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SURFACE RUNOFF FROM SLANTING FOREST ROADS*

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Abstract. The present analysis concerns the subject of surface runoff from slanting forest roads. In the Beskid Śląski area (Silesian Beskidy Mountains), where a drainage basin was completely afforested, sections of roads were selected to measure the water running off. In each section an open top culvert was installed. The analysis contains the already mentioned measurement methodology, characteristic features of both the drainage basin and the selected road sections, results the surface runoff measurement carried out on the selected road sections and finally the results of a simulated calculation of voluminal quotient of two values: surface runoff from the drainage area roads and precipitation over the drainage basin area ($q_{dr\ P}$) and a quotient of surface runoff from the roads in the drainage area and the runoff from the drainage basin ($q_{dr\ Q}$). The following values were estimated for the 2.1 mm rainfall rate: $q_{dr\ P}$ = 0.42%, $q_{dr\ Q}$ = 8.92%, whereas for the 9.8 mm rainfall the values were as follows: $q_{dr\ P}$ = 0.93% and $q_{dr\ Q}$ = 100.13%.

Key words: surface runoff, slanting forest roads, drainage basin

INTRODUCTION

According to Tomanek [1954] and Słupik [1972] surface runoff constitutes one of the most important links in the mountain water circulation chain. The runoff volume determines water supply of surface soil and the deep strata. A rudimentary condition for the surface runoff appearance is the existence of water on the ground surface (precipitation, melting snow or protruding water-conveying layers of the ground) and a complete or almost complete profile saturation. Thus the main features of surface runoff are, according to Słupik [1972], the frequency and type of rainfall (not its total amount), soil structure, soil exploitation during the rainy season as well as ground temperature during the snow season. Among other factors which are, however, of minor significance are slope exposure and soil humidity. Severe draught may therefore lead to the temporary hydrophobic quality of soil organic layers.

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Carrying out his research of surface runoff in the Szymbark Scientific Unit, Słupik [1972] recorded surface runoff of around 15 t $l \cdot min^{-1} \cdot ha^{-1}$ on potato cultivation and 10 t $l \cdot min^{-1} \cdot ha^{-1}$ on crop cultivation and meadows, after a thunderstorm rainfall (rate 60-90 mm during 1-2 hrs). Less intensive precipitation involves a smaller surface runoff. Moreover, in a forest it disappears completely due to characteristic features of a ground cover.

Runoff amount is thus directly modified by the condition of the road surface. Under extreme conditions, the ground is covered with an impermeable or permeable to a very limited extent layer. The impervious areas, characterized by water-resistance throughout all year, are those strongly urbanized where pavement is tight, and roads, including the soil surface roads. Runoff velocity (and energy) is regulated by ground inclination therefore mountainous or undulating areas are to a greater extent endangered by rapid outflow of this portion of water as well as by water erosion – the phenomenon having its immediate associations with surface runoff.

Roads constitute an indispensable element of a well managed property, however, the necessity to maintain their bearing capacity impels the use of specific structures and technologies. One of the most important conditions determining the high bearing capacity and passableness is constant drainage of the main body of a road, which consists mainly in creating downward grades and managing surface tightness.

The above mentioned road surface features combined with the conditions accelerating surface runoff reveal the same factors. This, consequently, leads to a conclusion that a road network located on a specific area (e.g. a mountain drainage basin) is one of the most important structures responsible the for fast drain which, in practice, becomes surface runoff from the reception basin. According to a number of scientists this factor greatly affects the intensity of mountain spring freshets [Słupik 1972, Gil 1990, Wicherek 1995]. Decreasing the runoff intensity will therefore increase soil saturation conditions, shorten the critical stream level periods, slow down the outflow and decrease erosion [Słupik 1972].

The research over water relations on a slant [Gołąb 2004] proves that a road dehydrates the grounds located in its vicinity. In the mountains, however, due to water excess this phenomenon is not so powerful to negatively affect soil fertility and therefore to influence vegetation. Yet the problem of draining effect caused by roads remains unsolved. The process consists in fast water supply from surface runoff to water-courses which drain the drainage basin and therefore water retention capacity of the ground is limited. Consequently, the amount of water available for every consumer decreases, the freshet wave increases and water deficiency is eventually much greater during low-water periods.

Other negative effects of the large and fast surface runoff include sheet and gully erosion present in all the areas in use, sediment concentration, silting of water courses and basins. Roads loose their assumed geometrical features as erosion cause linear carvings to appear. Due to these phenomena, passableness is impeded and roads may even be closed.

To sum up, the subject of the present research is surface runoff form slanting forest roads. The main objective of the paper was to elaborate the research methodology, to measure the runoff amount on selected sections of slanting forest roads, and finally to provide a simulated calculation of the amount of runoff from the roads in the entire drainage basin area.

SELECTION OF SITES FOR MEASUREMENT

The research was carried out at the experimental drainage basin of Potok Dupniański, belonging to the Department of Forest Engineering, located at the Wisła Forest Inspectorate (Beskid Śląski area). This small, densely afforested area is described in great detail by Suliński et al. [1997]. Herein its short version according to Czarniecka is provided [1998] (Table 1).

Table 1. Specification of geophysical parameters of the Dupniański stream drainage basin
Tabela 1. Zestawienie parametrów fizyczno-geograficznych zlewni Potoku Dupniańskiego

Geometry of the drainage basin – Geometria zlewni	
Actual surface – Powierzchnia rzeczywista	$A = 1.68$ km^2
Drainage length – Długość zlewni (osi pionowej)	$L_o = 2.09$ km
Main watercourse lenght – Długość cieku głównego	$L_m = 2.02$ km
Maximum width – Szerokość maksymalna	$B_m = 1.47$ km
Mean width – Szerokość średnia (A/L_m)	$B_{śr} = 0.83$ km
Circuit – Obwód	$O = 5.39$ km
Morphometry – Morfometria	
Maximum height – Wysokość maksymalna	$H_{max} = 881.90$ m a.s.l. – n.p.m.
Minimum height – Wysokość minimalna	$H_{min} = 492.70$ m a.s.l. – n.p.m.
Drop – Deniwelacja ($H_{max} – H_{min}$)	$\Delta H = 389.20$ m
Stream gradient – Spadek cieku ($H_{źr} – H_{ujścia}$)/L_m	$J_o = 16\%$
Hydrographic network – Sieć hydrograficzna	
Watercourse headwaters height – Wysokość źródła cieku głównego	H_h= 808.75 m a.s.l. – n.p.m.
Main watercourse mounth height – Wysokość ujścia cieku głównego	H_m= 492.70 m a.s.l. – n.p.m.
Total length of watercourse – Długość wszystkich cieków	$L_s = 5.77$ km
Water network density – Gęstość sieci wodnej (L_s/A)	$G_s = 3.43$ km·km^{-2}

Table 2 comprises a numerical specification of the roads which underwent the analysis.

On one of the roads within the drainage area 6 road sections were selected, each characterized by different parameters: the height of fill slopes, the presence of seepage from cut slopes, a grade-line decline of a roadway, the age of forest stand in the vicinity of a road, and finally the protection of a road by trees (Table 3). The road sections were deliberately chosen with reference to a cross slope of a road. Yet due to the unreliability of this parameter for roads built on the natural ground as well as to the presence of ruts, it was neglected.

Below, a detailed feature specification of the selected road sections is submitted.

Permeability of the road surface texture was measured according to the Niestierow method [Krajewski 1971], which was only slightly adjusted to the present conditions. The adjustment consisted in applying cylinders of 15 and 30 cm in circumference, sealing

Table 2. Characteristics of the drainage basin in respect of the existing roads
Tabela 2. Charakterystyka zlewni ze względu na istniejące drogi

Mean road width Średnia szerokość drogi m	Type of pavement Rodzaj nawierzchni	Total length of roads in the drainage area Długość dróg w zlewni m	Total road surface in the drainage area Powierzchnia dróg w zlewni m^2	Road density index Wskaźnik zagęszczenia dróg $m \cdot ha^{-1}$
4.5	asphalt asfaltowa	1 960	8 820	41.7
3	soil-surfaced gruntowa	3 652	10 956	
2	soil-surfaced gruntowa	1 386	2 772	
	Total – Suma	6 998	22 548	

Table 3. Features of the studied road sections
Tabela 3. Cechy odcinków badawczych

Section characteristics Charakterystyka odcinka	Section – Odcinek					
	A	B	C	D	E	F
Type of road pavement Rodzaj nawierzchni	Soil-surfaced, with large quantity of natural material in its structure Gruntowa z dużą ilością naturalnego szkieletu					
Measuring length of a section, m Długość odcinka, m	37.10	89.65	60.40	43.95	54.10	38.50
Mean width of a roadway, m Średnia szerokość jezdni, m	2.10	2.01	2.20	2.62	2.30	1.92
Roadway surface in a section, m^2 Powierzchnia jezdni na odcinku, m^2	77.91	180.20	132.88	115.00	124.43	73.79
Mean section gradient, % Średni spadek odcinka, %	1.82	1.97	8.22	9.17	8.37	9.65
Mean cut slope height, m Średnia wysokość skarpy wykopu, m	0.96	1.25	1.61	2.44	1.75	0.86
Mean fill slope height, m Średnia wysokość skarpy nasypu, m	0.45	0.23	0.65	0.87	0.38	0.82
Presence of seepage from a slope, yes, no Obecność wysięku wody ze skarpy, tak, nie	N	N	Y	Y	N	N
Age of a forest stand, years Wiek drzewostanu, lata	55	20	50	80	80	40
Road protection by trees, % Osłona drogi drzewostanem, %	70.6	8.5	29.4	30.0	40.0	40.0
Surface soil permeability coefficient, $cm \cdot min^{-1}$ Współczynnik wodoprzepuszczalności gruntu w nawierzchni, $cm \cdot min^{-1}$	0.003	0.004	0.000	0.000	0.004	0.005

any slots that appeared while fixing the cylinders in the ground with betonite clay, and finally avoiding the use of gravel as a protective layer against washing out ground particles. The soil in the road surface is tight and thus is not conducive to washing out, especially when the cylinders contain the appropriate amount of water.

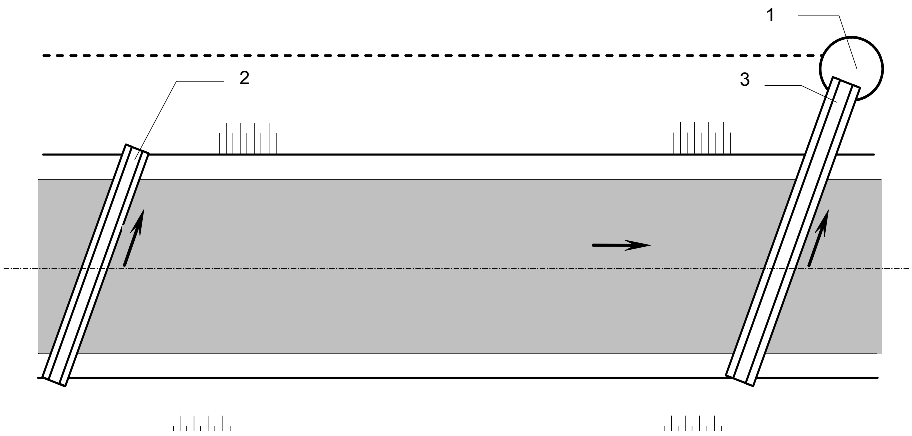
Results of the examination, whose aim was to characterize each of the selected road sections, are featured in Table 3. For the sake of comparison ground permeability was also measured on a natural slope (located outside the road strip). The achieved result (0.025 $cm \cdot min^{-1}$) fully corresponds to the results achieved for this type of measurement, carried out on natural grounds of the drainage area, by Szerszeń [1998].

Road protection provided by tree crowns, which through interception of precipitation affected the initial stage of surface runoff, was assessed as a weighted average, taking into account the duration of certain protective conditions for each road section. The appropriate values are presented in Table 3.

MEASURING EQUIPMENT

In order to estimate the volume of surface runoff on a particular road surface, within the highest ordinate of each road section the cutting-off open top culverts were installed whereas within the lowest one the measuring open top culverts were attached respectively.

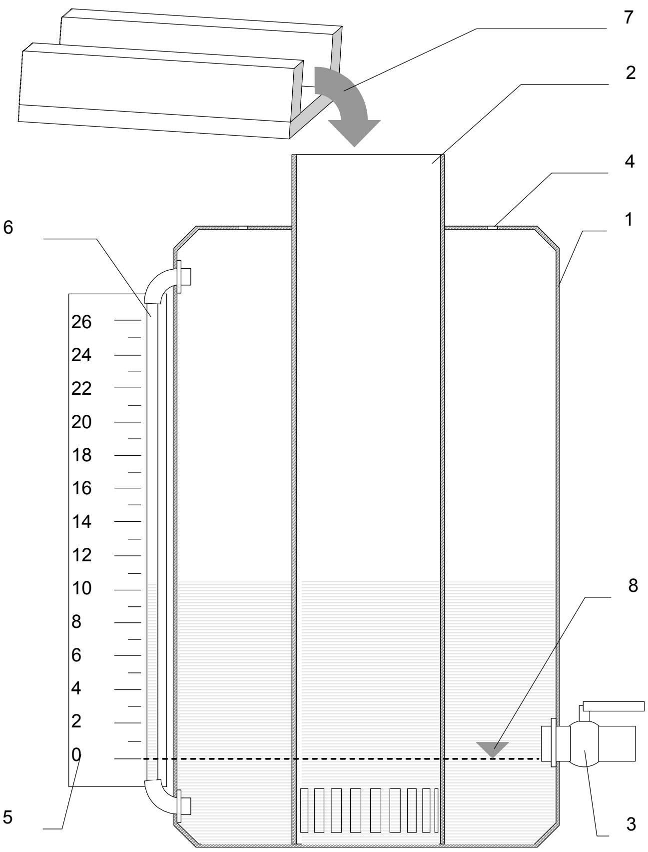
The structure of an open top culvert has been borrowed from "Katalog typowych wodospustów drogowych" (Catalogue of the Popular Road Open Top Culverts) [Koczwański et al. 1979]. Additionally, silicone sealing has been added to the combined wooden elements. The scheme of the examination section is presented on Figure 1.



List of explanations – Oznaczenia:
1 – measuring vessel – naczynie pomiarowe
2 – cutting-off open top culvert – wodospust odcinający
3 – measuring open top culvert – wodospust pomiarowy

Fig. 1. Scheme of the measuring section
Rys. 1. Schemat odcinka pomiarowego

The amount of runoff water from the examined sections was measured with a measuring vessel. The scheme is presented on Figure 2.



List of explanations – Oznaczenia:
1 – plastic tank – beczka plastikowa o pojemności 30 l,
2 – pipe reducing water movement in the tank – rura zmniejszająca falowanie wody w beczce,
3 – ball valvę φ 1 ¼ ″ – zawór kulowy φ 1 ¼ ″,
4 – air-escape aperture – otwór odpowietrzający,
5 – reading scale (individual laboratory scaling) – skala odczytowa (indywidualne skalowanie laboratoryjne),
6 – outer indicator of water level in tank – zewnętrzny wskaźnik ilości wody w beczce,
7 – directed flow of water from an open top culvert to a tank (directing element is invisible) – ukierunkowany przepływ wody z wodospustu do beczki (element kierujący niewidoczny),
8 – filling stag of a tank at the outset of every measurement – poziom napełnienia beczki w chwili rozpoczęcia każdego pomiaru.

Fig. 2. Scheme of the measuring vessel
Rys. 2. Schemat naczynia pomiarowego

METHODOLOGY OF MEASURING THE SURFACE RUNOFF INTENSITY FROM ROADS

Having assumed that quantity fluctuations are not very fast, the amount of water appropriate for measurement was that which ran off the road sections every 15 minutes (the examination commenced at the beginning of every time unit). Each measurement lasted for 5 minutes, however, if the measuring vessel had been filled faster, the time of a complete filling was recorded. Both the amount of water intercepted in the vessel as well as the time of the process were recorded in a diary. The measurement was carried out in all road sections simultaneously.

Rainfall quantity was read from the representative pluviometer at the outset of every time unit, which was also the outset of every surface runoff measurement.

Runoff intensity (q_s) from every measurement was calculated according to the notes from a diary. Further calculations required referring to an elementary microplot, which allowed for a comparison of the results, converting runoffs into the surface of the entire drainage area as well as the analysis of the influence of road section characteristic features on the runoff amount.

The values estimated through calculations (unitary values) were as follows: runoff intensity for every measurement (q'_s), mean runoff intensity in every time unit ($q'_{s\ 15}$), mean runoff intensity during the complete session (a measuring day) (Q'_s), and finally runoff volume from every section in every time unit ($v'_{s\ 15}$) and runoff volume during the complete session (V'_s).

MEASUREMENT RESULTS

Table 4 presented below contains some numerical quantities recorded outdoor and some runoff volume and intensity quantities calculated after a particular session (no precipitation), on the selected road section (D). This data, which was made even, concerns only the outset of the measuring session.

Table 4. Outdoor records as well as selected calculations referring to surface runoff from a forest road. Some data from July 24th, 2003 measuring session; road section D

Tabela 4. Zapisy terenowe oraz wybrane wyliczenia dotyczące odpływu powierzchniowego z drogi leśnej. Część danych z sesji pomiarowej 24.07.2003 roku na odcinku pomiarowym D

Outdoor measurements Pomiary terenowe			Runoff intensity Natężenie odpływu				Runoff volume Objętość odpływu	
Measurement outset Start pomiaru	*V* l	*t* s	from a section z odcinka	from 1 m^2 z 1 m^2			from 1 m^2 z 1 m^2	
			q_s $l \cdot s^{-1}$	q'_s $l \cdot s^{-1} \cdot m^{-2}$	$q'_{s\ 15}$ $l \cdot s^{-1} \cdot m^{-2}$	Q'_s $l \cdot s^{-1} \cdot m^{-2}$	$v'_{s\ 15}$ $l \cdot m^{-2}$	V'_s $l \cdot m^{-2}$
1	2	3	4	5	6	7	8	9
9^{00}	1.90	300	0.006	0.000055	0.000055	0.000043	0.05	1.70
9^{15}	1.90	300	0.006	0.000055	0.000055		0.05	
9^{30}	1.90	300	0.006	0.000055				

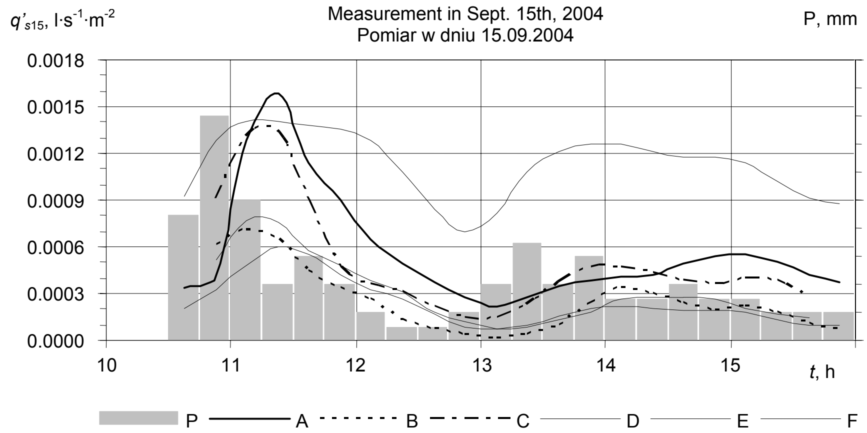
Table 4 – cont.

1	2	3	4	5	6	7	8	9
9^{45}	1.80	300	0.006	0.000052	0.000054		0.05	
10^{00}	1.80	300	0.006	0.000052	0.000052		0.05	
10^{15}	1.80	300	0.006	0.000052	0.000052		0.05	
10^{30}	1.80	300	0.006	0.000052	0.000052		0.05	
10^{45}	1.80	300	0.006	0.000052	0.000052		0.05	
11^{00}	1.75	300	0.006	0.000051	0.000051		0.05	
11^{15}	1.70	300	0.006	0.000049	0.000050		0.04	
11^{30}	1.70	300	0.006	0.000049	0.000049		0.04	
11^{45}	1.65	300	0.006	0.000048	0.000049		0.04	
12^{00}	1.60	300	0.005	0.000046	0.000047		0.04	
12^{15}	1.55	300	0.005	0.000045	0.000046		0.04	
12^{30}	1.55	300	0.005	0.000045	0.000045		0.04	
12^{45}	1.55	300	0.005	0.000045	0.000045		0.04	
13^{00}	1.50	300	0.005	0.000043	0.000044		0.04	
13^{15}	1.50	300	0.005	0.000043	0.000043		0.04	
13^{30}	1.50	300	0.005	0.000043	0.000043		0.04	
13^{45}	1.50	300	0.005	0.000043	0.000043		0.04	
14^{00}	1.45	300	0.005	0.000042	0.000043		0.04	
14^{15}	1.45	300	0.005	0.000042	0.000042		0.04	
14^{30}	1.45	300	0.005	0.000042	0.000042		0.04	

List of explanations: q_s – runoff intensity during a single measurement; q'_s – runoff intensity from the surface 1 m^2; $q'_{s\,15}$ – mean runoff intensity during a time unit from the surface 1 m^2; Q'_s – mean runoff intensity from the surface 1 m^2 during the complete measuring session; $v'_{s\,15}$ – runoff volume from the surface 1 m^2 during a time unit; V'_s – runoff volume from the surface 1 m^2 during the complete measuring session.

Oznaczenia: q_s – natężenie odpływu z pojedynczego pomiaru; q'_s – natężenie odpływu z powierzchni 1 m^2; $q'_{s\,15}$ – średnie natężenie odpływu w kwadransie z powierzchni 1m^2; Q'_s – średnie natężenie odpływu z powierzchni 1 m^2 w całej sesji pomiarowej; $v'_{s\,15}$ – objętość odpływu z powierzchni 1 m^2 w kwadransie; V'_s – objętość odpływu z powierzchni 1 m^2 w całej sesji.

The singular surface runoff graph featured below, was assessed on the basis of the data obtained during the session on Sept. 15th, 2004 (total precipitation during the session equals 9.8 mm).



List of explanation: $q'_{s\,15}$ – mean runoff intensity from surface 1 m² during a time unit; **P** – precipitation; ***t*** – time; **A, ..., F** – selected road sections.
Oznaczenia: $q'_{s\,15}$ – średnie natężenie odpływu w kwadransie z powierzchni 1 m²; **P** – opad atmosferyczny; ***t*** – czas; **A, ..., F** – odcinki badawcze.

Fig. 3. Means of runoff intensity (for 15 minute time units) from elementary microplots of 1 m², in a chosen session
Rys. 3. Średnie (dla kwadransów) natężeń odpływu z powierzchni jednostkowych (1 m²) w wybranej sesji

SIMULATION OF QUANTITIES OF THE SURFACE RUNOFF FROM ROADS FOR THE DRAINAGE BASIN

Knowledge of the number and quality of roads in the drainage area as well as, the quantities of singular runoff events on the selected road sections measured for varied precipitation, allowed for performing simulated calculations of the surface runoff from all the roads in the drainage basin.

These simulations appeared plausible under the following assumptions:

– ground, technical and hydrological conditions existing on the examined road as well as the nearby grounds become the mean conditions for the entire drainage basin

– distribution of precipitation over the entire drainage area is uniform.

These calculations were carried out in three stages:

1) calculating a quotient of runoff measured on the selected sections to the assumed maximum amount of water that might run off (total precipitation in the area). The achieved results (rainfall rate of 2.1 mm and 9.8 mm) are indicated in Table 5,

2) calculating a quotient of runoff counted for all drainage area roads to the precipitation in the drainage area. This quantity is later referred to as an "index value of the road surface runoff" and it uses the "$q_{dr\,P}$" symbol. The overall view of the conditions in the drainage basin makes one reject the conditions observed in section D (large and constant seepage from the cut slope) and so they should be excluded from the description of the entire drainage basin. Thus the output data for further calculations does not contain the already mentioned section (compare Table 5). The results of calculations (rainfall rate of 2.1 mm and 9.8 mm) are presented in Table 6,

Table 5. Values of relations between the measured runoff and the precipitation over the selected road sections during two sessions
Tabela 5. Wartości stosunków zmierzonego odpływu do opadu na powierzchnię odcinków dróg dla dwóch sesji

Section Odcinek	Session Oct. 21th, 2003 – Sesja 21.10.2003			Session Sept. 15th, 2004 – Sesja 15.09.2004		
	P mm	V'_s $l \cdot m^{-2}$	$\frac{V'_s}{P}$ %	P mm	V'_s $l \cdot m^{-2}$	$\frac{V'_s}{P}$ %
A	2.1	0.161	7.7	9.8	11.142	113.7
B		0.067	3.2		4.763	48.6
C		0.499	23.8		8.863	90.4
D		6.501	309.6		22.333	227.9
E		0.106	5.1		4.710	48.1
F		0.051	2.4		5.555	56.7
Mean value from a total Średnia z całości			58.61			97.56
Mean value without section D Średnia bez odcinka D			8.42			71.49
Mean value without sections C and D Średnia bez odcinków C i D			4.58			66.76

List of explanations: **P** – precipitation; ***V'ₛ*** – surface runoff volume from the surface 1 m^2 during the complete session.
Oznaczenia: **P** – opad atmosferyczny, V'_s – objętość odpływu z powierzchni 1 m^2 w całej sesji.

Table 6. Index values of road surface runoff ($q_{dr\ P}$) and road runoff from the drainage area ($q_{dr\ Q}$) during two sessions
Tabela 6. Wartości indeksów drogowego odpływu powierzchniowego ($q_{dr\ P}$) oraz drogowego odpływu ze zlewni ($q_{dr\ Q}$) dla dwóch sesji

Width of a road Szerokość drogi m	P mm	Quotient of the precipitation volume on the roads' surface to the rainfall volume on the surface of the entire drainage area Stosunek objętości opadu na powierzchnię dróg do opadu na powierzchnię zlewni %	Mean quotient of the runoff volume from roads to the precipitation on the roads' surface Uśredniony stosunek objętości spływu po drogach do opadu na powierzchnię dróg %	Calculated volume of water running off from roads in the entire drainage area Obliczona objętość wody spływającej po drogach w całej zlewni l	Quotient of the calculated volume of water running off from roads in the drainage basin to the volume of precipitation in the drainage basin Stosunek obliczonej objętości wody spływającej po drogach w zlewni do objętości opadu w zlewni %	Runoff from the drainage basin during a session Odpływ ze zlewni w czasie trwania sesji l	Quotient of the calculated runoff value on the roads in the drainage basin to the runoff volume in he drainage basin Stosunek obliczonej objętości spływu po drogach w zlewni do objętości odpływu ze zlewni %
4.5	2.1	0.53	66.00*	12 224.5	$q_{dr\ P}$ = 0.42	164 332.5	$q_{dr\ Q}$ = 8.92
3		0.65	8.40	1 937.2			
2		0.17	8.40	490.1			
4.5	9.8	0.53	66.00*	57 047.8	$q_{dr\ P}$ = 0.93	153 014.6	$q_{dr\ Q}$ = 100.13
3		0.65	71.49	76 758.0			
2		0.17	71.49	19 420.7			

List of explanations: **P** – precipitation. *Value accepted with regard to the type of road pavement.
Oznaczenia: **P** – opad atmosferyczny. *Wartość przyjęta ze względu na rodzaj nawierzchni.

3) calculating a quotient of runoff counted for all drainage area roads to the runoff from the drainage basin. This quantity is later referred to as an “index value of the road runoff from the drainage area”, and it uses the symbol “$q_{dr\ Q}$”. The results of calculations (rainfall rate of 2.1 mm and 9.8 mm) are featured in Table 6.

RESULTS AND CONCLUSIONS

The elaborated methods of measuring the amount of surface runoff from roads as well as its intensity allows for a detailed quantity examination of this element which is an element of the drainage area water balance, as well as for indicating the importance of this frequently encountered in literature problem.

The key principles of the method application are as follows: selection of road sections representative of the whole drainage area, installing open top culverts of a wide cross section in order to record the entire runoff, careful selection of a site to place a pluviometer so that its indications may extrapolate over the entire drainage area (a small drainage area improves greatly the quality of extrapolation), careful examination of geodetic parameters of the selected road sections, accurate performance and recording of individual runoff measurements as well as recording the exact time the following proceedings took place in.

In spite of a relatively short measurement interval, runoff intensity values measured successively indicate the great diversity, which leads to a conclusion that the process is dynamic. Every intensity fluctuation is reflected in runoff intensity. Such reaction may be observed only after some time has passed from the beginning of rainfall (about 30-45 min), which results from many factors including saturation of the pavement and main body of a road, permeability of the pavement soil, intensity of precipitation, road protection provided by tree crowns and, consequently, interception of precipitation as well as needles, twigs and undulations of the road pavement which are the direct cause of puddles.

Measurement under the relatively stable conditions allow for a numerical specification of the examined phenomenon. Obviously, the achieved results must not be immediately transferred to the other drainage areas as this process involves a greater number of regulating factors, which are unique for every drainage area. The results contained in the present paper allow one to notice the importance of the discussed problem under certain conditions. Having converted them with reference to the entire drainage area they are as follows: for the rainfall rate of 2.1 mm $q_{dr\ P}$ = 0.42%, $q_{dr\ Q}$ = 8.92% and for the rainfall rate of 9.8 mm $q_{dr\ P}$ = 0.93%, $q_{dr\ Q}$ = 100.13%. One must bear in mind, however, that summer and autumn in both 2003 and 2004 were deficient in rainfall, which resulted in a low water level in the watercourse draining the drainage area. Thus index values for the road runoff in the drainage area ($q_{dr\ Q}$) are high whereas for medium and low stream levels they will be relatively lower.

It cannot be forgotten that the above mentioned calculations of the runoff volume from the drainage area roads ($q_{dr\ Q}$) are compared to the runoff within the drainage area, both at the same time. Therefore they are not referred to the runoff which consisted in the rainfall evoking the measured runoff. According to this statement index values $q_{dr\ Q}$ are conditioned on precipitation in the period preceding a measurement, which serves as an unfavorable circumstance for their interpretation. The author of this paper suggests assuming this value as a characteristic feature of a given drainage basin, in a momentary stage of water balance components system.

To sum up, it must be mentioned that:

1. The methodology of measuring surface runoff applied in the research seems appropriate. Moreover the results it brings are fully convincing.

2. Having converted the achieved results into unitary values (those referring to a surface unit of the area runoff was in) they now constitute the initial values for calculating the index values defined in the present paper ($q_{dr\ P}$ and $q_{dr\ Q}$) and characterizing momentary stages of the drainage basin.

3. The volume of water running off the drainage area roads indicated in the paper, (and its comparison to precipitation and surface runoff) emphasizes the importance of this component of water balance in a discussion over the subject of retention and retarding water runoff from the drainage area. The importance of this component is even greater with low stream water levels and high precipitation.

4. Further research of the runoff from roads is, nevertheless, recommended as it leads to a more complete characterization of a drainage area, e.g. its analysis on the basis of a sequence of index values referring to different flume filling stages.

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ODPŁYW WODY PO LEŚNYCH DROGACH STOKOWYCH

Streszczenie. W opracowaniu poruszany jest problem odpływu powierzchniowego wody z leśnych gruntowych dróg stokowych. W lasach Beskidu Śląskiego, w zlewni całkowicie zalesionej, wybrano odcinki dróg, na których założono wodospusty i mierzono ilości spływającej wody. Przedstawiona jest metodyka pomiaru, cechy zlewni i wybranych odcinków drogi, wyniki pomiaru odpływu po powierzchni z wybranych odcinków dróg, a także wyniki symulacyjnego wyliczenia stosunku wielkości odpływu powierzchniowego z dróg w zlewni do opadu w zlewni ($q_{dr\ P}$) oraz stosunku wielkości odpływu powierzchniowego z dróg w zlewni do odpływu ze zlewni ($q_{dr\ Q}$). Dla opadu 2,1 mm uzyskano: $q_{dr\ P}$ = 0,42%, $q_{dr\ Q}$ = 8,92%, zaś dla opadu 9,8 mm $q_{dr\ P}$ = 0,93% oraz $q_{dr\ Q}$ = 100,13%.

Słowa kluczowe: odpływ powierzchniowy, leśne drogi stokowe, zlewnia

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