ORIGINAL PAPER

PRINCIPLES OF HYDROGEOMORPHOLOGY AS A BASIC PRECONDITION FOR SOLUTION OF TERRITORIAL STRUCTURE OF UNITARY SYSTEM OF AGRICULTURAL, FOREST AND WATER MANAGEMENT

ZÁKONY HYDROGEOMORFOLOGIE JAKO ZÁKLADNÍ PŘEDPOKLAD PRO ŘEŠENÍ TERITORIÁLNÍ STRUKTURY UNITÁRNÍ SOUSTAVY ZEMĚDĚLSKÉHO, LESNÍHO A VODNÍHO HOSPODÁŘSTVÍ

K. KUDRNA, M. ŠINDELÁŘOVÁ*

University of South Bohemia in České Budějovice, Faculty of Agriculture, Department of Agroecology, 370 05 České Budějovice, Czech Republic, Tel: + 420 387 772 414, Fax: + 420 387 772 402

Manuscript received: September 29, 2006; Reviewed: December 11, 2006; Accepted for publication: December 12, 2006

ABSTRACT

In the presented work, the laws of hydrogeomorfhology have been defined on the principle of symmetry and invariance, which are to be respected at solution of territorial structure of Unitary System of Agricultural, Forest and Water Management (USAFWM). The principle of the solution is a dominant position of the geomorphologic formation Gh of a given sea-level altitude in the analyzed part of territory, which determines control and regulation of all components of water balance. The newly formed territory unit, delimited around the geomorphologic formation by water streams, was called a hydrogeomorphologic region of the third order (HGR-3).

KEY WORDS: principle of symmetry; invariance; hydrogeomorphology; water balance

ABSTRAKT

V předložené práci jsou definovány zákony hydrogeomorfologie na principu symetrie a invariance, které je nutno respektovat při řešení teritoriální struktury unitární soustavy zemědělského, lesního a vodního hospodářství (USZLVH, resp. USAFWM). Principem řešení je dominantní postavení geomorfologického útvaru Gh o určité nadmořské výšce ve sledované části území, který determinuje řízení a regulaci všech složek vodní bilance. Nově vzniklý územní celek vymezený kolem geomorfologického útvaru vodními toky byl nazván hydrogeomorfologickým regionem 3. řádu (HGR-3).

KLÍČOVÁ SLOVA: princip symetrie; invariance; hydrogeomorfologie; vodní bilance

PODROBNÝ ABSTRAKT

Hydrogeomorfologii jsme definovali jako speciální část geomorfologie a je chápána jako spojení konzervativního prvku krajinného prostoru – reliéfu území a prvku dynamického – hydrologie v návaznosti na ostatní vědní obory – geologii, hydrogeologii, zemědělsko-lesní soustavy a vodní hospodářství. Nový přístup k řešení krajinného prostoru spočívá v tom, že dominantou území je geomorfologický útvar (Gh) jako řídicí prvek všech složek vodní bilance. Tento přístup umožnil na principu symetrie a invariance poznat a definovat uspořádání geomorfologických útvarů a na nich závislých vývěrů podpovrchových vod jako přírodní zákon, definovat úlohu zvodnělých vrstev (zvodně) jako zásobníku podpovrchových vod a jeho činnost na principu podobnosti s elektrickým obvodem jako autooscilační relaxační generátor vývěrových vod. Využití principu symetrie pak umožnilo vyjádřit vlastnosti nového územního útvaru, který jsme definovali jako hydrogeomorfologický region 3. řádu (HGR-3) na rozdíl od HGR-2, které jsou tvořeny symetrickými soubory regionů 3. řádu a HGR-1, které jsou utvářeny rozvodnicemi světových moří a oceánických pánví [1].

V práci je ukázána symetrie uspořádání geomorfologických útvarů a na nich závislých vývěrů podpovrchových vod, v podobě netlumených spirál, které zabezpečují zpoždění odtoku, rozptýlení jejich akumulace a tlaku. Jsou popsány i soutoky vodních toků jako hydrogeomorfologické útvary, v nichž dochází k transformaci bystřinného proudění v říční. Proto jsou i všechny soutoky spolu s vývěry na izočáře mezních stavů rychlosti proudění (IMS) a ve vertikálním směru na funkčních křivkách symetrie (FKS). Byl definován zákon uspořádání geomorfologických útvarů, vývěrů a soutoků. V práci jsou analyzovány dva hydrogeomorfologické regiony, v nichž jsou popsány jejich jednotlivé části, koncipováno blokové schéma hydrologického obvodu na základě teorie podobnosti s elektrickým obvodem, definován princip dopravního zpoždění proudění podpovrchových i povrchových vod. V práci byla soustředěna pozornost především na poznání symetrie vztahu Gh a vývěrů podpovrchových vod v oblasti střetu dvou zlomů Jáchymovského hlubinného zlomu a Blanické brázdy v Moldanubické oblasti tvořící jádro Českého masivu, které zaznamenalo mnoho metamorfních změn zejména hercynského stáří. Podrobnější vyhodnocení geologických a geomorfologických poměrů bude předloženo v dalších studiích této oblasti.

INTRODUCTION

Enormous demands on water cause need of new approaches to solution of land area, especially from side of those factors, which determine control and regulation of all components of water balance. That is why the aim of the presented work was to know and define principles, controlling relations between geomorphologic formations of land area and its water regime. We proceeded from the assumption that forming of world orogene is not a chance and that is why water regime dependent on it is not a chance. But it was necessary to determine, what are relations between a conservative element of land area – geomorphologic formations and relief in general, and its dynamic element – water regime – especially of groundwater. Already our previous project studies and analyses [7] showed, that a stabilizer of all biological processes in land area and a moving power of its development is groundwater – vadose as well as profound. We supposed, that a solution of relations between mentioned elements could fundamentally contribute to explanation of these problems. That is why we choose Gh as a dominant formation in land area, supposing it will be delimited by circumferential water streams and will thus form a closed system, which will show a higher grade of invariance. That is why it is also possible to use very effective regulation measures and especially to solve structural equilibrium of water balance. So it was possible to use methods resulting from the theory of similarity as an analogy of electric circuit on hydrologic circuit, and to explain process of delay of groundwater as well as surface water as a progressive element of land area, which secures its biological stability.

MATERIALS AND METHODS

Material

As source materials, map schemes, topographic sources, forestry and geologic maps and maps of world orogene have been used.

Methods

Points of streams round a geomorphologic formation Gh as well as points of confluences of spring streams have been abstracted, and their arrangement have been drawn. Connecting lines of Gh and springs have been drawn. Horizontal connecting lines in form of spirals marked limit stages of vadose underground water velocity as isolines of limit stages. Vertical connecting lines of springs have been drawn as functional curves of symmetry (FKS). Connecting lines of all Gh have been marked as isolines IGh. On the principle of theory of similarity of studied processes with an electric circuit,

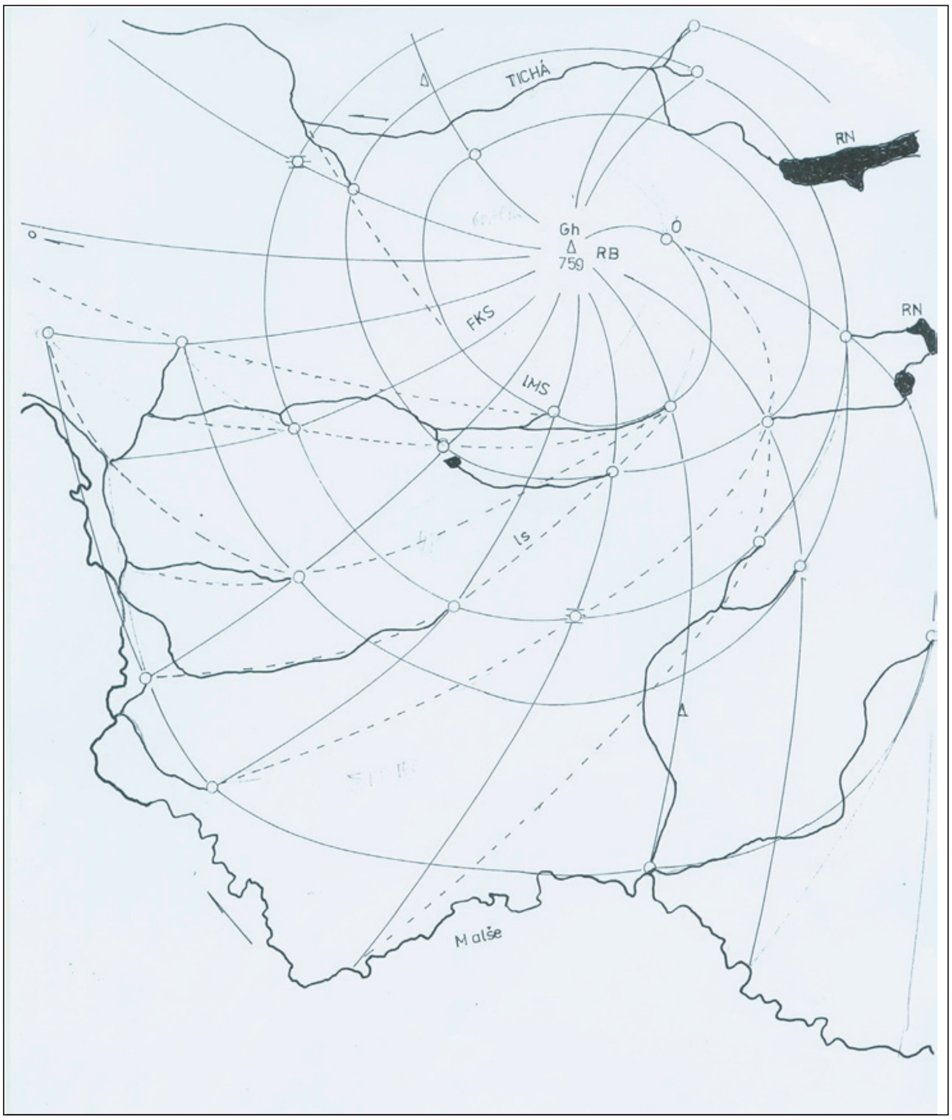

Figure 1: Arrangement of springs on real Gh Tichý (Malše catchment)
Obr. 1: Uspořádání vývěrů na reálném Gh Tichý (povodí Malše)

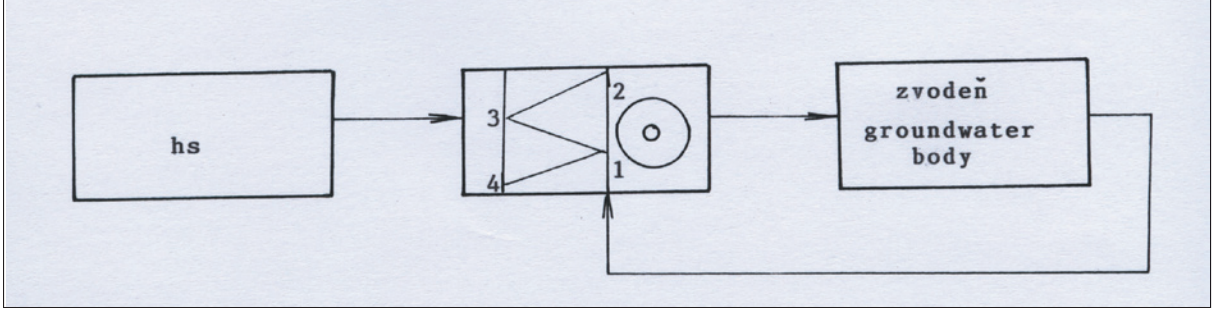

Figure 2: Block scheme of an autooscillative relaxation generator of hydrologic circuit
Obr. 2: Blokové schéma autooscilačního relaxačního hydrologického obvodu

block scheme of hydrologic circuit have been drafted, in which geomorphologic formation Gh is a head element. Analysis of real hydrogeologic formations HGR then enabled to derive transport delay of streaming water as a necessary principle of progressive development of land area for conception of Unitary System of Agricultural, Forest and Water Management (USAFWM).

RESULTS AND DISCUSSION

Arrangement of springs on real Gh Tichý (Malše catchment)

Main member of the observed territory is geomorphologic formation Gh 759, on which lateral surface precipitation is collected, infiltrated and by laminar flow carried over into first springs, forming a zone of primary saturation (ZPS). Arrangement of springs is on the lateral surface characterized by spiral symmetry in form of IMS (isoline of limit stages of mean velocity of underground water). The spring field reaches right to the circumferential stream – Malše, and so the zone of accumulation is miniature. FKS intersect individual springs vertically. As it concerns filtration, the movement along IMS is laminar, and IMS, which connects springs, present a line, on which laminar flow according to Darcy equation $v = k * i$ changes in turbulent one according to Chézy equation $v = C \sqrt{R*i}$. ZPS can be marked as an unstable focus, springs as stable knots, as here comes to limit state of laminar flow speed. Unsubdued spirals IMS secure delay of laminar flow; that is why this spiral system of arrangement of springs is a precondition for preservation of vadose water speed in limits of laminar flow. In groundwater body, it comes to enforced undulation as a result of the resistance of rock layer against flow; that is why crucial is pressure p, to overcome rock resistance for rise of a spring, in which comes to relaxation. Thus

$v(hsp) = f(i, p, Q)$.

Flow of water below a spring continues due to the slope of groundwater body isolator or by dividing of the stream (bifurcation) as a result of water accumulation (e.g. owing to an obstacle formed by a geologic layer), thus again by a change of pressure, when concentrated flow is being interrupted and overland flow comes into being. On the basis of theory of similarity, this process can be compared with an electric autooscillative relaxation generator [5]. Then we can express the circuit at change of individual quantities also as an auto-oscillating relaxation generator of spring waters. If we consider, as a water source, precipitation – hs, which after infiltration

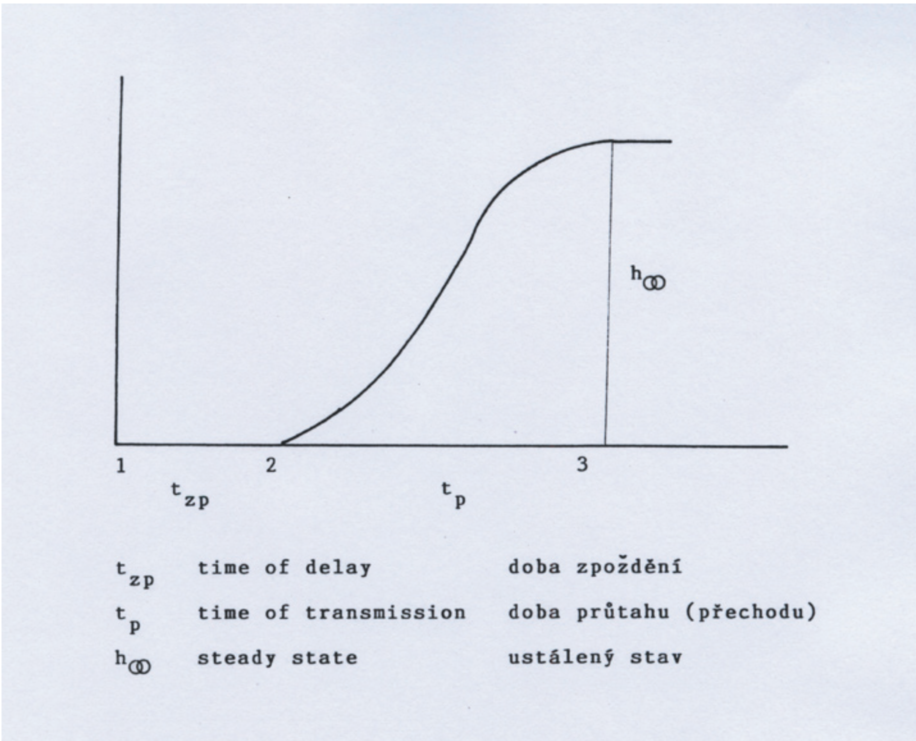

Figure 3: Transmission characteristic with hsp (groundwater) transport delay
Obr. 3: Přechodová charakteristika s dopravním zpožděním hsp (podpovrchových vod)

cause pressure in the rock – p_1, spring as a nonlinear element of the circuit f (p_2), which is determined by a feedback expressing dependence of water flow on spring and pressure, which exists in saturated layers – p_2, then the whole process can be expressed by a block scheme:

Relaxation circuit can be described by a nonlinear equation of the first order

$dx / dt = f(x)$

As a feedback is given by dependence of speed on the pressure, which at same conditions of groundwater body resistance results from water accumulation in the groundwater body, conditions of a multivalent function are formed, which is a precondition of oscillation of hsp flow. The process is going so: hs fills the groundwater body, create a water supply, which pressure grows and changes according to how much water is taken away by springs. If we consider, that in the groundwater body as a reservoir the pressure is fluctuating in time

dp_2 / dt,

and is growing in the direction to spring till a certain moment, when it culminates and then in the spring relaxes, and so it presents a nonlinear member of the circuit. Nonlinear characteristic then originates so, that at the input of hs the pressure in the groundwater

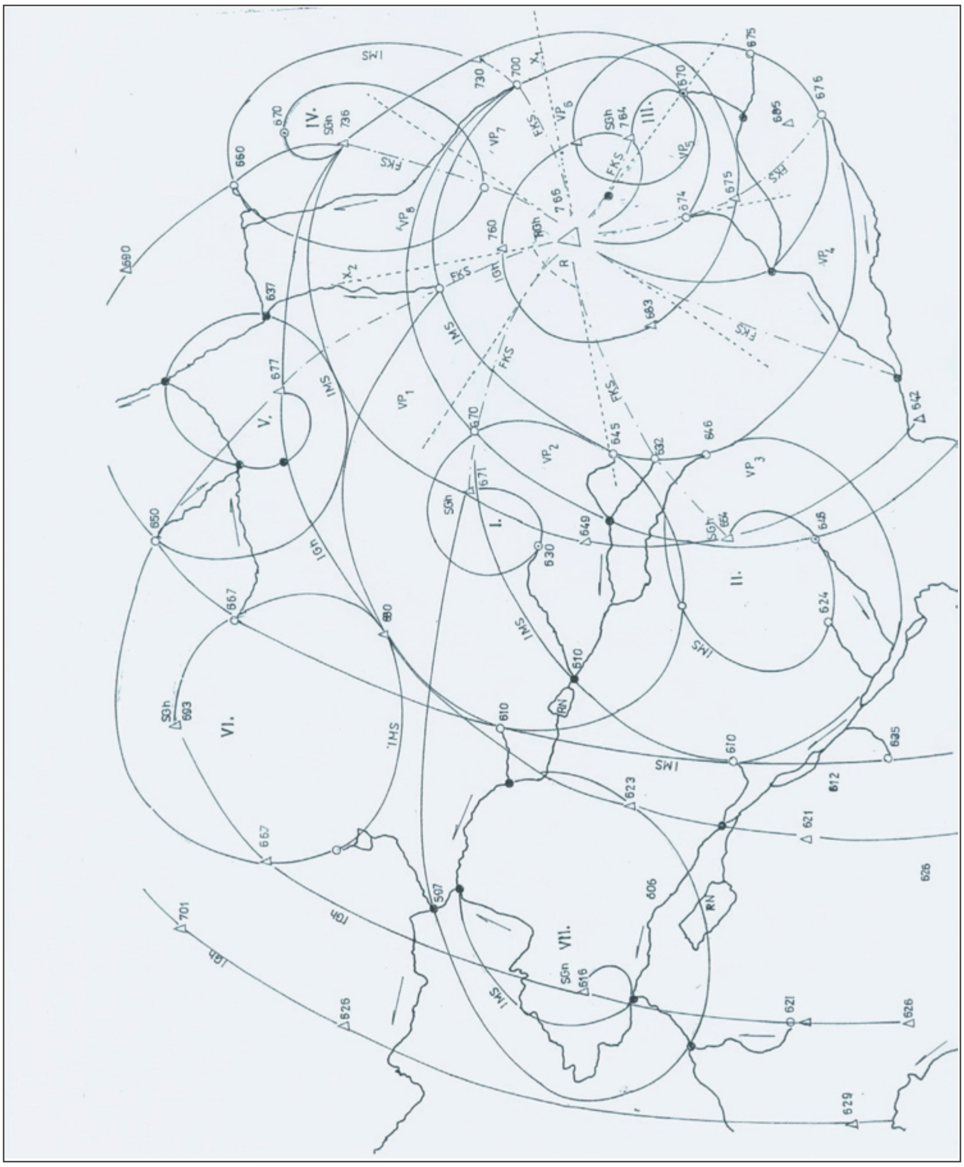

Figure 4: Hydrogeomorphologic analysis of Gh 766 (Mikolský hill, Malše river catchment)

Obr. 4: Hydrogeomorfologická analýza Gh 766 (Mikolský vrch, povodí Malše) body is growing till it is released by springs (from point 1 to 2). But after relaxation in the spring, the pressure in the groundwater body goes down to the point 3 and then after emptying it, to the point 1 and later on to the point 4 (figure 2). But in fact, the process is much more complicated. Especially, usually more springs are on the lateral surface of Gh, and connection of the groundwater body with the spring already exists. That is why the process of decreasing of p_2 should accelerate. However, a spiral arrangement of springs act against it. That is why the decrease of hsp runoff as well as p_2 is delayed. This delay is also the result of evapotranspiration of stands, especially forest ones, and water infiltration through the transit layers into profound groundwater so, as it goes just under forest stands. It comes to “transport delay” of hsp runoff into spring waters. Forest stands, agricultural systems, melioration measures, especially delaying drainage ditches and polders etc. are then effective means, forming conditions for transport delay on Gh. Here is also cleared up, why springs in forest massifs are moved in most cases right to their edges [6]. Similarly it can be explained, why at the equilibrate state of water balance the hsp member must be bigger than the runoff- one [3]. Transport delay can be expressed by a transmission characteristic (figure 3).

Transport delay is of extraordinary importance in ZPS till the time, when springs arise.

Function curves of symmetry as vertical connecting lines of springs therefore present steady regimes, and as they connect springs, which are an expression of stable knots at limit of stability, then these curves are also limit stable cycles of hsp flowing. Between them, if we proceed from Thom’s theory of catastrophes, non-stable flowing of hsp is going. In some cases, FKS connect alternately springs and Gh. Then it is a semi-stable cycle (figure 4).

Circumferential streams of Gh 766 are tributaries of the Malše river from the south side, the Malše river from the west side, and Mladoňovický stream from the east and west. Mladoňovický stream empties into the Malše. Worthy of attention is that the controlling Gh (RGh) controls water regime through 7 satellite Gh, from which it controls spring water streams. IMS exactly mark this situation. On the scheme, IGh and IMS are drawn separately, so that their relative coarse would be apparent. Spirals have their beginning in RGh, go together, or sometimes are crossing, but their coarse stays together till the springless zone (ZA), in which only spirals IGh prolong. These form here a special boundary behind which only confluences of spring streams are and where assert themselves satellite Gh VI and VII, that we mark as secondary ones, as against primary satellite Gh, which are tied directly on RGh (I, II, III, IV, V). All of them then are bound on RGh by function curves of symmetry. Tangents to FKS form between themselves right angles (dash-and-dash) and at the same time they form state plane X_1, X_2. Also all SGh are to RGh in right angle. HGR is thus divided symmetrically so, that each SGh saturates its own spring stream and at the same time is bound on RGh. Given symmetry indicates that orogene development did not pass accidentally. FKS are also attractors, presenting delay of run-off of hsp. If it is not so, a hard loss of stability of hsp flowing would occur. In this sense also act confluences of water streams, which thus become an important hydrogeomorphologic element in land area. As in confluences it again concerns change of speed, IMS lines connect also confluences together with springs. It proves, that there exists here an effort of nature to delay runoff of underground as well as surface waters. A confluence should express the point, in which, as a result of higher water supply, torrent flowing should arise. But it does not happen, as parameters of stream channel will be changed by erosion, and they do not allow arise of torrent flowing. All quantities, determining type of flowing, gain extreme values, kinetic energy is growing and the stream tries by the way of minimal resistance to change direction.

If we mark:

g – gravitation constant

O – wetted perimeter

α - coefficient of uniformity 1.0 ÷ 1.1

C – coefficient of velocity

B – breadth of stream in crest

Q – flow rating

S – flow cross-section,

then

$i_k = \frac{g O_k}{\alpha C^2 B_k}$, $h_k = \frac{\sqrt{\alpha q}}{g}$, where $q = \frac{Q}{B}$,

where index “k” marks critical values of individual quantities.

A higher flow rating Q, by influence of a higher kinetic energy, modifies the stream channel in bottom as well as in crest, so that parameters of critical values for river flowing i_k, h_k were not exceeded. That is why these limit transitions of velocity become characteristic points, together with springs. Similarity to spiral arrangement of springs, confluences and Gh can be observed also in arrangement of estuaries of all world water streams into seas and oceans. On the way from mainland to oceans, also the change of velocities in estuary of the stream to oceanic flow takes place. Their parameters are a reflection to all changes in the stream, are a characteristic of a changeover of river flowing to oceanic. Estuaries here act as a spring of mainland waters into oceans. That is why also they lie on two symmetric spirals (figure 5).

On the scheme also FKS and IMS and state coordinates with the center of Tibet plateau are marked off.

From mentioned it is evident, that all transitions of velocity have a tendency to decrease velocity of water, whether directly in groundwater body – keeping laminar flowing, or in streams – keeping river flowing in confluence, or in oceans – dispersion of river flowing by oceanic currents. This role on world mainland have plant societies, especially forests, which one the one hand delay and disperse chaotic and untidy input of precipitation by interception in crowns and on trunks of trees and increase in this way infiltration into groundwater body. On the other by evapotranspiration most of precipitation is consumed, and so run-off is regulated and delayed [2], [4].

That is why, if we understand progressive development of land area from hydrological view point as a most quick receipt and most quick consumption of precipitation, then all Gh, springs, confluences, agricultural-forest systems, polders, water basins, delaying drainage ditches, are factors, which cause transport delay in hydrologic circuit. The aim of this is, that the coarse of output values – transmission function – would approach to limit state of water balance equilibrium [3]. This transport delay therefore is a key precondition of progressive development of land area. More detailed solution of hydrogeologic and hydrogeomorphologic properties of the territory (depth of isolators, properties of collectors and others) has been solved by this time on other catchments (Blanice, Volyňka) by system methods and controlled by flow rates in long time series. After finishing analysis of the Malše, these analyses will be realized also on the Malše river catchment.

CONCLUSIONS AND RECOMMENDATIONS

In the presented work, principles of hydrogeomorphology have been drafted out, as a special branch of geomorphology and connection of a conservative element – relief of area – with a dynamic one – water regime of land area. On this basis, a principle of symmetric arrangement of geomorphologic formation (Gh), springs of underground waters and confluences of surface waters has been defined, isolines of limit states of underground

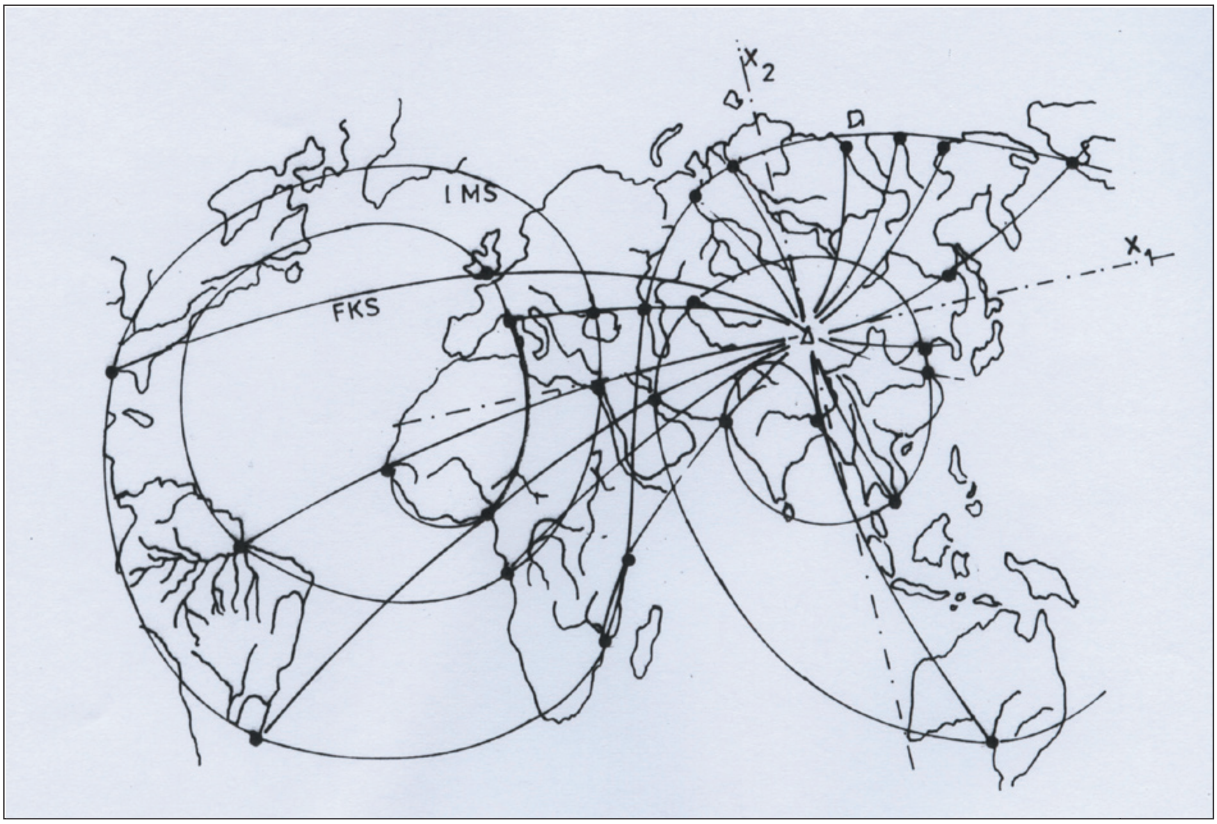

Figure 5: Map scheme of connection lines of estuaries of world water streams [1]

Obr. 5: Mapové schéma spojnic ústí světových vodních toků [1] water velocities and function curves of symmetry have been determined. Hydrogeomorphologic region of the third order (HGR-3) has been defined, as delimited by circumferential water streams and the dominant geomorphologic formation and its satellites. Knowledge of relations between them enabled to define the role of delaying of underground waters as well as surface runoff. The results become an important basis for studying of land area, forming a conception of landscape engineering and a unitary system of agricultural, forest and water management.

ACKNOWLEDGEMENT

This study was supported by the Grant Project of Ministry of Education of the Czech Republic, identification code MSM 6007665806.

REFERENCES

[1] Kudrna, K. Hydrotermické příčiny vzniku seismických a vulkanických poruch na Zemi. (Hydrothermic causes of seismic and volcanic disturbances on the Earth.) Kladno: Centrum pro zemědělské soustavy, 2001, 157 p.

[2] Kudrna, K., Šindelářová, M. Lesy jako plošný regulátor vodní bilance hydrologického obvodu. (Forests as an area regulator of water balance in hydrological circuit.) Lesnická práce, 2003, vol. 82, no. 2, p. 39-41.

[3] Kudrna, K., Šindelářová, M. Equilibrium of water balance as a basic precondition of progressive development of land area. (Rovnováha vodní bilance jako základní předpoklad progresivního vývoje krajinného prostoru.) Journal of Central European Agriculture, 2004, vol. 5, no. 4, p. 273-280.

[4] Kudrna, K., Šindelářová, M. Contribution to the possibility of improving of disturbed water balance on a catchment by forest stands on the principle of new water balance equation. (Příspěvek k možnosti vyrovnání porušené vodní bilance na povodí lesními porosty na principu nové rovnice vodní bilance.) Sb. IV. mezinárodního setkání EKOTREND 2005 „Obnova a funkce antropogenně ovlivněné krajiny“. ZF JU v Č. Budějovicích, 2005, s. 37.

[5] Kotek, Z., Kubík, S., Razím, M. Nelineární dynamické systémy. (Nonlinear dynamic systems.) Teoretická knižnice inženýra, 1973, s. 355.

[6] Kudrna, K. Možnosti vyhodnocení směrů podpovrchových vod. (Possibilities of assessment of underground water directions.) [Not published.]

[7] Kudrna, K. Řešení teritoriální struktury na hydrologicky důležitých povodích na základě analýzy vodní bilance. (Solution of territorial structure on hydrologically important catchments on the basis of water balance analysis.) [Projektová studie.] Jihočeská univerzita v Českých Budějovicích, zemědělská fakulta, 1992.

Symbols and indications used in the work
Použité symboly a označení

Symbol	Meaning	Význam
Rb	Watershed divide point	Rozvodnicový bod
C	Coefficient of velocity	Rychlostní součinitel
R	Hydraulic radius	Hydraulický poloměr
p	Pressure	Tlak
i	Slope	Sklon
v	Velocity	Rychlost
ZPS	Zone of primary saturation	Zóna primárního sycení
VP	Spring field	Vývěrové pole
ZA	Accumulation zone	Zóna akumulace
IMS	Isoline of limit stages of mean velocity of underground water	Izočára mezních stavů rychlostí proudění podpovrchových vod
hsp	Vadose groundwater	Podpovrchové vadózní vody
hhsp	Profound groundwater	Vody hlubinné (profundní)
HGR-3	Hydrogeomorphologic region of the 3rd order	Hydrogeomorfologický region 3. řádu
IGh	Isoline of limit sea-level altitudes of geomorphologic formations in a region	Izočára mezních nadmořských výšek geomorfologických útvarů v regionu
Gh	Geomorphologic formation	Geomorfologický útvar
RGh	Controlling geomorphologic formation	Řídicí geomorfologický útvar
SGh	Satellite geomorphologic formation	Satelitní geomorfologický útvar
FKS	Functional curve of symmetry	Funkční křivka symetrie
Q	Water volume in groundwater body	Objem vody ve zvodni
RN	Water reservoir	Vodní nádrž