ACTA HYDROLOGICA
SLOVACA

Ročník 19, č. 2, 2018, 296 – 303

FLOOD PROTECTION MEASURES TO PROTECT URBAN AREAS

Andrej Šoltész, Lea Čubanová, Adam Janík, Dana Baroková

The contribution is presenting possibilities of comprehensive and complex procedures for proper design of flood protection measures in several parts of Slovakia. The complex approach consisted of mutual integration of results of partial mathematical models – rainfall-runoff model, waste water network model, 1-D hydrodynamic modelling of open channel flow together with partially covered flows, 2-D hydrodynamic modelling of flooding the town residential area. According to the modelling process appropriate preventive flood protection measures have been designed and afterwards some of them realised in the territory, i.e. detention reservoirs in the mountain region above the urban regions. Designed flood protection measures should store the flood wave volume and mitigate the effect of flash floods on residential areas of small and even larger cities. Several case studies are described in the contribution to emphasize the variety of flood wave progress, its reduction in discharge and postponing in time in different hydrological, morphological and geological conditions of sub-mountain regions.

KĽÚČOVÉ SLOVÁ: flood, flood protection, hydraulic simulations, measures

PROTIPOVODŇOVÉ OPATRENIA NA OCHRANU SÍDIEL. Príspevok prezentuje možnosti komplexných návrhov pre vyhovujúce protipovodňové opatrenia vo viacerých častiach Slovenska. Komplexný prístup spočíva vo vzájomnej integrácii výsledkov čiastkových matematických modelov – zrážkovo-odtokového modelu, modelu stokovej siete, 1-D hydrodynamického modelovania otvorených korýt, 2-D hydrodynamického modelovania zaplavenia mestskej obytnej zóny. Podľa nasimulovaných výsledkov boli navrhnuté vhodné preventívne protipovodňové opatrenia a následne niektoré z nich realizované na území, napr. suché nádrže (poldre) v horskej oblasti nad mestskými sídlami. Navrhované protipovodňové opatrenia by mali zadržať objem povodňovej vlny a zmierňovať vplyv bleskových povodní na obývané oblasti malých a dokonca i väčších miest. V príspevku je popísaných niekoľko prípadových štúdií s cieľom zdôrazniť rozmanitosť vývoja povodňových vĺn, ich sploštenie a časový posun v rôznych hydrologických, morfologických a geologických podmienkach podhorských oblastí.

KEY WORDS: povodeň, protipovodňová ochrana, hydraulické simulácie, opatrenia

Introduction

Act No. 7/2010 Coll. on protection against floods defines the flood as the temporary flooding of a normally unflooded area due to the effect of natural factors such as precipitation, snow melting, obstacles created by glaciers, ice blockade, various barriers constraining continuous water runoff regardless of whether the obstacles prevent created water runoff in the stream river bed or on the terrain. The only cause of the flood that may be caused by the failure of a technical facility is a failure of the water structure, while the flood of the area must cause the water flooded from the river bed. The flood is a relatively rare phenomenon with extraordinary performance in the runoff process. The genesis of the devastating floods, in addition to the high precipitation, is caused by many other factors. Besides existing orographic, hydrogeological, pedological and vegetation conditions, it is the saturation of the catchment area caused by previous precipitation, accumulated snow, human activity (e. g. forest and agricultural management, development of the urban areas, rural settlements and landscape, construction of detention areas, stream training, etc.) (MŽP SR, 2011).

Basic reasons for the flood formation are (Act No. 7/2010):

- sudden or intense rainfall, which sum exceeds 100 mm per day. Such floods are called flash floods,
- long-lasting rainfall, often several (2–5) days, exceeding 50–125 mm per m^2, whereas it is possible that similar situation being repeated in a short time. They are mostly associated with the formation of long-term depression, in Slovakia, mainly occurring in summer and autumn,
- snow or ice melting,
- the occurrence of an obstacle in the stream river bed (e.g. the accumulation of iceberg or wood) and subsequent flooding of the neighbouring areas.

For the conditions in Slovakia it is possible to mention three basic ways through which the floods are flooding the territory (MŽP SR, 2011):

1. surface runoff caused by precipitation, intensive snow melting or combination of them:
   - by inflowing through the terrain from the hillslopes,
   - by preventing or restricting of the water runoff from the territory into the river beds,
2. by water coming up from the river beds to the banks:
   - when the discharge increasing above the flow capacity of the river bed,
   - after the obstruction occurrence in the stream river bed even at a relatively low discharge,
3. by groundwater rising above the terrain:
   - due to the persistent high water levels in the surrounding streams,
   - after high or total saturation of the soil with water in the previous period when other water from atmospheric precipitation cannot be absorbed.

The major part of population and goods are located in big urban areas so efforts for avoiding flood problems should be mainly focused on these areas. River overflowing does not always cause urban floods; they can also be caused by high rain intensities over the city combined with insufficient capacity of the sewer system. Special attention should be taken to the present drainage of rainwater, i.e. the capacity of the sewer systems of our cities (Julínek, Říha, 2017). A strategy to manage floods in an ecological manner should be based on improving river basin land-use, prevent in rapid runoff both in rural and urban areas, and improving a transnational effort to restore rivers' natural flood zones. It tends to reactivate the ability of natural wetlands and floodplains to mitigate flood impacts. Development of controlled detention reservoirs, which should be preferably used as extensive grassland or to restore alluvial forests at selected locations of former floodplains to reduce flood peaks, is also appropriate. In residential areas with limited space it is recommended to complement the flood protection by flood protection walls, mobile closures, superstructures or simple sandbags. The use of non-permanent forms of barrier for flood protection can provide much needed flexibility and increased opportunities for effective management of a wide range of flood events (UN/ECE, 2003).

Flood protection measures

The diversity of the nature makes impossible to apply everywhere a single method of the protection against floods. This fact, Law no. 7/2010 Coll. of Laws on flood protection, is establishing in five basic groups of preventive technical and non-technical measures to protect against floods (MŽP SR, 2011):

1. Measures that increase the retention capacity of the catchment or in suitable localities support natural water accumulation, slow down the water runoff from the catchment into the stream river beds and which protect the area from flooding by surface runoff, e.g. management of the forests, farmlands and urbanized areas (Kandra et al., 2017).
2. Measures that reduce the maximum flood discharges in the catchment, e. g. water structures (dams, weirs), reservoirs and detention reservoirs.
3. Measures that protect areas from flooding by water from stream river beds, e.g. river improvement works, dykes or floodplains.
4. Measures that protect areas from flooding by internal waters, e.g. system of the drainage channels and pumping stations.
5. Measures which ensure the flow capacity of the stream river beds, e.g. removal of sediments from the river beds and vegetation cover from their banks (Šlezingr, 2017).

The procedure of the flood protection measure design combines into one complex the technical knowledge, hydraulic calculations and simulations, requirements of the area of interest and spatial potentials. Each solved urban area is unique and therefore the design is limited for different boundary conditions, e.g. bridges, culverts directly in the stream, buildings very close to the streams, not sufficient place for the creating of the flooding areas, etc.

First of all, the basic data are required. Their validity (recency, accuracy) are the most important for the beginning of the preliminary design. From these data, the designer obtains relevant information and values for the design of the flood protection measures, because it is not possible to use standardized schemes of the flood protection, but every design needs an individual approach. The water management data contains information about hydrological situation in the river catchment (daily and annual discharges, precipitations, flood wave, its peak, duration and volume). The geomorphological data represent the terrain data, obtained by the survey and geodetic measurements of the area of interest. Besides, it is appropriate to use an available digital map for preliminary design. From these data should be detected the protected area and problematic parts. Based on the analysis of geology it is possible to design a stable cross section of the stream, to choose appropriate profile of the detention reservoir, etc. The designer should make a detailed survey of the stream and its vicinity, it means topography of the original stream, to determine the cross sections by the geodetic measurements and to find out the discharge and water level in the stream in the same time for achieving the relevant values for the future mathematical model calibration. In this way should be obtained a review of the depths, longitudinal slope of the river bed bottom, roughness coefficients and structures on the stream.

Next step is the creation of a mathematical model of the present state in order to identify critical parts of the area to be protected by the flood protection measures, thus detecting the flow capacity of the stream that endangers the neighbouring area with floods. Therefore, 1-D or 2-D mathematical model shall be used (1-D model is sufficient for the preliminary design), whose credibility is increased by calibration. In practice, it is not often that model is verified, because it is not possible to perform at the same time a water level and discharge measurements during flood period.

Consequently, the proposal of flood protection measures according to the specific situation and conditions can be specified. The proposal is then inserted into the mathematical model of the present state where the effects of the proposed measures are found out. Comparing the results of the analysis of the state without designed measures and with them, the suitability and effectiveness introducing flood protection measures can be evaluated.

Based on the previous information and data should be stated that each area of interest endangered by flood event requires individual approach in the design of the flood protection measures. Examples of proposed flood protection measures in river basins with different conditions solved in last years are presented in the next chapter.

Case studies and discussion

The following studies will show the possibilities of the flood protection measures design in different conditions of small municipalities with relatively small river catchments but high flood discharges. Every suggestion has been sensitively tried to use the given site's capabilities with regard to maximum flood protection, functionality as well as from ecological point of view.

Case study Píla

The village Píla was affected by destructive flash flood of the Gidra stream in June 2011. After this flood many buildings, roads and pavements had to be repaired but the flood protection was still non-existent. After the simulation of flood without proposed measures it was proceeded to design detention reservoirs because of spatial possibilities (wide valley) in mountain region above the village. The detention reservoirs above the village were proposed as not too high earth-fill dams. The reason for such decision was the fact that the structure better fit into natural landscape of valleys in Small Carpathians. When proposing detention reservoir, the most important value is the capacity discharge of downstream channel and its structures. Usually, structures as bridges or culverts have less capacity than the channel itself as it was in this case, as well. Firstly, there were 3 detention reservoirs chosen, after hydraulic evaluation two of them were designed for the flood protection purposes – one on the Kamenný stream and one (the upper) on the Gidra stream (Fig. 1., Table 1.).

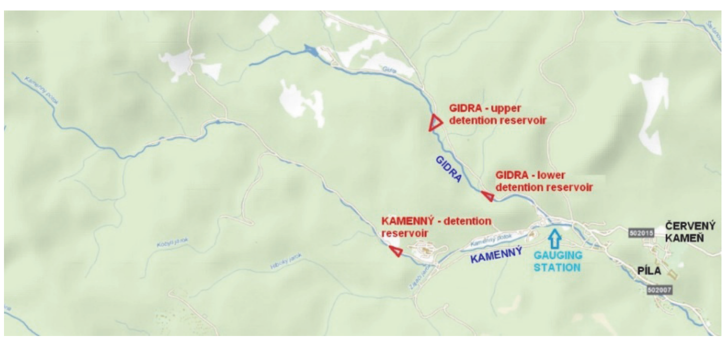

Fig. 1. Locations of the proposed detention reservoirs on the Kamenný and Gidra streams (Janík, Šoltész, 2017).
Obr. 1. Umiestnenie navrhovaných poldrov na potokoch Kamenný a Gidra (Janík, Šoltész, 2017).

Table 1. Dimensions of the proposed detention reservoirs (Janík, Šoltész, 2017)
Tabuľka 1. Rozmery navrhovaných poldrov (Janík, Šoltész, 2017)

Stream	Crest Altitude	Dam Height	Outlet Structure Diameter	Length of Dam Crest	Detention Volume
	(m a. s. l.)	(m)	(m)	(m)	(m^3)
Kamenný	306,2	5,6	1,10	80	50 000
Gidra-upper	300,5	5,5	1,00	140	108 000

By synergy of the detention reservoirs the meridian flow has been reduced from original 24.6 $m^3.s^{-1}$ to value 11.10 $m^3.s^{-1}$ and has been delayed by 1,25 hour (Janík, Šoltész, 2017, Pindjaková et al., 2016).

Case study Levice

Slovak lowlands have been suffering from floods. The floods are formed in connection with rainfalls (Valent, et al., 2014), arising water in rivers are rising groundwater up above the terrain (Velísková, et al. 2014). The river which flows through the district of Levice is the Podlužianka River with right-bank tributaries Čajkovský stream and Rybnícky stream. This area is often naturally flooded from all rivers during floods. Present conditions of the flood protection in the Levice district area are not sufficient. In case that the flood protection does not be realized in this location, surely flood flow rates will exceed and it will still cause massive damages on urban and private properties as in the past. The river bed training of the Podlužianka River in the central part of Levice town was done in 2004. The town is protected with walls situated along the river bed and in the areas where the bridges are, slide barriers were built. For the sufficient town protection it is necessary to ensure increased capacity of the river bed, to remove obstacles from the river bed, to adjust river banks and to store flood flow rates in detention reservoirs. Various alternatives were examined (up to 7 detention reservoirs Fig. 2. were proposed and simulated in one numerical unsteady flow model) and – on the basis of the economical and water management assessment – an alternative with 3 detention reservoirs (Table 2.) was chosen (Kelčík et al., 2016).

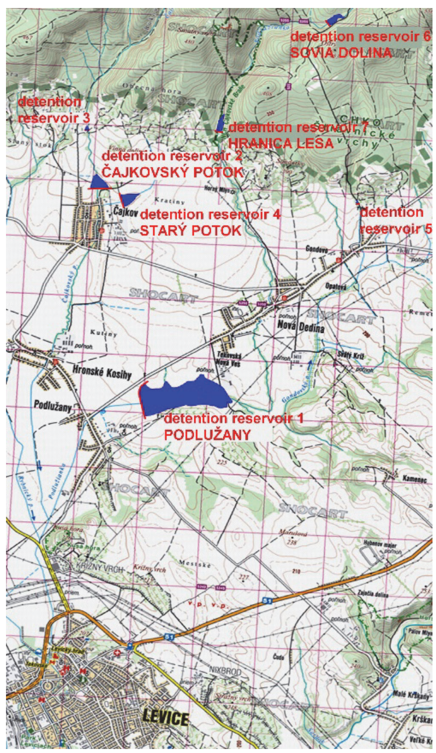

Fig. 2. Graphic presentation of the area of interest including situation of rivers and detention reservoirs (Hec-Ras) (Kelčík et al., 2016).
Obr. 2. Grafické znázornenie záujmovej oblasti s tokmi a poldrami (Hec-Ras) (Kelčík et al., 2016).

Table 2. Dimensions of the proposed detention reservoirs (Kelčík et al., 2016)]
Tabuľka 2. Rozmery navrhovaných poldrov (Kelčík et al., 2016)

Stream	Crest Altitude	Dam Height	Outlet Structure Diameter	Length of Dam Crest	Detention Volume
	(m a. s. l.)	(m)	(m)	(m)	(m^3)
Podlužianka (rkm 12,6)	174,5	5,5	2 x 1,60	550	670 506
Podlužianka (rkm 19,9)	248,5	9,4	1,50	80	84 158
Čajkovský	202,4	6,9	1,30	365	181 907

Case study Bardejov

Analysis of the flood protection of the Bardejov town was performed because of insufficient flood protection of the centre of the city. Capacity of the Topľa River bed in the urban area of the town of Bardejov is insufficient resulting in repeated floods. Because it is a downtown with a dense build-up, it was not possible to enlarge the dykes by earth, also river bed could not be improved or extended. Therefore, the flood protection of the middle part of the city was already realized by building of concrete walls (Fig. 3.). This realization was assessed by one dimensional open channel flow model of the Topľa River in Bardejov in non-uniform steady flow conditions. The results of mathematical modelling showed that flood protection walls designed and realized in the central part of the town (phase I.) must be supplemented in upstream and downstream sections (phase II. and III.) to ensure flood protection in the whole city (Fig. 4.). Recommended measures will increase flood protection of the town of Bardejov (Šoltész et al., 2018b).

Fig. 3. Realized concrete flood protection walls in the middle part of Bardejov town (phase I.) (Šoltész et al., 2018b).
Obr. 3. Realizované betónové protipovodňové steny v centrálnej časti Bardejova (fáza I.) (Šoltész et al., 2018b).

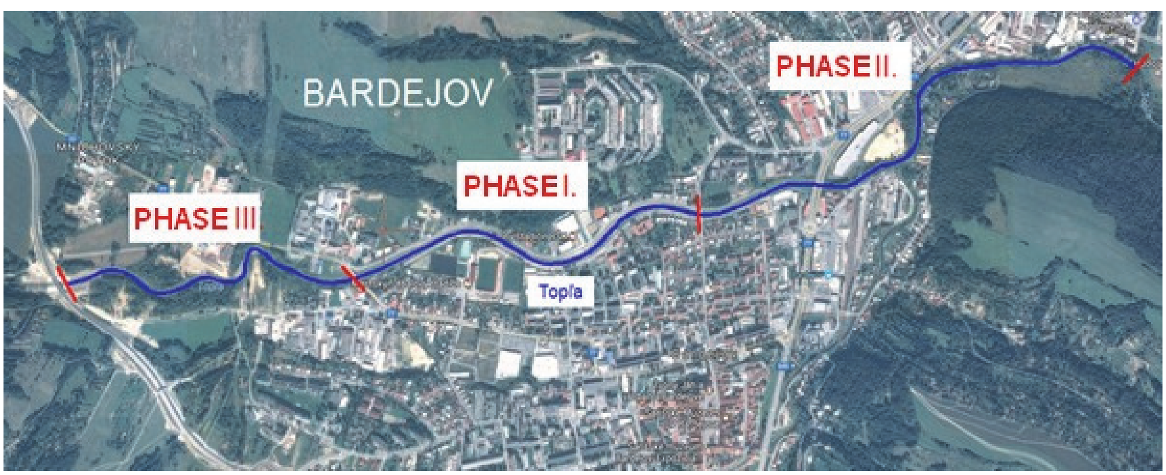

Fig. 4. Ortho-photo map with planned phases of the flood protection of Bardejov town (phase II. and III.) (Šoltész et al., 2018b).
Obr. 4. Ortofoto mapa s plánovanými fázami protipovodňových opatrení mesta Bardejov (fáza II. a III.) (Šoltész et al., 2018b).

Case study Veľká Lúka

The stream Lukavica flows through the small village Veľká Lúka (located between towns Sliač and Zvolen). During common hydrological situation this stream flows by the minimum water level (few centimetres). Houses in the central part of the village are built densely along the stream. River training of the Lukavica stream was done only partially in different periods and for different capacities. In addition, there are two road bridges as well as a railway bridge (culvert) and a ford on the stream. The problem is the new building development under the central part of the village which was already affected by floods (heavy storms and rapid snow melting – 2009, 2013, 2016). The river bed is loaded with sediments and overgrown with bush and willows. According to hydraulic analyses and simulations based on the actual geodetic measurements of the area of interest, it has been proved that even by clean-up of the river bed (sediment dredging) there is insufficient flood protection of the municipality (Fig. 5.). Expansion and the river bed improvement nor the dyke’s construction is impossible, therefore a detention reservoir was proposed above the village (Fig. 6.). However, the volume of the flood wave volume is so big that a relatively large detention reservoir was proposed as well as the river bed maintainance in the village. In the part of expected planned house building damming of river banks by small walls was proposed, so that the outflowing discharge from the detention reservoir could not cause damages anymore (Kamenský, 2003), (Šoltész et al., 2018 a).

Fig. 5. Cleaning of the Lukavica river bed in the central part of the village Veľká Lúka (Šoltész et al., 2018 a).
Obr. 5. Čistenie koryta toku Lukavica v centrálnej časti dediny Veľká Lúka (Šoltész et al., 2018 a).

Fig. 6. Ortho-photo map with the situation of the planned detention reservoir above the village (Šoltész et al., 2018 a).
Obr. 6. Ortofoto mapa s umiestnením plánovaného poldra nad dedinou (Šoltész et al., 2018 a).

Conclusion

Flash floods that occur mainly in small water catchments are a specific case of devastating floods caused by rains with short duration, relatively large and signifycantly varying intensity; typically affecting small areas. The effects of flash floods – if they are not caused by a series of storms or a progressive flood – will typically disappear after a few tens of kilometres of flow in streambed. Since 1995 up to now more than hundred floods occurred in Slovakia, and the frequency of their occurrence seems to be increasing (MŽP SR, 2011). Analyses of precipitation volume, runoff, their time course and situation on the affected river basins confirm that catastrophic flood events – as large surface range as well as in small river basins – are definitely caused by a large sum of high precipitation intensity that have fallen into basins almost completely saturated by previous precipitation.

Flash floods are becoming a phenomenon that endangers people more and more often in many Slovak sub-mountain regions. Flash floods also called storm or sudden floods are a specific type of rain floods which typical sign is an intensive increase of water level in the river in a short time period (usually couple of hours). Mostly appear such floods on small streams in upper parts of river basins after extreme storm rainfalls. Rainfall intensity and duration limits are not possible to determine exactly. They are dependent on many factors as type and shape of landscape, soil water saturation and nonetheless they depend on anthropogenic activity (inadequate land use). Due to the extremely short time of flood beginning it is very difficult to alarm inhabitants and for carrying out operative flood protection measures like mobile flood-protection barriers it is mostly too late. That is the reason why it is necessary to prepare appropriate flood-protection measures which do not need any operation and they fulfil their function automatically.

Acknowledgement

The contribution was developed within the frame of and based on the financial support of the VEGA 1/0800/17 project "Optimization of the flood protection of municipalities in river basin of mountain streams".

The contribution was also developed within the frame and based on the financial support of the APVV-15-0489 project „Analysis of droughts by multi-criterial statistical methods and data mining from the viewpoint of preventive structures in a landscape".

References

Act No. 7/2010 Coll. on protection against floods [In Slovak: Zákon č. 7/2010 Z. z. o ochrane pred povodňami]

Janík, A., Šoltész, A. (2017): Flash flood mitigation modelling – Case Study Small Carpathians. *Pollack Periodica*, Vol. 12, no. 2, 103–116.

Julínek, T., Říha, J. (2017): Assessing stream water quality influenced by storm overflows from sewers. *Pollack Periodica*, Vol. 12 no, 2, 117–128. doi:10.1556/606.2017.12.2.10

Kandra, B., Tall, A., Gomboš, M., Pavelková, D. (2017): *Analysis of heavy soils water retention curves with respect to volume changes*. Paper presented at the IOP Conference Series: *Earth and Environmental Science*, Vol. 92 no, 1. doi: 10.1088/1755-1315/92/1/012025

Kamenský, J. (2003): Increase of polders efficiency by means of discharge control at functional structure [In Slovak: Zvýšenie účinnosti poldrov reguláciou prietoku funkčným objektom.] *Acta hydrologica Slovaca*, Vol. 4, no. 2, 276–281.

Kelčík, S., Pindjaková, T., Šoltész, A. (2016): Assessment and design of the flood protection measures in the district of Levice (Slovakia). *Pollack Periodica*, Vol. 11, no. 1, 35–41.

MŽP SR (2011): *Analysis of the state of flood protection in the territory of the Slovak Republic* (Annex 1). [In Slovak: Analýza stavu protipovodňovej ochrany na území Slovenskej republiky (Príloha č. 1)]. [online] <https://www.minzp.sk/files/sekcia-vod/priloha_1-suhrn_vysledkov_analyzy.pdf>

Pindjaková, T., Kelčík, S., Šoltész, A. (2016): Simulation of flood progress on the river Gidra. *Pollack Periodica*, Vol. 11, no. 1, 25–34.

UN/ECE (2003): The United Nations and Economic Commission for Europe document „*Best practices on flood prevention, protection and mitigation*".[online] <https://www.floods.org/PDF/Intl_BestPractices_EU_2004.pdf>

Šlezingr, M., Marková, J., Gernešová, L. (2017): The Effects of Selected Types of Active Bank Stabilization. *Procedia Engineering*, Vol. 190, 653–659. [online] <https://www.sciencedirect.com/journal/procedia-engineering/vol/190>

Šoltész, A., Čubanová, L., Janík, A., Živčicová, K. (2018 a): *Veľká Lúka – protipovodňové opatrenia v povodí toku Lukavica*. SvF STU v Bratislave, 39 p.

Šoltész, A., Janík, A., Čubanová, L. (2018 b): Štúdia protipovodňovej ochrany Bardejova. *Influence of anthropogenic activities on water regime of lowland territory*, Proceedings of peer-reviewed contributions, 1. vyd. Bratislava: Ústav hydrológie SAV, 281–289.

Valent, P., Danko, M., Miklánek, P. (2014): Analýza citlivosti zrážkovo-odtokoveho modelu [In Slovak Sensitivity analysis of a rainfall-runoff model] *Acta Hydrologica Slovaca*, Vol. 15, no. 2, 267–280. [online] URL: <http://www.epi.sk/zz/2010-7#p2

Velísková, Y., Koczka Bara, M., Dulovičová, R., Schügerl, R. (2014): Influence of surface water level fluctuation and riverbed sediment deposits on groundwater regime. *Journal of Hydrology and Hydromechanics*, Vol 62, no. 3, 177–185. doi:10.2478/johh-2014-0030

PROTIPOVODŇOVÉ OPATRENIA NA OCHRANU SÍDIEL

Článok popisuje povodne, resp. bleskové povodne. Zaoberá sa ich klasifikáciou podľa Zákona č. 7/2010 Z. z. o ochrane pred povodňami, pričom udáva aj možné protipovodňové opatrenia (vyčistenie koryta od sedimentov a náletových drevín, úprava koryta na zvýšenie jeho kapacity, výstavba hrádzí, nádrží, poldrov, vytváranie oblastí, ktoré je možné zaplaviť bez ohrozenia životov a majetku). Na základe skúseností možno ale konštatovať, že každý prípad treba posudzovať individuálne, s ohľadom na hydrologické, morfologické, či geologické podmienky danej oblasti postihnutej povodňou, resp. opakujúcimi sa povodňami. Keďže nastávajú značné výkyvy v počasí, zrážky sú nerovnomerne rozložené v rámci roka, ako aj v rámci územia Slovenskej republiky. Preto povodňové situácie vznikajú aj na miestach, ktoré predtým nebývali postihnuté týmito nepriaznivými hydrologickými javmi (vybreženie vody z toku, zaplavenie extravilánu, intravilánu obcí, pivníc domov, atď.).

Postup návrhu protipovodňových opatrení kombinuje technické znalosti, hydraulické výpočty a simulácie, požiadavky záujmovej oblasti, ako aj priestorové možnosti tej ktorej lokality. Každá riešená oblasť je jedinečná a návrh je obmedzený rôznymi okrajovými podmienkami, napr. mostami, priepustami v toku, výstavbou v blízkosti toku, nedostatočnou plochou na vytvorenie záplavovej oblasti, atď. V prvom rade sú potrebné čo možno najaktuálnejšie údaje, a to vodohospodárske (hydrologické údaje), geomorfologické (zameranie záujmovej oblasti – toku (zameranie topografie, hladiny a prietoku v rovnakom čase, potrebné pre kalibráciu matematického modelu), oblasti s plánovaným poldrom) a geologické. Na základe týchto údajov je možné vytvoriť kalibrovaný model súčasného stavu a na základe výsledkov z neho získaných navrhnúť vhodné protipovodňové opatrenia. V článku sú ďalej uvedené rôzne príklady riešených prípadových štúdií protipovodňových opatrení v mestách a obciach na Slovensku.

Prípadová štúdia Píla – obec Píla bola postihnutá povodňou v roku 2011. Poškodené cesty a mosty boli síce opravené, ale protipovodňové opatrenia stále chýbali. Kvôli prekážkam v toku (mosty, priepusty), nebolo možné zväčšiť kapacitu koryta toku, preto boli simulované rôzne varianty poldrov umiestnených na obcou. Ako najvhodnejší vyšiel variant s dvoma poldrami, a to na Kamennom potoku a na Gidre.

Prípadová štúdia Levice – v okrese Levice spôsobujú problémy rieka Podlužianka s prítokmi Čajkovský a Rybnícky potok. Koryto Podlužianky bolo v Leviciach upravené v roku 2004 (protipovodňové steny pozdĺž toku). Na zvýšenie kapacity toku bolo navrhnuté vyčistenie koryta a úprava brehov, pričom na zachytenie povodňových prietokov boli navrhnuté 3 poldre nad Levicami (dva na Podlužianke a jeden na Čajkovskom potoku).

Prípadová štúdia Bardejov – rieka Topľa nemá v Bardejove dostatočnú kapacitu na odvedenie povodňových prietokov. Keďže centrum je husto osídlené aj popri rieke, nie je možné koryto upraviť (rozšíriť, meniť smerové a sklonové pomery, navýšiť zemné hrádze), preto bola realizovaná výstavba betónových protipovodňových múrikov v centrálnej časti (etapa I.). Po simuláciách v matematickom modeli, bola preukázaná potreba pokračovať s týmito múrikmi ako po, tak aj proti prúdu od realizovanej etapy (etapy II. a III.). Len tak bude zabezpečená protipovodňová ochrana Bardejova v celom riešenom úseku.

Prípadová štúdia Veľká Lúka – obec je ohrozovaná potokom Lukavica, ktorý bol upravený v rôznych obdobiach a na rôzne kapacity. Okolie potoka je husto osídlené, pričom na potoku sú 2 cestné mosty, 1 železničný most a brod. Problémom je nová výstavba na pravom brehu v tesnej blízkosti potoka, ako aj plánovaná výstavba na opačnom brehu (postihnuté povodňami v rokoch 2009, 2013, 2016). Koryto je značne zanesené a zarastené, ale ani prečistenie by nezvýšilo dostatočne jeho kapacitu. Na základe simulácií v matematickom modeli boli navrhnuté nasledujúce opatrenia – odstránenie sedimentov z koryta, náletových drevín z brehov, výstavba nízkych múrikov v centrálnej časti obce a výstavba poldra nad obcou.

Keďže povodne nás ohrozujú stále viac, pričom je to viac menej neočakávaný fenomén, je potrebné zabezpečiť ochranu ľudí a majetku vhodnými protipovodňovými opatreniami, ktoré budú spĺňať ako ekologické, tak aj ekonomicko-prevádzkové hľadiská.

prof. Ing. Andrej Šoltész, PhD.
Ing. Lea Čubanová, PhD.
Ing. Adam Janík
doc. Ing. Dana Baroková, PhD.
Department of Hydraulic Engineering STU FCE
Radlinského 11, 810 05 Bratislava,
Slovak Republic
E-mail: andrej.soltesz@stuba.sk
lea.cubanova@stuba.sk
adam.janik@stuba.sk
dana.barokova@stuba.sk