THE INFLUENCE OF CLIMATE CHANGES ON THE MANAGEMENT OF STORMWATER FROM THE HEARTH OF RURAL AND URBAN LOCALITIES

Doctoral Thesis - Abstract

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The PhD thesis was developed on the basis of studies and research carried out in the Department of Hydrotechnical Engineering, Faculty of Civil Engineering, Politechnica University Timisoara.

The content of the thesis is structured on 7 chapters developed on 212 pages, including 176 figures and 24 tables in which information and original results of the research carried out are synthetically presented, as well as a bibliography containing 127 classical and current representative bibliographical titles.

The research topic addressed is highly topical, following the new European requirements that provide for the promotion of the concept of the realization of separate sewerage systems, and the following objectives are highlighted:

- to establish study areas in rural and urban areas for the provision of a centralised rainwater drainage system suitable for climate change;
- to establish an analytical relationship for determining the design rainfall intensity for specific rural and urban areas in Romania;
- sizing rainwater drainage systems according to the design rainfall frequencies recommended by SR 1846-2:2007, NP 133/2022 and F. Reinhold's relation,
- establishment of a diagram for determining the design rainfall intensity for zone 13, according to STAS 9470-73 with the superposition of the design rainfall frequencies f(1/1), f(1/2), f(1/5), f(1/10) and f(1/30) determined with F. Reinhold's relation;
- modelling the storm drainage systems of the areas analysed with the Mike Urban software;
- comparison of analytical results with modelling results;
- superimposing heavy rainfall situations over storm drainage systems sized according to SR 1846-2:2007 and NP 133/2022,
- identification of the areas affected by climate change as a result of the overlap of the exceptional situation and establishment of technical solutions to limit them.

The achievement of the basic objective of the proposed research programme was carried out in the following work steps:

- documentation and presentation of the current state of research on stormwater management in rural and urban areas;
- sizing of storm drainage systems for a rural residential area, an industrial area and an urban plot;
- modelling the storm sewer system for the rural residential area in the Mike Urban programme;
- interpretation of the results from the analytical calculations and modelling of the storm

sewer system for the rural residential area.

Chapter 1, **Introduction**, presents the importance and timeliness of the research topic in the current context of climate change.

Climate change is a natural weather phenomenon, which can be slow, occurring over long periods of time (eras, millennia, etc.) or rapid, occurring over relatively short periods of time. They can influence both the climate and the weather of the planet.

Sources of greenhouse gases come from: fuel combustion; agricultural practices, CH_4 emissions from animal digestion, manure management and rice cultivation; reduction of woodland; land application of animal manure; waste incineration; untreated wastewater; flue gas from thermal power plants and untreated industrial waste.

Urbanisation is the process of territorial, demographic and functional transformation of cities or rural and urban settlements through their territorial expansion. This process leads to a decrease in green spaces, a reduction in the infiltration capacity of rainwater into the soil and an increase in the concentration of pollutants in the air.

Alternative climate change, which takes place over relatively short periods of time, can trigger particularly dangerous phenomena not only for humans but also for the environment.

The effects of climate change influence stormwater management during both heavy floods and prolonged droughts.

Prolonged droughts and periodic floods lead to significant damage to agriculture, industry, energy, water management and especially to the population.

These climatic changes have meant that during heavy rainfall some localities face areas at high risk of flooding, and during periods of prolonged drought water and sanitation systems will face specific problems in meeting the needs of water users.

Chapter 2, **Sewerage systems,** presents the importance of sewers, outlining the characteristics of sewage, drainage conditions, schemes and sewerage systems.

Also in this chapter the design of sewerage systems is recommended.

These methods are based on the NP 133/2022 - Regulations on the design, execution and operation of water supply and sewerage systems of municipalities and the STAS in force.

In the current context with the advent of climate change, rainwater drainage systems must be carried out in a separate system.

The objectives of the research take into account the development of rural and urban areas, spatial planning and town planning in the context of climate change and even extreme phenomena.

These objectives highlight the ways of calculating, collecting and storing stormwater to significantly reduce the risks of flooding and environmental pollution.

The research is based on case studies for the design and modelling of centralised storm drainage systems, the results of which are translated into graphs and tables.

The results lead to a number of conclusions that highlight the need to choose optimal systems for efficient stormwater management in rural and urban settlements with climate change.

The case studies within the research theme focused on stormwater management within specific areas, specific to rural and urban localities.

Chapter 3, **Current status of stormwater management in the context of climate change**, examines stormwater management in rural and urban settlements.

Over the years, the development of populated and industrial centres has led to a significant reduction in the area of agricultural land, green areas and even diversions of drainage channels.

The effects of urbanisation are reflected in the way stormwater management in these areas should be carried out, especially in the context of climate change.

The increasing existence of concrete surfaces compared to green areas resulting from the galloping pace of construction has made it possible to change the stormwater runoff coefficient in urban and rural areas by 60% to 70%.

Proper and efficient stormwater management significantly reduces the risk of flooding and protects groundwater and surface water to the greatest extent possible from pollution and reduces its negative effects on their quality.

At the same time, stormwater collected in sewerage networks is a significant additional source of water that can be used for domestic and agricultural activities during prolonged droughts.

In the current context of climate change, short-, medium- and long-term stormwater management measures are needed for rural and urban communities.

For the efficient management of stormwater from impervious and built-up areas, appropriate measures and technical solutions are needed on how to collect and use it.

These solutions and measures should be environmentally friendly by implementing the concept of retaining rainwater at the point of fall through alternative control methods.

Sustainable concepts should be based on the reduction of impervious surfaces, the identification and development of favourable routes for the discharge of rainwater into watercourses by applying ecological methods in a sequential control system.

The implementation of alternative methods with reduced environmental impact, such as green infrastructure, aims to achieve the following:

- using stormwater as an additional water resource;
- managing stormwater near the site of its fall;
- surface water management with the application of sequential methods of surface water control;
- infiltration of rainwater into the soil;
- flow reduction by storing stormwater in retention ponds;
- stormwater treatment for environmental protection.

Infiltration of rainwater into the soil is the best environmental solution to significantly reduce the flow rates to the treatment plant and to the waterways.

The solutions for infiltration of rainwater into the soil require an individual decision in each case, which must take into account the concentration of pollutants, the geotechnical characteristics of the soil, the groundwater level and the pre-treatment of the water to be infiltrated.

The following additional measures are proposed to reduce the maximum stormwater discharges to the sewerage network:

- reduction of impervious surfaces;
- creation of wet, dry, filtering vegetation strips;
- green roofs;
- permeable pavements,
- rainwater storage gardens;
- bioretention;
- wet and extended retention ponds.

It is recommended that sewage networks be made separate.

The management of stormwater from the public domain within a municipality is provided by the local authority in terms of collection, transport, treatment, storage and disposal/use of conventionally clean water.

Stormwater from privately owned areas must be managed independently by parcel owners based on the areas and flows collected.

Chapter 4, S**izing stormwater drainage systems in the context of climate change. Case studies**, examines the development of 3 areas presented in sub-chapters 4.1, 4.2 and 4.3.

For each studied area, the sizing calculation of the storm drainage system was performed at design rainfall frequencies f (1/1), f (1/2), f (1/5), f (1/10) and f (1/30) according to SR 1846-

2:2007, NP 133/2022 and F. Reinhold's relation.

The rain frequency of f (1/30) was taken into account following the situation in 2010, when rainfall reached a significant rainfall height of h = 50 mm for a rain duration of tp = 40 min.

The rainfall intensity diagram for zone 13, provided in STAS 9470-73, for the areas studied, can no longer provide realistic values for the calculation intensities in exceptional situations.

For the determination of the design rainfall intensity in exceptional situations, F. Reinhold's relation is a solution that can be adapted to the new climate changes. Each study area was sized and evaluated from a technical and economic point of view.

In Chapter 5, **Storm sewer system modelling using the Mike Urban program**, the structure of the Mike Urban program and the numerical modelling of the storm sewer system described in subchapters 5.1 and 5.2 are presented.

MIKE URBAN is used for modelling water supply networks and storm sewer systems.

The construction of the numerical model was based on topographic surveys carried out in STEREO 70 system for the studied area, identifying all geometric elements of the studied site.

By modelling the storm sewer network, the boundary of the study area and boundary conditions that take into account the street pattern were determined.

For the storm sewer network, the roughnesses corresponding to the pipe material were used for each pipe section.

For the runoff model, calculated runoff coefficients were used for each section of the street grid according to the distribution of sidewalks, green areas and roadway.

The numerical models in the study are based on the topographic survey and hydrogeological conditions of the site.

The structure of the street grid consisting of road, pavement and green space was also considered.

These studies have determined:

1) Limiting the area studied for stormwater modelling in and out of the storm sewer network during periods of heavy rainfall

2) Boundary conditions for movement of water off the street fabric for runoff modeling and movement of water into the storm sewer network.

These conditions are:

- Key rainfall versus time curve conditions for each perimeter related to street tracts for the runoff model.

- conditions on the volume of water that can be accumulated in the retention basin under different scenarios for the movement model;

- loading of the sewer network with stormwater into the manholes for the movement model based on the time-varying storm flows from the runoff model results

3) Hydraulic characteristics of the studied models

For the runoff model, runoff coefficients calculated for each sector of the road layout were used according to the distribution of pavements, green areas and carriageways.

For the storm sewer network, the roughnesses corresponding to the pipe material were used for each pipe section.

Modelling the hydrodynamics of rainfall runoff in storm sewer networks in MIKE URBAN - MOUSE requires the definition of a MOUSE network and the creation of a MOUSE model.

The model created consists of the following elements:

- Nodes (manholes, retention basin)

- Circular pipes.

At this point the storm sewer network is created as a MOUSE model and the definition of the rainfall runoff surfaces (Catchment) for the creation of the runoff model.

In MIKE URBAN, the user can quickly prepare a rainfall-runoff model configuration with the desired level of detail and use the calculated runoff as a load on the collection network.

It should be noted that the calculation of runoff and its subsequent use as a network load are in principle two distinct steps in the modelling process.

The steps involved in preparing a rainfall-runoff model are:

- Definition of MIKE URBAN catchments
- Catchment connections, i.e. specifying the point of runoff flow into the network. If this is not done before running the runoff simulations, the calculated results will not be able to be connected to the network.
- Specification of hydrological model parameters
- Definition of precipitation, i.e. definition of the precipitation boundary state
- Runoff calculations

Runoff surfaces are essential for any hydrological model. In MIKE URBAN, the geographical extent of a catchment is determined by the perimeter of the catchment polygon. In this model, we delineate the catchment area into smaller sub-catchments in order to allocate surface generated runoff to nodes in our network.

These surfaces represent the street spans associated with the manholes into which they drain via the culverts. Depending on the geometrical dimensions and the distribution of pavements, green spaces and carriageways, these surfaces have different geometrical and hydraulic characteristics.

Chapter 6, **Interpretation of the obtained results** presents the analytical calculations carried out for the 3 studied areas.

In sub-chapter 6.1, the values obtained for design rainfall intensities, flow rates, diameters, storage volumes and investment values for the 3 studied areas at frequencies f (1/1), f (1/2), f (1/5), f (1/10) and f (1/30), according to SR 1846-2:2007, NP 133/2022 and F. Reinhold's relation, are comparatively analysed.

In subchapter 6.2, modelling results with Mike Urban software for rural residential area are presented.

For the rural residential area, the rainfall frequency was f (1/1) according to SR 1846-2:2007.

With the entry into force of NP 133/2022, the normal calculation rainfall frequency of f (1/5) was adopted for municipalities with a population of less than 100,000 inhabitants.

Most of the existing storm sewer networks have been designed and executed for the design rainfall frequency of f (1/1) according to SR 1846-2:2007.

With the climatic changes, which have occurred in the recent period, it is necessary to compare the analytical results for rainfall frequencies for f (1/1) according to SR 1846-2:2007 and f (1/5) according to NP 133/2022 with the exceptional situations recorded so far for the study area.

Figure 1 shows the calculation diagram for zone 13 of Romania, showing the rain frequencies for f (1/1), f (1/2), f (1/5), f (1/10) and the related frequency f (1/30) determined for the exceptional situation occurring in 2010 in the studied area, from the F. Reinhold relation.

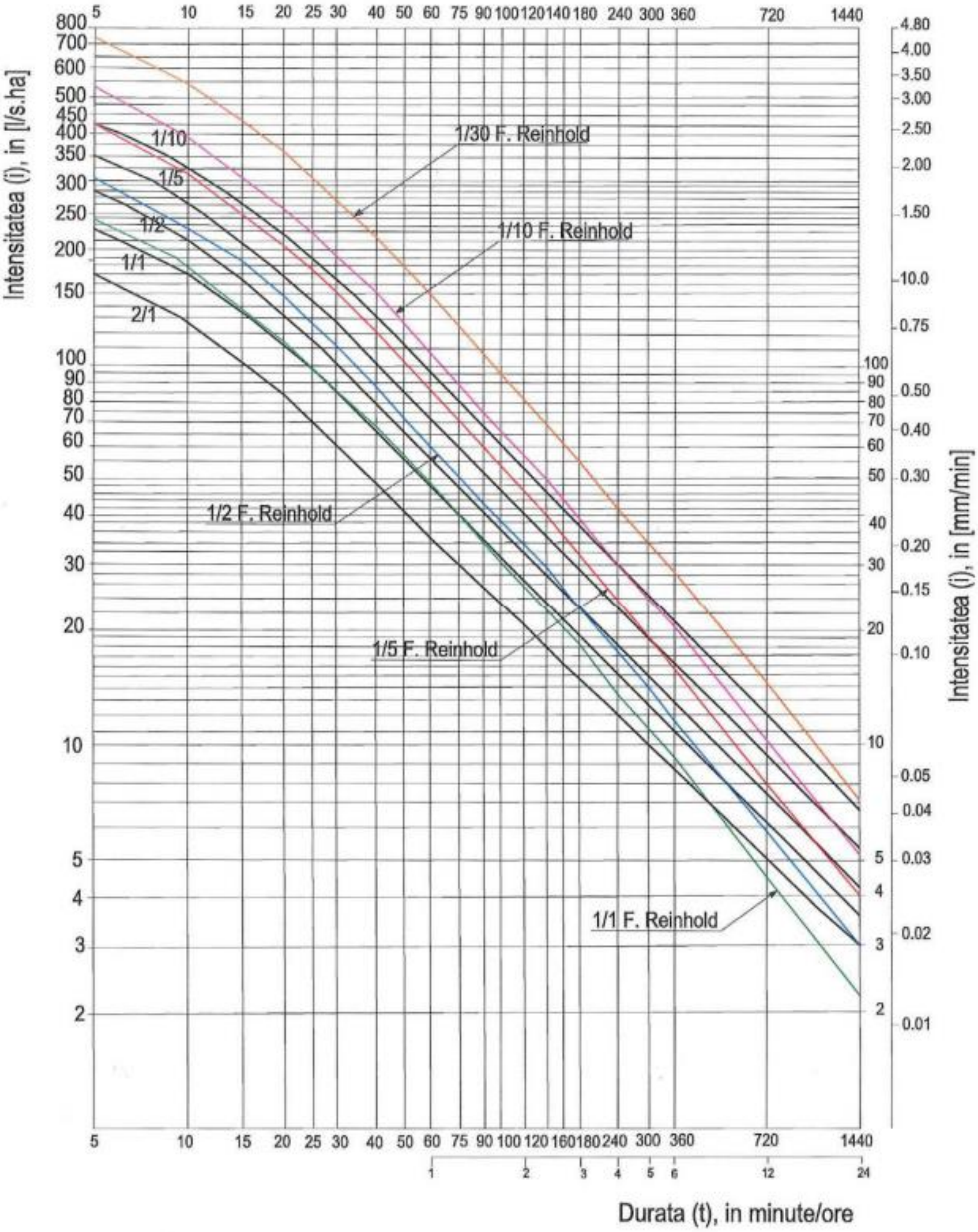

Fig. 1 Calculated rainfall intensity diagram for the study area

F. Reinhold's computational relationship ensures expeditious determination of computational rainfall intensities that are closer to the actual situations that occur in the context of climate change.

The modelling of the storm sewer system for the frequencies f (1/1), f (1/5) and f(1/30) according to SR 1846-2:2007, NP 133/2022 and F. Reinhold's relation resulted in some corrections in terms of diameter sizing.

Comparison of the results of the analytical calculations of the rural storm sewer system is made for design rainfall intensities, design flows, diameters, storage volumes, investment values for design frequencies f (1/1), f (1/5) and f(1/30), according to SR 1846-2:2007, NP 133/2022 and F. Reinhold's relation.

Also in this chapter the superposition of an exceptional situation related to a design rainfall frequency f (1/30) over a storm sewer system modelled at design rainfall frequency f (1/5) according to NP 133/2022 and F. Reinhold's relation is analysed.

Chapter 7, **Conclusions**, sets out the final conclusions for stormwater management in rural and urban settlements under the influence of climate change.

The personal contributions made in the PhD thesis: Influence of climate change on the management of stormwater in rural and urban settlements consist of:

- analysis of how existing legislation for stormwater drainage in populated centres can be applied in the context of climate change;
- the introduction of a calculation formula for determining rainfall intensity, adapted to the studied area, which can be applied with good results to all rural and urban areas in our country under the new climate changes;
- to complete the calculation rainfall intensity diagram for zone 13 with the rainfall frequency of f (1/30) for a situation with exceptional rainfall in 2010 characteristic of climate change;
- study of stormwater management in the context of climate change for 3 zones: urban area, rural area and a residential plot;
- analytical sizing of storm drainage systems for the studied areas for recommended design frequencies of f (1/1) and f (1/2) according to SR 1846-2:2007 and f (1/5), f (1/10) according to NP 133/2022;
- modelling of the storm drainage system in the rural area studied using the Mike Urban software;
- comparative analysis of the results obtained from the analytical calculations and those obtained from the modelling with Mike Urban;
- synthesis of the comparative results obtained from the analytical calculations and those obtained from the modelling, with the necessary corrections following the modelling;
- superimposing an exceptional situation related to a design rainfall frequency f (1/30) over a storm sewer system modelled at design rainfall frequency f (1/5) according to NP 133/2022 and F. Reinhold's relation;
- solutions for a good functioning of the existing storm drainage system in case of heavy rainfall situations by adapting special construction works and installations. In the case of the studied area for the limitation of flooding areas within the storm sewerage systems additional water storage basins, pumping stations equipped with an additional number of pumps to be operated only in exceptional cases should be provided.

Personal contributions and future research perspectives are also presented:

- use of the model by the Mike Urban program for existing storm sewer systems to simulate heavy rainfall situations for different study areas;
- research on the solutions adopted for the operation of these existing sewerage systems under the influence of climate change,
- adaptation of the F. Reinhold relation for determining the design rainfall intensity for all areas in Romania;
- use of the studies carried out for the revision of the regulations, and of the existing STAS currently under discussion, to adapt them to the current requirements imposed by climate change;
- analysis/expertise of the functioning of existing rainwater drainage systems, exposed to exceptional situations of heavy rainfall, in order to establish solutions to limit flood areas;
- further development, through case studies, of areas with permeable land;
- harnessing rainwater to enrich drinking water resources, which in the context of climate change/protracted droughts will be increasingly limited.

The final part of the dissertation presents the bibliography, which includes 127 bibliographical titles from the country and abroad, among which we mention 24 significant reference titles:

[1] Bastian H. W., (2009), Capture and household use of water from precipitation, M.A.S.T., FEDPRINT Publishing House, Bucharest;

[2] Bica I., (2000), Urban Hydraulics and Hydrology, Matrix Rom Publishing House, Bucharest;

[3] Cotoarbă L., Florescu C., Stăniloiu C., Crețan A., (2018), Assessments regarding the need for collecting, snoring and using the meteoric waters from household scans in populated centers, Vol.18, Issue: 3.1, p 109-114, 18th International Multidisciplinary Scientifc Geoconferencence SGEM Scientific Bulletin, Albena, Bulgaria;

[4] Cotoarbă L., Florescu C., Stăniloiu C., Pişleagă M., (2018), Considerations on meteorological water management in localities under the influence of climate change, Vol. 18, Issue: 3.1, p. 137-142, 18th International Multidisciplinary Scientifc Geoconferencence SGEM Scientific Bulletin, Albena , Bulgaria;

[5] Cotoarbă L., Florescu C., Stăniloiu C., (2017), The effect and the influence of climate change on the meteoric water Management in residential and industrial zones, Scientific Bulletin of The Polytechnic University of Timisoara, Transitions on Hydrotechnics, Romania, Volume 62(76), Issue 2, p.10-14;

[6] Cotoarbă L., Florescu C., Bădăluță C., Vișescu M., (2020), Storm – water Management in Industrial Areas in Built-Up Area and Non-Built-Up Areas, 5th Word Multidisciplinary Civil Engineering – Architecture – Urban Planning Symposium, Vol. 960, WMCAUS, 1-5 septembrie, Prague;

[7] Cotoarbă L., Florescu C., Bădăluță M. C., Vișescu M., (2020), Modelling of Storm –water Drainage Systems in Residential Areas, 5th Word Multidisciplinary Civil Engineering – Architecture – Urban Planning Symposium, Vol. 960, WMCAUS, 1-5 septembrie, Prague;

[8] Florescu C., Stăniloiu C., Podoleanu C. E., Mirel I., (2012), Reducing the risk of flooding in areas with high vulnerability with in Timisoara city, Scientific Bulletin of The Politehnica University of Timişoara, Transations on Hidrotechnics, Romania, Tom 57(71), Fascicola 2, p.9-16;

[9] Giurma I., Crăciun I., Giurma C-R,. (2009), Hydrology, Politehnium Iasi Publishing House;

[10] Giurma I., (2004), Special Hydrology, Politehnium Iași Publishing House;

[11] Giurconiu M., Jura C., Popa Gh., Mirel I., (1964), Hydraulic and economic study of the functional system consisting of network, retention basin and pumps in storm water drainage. Polytechnic Institute Timișoara. Communications of the conference on Hydraulic Machines, part III;

[12] Giurconiu M., Mirel I., Păcurariu M., Popa G., (1977), Diagrams, nomograms and tables for the calculation of waterworks, Facla Publishing House;

[13] Haque M. M.l, Rahman A., Samali B., (2016), Evaluation of climate change impacts on rainwater harvesting. Journal of Cleaner Production, Volume 137, November 2016, p. 60-69;

[14] Kainz H., Kauch E. P., Renner H., (2005), Siedlungswasserbau und Abfallwirtschaft, Manz Verlag Schulbuch, Wien;

[15] Kauch E.P., Renner H., Schlachter H., (2000), Siedlungswasserbau 1 – Wasserwersor - gung.7. Aufl., Manz Verlag Schulbuch, Wien;

[16] Mirel I., Achim C., Gârbaciu A., (2007), Considerations on storm water discharge in housing areas without outfalls. Proceedings of the conference "Building installations and environmental comfort, Timisoara, p.291-297;

[17] Mirel I., Carabeț A., Virag I., Oncia S., Fazakas P., (1998), Watershed use for meteoric water captation on the area of populous cesntres in the plain regios, Conferința Internațională Novi Sad, Yugoslavia;

[18] Stăniloiu C., Florescu C., (2012), Possibilities of rain water in households, Scientific Bulletin of The Politehnica University of Timişoara, Transations on Hidrotechnics, Romania, Tom. 57(71), Fascicola 2, p.29-32;

[19] Stăniloiu C., Florescu C., Cotoarbă L., (2020), About the history of sewerage and treatment plants, Scientific Bulletin of The Politehnica University of Timişoara, Transations on Hidrotechnics, Romania, Volume 65(79), Issue 1, p.45-48.

[20] Terêncio D. P. S., Fernandes S. L. F., R. Cortes M. V., Moura J. P., Pacheco F.A. L.., (2018), Rainwater harvesting in catchments for agro-forestry uses: A study focused on the balance between sustainability values and storage capacity. Science of The Total Environment, Volumes 613–614, 1 February 2, p.1079-1092;

[21] *** NP 133-2022, Standard for the design, execution and operation of water supply and sewerage systems in municipalities Vol. 2;

[22] *** SR 1846-2:2007, Outdoor sewers. Design requirements. Part 2: Determination of storm water flow rates;

[23] *** SR 8591-1997, Underground Civil engineering networks. Site conditions;

[24] *** STAS 9470/73. Maximum rainfall. Intensities, durations, frequencies;