HYDROGEOMORPHOLOGIC ANALYSIS OF LAND AREA
HYDROGEOMORFOLOGICKÁ ANALÝZA KRAJINNÉHO PROSTORU

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ABSTRACT

In connection with conception of Unitary System of Agricultural, Forest and Water Management, there was necessary to explain relations between stationary and dynamic elements of land area. Knowledge of symmetry of structure of springs of underground waters then led to further explanation of principles which enabled to define land area as a formation making up a hydrogeomorphologically closed system. That is why, in the presented work, relation between a stationary and a dynamic component of land area – geomorphology of area and hydrologic circuit, which determine the state and development of land area in the biosphere, are being solved.

KEY WORDS: land area;hydrogeomorphologic region;unitary system;underground water

ABSTRAKT

V souvislosti s koncepcí Unitární soustavy zemědělského, lesního a vodního hospodářství bylo nutné vyjasnit vztahy mezi stacionárními a dynamickými prvky krajinného prostoru. Poznání symetrie struktury vývěrů podpovrchových vod pak vedlo k dalšímu vysvětlení zákonitostí, jež umožnilo definovat krajinný prostor jako útvar tvořící hydrogeomorfologicky uzavřenou soustavu. Proto v předložené práci je řešen vztah stacionární a dynamické složky území – geomorfologie území a hydrologického obvodu, které determinují stav a vývoj krajinného prostoru v biosféře.

KLÍČOVÁ SLOVA: krajinný prostor;hydrogeomorfologický region;unitární soustava;podpovrchové vody

PODROBNÝ ABSTRAKT

V práci je analyzován hydrogeomorfologický region, jehož definice vyplývá ze vztahu stacionární soustavy dané geomorfologií území a dynamické soustavy hydrologické, která je její funkcí. Vytváří se tak hydrogeomorfologická struktura území, kterou jsme nazvali hydrogeomorfologickým regionem (HGR). Uspořádání výškových bodů a vývěrů vadozních vod má charakter netlumených spirál, podobně jako vývěry hlubinných vod jsou uspořádány podle soutoků povrchových vod a tvoří rovněž spirálu. Vznikají tak tři spirály: spirála výškových bodů IGh, spirála vývěrů vadozních vod, jež představuje mezní stav proudění a nazvali jsme ji jako funkční křivku symetrie FKS a posléze třetí spirála – vývěry hlubinných vod, jež jsou soustředěny do soutoků vod povrchových. Tyto tři spirály tvoří symetrickou strukturu regionu.

V práci byla provedena hydrogeomorfologická analýza regionu Novohradské hory (Gh 1111) – Javorová skála (Gh 723) ve Vlašimské vrchovině, Boubín Gh 1362 v Šumavském pohoří a Gh 738 v Javořické vrchovině (obr. 1). Byly stanoveny směry hlubinných a vadozních vod a vykreslena spirála soutoků jako vývěrů vod hlubinných v soutocích Vltavy, Lužnice, Malše a Nežárky. V 1. detailu byl pak sledován soutok Vltavy a Lužnice, kde dominantní postavení má Gh 528 a jako satelitní Gh 503 (obr. 2). Směry proudění hlubinných vod pak prokázaly, že Gh 528 ovládá celý region směrem k Vltavě. Ukázalo se rovněž, že počet vývěrů ve vývěrovém poli Gh 528 odpovídá počtu směrů hlubinných vod vyjádřených jako LGS. Tyto směry představují zvodeň hlubinných vod, která se vytváří pod satelitními Gh a jejich zónami primárního sycení (ZPS), které jsou vykresleny jako spojnice vývěrů vadozních vod a kolem každého Gh tvoří smyčky (strofoidy). Tyto smyčky jsou plochami, na nichž infiltrují srážkové vody jednak do vadozních vod, jednak do vod hlubinných, ovšem za podmínky, že tu existuje princip dopravního zpoždění, tj. že část srážkových vod je zpožděna a akumuluje se jako hlubinné vody odtékající v podélném směru, zatímco ostatní voda je spotřebována jednak na transpiraci, jednak filtruje do vadozních vod ve směru příčném (obr. 3). Toto zpoždění vytvářejí lesní porosty, které jsou s to tuto transformaci provést. Proto jsme tyto plochy nazvali zónami primárního sycení a vzhledem k jejich funkci by měly být zalesněny. Avšak jak ukázaly naše studie, jejich zalesnění ve sledovaném regionu činí pouze 31,3 % a ve značné míře nejsou zalesněny vůbec.

V 2. detailu (obr. 4) je analyzován jediný směr proudění hlubinných vod mezi Gh 503 a soutokem Gh 395 na řece Lužnici. Zde na 12,5 km trase se prokázaly všechny zákonitosti, jež jsme zjistili na velkých HGR, zejména pak úloha lesních komplexů na ZPS ve vytváření akumulace a směrů hlubinných a vadozních vod.

INTRODUCTION

If the principles of structure of land area should be described, it is necessary to know the principles of development of individual hydrogeomorphologic regions, that means to analyze a wide area, in which we can determine principles of move of underground as well as surface waters in dependence on geomorphology of this area. Such area, which can be characterized by confluence of two ore more water streams and by the dominant geomorphologic formation RGh, eventually by some further satellite formations (SGh), is called hydrogeomorphologic region HGR [5]. Its basic property is the reality, that it is a stationary system Gh and a corresponding dynamic system – hydrological circuit, a system, which is its function. If we think about the regulation of this move, then there are especially agricultural and forest systems, which, in connection with water management systems, regulate dynamics and especially structure of components of water balance and its symmetry. From the given reasons, we have outlined USZLVH as a regulator of water balance, and it holds true, that

ZS, VH = f (LS)

It has been proved, that these relations are extraordinarily tight. Disturbing of water balance of all continents consists especially in, that precipitation on transpiration and for saturation of vadose and deep-seated waters, is in short supply, while evaporation and runoff are absolutely prevailing. Results of our works on the Blanice and the Volyňka rivers unambiguously proved [2, 3], that saturation of the groundwater body limited and balanced stream flows, increased transpiration and limited evaporation and therefore increased also photosynthesis and absorption of CO_2 [8]. Here, the principle of transport delay of non-source quantities of water balance in hydrological circuit is applied in full. It has been proved, that there are forests, which as a perennial plantation are able to transform non-useful evaporation into useful transpiration by delay of run-off of surface waters and transform them into vadose and deep-seated waters. That is why we put great stress on afforestation especially of zones of primary saturation, where they have especially role in accumulation of deep-seated waters, and as these waters have springs in confluences of surface streams, regulate thus also stream flow of surface waters. Thus the surface branch of hydrologic circuit changes into underground branch with considerable transport delay of non-source quantities of water balance. Agricultural crop stands also have considerable ability to transpiration, but they have not ability to impound overland run-off, their ability to limit evaporation permanently is very sporadic and they quite lack the ability to transfer water into deep-seated waters. Similarly do not water management works – reservoirs or polders; they impound runoff, but at the same time increase evaporation from free surface water level. Function of water reservoirs in this regard would apply only in the case, that they are built on pervious subsoil, so that they can saturate underground waters. That is why the arrangement of forest areas on hydrologically responsive parts of HGR is an essential necessity.

MATERIALS AND METHODS

As a source material, hypsometric data and forest maps, ecological maps have been used; numerous data have been verified by direct measuring in forest wells. The solution is based on the hydrogeomorphologic map of the CR drawn [4]. According to springs of vadose groundwaters and confluences round a Gh, horizontal connecting lines (IMS) and vertical connecting lines (FKS) from the center of the Gh have been drawn, and – as tangents from the first and the following spring to the nearest IMS, LGS were derived, which show the direction of flow of deep-seated groundwater emptying in confluences of water streams. Spirals have then been examined by the method of Candi-Rollett. FKS have been established in opposite direction of LGS from appropriate Gh. They show directions of vadose water flows.

The solution has been worked out for the whole hydrogeomorphologic region delimited by spirals IMS for Gh 1111 Novohradské hory (Nové Hrady Mountains) and Javorová skála (Javorová Rock) Gh 723; detailed analysis has been worked out for Gh 528 and Gh 503 and confluence of the Vltava and Lužnice rivers, and the second detail for the direction of deep-seated waters Gh 503 and dimension 395 on the length of 12.5 km.

RESULTS

The hydrogeomorphological analysis has been worked out in three levels:

In the hydrogeomorphologic region Novohradské hory (Nové Hrady Mountains) – Javorová skála (Javorová Rock) on the area of 5265 km^2, on the confluence of the Vltava and Lužnice rivers on the area of 334 km^2, and finally on the level of one direction of profound waters on the length of 12.5 km^2. The directions of vadose and deep seated waters have been drawn and the schema have been worked out:

1. Hydrogeomorphologic analysis of the Novohradské hory – Javorová skála region
2. Hydrogeomorphologic analysis of the confluence of the Vltava and Lužnice rivers
3. Hydrogeomorphologic analysis of deep-seated water flow direction
4. Stream flow of deep-seated waters through the forest massif of 11 km^2 from Gh 503, and indication of vadose water directions

DISCUSSION

Novohradské hory (Nové Hrady Mountains) 1111 and Gh 723 Javorová skála (Javorová Rock) includes on the area 5265 km^2 confluences of the Vltava river with the Otava, Malše and Lužnice rivers. Thus basic microregions are formed, defined by confluences of mentioned streams and hydrologically controlled by these Gh. The highest Gh then frame the whole HGR into a symmetric elliptical shape, which corresponds exactly to the course of IMS of all geomorphologic formations of the region. Round each Gh, the loop creates in the form of strophoid curve as a curve of third degree, of equation which in Cartesian coordinates has the form $x^3 - y^3 - 3axy = 0$. Spirals LGS have been analyzed using the Candi-Rolett method as logarithmic spirals.

Properties of Gh are given by the dynamics of underground waters, expressed by their directions and the spring field of deep-seated waters in confluences of surface waters. Horizontal connecting lines of springs of vadose waters we term as isolines of limit stages of laminar flow (IMS), which form round every Gh a regular, not-dumped spiral. The velocity of flow here does not exceed the value of laminary flow given by the Darsy equation $v = k * I$ (where v – velocity, k – coefficient of filtration, i – slope). Vertical connecting line of springs of vadose waters (marked as FKS – functional curve of symmetry) indicates the highest slope of flow of vadose waters, but even here over-speeding is not possible, as springs on this direction will interrupt the laminar flow and the flow passes into a turbulent flowing according the Chézy equation $v = C * \sqrt{R}$, where C – hydraulic coefficient (for example according Agroskin $17.72\,k + \log R$), R – hydraulic mean depth and i – slope. These sudden transitions determine the dynamics of vadose water movement – from a laminar flow (filtration) to a turbulent flow. FKS are marked by a broken line and come always from the center of Gh.

As indicators of directions of deep-seated waters logarithmic spirals (LGS) function – dot-and-dash lines, which come from the first springs of ZPS as tangents, cross the first nearest spring on the neighbouring IMS

Figure 1. Hydrogeomorphologic analysis of the Novohradské hory – Javorová skála region (Gh 1111 – Gh 723)
Obr. 1. Hydrogeomorfologická analýza regionu Novohradské hory – Javorová skála (Gh 1111 – Gh 723)

and lead to the nearest confluence of surface flows (rivers and streams), which are their springs.

In numerous cases FKS and LGS meet. This indicates dependence of deep-seated and vadose waters; sometimes, vadose waters spring out, deep-seated waters continue up to the confluence of surface flows. Here, waterbed is being eroded, as a result of it the flowing speed is limited, and the flow thus goes on in the regime of river flowing. Confirmation that deep-seated waters spring in confluences is in the reality, that confluences form the like spiral as springs of vadose waters do. Figure 1.

In our HGR, there are twelve these transitions, and in the schema they are marked by numerals on the marked spiral of confluences. Their arrangement is therefore not random. So we get structure of HGR. Symmetry of the structure is determined by the spiral of confluences of water streams of the region, thus of springs of deep-seated waters. The symmetry is also reflected by the elliptical arrangement of boundary Gh of the region; at the same time this boundary line is formed by the connection line of all springs of vadose waters including already mentioned strophoid curves round each Gh. Thus it is being proved, that Gh with springs of vadose waters and deep-seated waters in confluences of surface streams create structure of hydrogeomorphologic region and land area, which is symmetric.

Studies of orogenic development of the European continent [4] showed, that on the territory of the Czech basin there are 5 such symmetric formations arranged according right angles and tangents to the individual elliptic formations – HGR, which exactly correspond to the principles of orogenic development of this continent.

To prove this structure on a smaller area, hydrogeomorphologic analysis has been performed on a smaller area – of 334 km^2 on the confluence of the Vltava and Lužnice rivers. From the scheme in figure 2, the same regularity as in the previous case is evident. RGh 528 controls regime of deep-seated waters, which springs end in confluences of tributary streams into the Lužnice or into the Vltava rivers (dot-and-dash lines). From RGh 528, LGS lead from the first springs of vadose waters and as intersections of next springs on some of the neighbouring IMS, as tangents, and run through numerous ZPS on Gh 442, 430, 504, where they are filled by vadose waters and empty either in the Vltava river or in tributary streams of the Lužnice river. The length of these directions of deep-seated waters is around 20 km and gradient of flow is 0.0067-0.0071.

From the center go out in inverse sense FKS, which would in elongation also reach confluence of deep-seated waters, but they end in the first or the second spring. This reality finishes the symmetry of directions of underground waters. Course of LGS and FKS is marked by numerals 1 ÷ 9. Vadose waters can reach only the 1st to the 2nd spring, i.e. the ledge of the spring field.

Deep-seated and vadose waters can meet not only in confluences. In figure 2, vadose and deep-seated waters from Gh 528 and Gh 503 go against each other. At their meet fish ponds without inflow come into being. On the scheme they are marked by numerals 1 ÷ 11.

Accumulation and move of underground waters confirms the principle, which we understand as a "transport delay in the hydrologic circuit". It consists in the following: to saturate vadose and deep-seated waters from ZPS it is necessary overland flow (runoff) to be delayed, and as a result of this, maximum water from precipitation be transported into source components of water balance, i.e. hstr and hsp, thus evaporation hsev and runoff hso would be limited, and so deep-seated waters could be accumulated. Only perennial forest stands can create this delay. It then creates the need for afforestation of zones of primary saturation ZPS. This fact is confirmed also by AMBROS [1], who found out, that in the 1st ÷ 3rd vegetation stage (VS) of beech and oak forest, direct runoff reaches its maximum and infiltration is zero. On the contrary, in higher elevations – up to 5th VS, in agreement with quick infiltration of precipitation and thus enrichment of underground waters – water-management importance of forests grows. On this knowledge, he recommended also protection of mountain pine stands in mountain regions (up to 8th VS). In our case originated primarily fishponds on directions of deep-seated and vadose waters at the edges of forest massifs (29.5 km^2). In these forests, surface runoff and evaporation is minimal, the most precipitation comes into hstr and underground waters. That is why, on the meet of deep-seated and vadose waters, inflowless (spring) fishponds come into being. As for the rest of the region of 147 km^2, square measure of forests does only 39 %, and from the total square measure of ZPS (18.22 km^2) only 5.7 km^2 is forested, that is 31.28 %, thus only 1 % more than does the percentage of forestation of the region in general. Forests are distributed randomly, without relation to stated principles of flow of underground waters, while the east part is covered by forest complex.

Interesting finding is provided by direction of deep-seated and vadose waters from Gh 503 in northeasterly direction, where a large peat massif (9.18 km^2) (hatched) came into being.

In figure 3 and 4, there is a detail of direction of deep-seated waters coming from Gh 503 and emptying on 12.5 km into the confluence of a small stream with the Lužnice river. (Marked "K".) The direction goes through the forest massif (Gh 476) of a square measure 11 km^2.

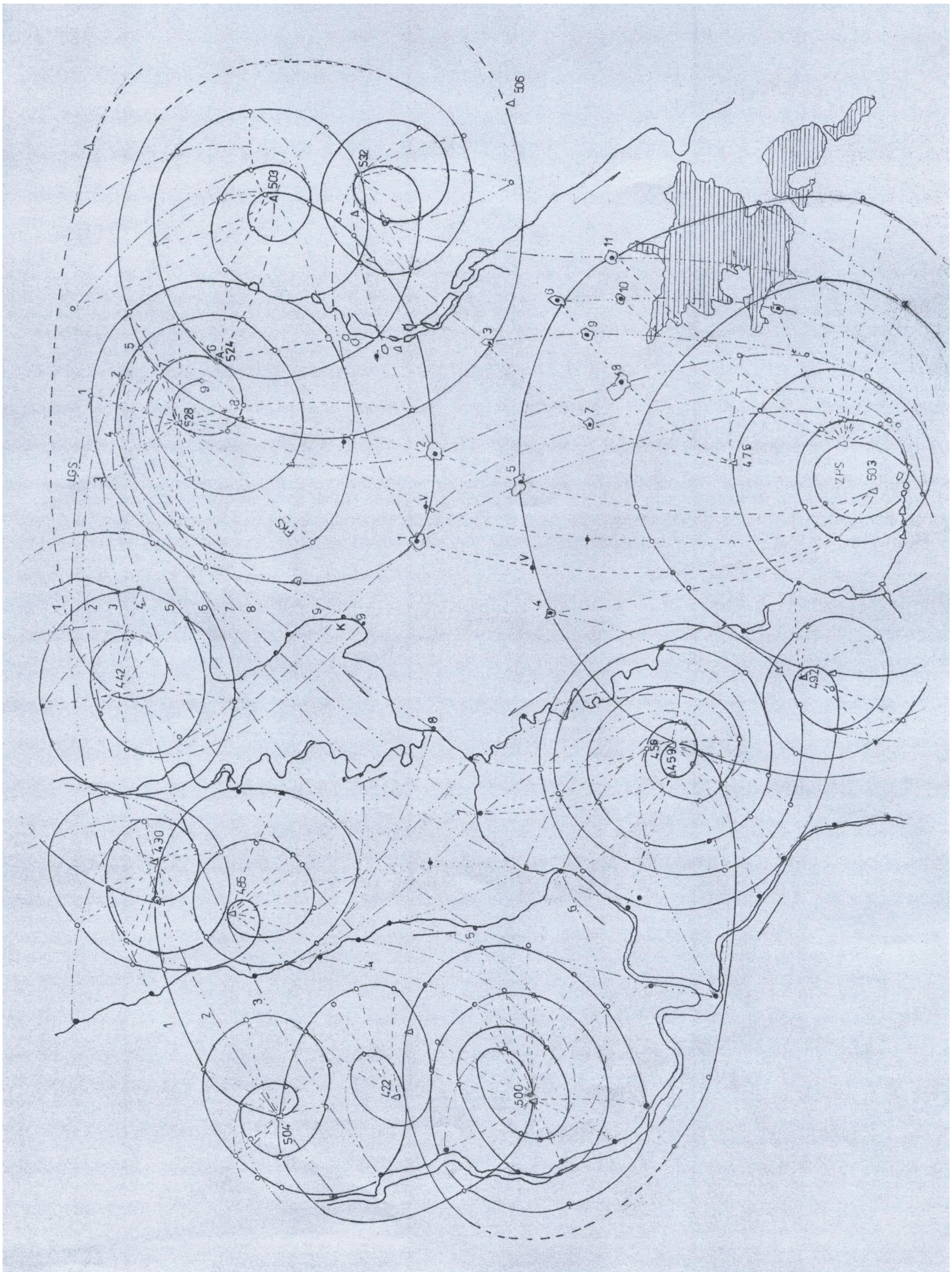

Figure 2. Hydrogeomorphologic analysis of the confluence of the Vltava and Lužnice rivers (RGh 528 and SGh 503)
Obr. 2. Hydrogeomorfologická analýza soutoku Vltavy a Lužnice (RGh 528 a SGh 503)

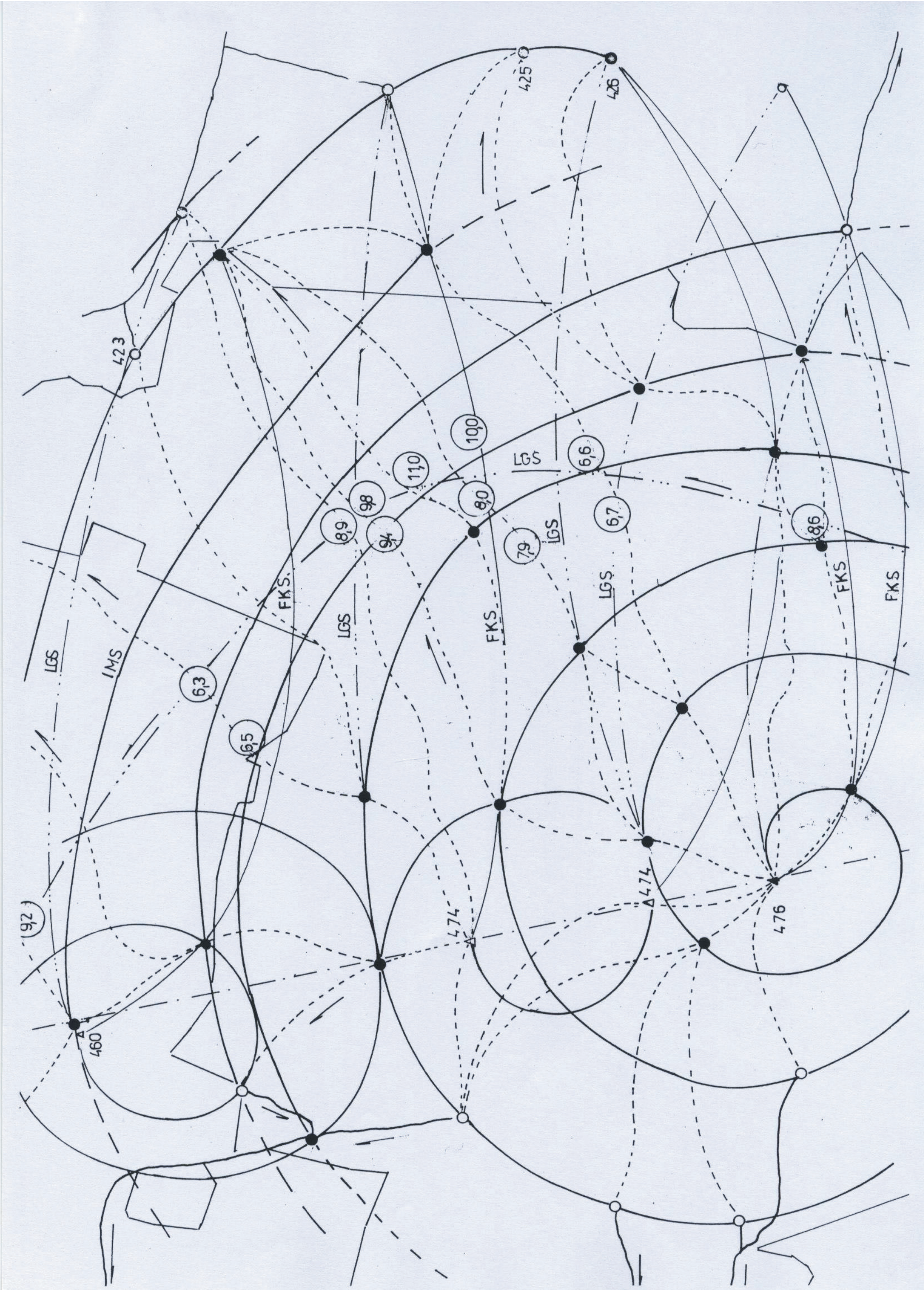

Figure 3. Hydrogeomorphologic analysis of deep-seated water direction SGh 503 – confluence 395
Obr. 3. Hydrogeomorfologická analýza směru hlubinných vod SGh 503 – soutok 395

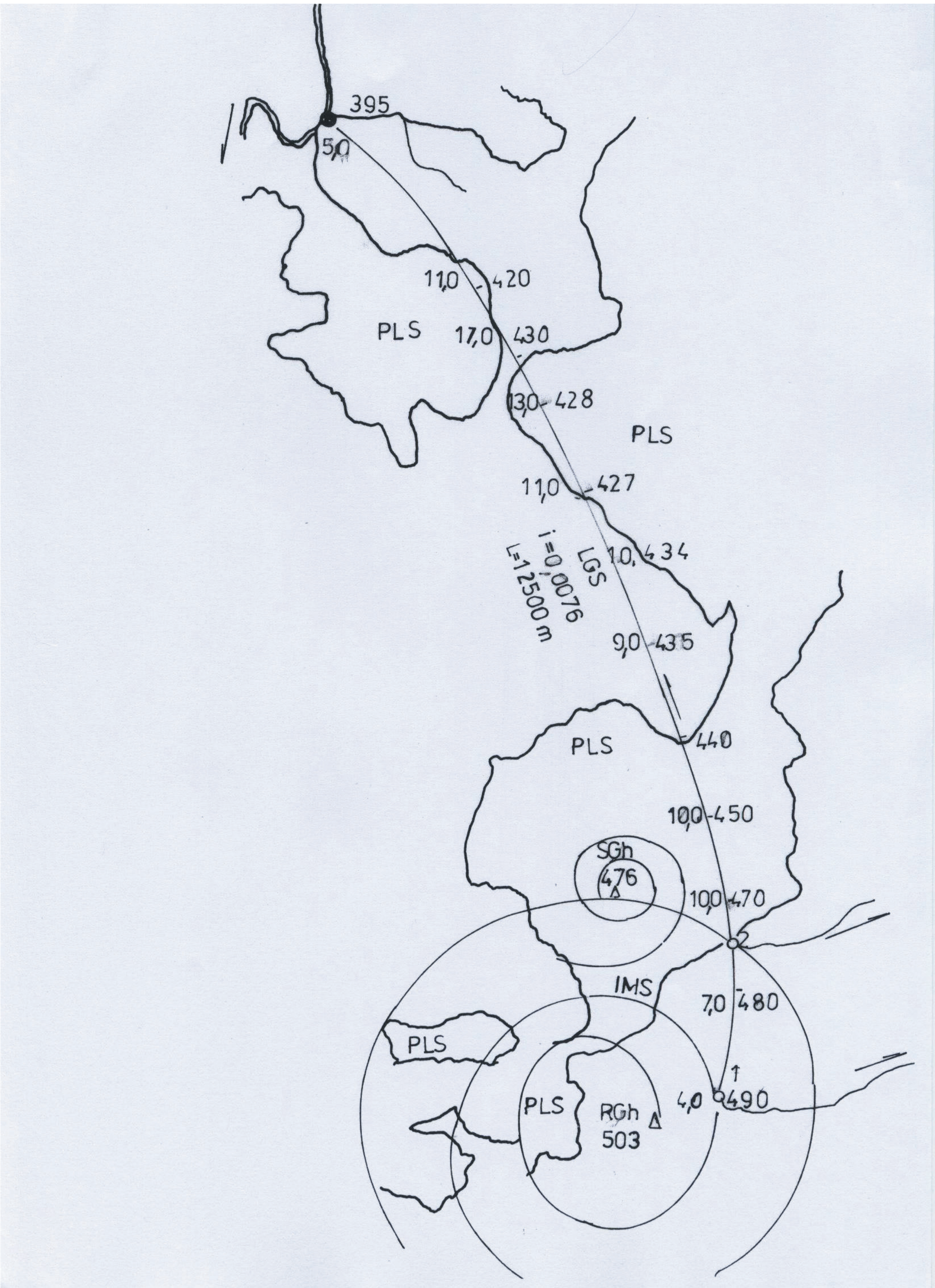

Figure 4. Accumulation of deep-seated waters and move of vadose waters in forested area Gh 476 (detail to figure 3)
Obr. 4. Akumulace hlubinných vod a pohyb vadózních vod na zalesněném území Gh 476 (detail k obr. 3)

On its way it saturates two inflowless fishponds (5 and 1), and in its spring (confluence) is supported by the direction of vadose waters FKS from Gh 528. On the forest formation (Gh 476) vadose waters are being formed, leading in cross direction into springs at the edge of the forest massif (in figure 3 the are marked by white circles). The forest massif did not allow development of springs, a part of water transferred into transpiration, delayed runoff of vadose waters, and instead of springs only interferences and bifurcations of flow were developing on this direction of flowing. The connecting line of these points then showed, that it concerns again limit stages within the frame of filtration and that is why they are arranged just in the same way, as springs would be – in a spiral (black circles). The forest delayed this runoff and so created possibility of accumulation of deep-seated waters in ZPS (Gh 476, 474 and 460). The direction of flow of deep-seated waters through the forest massif is on the figure 4 with marked depths. Noteworthy is, that FKS from these Gh, going out their center, meet again LGS going out as tangents from individual Gh in springs at the edge of the forest massif (white circles). Thus the symmetry of directions of deep-seated and vadose waters is being confirmed, just with this, that vadose waters spring on the surface, while in ZPS round Gh deep-seated waters accumulate, longitudinally directed into the "K" direction on the Lužnice river. The direction of their flow is stationed according elevations, with marking its depth on the line of 12.5 km and slope 0.0076. On the stated direction, a big pumping station has been built on the elevation 430. Moreover, as is evident from figure 2, the direction of deep-seated waters is supported in RN 1 by considerable input of deep-seated waters from Gh 532. Practice then shows that there is considerable excess of underground water.

CONCLUSIONS AND RECOMMENDATIONS

Hydrogeomorphological analyses proved, that HGR, owing to its properties given by its symmetric structure of the system "Gh – hydrological circuit", is a basic unit of land area. Dominant position of Gh and directions of underground waters are a key factor. It proves, that the basic moment of symmetry of hydrological balance, expressed by equation, is the principal of transport delay in hydrological circuit, which enables transformation of non-source components of water balance into source ones as influence of forest stands. That is why all forestry, agricultural and water management measures must be considered so, that they always lead to establishment of symmetry of water balance, hydrological stability and invariance of the whole unitary system of agricultural, forest and water management.

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Symbols and indications used in the work
Použité symboly a označení

Symbol	Meaning	Význam
HGR	Hydrogeomorphologic region	Hydrogeomorfologický region
Gh 700	Geomorphologic formation of 700 m above-sea-level elevation	Geomorfologický útvar o nadmořské výšce 700 m
VP	Spring field	Vývěrové pole
RGh	Controlling Gh in HGR (for example RGh 1111)	Řídicí Gh v HGR (např. RGh 1111)
SGh	Satellite Gh	Satelitní Gh
ZPS	Zone of primary saturation	Zóna primárního sycení
hsp	Vadose underground water (shallow)	Podpovrchové vody vadózní (mělké)
hhsp	Deep-seated underground water	Podpovrchové vody hlubinné
Shsp	Direction of flow of vadose water	Směr toku vadózních vod
Shhsp	Direction of flow of deep-seated water	Směr toku hlubinných vod
hso	Surface run-off water	Odtokové vody povrchové
FKS	Functional curve of symmetry – connecting line (vertical) of vadose water springs	Funkční křivka symetrie – spojnice (vertikální) vývěrů vadózních vod
LGS	Logarithm spiral – direction of deep-seated water flow	Logaritmická spirála – směr toku hlubinných vod
IMS	Connecting line of vadose water springs (speed limit states)	Spojnice vývěrů vadózních vod (mezní stavy rychlosti)
Igh	Isoline connecting Gh	Izočára spojující Gh
ZS	Agricultural system	Zemědělská soustava
LS	Forest system	Lesní soustava
ZLS	Agricultural and forest system	Zemědělskolesní soustava
USZLVH	Unitary system of agricultural, forest and water management	Unitární soustava zemědělského, lesního a vodního hospodářství
RN	Fish ponds	Rybniční nádrže
hstr	Consumption of water for transpiration	Spotřeba vody na transpiraci
Hsev	Consumption of water for evaporation	Spotřeba vody na neproduktivní výpar (evaporaci)
V	Water Treatment, pumping station, wells	Vodárenské zařízení, čerpací stanice, studny
PLS	Forest area	Plocha lesů