HYDROLOGIC RISK – RESERVOIRS: AN OLD AND CURRENT IMPERATIVE

G. ROMANESCU[1]*, A. M. ROMANESCU*[1]

ABSTRACT. – Hydrologic risk phenomena have always affected human activity. For this reason, humankind has always sought ways of preventing and mitigating floods. Human activity has marked the environment. All human constructions change the normal pace of processes; it depends on what angle one uses to analyze the issue. Most of the times, reservoirs have complex functions, but large ones are destined mainly to preventing or mitigating hydrologic risks. The oldest reservoirs were built during Antiquity, yet the boom of such complex constructions was registered after 1950. On world level, it is worth mentioning the hydrologic basins of Columbia (USA), Chang Jiang (China), Angara (Russia), etc. The hydrographical basins in Romania comprising significant hydrotechnical works are Siret, Argeș, Jiu, Olt, Ialomița, etc. This study underscores the positive role played by reservoirs in flood mitigation and in the positive modification of the landscape.

Key words: hydrologic risk, reservoirs, flood mitigation, hydrotechnical developments

1. INTRODUCTION

Hydrologic risk phenomena are specific to the East of Europe; in the past few years, they have multiplied significantly, mostly on the Romanian territory. The underlying cause is the increasing level of deforestations. In the past five years, most rivers in the East of Romania have exceeded their historic discharges by far, (Romanescu, 2009a,b,c,d,e) which has led to an increase in material damage and deaths. This mechanism also affected the Pruth River, the second most important river in the Moldavian Plateau and one of the main rivers in Romania.

Floods have been extensively treated in the national and international literature; however, correct conclusions have not always been formulated and the best measures have not always been applied. The Romanian literature on hydrologic risk phenomena that have affected the eastern part of the country or its entire territory

[1]Department of Geography, Faculty of Geography and Geology, "Al.I.Cuza" University of Iasi, Bd.Carol I, 20A, 700505 Iasi, Romania. E-mail: romanescugheorghe@gmail.com

is well represented: Cantemir, 1716; Chiriac et al., 1980; Mociorniță, 1965; Mustață, 1964; Pandi & Mika, 2003; Pandi & Moldovan, 2003; Podani, 1993; Podani & Zăvoianu, 1992; Romanescu, 2003, 2005, 2006a,b,c,d,e, 2009, 2013; Romanescu et al., 2013a,b; Șelărescu & Mustățea, 1994, 2005; Sorocovschi, 2002, 2003, 2004a,b, 2005, 2006, 2007; Șerban et al., 2004; Telteu & Zaharia, 2012, etc. At the same time, it is worth reminding that most general or punctual data was taken over from the vast international hydrologic literature; national authors only noted the most important or the more recent findings: Barroca et al., 2006; Bravard & Petit, 2000; Brilly & Polic, 2005; Brun, 2006; Castaldini, 2006; Gazelle & Maronna, 2009; Glade et al., 2005; Jordan & Jennings, 1991; Konecsny, 2005; Komma et al., 2007; Lassere, 2006; Loczy, 2012; Loczy et al., 2014; Millot et al., 2014; Picon, 2006; Milelli et al., 2006; Perry & Combs, 1998; Plattner et al., 2006; Portela & Delgado, 2009; Taramasso et al., 2005; Touchart, 2006, etc.

This study emphasizes on the importance of hydrotechnical constructions within the large hydrographical basins affected by hydrologic risk. The history of building reservoirs with complex functions is underlined for Romania and for the entire world.

2. METHODOLOGY

The international bibliography on hydrologic risk is extremely rich. In Romania, numerous studies have been conducted on hydrologic risk phenomena, mostly concerning floods. Data within the Romanian and international scientific literature has been used. Some data has been collected from the Siret Water Basin Administration (Bacău) and from the Pruth-Bârlad Water Basin Administration (Iasi); we used personal observations from the research conducted on the Romanian territory, too.

3. RESULTS AND DISCUSSIONS

A dam is a hydrotechnical work with an existing or proposed structure, capable of ensuring the permanent or non-permanent accumulation of water, of industrial liquid or solid waste deposited underwater (from chemical and energetic industries and from tailings management facilities within the mining industry), whose breaking may produce the uncontrolled loss of its contents. Such an event would have significant negative effects upon the social, economic and/or natural environment (definition included in the Emergency Government Ordinance 244/2000 on the safety of dams – republished).

Countries with a significant deficit in precipitations (thus, in liquid runoff) on their hydrographical arteries have to build dams and reservoirs. It is necessary to build dams in Romania because 95% of the rivers are less than 50 km long. Only four Romanian rivers measure more than 500 km: Siret, Pruth, Mureş and Olt. The mean multiannual discharge of Romanian rivers is only 1,172 m^3/s (that is, a volume of 37 million m^3). Territorial repartition and the unequal runoff regime determine rivers to supply an annual volume of only 5-6 million m^3/s (Romanian Committee on Large Dams, 2000; Gâștescu, 1998a,b; Gâștescu & Rusu, 1980; Rădoane & Rădoane, 2004; Romanescu, 2006c,d, 2012; Șerban et al., 1989).

Most rivers in the Moldavian Plateau, in Dobrogea and in the Romanian Plain are dry during the summer and they have no runoff during the winter because their waters are frozen. Only large rivers – classified as rank four in the Horton-Strahler ordering system – have permanent runoff (Romanescu, 2012). Reservoirs have been built since Antiquity, but in the past 60 years, their number has grown at an exponential rate (Fig. 1). Most dams were built in the period 1980-1990. After 1990, no dam has been built on the Romanian territory. Most dams in Romania measure less than 20 m in height (108 of them), while only two of them are more than 180 m high (Fig. 2).

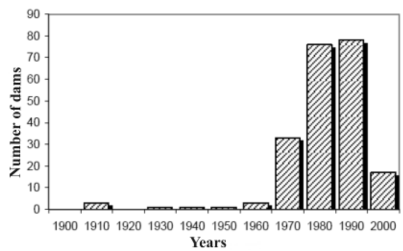

Figure 1. Rhythm of dam building on the Romanian territory (after Rădoane, Rădoane, 2004)

Most reservoirs are in the Siret hydrographical basin, followed – at great distance – by Olt, Argeş, Ialomița, Mureş, Jiu-Cerna, Someş, the Criş Rivers, etc (Fig. 3). On the Pruth River, only one dam was built in the Romanian sector: Stânca-Costești.

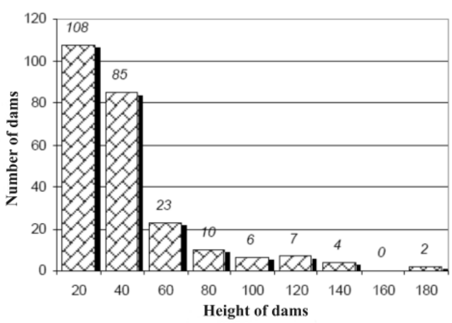

Figure 2. Number and height of dams on the Romanian territory (after Romanian Committee on Large Dams, 2000)

The latest archaeological research has revealed vestiges of dams dated around 4,000 years ago. They were built in zones with precipitation deficit, mainly in the Arab countries.

They were used for the water supply of human settlements and for irrigations. Ma'rib of Yemen is the best preserved such dam; it was built downstream in the year 750 BC (Fig. 4, 5) and the construction process took around 100 years. It measured 4 m and it was made of clay and stone. The ancient dam was re-elevated in 1968; currently, it measures 38 m in height. The lake accumulated a water volume of 398 million m^3.

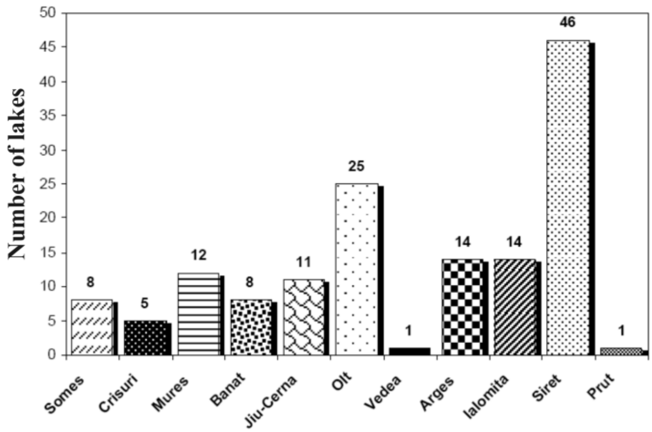

Figure 3. Number of reservoirs in Romania by hydrographical basins (after Rădoane, Rădoane, 2004)

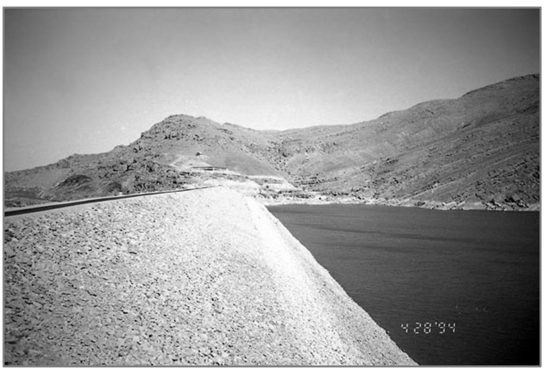

Figure 4. The dam of the Ma'rib Lake in Yemen, rebuilt in 1968 (after www.icold-cigb.org, 2013)

Figure 5. Inscriptions on the original stone of the Ma'rib dam, constructed in 750 BC (after www.icold-cigb.org, 2013)

Figure 6. The Ben-e-Golestan dam in Iran, constructed in AD 1350
(after www.icold-cigb.org, 2013)

The main role of reservoirs was to supply water for human settlements during dry season. The oldest dam still in function was made of rockfill in AD 1350 on the Syrian territory – modern Iran (Ben-e-Golestan) (Fig. 6). In 2280 BC, a complicated system of dams and channels was built in China, which unfortunately no longer functions. The Sayamaike dam is the oldest in Japan: it was built in the 7th century AD (Fig. 7); it has been significantly altered in time, but it has always preserved its complex use.

Figure 7. Aerial image of Lake Sayamaike Dam in Japan, built in the 7th century AD (after www.icold-cigb.org, 2013)

In Sri Lanka, numerous inscriptions and chronicles attest the existence of dams as early as the 6th century BC. Most of them were built for irrigation purposes. One of the largest dams was built during the reign of King Mahasen (AD

276-303), but it was destroyed in 1900. It was restored in 1901 and it is still active (Fig. 8). On the territory of Sri Lanka, over 50 old dams were restored.

Figure 8. The Nachchcduwa dam of Sri Lanka, built in the period AD 531-551

The old system of dam building – with slopping walls and high water spillway – continued to be used in the contemporary period (Fig. 9, 10, 11). Unfortunately, the material was not always wisely chosen and sometimes the dams broke.

Figure 9. Rock pattern of the Giritale Dam in Sri Lanka, built in the period AD 608-618 (after www.icold-cigb.org, 2013)

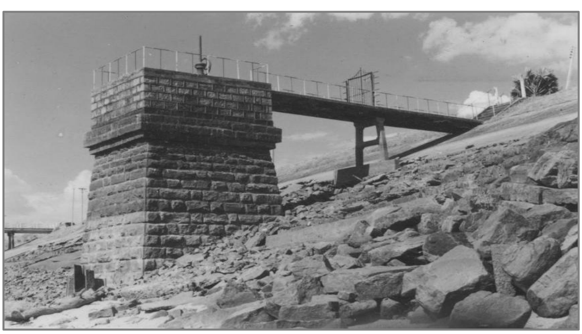

Figure 10. The ancient Minneriya tower, built in the period AD 276 - 303 in Sri Lanka. It was restored in 1901 and it has irrigation purposes (after www.icold-cigb.org, 2013)

Figure 11. Old dam for irrigations in Egypt (after www.icold-cigb.org, 2013)

The Roman dam building system was based on the small heights of crests. The most famous dam is Cornalbo, in Spain, 24 m high (78 feet) and 185 m long (606 feet).

Following the Roman domination, only small dams were built in Spain for a very long period. Only in the 16th century, large dams began to be built. In the 19th century, European engineers built dams even 45-60 m high (150-200 feet). The old dams were built for supplying water to localities, for irrigations and flood mitigation. The energetic and sailing functions were added only after 1800.

Figure 12. Construction of the first reservoirs (Antiquity and Middle Ages) on the Romanian territory (after Dăscălescu, 2000)

The tourist or recreation function is relatively new and it keeps acquiring new dimensions. Most dams built recently have complex functions. The first mentions in documents of dams built on the Romanian territory date to the 12th century, when the ponds of Saard and Cristural were built near Turda (Fig. 12).

The oldest reservoir (Tăul Mare) – still in function – dates to 1740; it was built in the Metaliferi Mountains, for the gold mines. The first ponds for felting mills date since 1448, and they were encountered in the region of Braşov. In the period 1503-1550 there were 28 ponds.

The Moldavian ponds were first mentioned in documents in the 15th-16th centuries: Hârlău, Belceşti, Şipote, Dinischean, etc. During the reign of Vasile Lupu, Dracşani Lake was extended; currently, it is the largest pond in Romania, with a surface of 486 ha and a volume of 5.5 million m^3. On Bawr's map, (1781-1797) there were 134 ponds, while on Otzellowitz's map, (1790) 372 ponds. On the Russian map – edited in 1850 – 126 ponds were represented; however, the map of 1850-1900 included 1,144 ponds (Băican, 1970).

The first hydroelectric power plants were built at the end of the 19th century: Bucureşti (1890) on the Dâmboviţa River; Sadu (1896) in the Sibiu County. By 1940, 128 hydroelectric power plants were constructed. The largest reservoirs have been built starting with 1960, when the hydroelectric power plant of Stejaru on the Bistriţa River was inaugurated (it comprises the Izvorul Muntelui reservoir). The boom of hydroelectric power plants was registered in the period 1980-1990, when 78 such plants were opened.

The tradition of hydrotechnical works and the value of the Romanian school in the field have been acknowledged by the International Commission on Large Dams, which includes 80 countries. Romania ranks the 19th in total number of dams and the ninth in Europe (Romanescu et al., 2013).

The tradition of hydrotechnical works and the value of the Romanian school in the field have been acknowledged by the International Commission on Large Dams, which includes 80 countries. Romania ranks the 19th in total number of dams and the ninth in Europe (Romanescu et al., 2013).

In Romania, there are 246 large dams, half of which are less than 40 m high. The highest Romanian dam is Gura Apelor – on Pârâul Mare, in the Retezat Mountains – and it measures 168 m. Other 1,500 dams do not measure more than 15 m, while reservoirs comprise a volume of 1 million m^3 (Rădoane & Rădoane, 2004, 2005). Most large lakes in Moldavia are man-made; only a few are natural (Lala, Buhăescu, Roşu, Crucii, Sfânta Ana) (Fig. 13).

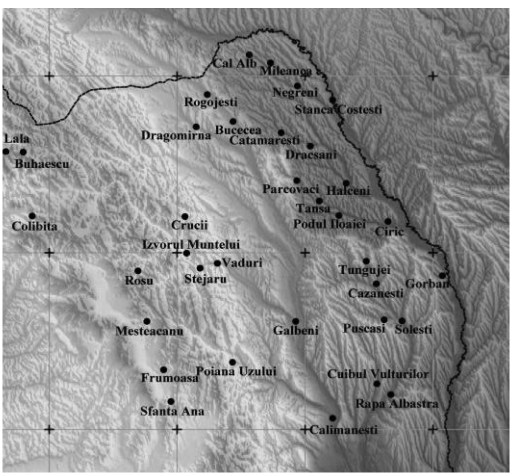

Figure 13. Geographic distribution of large lakes on the Moldavian territory

4. CONCLUSIONS

Floods are natural risk phenomena that occur in almost all climatic areas. For this reason, humankind has always been concerned with preventing and mitigating phenomena with negative effects on human activity. Reservoirs often have complex functions, and the largest of them were built for flood mitigation.

Most hydrographical basins in Romania are developed from a hydrotechnical perspective. Unfortunately, the recrudescence of heavy rains determined an intensification of hydrologic hazards. Under such circumstances, some hydrotechnical works failed to mitigate floods, and the latter took over the entire stream or certain sectors with deficits: Siret, Pruth, Suceava, Trotuș, Moldova, Tazlău, Sucevița, Mureș, Someș, the Criș Rivers, etc.

Acknowledgments

Our sincerest gratitude goes to the Geo-archaeology Laboratory within the Faculty of Geography and Geology of the "Alexandru Ioan Cuza" University of Iasi, which provided the equipment and processed the data.

REFERENCES

1. Barroca, B., Bernardara, P. & Mouchel, J.M. (2006), *Indicators for identification of urban flooding vulnerability*. Natural Hazards and Earth System Sciences, 6: 553-561.
2. Băican, V. (1970), *Iazurile din partea de est a României oglindite în documentele istorice și cartografice din sec. XV-XIX*. Scientific Annals of the Alexandru Ioan Cuza University, Iași, II, XVI.
3. Bravard, J.P. & Petit F. (2000), *Les cours d'eau. Dynamique du système fluvial*. Paris: Armand Colin.
4. Brilly, M. & Polic, M. (2005), *Public perception of flood risks, flood forecasting and mitigation*. Natural Hazards and Earth System Sciences, 5(3): 345-355.
5. Brun, A. (2006), *La politique de l'eau en France (1964-2004). Un bilan discutable*. In: Politiques de l'eau. Grands principes et réalités locales, A. Brun, F. Lassere (Eds.), Presses de l'Université du Québec, 17-46.
6. Cantemir, D. (1716), *Descriptio Moldaviae*. Berlin.
7. Castaldini, D. (2006), *Geomorphological aspects of the flood hazard in the area berween the rivers Po, Secchia and Panaro (Po plain, northern Italy)*. Riscuri si catastrofe, 5(3): 163-174.
8. Chiriac, V., Filoti, A., Manoliu, I.A. (1980), *Prevenirea și combaterea inundațiilor*. București: Ceres.
9. Comitetul Român al Marilor Baraje. (2000), *Dams in Romania*. Romanian National Committee on Large Dams, Bucharest.
10. Dăscălescu, N. (2000), *History of Dam Construction in Romania*. Romanian National Committee on Large Dams, Bucharest, 16-26.
11. Gâștescu, P., & Rusu, C. (1980), *Evaluarea resurselor de apă din râuri și amenajarea bazinelor hidrografice în România*. Terra, XII(XXXII), 2.
12. Gâștescu, P. (1998a), *Limnologie și Oceanografie*. Bucharest: H.G.A., Tempus.
13. Gâștescu, P. (1998b), *Hidrologie*. Târgoviște: Roza Vânturilor.
14. Glade, T., Anderson, M. & Crozier, M.J. (2005), *Landslide hazard and risk*. Singapore: Wiley et Sons.

15. Jordan, P.R. & Jennings, M.E. (1991), *Quantification of floods and droughts*. In: Paulson RW, Chase EB, Roberts RS, Moody DW (eds), National Water Summary 1988-1989, hydrologic events and floods and droughts. US Geological Survey Water-Supply Paper, 2375: 158-161.
16. Komma, J., Reszler, C., Blöschl, G. & Haiden, T. (2007), *Ensemble prediction of floods – catchment non-linearity and forecast probabilities*. Natural Hazards and Earth System Sciences, 7 (4): 431-444.
17. Konecsny, K. (2005), *Reducerea gradului de impadurire ca factor de risc in formarea inundatiilor in bazinul hidrografic Tisa superioara*. Riscuri si catastrofe, 4(2): 165-174.
18. Lassere, F. (2006), *La gestion de l'eau dans les agglomérations de l'ouest américain. Les autorités locales et régionales privilégient toujours une gestion cloisonnée en attendant la crise*. In: Politiques de l'eau. Grands principes et réalités locales, A. Brun, F. Lassere (Eds.). Presses de l'Université du Québec, 225-251.
19. Loczy, D. (2012), *Floodplain rehabilitation schemes: example of the Kapos floodplain, Hungary*. Water resources and wetlands. Conference proceedings, 14-16 September 2012, Tulcea-Romania, 71-80.
20. Loczy, D., Deszo, J., Czigany, S., Gyenizse, P., Pirkhoffer, E. & Halasz, A. (2014), *Rehabilitation potential of the Drava river floodplain in Hungary*. Water resources and wetlands. Conference proceedings 11-13 September 2014, Tulcea-Romania, 21-29.
21. Milelli, M., Llasat, M.C. & Ducrocq, V. (2006), *The cases of June 2000, November 2002 and September 2002 as examples of Mediterranean floods*. Natural Hazards and Earth System Sciences, 6(2): 271-284.
22. Millot, C., Touchart, L., Bartout, P., Azaroual, A. & Aldomany, M. (2014), *Ponds: conservation through a better management of environmental impacts. Diversion: an optimal management? The case of Loire headwater catchment*. Water resources and wetlands. Conference proceedings 11-13 September 2014, Tulcea-Romania, 110-115.
23. Mociorniță, C. (1965), *Calculul debitelor maxime pe râurile din Republica Populară Română*. Meteorologie, hidrologie și gospodărirea apelor, 1.
24. Mustață, L. (1964), *Analiza formarii si metodica de calcul a hidrografelor viiturilor pluviale pe râurile din Republica Populară Română*. Studii de hidrologie, 11.
25. Pandi, G. & Mika, I. (2003), *River runoff extremes and tendencies: factors of risk likely related to global climate*. Riscuri si catastrofe, 2: 116-129.
26. Pandi, G. & Moldovan F. (2003), *Importanta prognozelor in diminuarea riscurilor meteorologice si hidrologice*. Riscuri si catastrofe, 2: 303-312.
27. Perry, C.A. & Combs, L.J. (1998), *Summary of floods in the United States, January 1992 through September 1993*. U.S. Geological Survey Water-Supply Paper, 2499: 286.
28. Picon, B. (2006), *Crises latentes et crises révélées. Le cas du risque inondation dans le delta du Rhône*. Riscuri si catastrofe, 5(3): 191-102.
29. Plattner, Th., Plapp, T. & Hebel, B. (2006), *Integrating public risk perception into formal natural hazard risk assessment*. Natural Hazards and Earth System Sciences, 6(3): 471-483.
30. Podani, M. & Zavoianu, I. (1992), *Cauzele si efectele inundatiilor produse in luna iulie 1991 in Moldova*. Studii si cercetari de geografie, 39: 71-78.

31. Portela, M.M. & Delgado, J.M. (2009), *A new plotting position concept to evaluate peak flood discharges based on short samples*. Water Resources Management, 5: 415-428.
32. Rădoane, N. & Rădoane, M. (2004), *Lacurile de baraj din bazinul râului Siret*. Qnnqls of the "Ştefan cel Mare" University, 13: 77-88.
33. Rădoane, M. & Rădoane, N. (2005), *Dams, sediment sources and reservoir silting in Romania*. Geomorphology, 71: 112-125.
34. Romanescu, G. (2003), *Inundatiile – între natural și accidental*. Riscuri si catastrofe, 2: 130-138.
35. Romanescu, G. (2005), *Riscul inundațiilor în amonte de lacul Izvorul Muntelui și efectul imediat asupra trăsăturilor geomorfologice ale albiei*. Riscuri si catastrofe, 4: 117-124.
36. Romanescu, G., Romanescu, Gabriela, Minea, I., Ursu, A., Margarint, M.C. & Stoleriu, C. (2005), *Inventarierea și tipologia zonelor umede din Podișul Moldovei. Studiu de caz pentru județele Iași și Botoșani*. Bucharest: Editura Didactică și Pedagogică.
37. Romanescu, G. (2006a), *Complexul lagunar Razim-Sinoie. Studiu morfohidrografic*. "Alexandru Ioan Cuza" University Press, Iaşi, 179.
38. Romanescu, G. (2006b), *Inundațiile ca factor de risc. Studiu de caz pentru viiturile Siretului din iunie 2005*. Iași: Terra Nostra.
39. Romanescu, G. (2006.c), *The effect of the catastrophic inundations from Siret river's lower basin (Romania) from July 2005 in the context of the global climatic change*. Riscuri și catastrofe, 5(3): 2003-218.
40. Romanescu, G. (2006d), *Hidrologia uscatului*. Iași: Terra Nostra.
41. Romanescu, G. (2009e), *Evaluarea riscurilor hidrologice*. Iași: Terra Nostra.
42. Romanescu, G. (2013), *Floods in the Siret and Pruth Basins*. In: Geomorphological Impacts of Extremes Weather, Loczy D. (Ed.). Case Studies from Central and Eastern Europe. Springer, Dordrecht.
43. Romanescu, G., Dinu, C., Radu, A., Stoleriu, C., Romanescu, A.M. & Purice, C. (2013a), *Water qualitative parameters of fluviatile limans located in the south-west of Dobrudja (Romania)*. International Journal of Conservation Science, 4(2): 223-236.
44. Romanescu, G., Stoleriu, C.C. & Enea, A. (2013b), *Limnology of the Red Lake, Romania. An Interdisciplinary Study*. Springer, Dordrecht.
45. Sorocovschi, V. (2002), *Riscuri hidrice*. Riscuri și catastrofe, 55-65.
46. Sorocovschi, V. (2004a), *Percepția environmentală și răspunsurile umane față de risc*. Riscuri și catastrofe, 1: 25-38.
47. Sorocovschi, V. (2004b), *Percepția riscurilor induse de inundații. Rezultatul unui sondaj de opinie desfășurat în Dealurile Clujului și Dejului*. Riscuri și catastrofe, 1: 122-137.
48. Sorocovschi, V. (2005), *Prevenirea riscurilor naturale*. Riscuri și catastrofe, 4(2): 39-50.
49. Sorocovschi, V. (2006), *Categoriile de atribute ce definesc evenimentele extreme. Un punct de vedere*. Riscuri și catastrofe, 5(3): 33-42.
50. Sorocovschi, V. (2007), *Vulnerabilitatea componentă a riscului. Concept, variabile de control, tipuri și modele de evaluare*. Riscuri și catastrofe, 6(4): 58-69.
51. Șelărescu, M. & Podani; M. (1993), *Apărare împotriva inundațiilor*. Editura Tehnică, Bucharest.

52. Șerban, G., Sorocovschi, V. & Fodorean, I. (2004), *Riscuri induse de amenajarea hidrotehnica a iazurilor de pe Valea Șesului (Campia Transilvaniei)*. Riscuri și catastrofe, 1: 159-172.
53. Șerban, P., Stănescu, V. & Roman, P. (1989), *Hidrologie dinamică*. Bucharest: Editura Tehnică.
54. Taramasso, A.C., Gabellani, S. & Parodi, A. (2005), *An operational flash-flood forecasting chain applied to the test cases of the EU project HYDROPTIMET*. Natural Hazards and Earth System Sciences, 5(5): 703-710.
55. Telteu, C.E. & Zaharia, L. (2012), *Morphometrical and dynamical features of the South Dobrogea lakes, Romania*. International Conference of Environment-Landscape-European Identity, Provedia Environmental Sciences, 14: 164-176.
56. Touchart, L. (2006), *Lacs et risques. Un essai de typologie*. Riscuri și catastrofe, 5(3): 13-20.