

Abstract of the Ph.D. thesis

The influence of roads on surface runoff formation in the urbanised area on the example of Kielce

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In the structure of the land cover of urban areas, a significant contribution of impervious surfaces can be observed, such as roofs, roads, car parks, squares and pavements. This leads to an increase in surface runoff volume and its dynamics. However, the literature lacks detailed information on the share of the area of various impervious surface types in the land cover structure of even small urban catchments, although having such information at the catchment scale is very important in modeling of hydrological processes. This may be due to the lack of representation of these objects in available spatial databases.

Analyses of the road surfaces impact, often along with other land cover types, on the surface runoff in small urban catchments so far have mainly focused on determining the discharge and physicochemical properties of water in terms of pollutants accumulated and transported from these catchments. A number of studies point to the significant role of road surfaces in shaping the surface runoff and its parameters in rural or forested areas. This topic in relation to the urban areas was tackled in few works and so far is not sufficiently recognised. There is a lack of a comprehensive study showing the real share of roads in the land cover structure of urban catchments, as well as their role in shaping the dynamics and quality parameters of surface runoff waters. Taking this into consideration, the research goal of the present investigation was to determine the importance of roads in the city in the conditions of changing land cover structure, in the formation of the surface runoff and in the physicochemical characteristics of the waters resulting from this process on the example of Kielce. This included: i) detailed large-scale land cover analysis with particular regard to roads, based on aerial photographs taken in 1944, 1977 and 2014; ii) numerical surface runoff modelling in urban catchments taking into account land cover conditions in 1944, 1977 and 2014; iii) estimation of the dissolved and clastic material supply areas and sources in urban catchments; iv) determination of the transformation of selected physicochemical properties of the road runoff waters.

To achieve the stated research goal a wide range of methods was used: i) spatial analysis in geographic information systems (aerial photographs geo-referencing, large-scale land cover database building, surface flow directions modeling, catchment water retention capacity modeling, calculations of the area and length, spatial relationship analysis, map algebra); ii) hydrological modeling in HEC-HMS software (flood discharge numerical modeling in the Silnica river catchment and its subcatchments in the land cover conditions of 1944, 1977 and 2014 and using different input design rainfall intensities, SCS-CN method and Clark's Unit Hydrograph); iii) field analysis (in-situ measurements of physicochemical parameters of the road runoff water – temperature, pH, electrical conductivity, measurements of precipitation sums and intensity); iv) laboratory analysis (suspended solids concentration in the road runoff water by the filtration method, granulometric analysis of the sediments accumulated on the road surfaces by the sieve method); v) statistical analysis of the obtained results (regression and correlation analysis).

The performed research allowed to formulate the following general conclusions:

- In the areas being subject to intense urbanisation processes, there is a tendency to increase the area of impervious surfaces (especially roads) between which there exist strong spatial relations.
- In urban catchments, the share of buildings area is comparable to that of roads, and the area of land cover types related to communication (roads, squares, car parks and pavements) is generally twice as large as the specified building area.
- Dynamic growth of the impermeable surfaces area in urban catchments causes a continuous variation of the surface runoff conditions, the hydrological effect of which is an increase in the sum of effective precipitation and, consequently, a several fold increase of flood waves culmination and a significant decrease in time of their concentration.
- Roads in urban catchments direct and concentrate the surface runoff, and are in consequence particularly vulnerable to the effects of water erosion, transport and accumulation processes occurring at that time. They become an efficient source of material transported in the surface runoff waters.
- Supply areas that generate surface runoff in urban catchments are unnaturally extensive and function even after low precipitation (1-2 mm), often reaching water divides, and thus roads, due to their considerable surface area and density, become both an important place of the transformation of precipitation into the surface runoff as well as a corridor for waters flowing from other surfaces.
- In the process of surface runoff along roads in the summer season, a significant transformation of physicochemical parameters of water is noticeable, including concentration of suspended solids (an increase in the first phase of the process), concentration of dissolved material (initially a decrease and then an increase), as well as an increase of its temperature. During this period, the concentration of suspended solids in the runoff waters from bituminous roads is many times lower than from dirt roads.

