 185, 186, 187, 188, 189
	A2	021, 221, 222, 223, 233, 261, 262, 263, 291, 292, 293, 294, 295, 296, 297, 298, 299
B	**B1**	131, 133, 141, 142, 143, 161, 162, 163, 171, 172, 173, 174, 175, 176, 177, 178, 179, 191, 192, 193, 194, 195, 196, 197, 198, 199
	B2	231, 232, 241, 242, 243, 251, 252, 253, 271, 272, 273, 274, 275, 276, 277, 278, 279, 281, 282, 283, 284, 285, 286, 287, 288, 289
	B3	031, 321, 322, 323, 333, 351, 352, 353, 361, 362, 363, 381, 382, 383, 384, 385, 386, 387, 388, 389, 391, 392, 393, 394, 395, 396, 397, 398, 399
C	**C1**	041, 421, 422, 423, 431, 432, 433, 441, 442, 443, 451, 452, 453, 461, 462, 463, 471, 472, 473, 474, 475, 476, 477, 478, 479, 481, 482, 483, 484, 485, 486, 487, 488, 489, 491, 492, 493, 494, 495, 496, 497, 498, 499
	C2	331, 341, 342, 371, 372, 373, 374, 375, 376, 377, 378, 379

Risk category A1: more than 4-6 m thick gravel bed occurs on the surface or 2 or more than 2 m thick sand bed can be observed below at least 2 m thick gravel bed on the surface.

Risk category A2: more than 4-6 m thick sand bed occurs on the surface or 2 or more than 2 m thick gravel bed can be observed below at least 2 m thick sand bed on the surface.

Risk category B1: silt or clay occurs below at least 2 m thick gravel bed on the surface.

Risk category B2: silt or clay occurs below at least 2 m thick sand bed on the surface.

Risk category B3: more than 4-6 m thick silt bed occurs on the surface or sand or gravel can be observed below at least 2 m thick silt bed on the surface.

Risk category C1: more than 2 m thick clay bed occurs on the surface.

Risk category C2: 2 or more than 2 m thick clay bed occurs below at least 2 m thick silt bed on the surface.

The third step should be the determination of groundwater level in the investigated area by in-situ measurements or by means of the map "Hydrostatic level of the groundwater below the surface".

Finally as a result of the combined interpretation of lithological categories and groundwater level the risk of excess water inundation can be assessed in the area (Table 3).

1. The highest risk (80 %) occurs when groundwater is closer than 1 m to the surface and

- more than 2 m thick clay bed can be observed on the surface. This clay of low permeability delays infiltration of precipitation to deeper horizons or the thin surface layer above groundwater level becomes quickly saturated with water through the cracks in the clay;

- 2 or more than 2 m thick clay bed occurs below at least 2 m thick silt bed on the surface. Water rises in the silt of strong capillary lifting capacity near the surface and accelerates the saturation of the surface formation with precipitation water or the near-surface clay bed is damming back infiltrating water;

- silt or clay occurs below at least 2 m thick gravel or sand bed on the surface. In this case infiltrating water can be dammed back by near-surface fine sediments of low permeability;

- more than 4-6 m thick silt bed occurs on the surface or sand or gravel can be observed below at least 2 m thick silt bed on the surface. In this case water rises in the silt of strong capillary lifting capacity near the surface and accelerates the saturation of the surface formation with precipitation water.

Table 3**. Possibility of excess water inundation**

Possibility of excess water inundation %	**Risk categories of the rock development types**	**Hydrostatic level of groundwater under the surface m**	**Code on the map**
0	A1, A2	>2	1
10	A1, A2	1-2	2
30	B1, B2, B3,	>2	3
60	C1, C2	>2	4
	C1, C2	1-2	
	B1, B2	1-2	
	A1, A2	<1	
80	B1, B2, B3, C1, C2	<1	5

2. The risk of excess water inundation is high (60 %) when groundwater is closer than 1 m to the surface and more than 4-6 m thick gravel or sand occurs on the surface or sand can be observed below at least 2 m thick gravel or conversely, gravel occurs below at least 2 m thick sand. In this case near-surface groundwater is damming back infiltrating water though there is a good chance for further migration in the sediments of high permeability.

The risk of excess water inundation is also high (60 %) when groundwater level is between 1-2 m below the surface and silt or clay occurs below at least 2 m thick gravel or sand bed. In this case infiltrating water is dammed back by the finer sediments of low permeability that also hamper its migration toward deeper horizons.

The risk of excess water inundation is also high (60 %) when groundwater level is more than 1 m below the surface and

- more than 2 m thick clay bed occurs on the surface. In this case the clay of low permeability delays infiltration of precipitation, nevertheless deeper groundwater and water infiltrating from the surface rarely make contact;

- more than 2 m thick clay occurs below at least 2 m thick silt on the surface. In this case the clay of lower permeability hampers or impedes the migration of infiltrating water toward deeper horizons. Through this backwater effect coupled with capillary lift water can rise close to the surface and make contact with infiltrating water.

3. The risk of excess water inundation is intermediate (30 %) when groundwater level is lower than 2 m below the surface and

- silt or clay occurs below at least 2 m thick gravel or sand bed on the surface. In this case groundwater is further away of the surface but finer deposits of low permeability can hamper or impede the migration of infiltrating water toward deeper horizons generating backwater effect;

- more than 4-6 m thick silt occurs on the surface or gravel or sand can be observed below at least 2 m thick silt on the surface. In this case water rises easily in the silt of strong capillary lifting capacity but it should cover longer distance and has less chance to get in touch with water infiltrating from the surface.

4. The risk of excess water inundation is low (10 %) when groundwater level is between 1-2 m below the surface and more than 4-6 m thick gravel or sand bed occurs on the surface or sand or gravel occurs below at least 2 m thick gravel or sand bed, respectively. Infiltrating water migrates easily to deeper horizons through the coarse sediments of high permeability. The only obstacle in their path is groundwater relatively close to the surface.

5. The risk of excess water inundation is absent (0 %) when groundwater level is more than 2 m below the surface and more than 4-6 m thick gravel or sand bed occurs on the surface or sand or gravel occurs below at least 2 m thick gravel or sand bed, respectively. Infiltrating water passes easily to greater depths through the coarse sediments of high permeability without encountering any obstacles.

6. SUMMARY

Looking at the map of the risk of excess water inundation (Fig. 4) in the Bihari-plain it can be stated that the risk of excess water inundation is substantially high in extensive areas as a result of the geological setting. It is essentially due the low permeability of the sediments occurring on the surface as well as to groundwater close to the surface. The risk is low only where groundwater level is lower than 2 m below the surface and the sediments above groundwater level are of high permeability and of low capillary lifting capacity e.g. sand.

In summary, it can be stated that areas of high risk of excess water inundation due to geological factors are more extensive than those influenced solely by relief and other geomorphological characteristics. It warns us that geological factors of the risk of excess water inundation are present and act in those regions as well where due to different reasons excess water has not yet developed. Attention should be kept to avoid excess water inundation there or at least to minimise its appearance. This objective can be met by applying appropriate agricultural and water management methods.

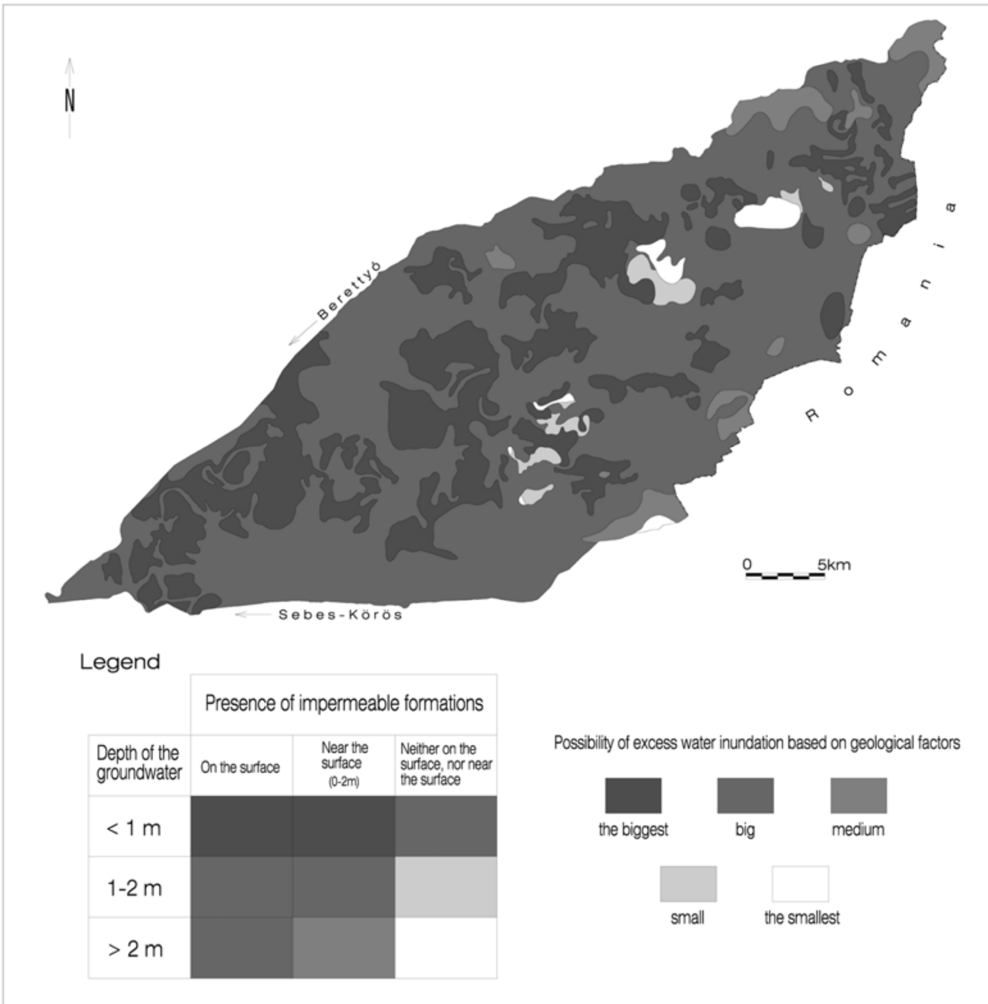

Fig. 4 Possibility of excess water inundation based on geological factors

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REFERENCES

Belford B., McFarlane D., *Managing waterlogging and inundation in crops*. 1993. Farmnote 80/93

Goldsmith E., Hildyard N., *Management and maintenance - perennial problems, Chapter 12 of The Social and Environmental Effects of Large Dams*. Volume 1. 1984. Overview. Wadebridge Ecological Centre, Worthyvale Manor Camelford, Cornwall PL32 9TT, UK.

Goldsmith E., *Learning to live with Nature: The lessons of traditional irrigation*. 1998. May-

June, The Ecologist Vol. 28 No. 3,
Kerék B., Kuti L., Vatai J., *Az Északkelet-Alföld felszíni–felszínközeli képződményeinek és a bennük mozgó talajvíznek az agrogeológiai–környezetföldtani jellemzése.* 2001. Acta Geographica, Geologica et Meteorologica Debrecina, Tom. XXXV., 103-116.
Kuti L., Kerék B., Tóth T., *Magyarország sík- és dombvidéki tájainak agerogeológiai jellemzése.* 2005. Tájökológiai Lapok, 3. évf. 1. kötet, 83–97.
Kuti L., Mikó L., Gecsei É., *A belvizesedés kialakulásának magyarázata az Alföld ÉK-i részén*. 1989. A MHI VIII. országos vándorgyűlésének kiadványa, 125- 130.
Nagy L., *Az árvizek típusai* 1999. Az EUROFOOD projekt 2. rész. Víztükör, 2. szám,.
Pálfai I. *A belvíz definíciói*. 2001. Vízügyi közlemények, LXXXIII. évfolyam 3. füzet, 376–392.
Stone P., *Combined forces work to fight salinity*. 2004 Farming ahead No. 154, November,. 24-26.

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