Survey of Efficiency of Erosion and Flood Control Measures at the Němčický Stream

Jana UHLÍŘOVÁ

Department for Land Use Planning, Research Institute for Soil and Water Conservation, Brno, Czech Republic

Abstract: The article presents the initial part of the research of the efficiency of erosion and flood control measures designed in the experimental basin of the Němčický stream. A long term observation of discharges, rainfalls, and some water quality indicators was introduced at 2 experimental profiles. We have elaborated a study of the erosion threat for discovered areas, where the realisation of protective measures is necessary to reduce soil loss. Besides the erosion control, the sheet grassing contributes to a better water retention by the agricultural countryside. The efficiency of the designed measures ascertained by model evaluation proved that grassing of 49 ha of arable land (from total 183 ha) and the exclusion of erosive dangerous crops growing (on 21 ha) should decrease the centenary discharge by 18% and the amount of the transported suspended matter by 29%. The observation will continue after realisation of the erosion control measures and of a polder, which was designed for sufficiently effective flood protection, and the measurements will be compared with the preliminary and model values.

Keywords: sheet water erosion; flood; extreme rainfall – runoff events; protective measures; efficiency; complex land use adjustment; ERCN

Water soil erosion and water retention in the countryside are among the smartest problems of the recent world ecology. We have difficulty in the recognition, description, and quantification of erosion, and limited information of events that cause erosion (Boardman 2006).

The following protective measures are used, in the frame of the complex land use adjustment, to restrict the surface runoff and to increase the land retention:
- grassing (or forestation) of areas or belts,
- insertion of a road with infiltration belt or interceptive ditch,
- hedges with ridges and accompanying greenery,
- polders and retention reservoirs.

Protective measures are polyfunctional, with reference to the requirements of nature conservation and improvement of landscape aesthetics (Uhlířová 2004). Their parameters are dimensioned by the models of erosion soil lost and maximum outflows in a profile. Empiric data on the efficiency of soil and water protective arrangements are rare. For this reason, the measurements of rainfalls and discharges and of suspended matter content were introduced at some experimental

Supported by the Ministry of Agriculture of the Czech Republic, Project No. MZE 00027049.

catchments and areas of our institute. One of them is the Němčický stream.

The land use adjustment proceeds in the studied watershed of the Němčický stream and the erosion and flood control measures are projected here. Their realisation will be possible due to the change of ownership – the project will delimitate parcels for protective grassing, hedges, polders, etc. The realisation of the arrangements is expected very soon, because the area of the Moravian Karst was damaged by a strong flood in the spring of 2003 and as a result the inhabitants and authorities pay marked attention to the flood control. We used the opportunity to gauge extreme rainfall – runoff events before and after the realisation of the protective arrangements.

MATERIALS AND METHODS

The experimental basin of the Němčický stream is situated on the northern border of the Moravian Karst, north from Brno. The relief is shaped by gently rugged, long, soft slopes of the Drahanská highlands. The average elevation is 606 m a.s.l. Climatic conditions are slightly warm, slightly wet, characterised by the annual average rainfall total of 652 mm and the average air temperature 6°C.

The geological base is predominantly formed by culm greywacke. A smaller part of the area studied area lies on acid rocks from the granite group. Cambisols, Stagno-gleyic Luvisols, and Planosols (by the WRB soil classification) have evolved on this ground. The soles of the stream valleys are covered with Eutric Gleysols on the deposited sediments. Soils are sandy-loamy and loamy.

Two Thomson's weirs were built on the main stream near the designated polder. One of them (N2) is situated above the maximal polder backwater zone and the second one below the projected polder dam (N1). The basin area closed in profile N1 is 352 ha, where arable land predominates (183 ha), forest covers 124 ha and grassland only 10 ha. The ultrasonic probes at both profiles gauge the water level every 10 minutes and compute the discharge rate. Rainfalls are observed at the meteorological tower of Mendel's Agricultural and Silvicultural University of Brno, which is situated on the border of the catchment. Water samples are taken through automatic samplers embedded in the banks. The samples from the rising flood waves are analysed for suspended sediment, nitrate, and phosphate contents. The results are interpreted in time and in the relations to the actual natural and anthropic conditions.

The study of erosion and flood control was elaborated for the Němčický experimental basin (Podhrázská & Uhlířová 2005). The sheet erosion threat was analysed by the universal equation (USLE), according to the methodology (Janeček *et al.* 2005), with the use of modern GIS technologies (Warren *et al.* 2005). The average annual soil loss, calculated for runoff lines, was compared with the limits (Tables 1, 2 – selected lines with the limit excess). The localisation of protective grassing was made with regard to the erosion threat and the categorisation of potential soil infiltration capacity (Janglová *et al.* 2003; Uhlířová 2005).

For the erosion threat analysis twenty runoff lines were drawn on the base of contour lines in the topographic map 1:5000 for the model basin. The lines are localised equally to represent the slant blocks of agricultural land (Figure 1). By the calculation of the long-term yearly soil losses according to the USLE (Janeček *et al.* 2005) and by the comparison with the limits we found out that 9 lines exceed the admissible washing-off limits. Table 1 includes selected lines with the overstepped limit of the water erosion soil loss.

From the areal point of view, we can say that roughly 50% arable land is potentially threatened by water erosion. The project of the erosion control measures was elaborated for these risk areas (Figure 2). Grassing was designed of the heel of slope in the block represented by line No. 3. The grassing verges into the protective grassing of the thalweg. This thalweg is one of the Němčický stream source regions and its protection against areal agricultural pollution is very important in the light of the surface water quality preservation or improvement. Line No. 7 is situated on a sharp slope above the Němčický stream. The whole slope is covered by shallow soil and it is advisable to grass this slope in the light of the soil protection from erosion and the water protection from pollution by accelerated infiltration. There is farming on a very long and plane slope in the northwest part of

Table 1. Erosive washing-off – present state

Line No.	3	7	6	10	11	12	13	15	16	17	18	19	20
l 1 (m)	140.58	132.02	207.32	98.22	79.71	112.58	182.65	122.50	184.70	77.55	106.73	56.19	35.27
h 1 (m)	6.00	13.50	13.00	4.00	4.00	8.00	10.00	7.00	11.00	4.00	9.00	3.00	5.00
K1	0.30	0.30	0.34	0.30	0.30	0.49	0.49	0.49	0.49	0.48	0.30	0.34	0.49
c1	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
s 1 (%)	4.27	10.23	6.27	4.07	5.02	7.11	5.47	5.71	5.96	5.16	8.43	5.34	14.18
S 1	0.17	1.04	0.16	0.09	0.04	0.11	0.13	0.16	0.21	0.06	0.08	0.06	0.19
l 2 (m)	94.95	13.60	118.57	64.36	219.58	82.16	69.15	95.70	166.79	99.56	104.36	85.62	73.65
h 2 (m)	6.00	1.00	10.00	4.00	14.00	7.00	8.00	8.00	11.00	3.50	6.00	8.00	7.00
K2	0.30	0.30	0.55	0.30	0.30	0.49	0.49	0.49	0.49	0.48	0.30	0.34	0.39
c2	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
s 2 (%)	6.32	7.35	8.43	6.22	6.38	8.52	11.57	8.36	6.60	3.52	5.75	9.34	9.50
S 2	0.33	0.10	0.24	0.17	0.31	0.18	0.23	0.37	0.40	0.09	0.09	0.38	0.47
l 3 (m)			168.43	80.96	130.35	79.66	167.52	57.95		135.73	93.27	87.74	57.78
h 3 (m)			7.00	4.00	6.00	8.00	13.00	4.00		3.00	6.00	3.00	3.00
K3			0.55	0.30	0.30	0.49	0.49	0.49		0.50	0.50	0.50	0.39
c3			0.200	0.200	0.200	0.200	0.200	0.200		0.200	0.200	0.200	0.200
s 3 (%)	0.00	0.00	4.16	4.94	4.60	10.04	7.76	6.90	0.00	2.21	6.43	3.42	5.19
S 3	0.00	0.00	0.17	0.20	0.17	0.27	0.38	0.21	0.00	0.11	0.12	0.15	0.23
l 4 (m)						121.87	36.66				215.72		
h 4 (m)						9.00	1.00				9.00		
K4						0.39	0.39				0.50		
c4						0.200	0.200				0.200		
s 4 (%)	0.00	0.00	0.00	0.00	0.00	7.38	2.73	0.00	0.00	0.00	4.17	0.00	0.00
S 4	0.00	0.00	0.00	0.00	0.00	0.32	0.03	0.00	0.00	0.00	0.20	0.00	0.00
Sa li (m)	235.53	145.62	494.32	243.54	429.64	396.27	455.98	276.15	351.49	312.84	520.08	229.55	166.70
Sa hi (m)	12.00	14.50	30.00	12.00	24.00	32.00	32.00	19.00	22.00	10.50	30.00	14.00	15.00
s (%)	5.09	9.96	6.07	4.93	5.59	8.08	7.02	6.88	6.26	3.36	5.77	6.10	9.00
R	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15
L	3.26	2.57	4.73	2.61	4.41	4.23	4.54	3.53	3.99	2.88	4.85	3.22	2.74
S	0.50	1.14	0.57	0.47	0.52	0.88	0.77	0.73	0.62	0.26	0.49	0.60	0.88
K	0.30	0.30	0.46	0.30	0.30	0.46	0.48	0.49	0.49	0.49	0.42	0.40	0.41
Shape	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
P	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
G (t/ha/rok)	2.28	4.08	5.79	1.70	3.17	7.90	7.76	5.84	5.57	1.71	4.64	3.56	4.61
Limit	1	1	10	1	4	1	1	4	4	4	4	1	4

Table 2. Erosive washing-off – with designed measures

Line No.	3	7	6	10	11	12	13	15	16	17	18	19	20
l 1 (m)	124.14	132.02	29.08	98.22	79.71	112.58	182.65	122.50	184.70	77.55	106.73	56.19	35.27
h 1 (m)	4.00	13.50	1.00	4.00	4.00	8.00	10.00	7.00	11.00	4.00	9.00	3.00	5.00
K1	0.30	0.30	0.34	0.30	0.30	0.49	0.49	0.49	0.49	0.48	0.30	0.34	0.49
c1	0.120	0.005	0.005	0.120	0.120	0.005	0.005	0.120	0.120	0.200	0.200	0.005	0.005
s 1 (%)	3.22	10.23	3.44	4.07	5.02	7.11	5.47	5.71	5.96	5.16	8.43	5.34	14.18
S 1	0.11	1.04	0.00	0.09	0.04	0.11	0.13	0.16	0.21	0.06	0.08	0.06	0.19
l 2 (m)	111.39	13.60	178.23	64.36	219.58	82.16	69.15	95.70	123.58	99.56	104.36	85.62	31.73
h 2 (m)	8.00	1.00	12.00	4.00	14.00	7.00	8.00	8.00	9.00	3.50	6.00	8.00	3.00
K2	0.30	0.30	0.34	0.30	0.30	0.49	0.49	0.49	0.49	0.48	0.30	0.34	0.39
c2	0.005	0.005	0.200	0.120	0.120	0.005	0.005	0.120	0.120	0.200	0.200	0.005	0.005
s 2 (%)	7.18	7.35	6.73	6.22	6.38	8.52	11.57	8.36	7.28	3.52	5.75	9.34	9.45
S 2	0.45	0.10	0.17	0.17	0.31	0.18	0.23	0.37	0.33	0.09	0.09	0.38	0.17
l 3 (m)			118.57	80.96	130.35	48.63	167.52	57.95	43.22	61.44	93.27	87.74	41.92
h 3 (m)			10.00	4.00	6.00	5.00	13.00	4.00	3.00	1.50	6.00	3.00	4.00
K3			0.55	0.30	0.30	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.39
c3			0.200	0.120	0.120	0.005	0.005	0.120	0.005	0.200	0.200	0.005	0.005
s 3 (%)	0.00	0.00	8.43	4.94	4.60	10.28	7.76	6.90	6.94	2.44	6.43	3.42	9.54
S 3	0.00	0.00	0.24	0.20	0.17	0.17	0.38	0.21	0.12	0.05	0.12	0.15	0.30
l 4 (m)			168.43			31.03	36.66			74.30	126.97		57.78
h 4 (m)			7.00			3.00	1.00			1.50	6.00		3.00
K4			0.55			0.49	0.39			0.50	0.50		0.39
c4			0.200			0.005	0.005			0.005	0.200		0.005
s 4 (%)	0.00	0.00	4.16	0.00	0.00	9.67	2.73	0.00	0.00	2.02	4.73	0.00	5.19
S 4	0.00	0.00	0.17	0.00	0.00	0.11	0.03	0.00	0.00	0.06	0.13	0.00	0.23
l 5 (m)						121.87					88.75		
h 5 (m)						9.00					3.00		
K5						0.39					0.50		
c5						0.005					0.005		
s 5 (%)	0.00	0.00	0.00	0.00	0.00	7.38	0.00	0.00	0.00	0.00	3.38	0.00	0.00
S 5	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.07	0.00	0.00

Table 2 to be continued

Line No.	3	7	6	10	11	12	13	15	16	17	18	19	20
Sa li (m)	235.53	145.62	494.31	243.54	429.64	396.27	455.98	276.15	351.50	312.85	520.08	229.55	166.70
Sa hi (m)	12.00	14.50	30.00	12.00	24.00	32.00	32.00	19.00	23.00	10.50	30.00	14.00	15.00
s (%)	5.09	9.96	6.07	4.93	5.59	8.08	7.02	6.88	6.54	3.36	5.77	6.10	9.00
R	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15
L	3.26	2.57	4.73	2.61	4.41	4.23	4.54	3.53	3.99	2.88	4.85	3.22	2.74
S	0.56	1.14	0.58	0.47	0.52	0.88	0.77	0.73	0.67	0.26	0.49	0.60	0.88
K	0.30	0.30	0.46	0.30	0.30	0.46	0.48	0.49	0.49	0.49	0.42	0.40	0.41
Shape	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	0.066	0.005	0.189	0.120	0.120	0.049	0.047	0.120	0.106	0.154	0.167	0.076	0.074
P	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
G (t/ha/rok)	0.83	0.10	5.56	1.02	1.90	0.20	0.19	3.50	3.18	1.31	3.86	0.09	0.12
Limit	1	1	10	1	4	1	1	4	4	4	4	1	4
Measure	B	C	C	A	A	C	C	A	A & C	B	B	C	C

A – exclusion of growing of erosive – danger crops; B – grassed thalweg; C – sheet grassing

the basin, in the local track of Klučeniny (line No. 6). The highest part of the slope, below the forest, is covered by shallow soil. Although the soil loss limit was not exceeded, according to the calculation (G = 5.79 t/h/year, limit 10 t/h/year), local grassing was designed there for the undesirable matters (nutrients, pollutants) transport retardation through the shallow soil profile to the Němčický stream source area (according to methodical principles by Janglová *et al.* 2003). The soil water erosion threat is an areal problem mostly in the southern part of the watershed, where very long blocks of arable soil fall towards the stream valley. Here, shallow soils also occur locally. The situation in the block represented by lines 10 and 11 can be sufficiently solved by the exclusion of erosive dangerous crops growing (maize, root-crops, etc.). There is a very sharp slope with shallow soil in the section between the road and the stream (lines 12, 13, and 20). The average annual soil losses would be reduced below the admissible value by sheet grassing. Lines No. 15 and 16 are situated on the slope above the planned polder. Here, the exclusion was designed of erosive dangerous crops growing and, in addition, grassing of the slope heel is needed, where the movement of the polder water line is presumed. The water level spreading is supposed to take place beyond the road. Grassing of the thalweg was designed (lines 17 and 18), that is essential from the erosion control point of view in this location. The right slope above the polder (line 19) requires sheet grassing. The erosion control measures were designed as to be able to decrease the annual soil loss to or below the admissible limits over the whole agricultural land in the basin.

Software ERCN was used for maximal discharges calculation which is based on the CN method (curve numbers). The distinction of the method is that it takes into account natural and anthropic characteristics of the drainage area. The basic input of the method of CN curves is the distribution of the precipitation amount at a definite time, providing its space uniform distribution on the catchment area. The volume of the rainfall is transformed into the outflow volume with the help of numbers of outfall curves; the

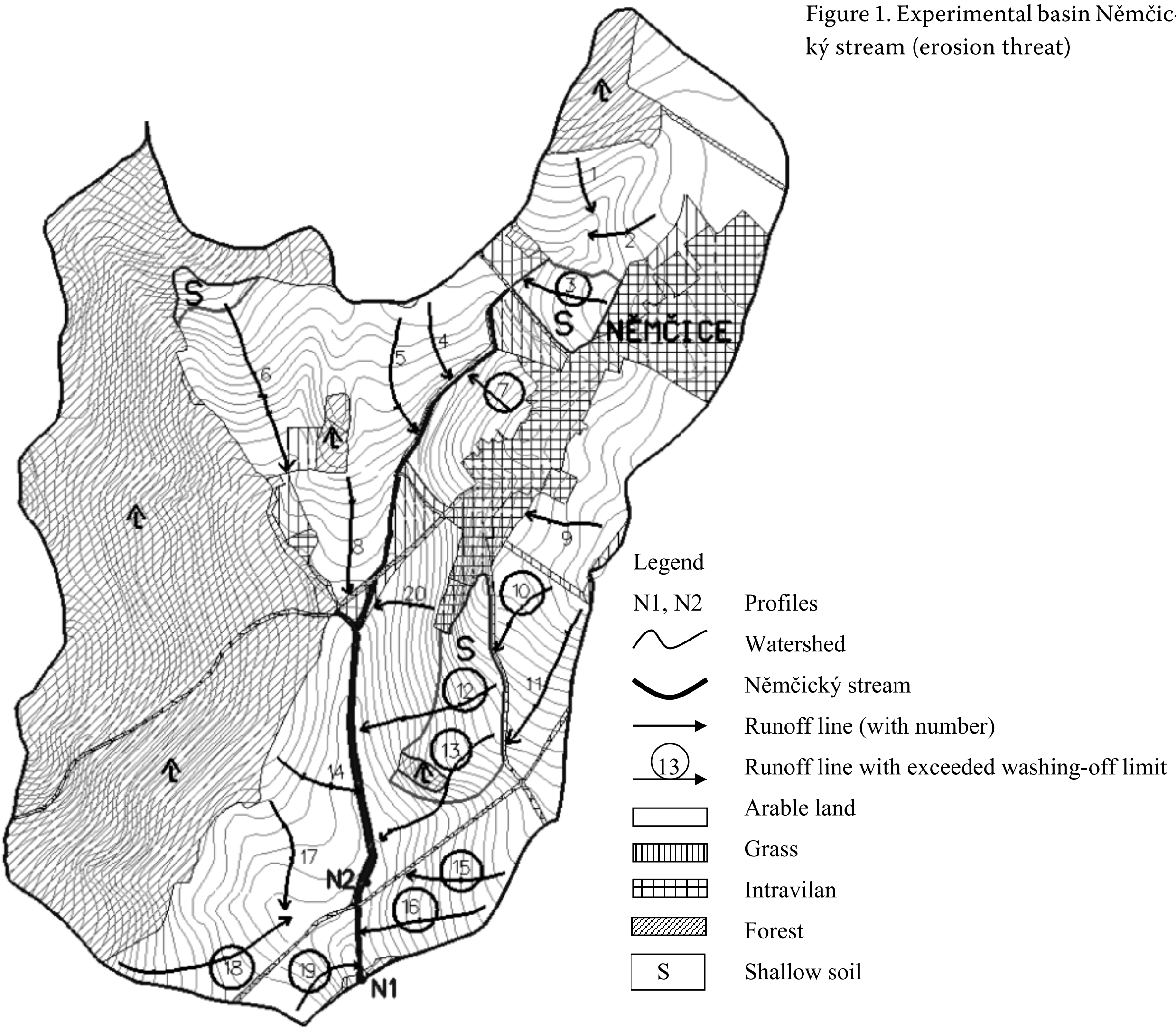

Figure 1. Experimental basin Němčický stream (erosion threat)

time of the outflow concentration is calculated. The method by Williams and Berndt was used for modelling the transport of insoluble matters. Table 3 presents the input data and results. Long term meteorological characteristics were taken from the station Sloup, 5 km from Němčice.

RESULTS AND DISCUSSION

The design of the erosion and flood control measures is visible in Figure 2, and the calculation of the designed measures efficiency (USLE) is included in Table 2. About 50% of the agricultural land is threatened by surface erosion. The analysis by means of the universal equation proved that it is necessary to grass 49 ha of arable land and to avoid the growing of erosive danger crops on additional 21 ha (Figure 2) in order to achieve the soil washing-off decrease below the admissible limits. The design of grassing was focused on steep slopes, localities with shallow soils and some alluviums. Both types of the erosion control measures are predominantly located at the southeast part of the experimental basin and near the polder. The measures were designed in compliance with the recommended methodology (Janeček *et al.* 2005). According to Wang *et al.* (2006), forestation is the best practice for the control of water runoff and soil erosion. But we have to consider the real conditions of Czech rural countryside and the demands for the agriculture production. So goal-directed grassing and proper farming are preferred in the design.

The efficiency of the intended erosion measures was modelled and the results for profile N1 are readable in the lower part of Table 3. According

Table 3. Centenary discharge and transport of suspended matter (profile N1)

Parameters	Present state	State after erosion control measures realization
Catchment area (ha)	351.8	351.8
Max. 24 hours rainfall total (mm)	84.8	84.8
Average length (m)	2871	2871
Average slant (%)	7.11	7.11
Factor K	0.43	0.43
Factor C	0.15	0.13
Average CN	74.08	71.50
Sheet runoff		
Length (m)	100	100
Roughness	0.24	0.24
Hydraulic slant (tgα)	0.025	0.025
2 years 24 hours rainfall (mm)	36.5	36.5
Time of concentration Tta (h)	0.84	0.84
Concentrated runoff		
Length (m)	748	748
Hydraulic slant (tgα)	0.037	0.037
Surface	unconsolidated	unconsolidated
Speed (m/s)	0.946	0.946
Time of concentration Ttb (h)	0.22	0.22
Trunk runoff		
Length (m)	1 361	1 361
Roughness	0.033	0.033
Hydraulic slant (tgα)	0.023	0.023
Speed (m/s)	3.087	3.087
Profile surface (m^2)	2.72	2.72
Wetted perimeter (m)	4.94	4.94
Hydraulic radius (m)	0.551	0.551
Time of concentration Ttc	0.122	0.122
Time of total concentration Tc	1.182	1.182
Direct runoff (mm)	28.82	24.38
O_{100} (m^3)	101 376	85 774
Q_{100} (m^3/s)	11.95	9.84
G (t)	15 866	11 231

O_{100} – volume of centenary discharge; Q_{100} – centenary discharge; G – transport of suspended matter from the centenary rainfall to the calculations, the measures decrease the annual soil loss below the admissible limits for the agricultural land in the basin studied. Grassing and proper farming are also able to decrease the outfall (by 18%) and transport of suspended matter (by 29%) during centenary storm, but not sufficiently. It is not possible to grass or afforest a large area, because we have to respect the conditions for sustainable farming. During extreme rainfall – runoff events, grassing or a proper farming system cannot provide a sufficient protection for the stream and basin from the flood harmful effects. Technical line and sheet devices have a higher influence on the water drain and retention and the flood wave transformation. Therefore, a technical flood control arrangement (reservoir) is needful at the experimental basin Němčický stream.

The designed dam of the polder (Figure 2) should be 5 m high and 206 m long in the crest. The embankment will be homogenous, from clay, covered by gravel and, on the water side, by stones. The armoured concrete construction of the surplusing and diversion combined works will have maximum height of 6.3 m. The object will be founded at the heel of the left bank, to the disintegrated culm greywacke. An eductive pipe (400 mm) will be further installed to the baseplate. The feed shaft will be instrumental to the manipulation with waters in the standing space. The bar screen is designed before the input to the outlet, which prevents its clogging by shingle at flood. The surplusing and overfall arrangement includes the incoming and outlet channels, whose part below the slippage has an increased roughness for the water energy

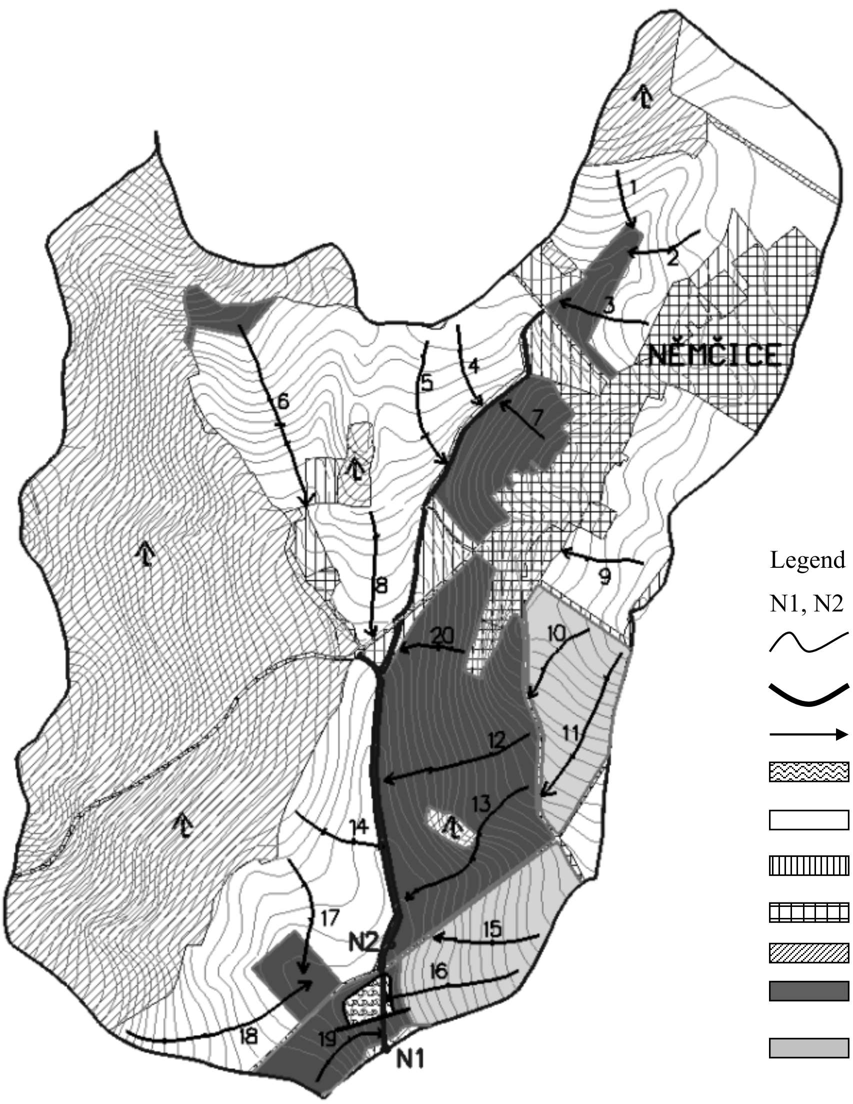

Figure 2. Design of erosion and flood control measures

inhibition. The retention space (62 000 m^3) was derived from the hydrograph, elaborated by the Czech hydro-meteorological institute for the centenary outflow. The standing (constant) water space (4000 m^3) was designed for ecological reasons, to create littoral belt and increase biodiversity and genetic potential of the territory.

Preliminary results of gauging

Table 4 summarises extreme discharges and contents of soluble and insoluble matter transported by rising flood water as measured during the years 2005 and 2006 at the experimental profiles N1 and N2 on the Němčický stream. The excess limit is about 12 l/s, when automatic sampler starts to work. It is possible to see two important flood cases. The storm on 23.5.2005 was stronger in Bohemian highlands and its influence was not so expressive in the Němčický stream basin. The highest rainfall and outflow in the year 2005 was registered on 12.9. Maximum discharge reached 1121.8 l/s in the lower closure profile N1 (N2 lays 270 m above N1 on the stream and culminations are generally little lower). The flow transported 11 550 mg/l of suspension in water during the flood culmination on N1.

The snow melting caused a discharge of 1153 l/s at N1 on 29.3.2006. Water transported high concentrations of insoluble matter and nitrates. On 7.8.2006, we gauged the second significant event with the culmination of 960 l/s at N1. The content of suspended particles in water was 1247 mg/l.

The concentrations of nitrates are not the main problem – they match the 3rd class according to the Czech technical standard for the quality of surface water. The stream is more polluted by phosphates due to the municipal outfalls from the near village. The pollution by suspended particles rises manifold during flood situations. This phenomenon is caused by the swirling of the bottom sediments, bottom and bank erosion, and by erosion flushing of soil particles mostly from farming fields.

Table 4. Values measured during strong rainfall – runoff events

Date	Profile	Q (l/s)	Causal rainfall total (mm)	Analyses		
				NO^{3-} (mg/l)	PO_4^{3-} (mg/l)	susp. matter (mg/l)
23.5.2005	N1	161.1	53	19.5	2.31	1 553
	N2	163.0		19.2	2.00	1 262
31.5.2005	N1	110.0	20	25.1	1.97	208
	N2	100.4		11.0	4.16	270
3.8.2005	N1	113.1	43	11.2	2.62	508
	N2	107.3		14.3	3.47	27
15.8.2005	N1	96.3	19	11.0	2.30	48
	N2	94.6		9.8	2.74	98
12.9.2005	N1	1 121.8	77	5.6	0.88	11 550
	N2	760.0		10.8	1.52	4 213
29.3.2006	N1	1 153.0	snow melting	49.2	0.69	1 284
	N2	1 110.3		55.5	0.74	1 634
1.5.2006	N1	377.5	61	58	0.34	658
	N2	281.5		56	0.42	735
7.8.2006	N1	959.9	199	21.4	0.91	1 247
	N2	704.7		14.5	1.67	669
Average background		12		14	2.0	35

Q – peak discharge

If we consider the Dostal´s *et al.* (2006) results, we can say that approximately 40% of the annual soil losses enter the water courses. It is very difficult to separate the suspended load to eroded soil particles and turbid bottom sediments and material of the banks. According to some studies, the sediment from sheet and rill erosion has a coarser texture than the fine sediment from channel erosion (Ouyang & Bartholic 2006). Collins *et al.* (1997) made a reconstruction of the sediment provenance in the upper Severn catchment. They estimated that the canal bank erosion contribution to the suspended matter is from 3 to 25%. The stabilised bottom and banks of the Němčický stream enable us to estimate that most of the material transported during heavy storms enters the surface runoff. Bača (2006) reported that the suspended sediment concentration during the base flow is constant and he uses the concentration from the beginning of the flood wave. Thus it is possible to calculate the concentration associated with the direct runoff and to compare different rainfall – runoff events. But he calls attention to the hydrograph separation problems. A number of authors acknowledged large spatial and temporal variations in the suspended sediment transport in water flows (e.g. Evans & Gibson 2006). Because the data from this study cover only 2 years, the conclusions may not be representative for longer term averages. According to Jambor (2000), the erosion events are more frequently caused by heavy rains than by snow melting, and geomorphic effectiveness of snowmelt events is lower. We registered strong snow melting in the beginning of the year 2005, but the gauging device was not yet in operation. The snow melting on 29.3.2006 is, as for discharges, comparable with the events on 12.9.2005 and 7.8.2006. The transported amount of suspended matter was lower than on 12.9.2005 (lack of vegetative cover) and similar to 7.8.2006 (good cover). The results obtained are comparable to the results of the suspended sediment research in other small basins in central Europe (e.g. Bača 2006; Hejduk *et al.* 2006).

CONCLUSIONS

The results presented survey the rainfall and runoff conditions in the experimental basin before the realisation of the erosion and flood control measures. The necessity of soil and water protection and of water retention increase was proved, in connection with two risk situations that occurred last year. We suppose that the projected polder will be able to hold centenary discharge and to leak at the most 4000 l/s during a flood. The modelled efficiency showed that the erosion control measures, projected predominantly on the risk slopes in the catchment, should decrease the centenary discharge by 18% and the amount of the transported suspended matter by 29% (Table 3). The observation will continue after the realisation of the erosion control measures and the polder, and the results will be compared with the preliminary and model values.

Meanwhile, only two-year analysis shows the trend of a higher input of nitrates to water in the spring season. But our main task is the survey of the suspended matter transport and the influence of the protective measures on its restriction. There exists a readable protective effect of the vegetative cover. In the year 2006, grass growth was introduced on the most erosive slope (represented by lines 12, 13 and 20). In the following years, we suppose to lower the suspended matter concentration in the stream. The main goal of the whole project is to prepare the methodology for designing and evaluating erosion and flood control measures in the frame of the complex land use adjustment.

References

Bača P. (2006): Factors controlling suspended sediment dynamics during rainfall – runoff events in a small basin. Journal of Hydrology and Hydromechnics, **54**: 43–57. (in Slovak)

Boardman J. (2006): Soil erosion science: Reflections on the limitations of current approaches. Catena, **68**: 73–86.

Collins A.L., Walling D.E., Leeks G.J.L. (1997): Sediment sources in the Upper Severn catchment: a fingerprinting approach. Hydrology and Earth System Sciences, **1**: 509–521.

Dostal T. *et al.* (2006): Czech Republic. In: Boardman J., Poesen J. (ed.): Soil Erosion in Europe. John Wiley & Sons Ltd., Chichester, 107–116.

Evans D.J., Gibson C.E. (2006): Sediment in the river Bush, Northern Ireland: Transport, sources and management implications. In: Owens P.N., Collins A.J. (ed.): Soil Erosion and Sediment Redistribution in River Catchments. CABI, Oxfordshire.

Hejduk L. *et al.* (2006): Suspended sediment transport during rainfall and snowmelt-rainfall floods in a small lowland catchment, central Poland. In: Owens P.N., Collins A.J. (ed.): Soil Erosion and Sediment Redistribution in River Catchments. CABI, Oxfordshire.

Jambor P. (2000): Water erosion pursuant to a season in the years 1990–2000. In: Proc. SSPLVV SAV Congr. SAV, VÚPOP, September 6–9, 2000, Zvolen, 49–54. (in Slovak)

Janeček M. *et al.* (2005): Agricultural Soil Erosion Control. 2nd Ed. ISV, Praha. (in Czech)

Janglová R., Kvítek T., Novák P. (2003): Soil infiltration capacity categorization on the basis of the geoinformatic elaboration of soil surveys data. Soil and Water, **2**: 61–81. (in Czech)

Ouyang D., Bartholic J. (2006): Predicting sediment delivery ratio in Saginaw Bay watershed. Michigan State University, Michigan. Available at http://www.iwr.msu.edu/~ouyangda/sdr/sag-sdr.htm.

Podhrázská J., Uhlířová J. (2005): Erosion and Flood Control Study in Model Areas. [Research Report.] VÚMOP, Praha. (in Czech)

Uhlířová J. (2004): Soil and water protection – principles and realizations. In: Soil Conservation in a Changing Europe. ESSC, May 25–28, 2004, Budapest, 293–295.

Uhlířová J. (2005): Integrated soil and water conservation in the catchment of Kopaninsky stream. Soil and Water, **4**: 106–109. (in Czech)

Wang E. *et al.* (2006): Predicting soil erosion for alternative land uses. Journal of Environmental Quality, **35**: 459–467.

Warren S.D. *et al.* (2005): Validation of a 3-D enhancement of the Universal Soil Loss Equation for prediction of soil erosion and sediment deposition. Catena, **64**: 281–296.

Received for publication January 15, 2007
Accepted after corrections June 7, 2007

Corresponding author:

Ing. Jana Uhlířová, Výzkumný ústav meliorací a ochrany půdy, v.v.i., oddělení pozemkových úprav,
Lidická 25/27, 602 00 Brno, Česká republika
tel.: + 420 541 126 281, fax: + 420 549 255 574, e-mail: uhlirova@vumopbrno.cz