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GIS AIDED EROSION RISK ANALYSES ON THE VODNO MOUNTAIN

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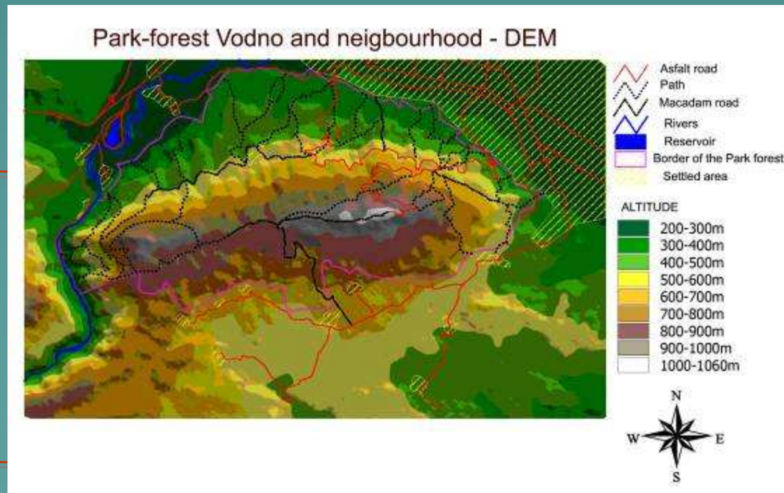


Background

- Erosion processes >>> damages:

- On site –

  soil losses;

  water loss,

  landscape deterioration

- Off site –

  torrential flash floods >> damages on houses and infrastructure,

  filling up reservoirs,

  mechanical and chemical pollution of the water

- **Risk** is a concept that denotes a potential negative impact to an asset or some characteristic of value that may arise from some present process or future event.

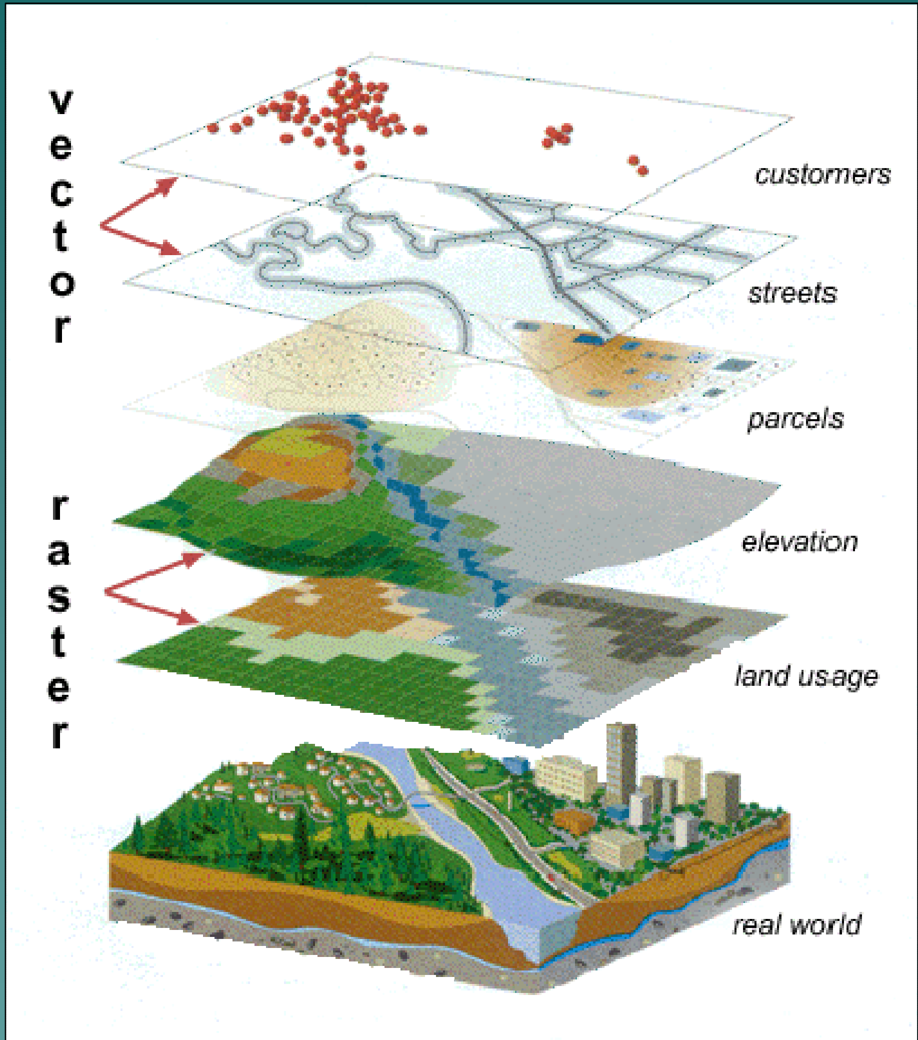
- In everyday usage, *risk* is often used synonymously with the probability of a known loss. Usually, the probability of that event and some assessment of its expected harm must be combined into a believable scenario (an outcome), which combines the set of risk, regret and reward probabilities into an expected value for that outcome.
- Paradoxically, a probable loss can be uncertain and relative in an individual event while having a certainty in the aggregate of multiple events.

- **Risk management** is the human activity which integrates
- risk recognition,
- risk assessment,
- developing strategies to manage it,
- mitigation of risk using managerial resources.

- The strategies include transferring the risk to another party, avoiding the risk, reducing the negative effect of the risk, and accepting some or all of the consequences of a particular risk.

- The GIS represents set of tools which can make the life easier to the user. GIS modeling presents an opportunity to automatise the process of production of output with standardized input and already set parameters.

- There have been several developed software packages which implement these algorithms into the spatio-digital environment related to erosion and torrent risk assesment as: (HEC-RAS, WEPP, ARC-hydrotools,, USLE, KINEROS…..).



Aims

- The aim of this study is:
- To create GIS-model for assessment erosion and torrential risk based on the methodologies of Gavrilovic

- Erosion Risk was assessed as:
- Actual risk (based on present situation)
- Potential risk (scenario was created for a hypothetic situation i.e. to back to the period before 50')

- Risk of torrents was assessed on the similar way but in this assessment the risk was estimated for the urban area

- The objectives of this study are:

- To recognize erosion and torrent risk
- To create basic numerical and graphical (GIS) dataset

- To assess the on site erosion risk using GIS
- To assess the torrential risk

Methodology

- The issue of soil erosion and torrent control has very crucial spatial extent. GIS systems encompass all the important tools for this purpose.
- The most used methodologies related to erosion and torrents are by Gavrilovic
- In this case study two main methods have been tested for applied GIS use:
  - Estimation of maximal water discharge - Q_{max}; (by Gavrilovic)
  - Estimation of erosion coefficient – Z - and transported sediment - G; (Erosion Potential Model by Gavrilovic)
  - Estimation of hydraulic conditions of the present drainage channel using Shaesy model for V

Estimation were carried out in actual and hypothetic situation

Estimation of water discharge

- $Q_{max} = A\ S_1\ S_2\ W\ (2gDF)^{0,5}$
- **Q_{max} – maximal water discharge m^3/s**
- **A** – catchment shape coefficient **A=0.195 * S/ L**

  S – catchment perimeter ; **L** – water course length
- **S_1** – permeability coefficient of the area
- **S_2** – vegetation cover coefficient
- **W –** retention of discharge in case of intensive rainfall or snow meltdown **$W = h (15 – 22h – 0.3 L^{0.5})$**
- **h –** amount of intensive rainfall,
- **$(2gDF)^{0.5}$** – energetic potential of the waters during intensive rainfall
- **g –** gravitational constant 9.81 (m/s^2)
- **D –** average height difference $D=N_{average} - N_{min}$
- **F –** catchment area

Estimation of sediment quantity

- $G = T\ H_{an}\ \pi\ Z^{1.5}\ F\ Rn$

- **G – mean annual quantity of transported material [m³/s]**
- **T** – temperature coefficient; T=(t / 10 + 0.1);
  t – annual average temperature;
- H_{an} – annual average sum of rainfall [mm]

- **π** = 3.14
- **Z** - Average erosion coefficient in the catchment
- **Rn** - retention coefficient of the catchment
- $Rn = (S * D)^{0.5} / (0.25 * (L + 10))$

Estimation of channel hydraulic capacities

- $Q = F * V$

- **F –** cross profile area – m^2
- V – mean water velocity m/s

- $V = K\ C\ (R\ J\ )^{\wedge 0,5}$

- K – torrential coefficient
- C – velocity coefficient by Basin
- R – hydraulic radius $R = F / O$
- J – bad slope

Dataset

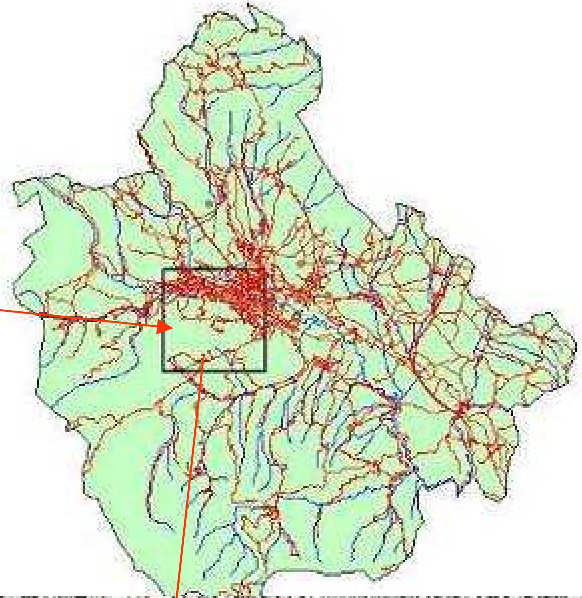
The dataset was comprised of:

- 1:25,000 topographic maps
- Land cover/use map, vector (1:50,000)
- Geology map, vector (1:100,000)
- Soil map,
- Torrential map
- Drainage map
- DEM (Digital Elevation Model), raster
- Climatic data, tabular data

- The Land cover/use extraction was based on the CORINE land cover classification and it was used for establishing the vegetation parameters. The land cover classes were extracted from Landsat ETM+ satellite imagery using **object oriented classification approach** and after it was updated with the method of photo-interpretation using Ikonos imagery.

- The DEM was with cell size of 80m. The accuracy of the DEM was checked using trigonometric points from the topographic maps which are claimed to have accuracy of 0.5m by the producer. There were 198 points taken for accuracy and it yielded quite good results, the RMSE (Root Mean Square Error) was 18.9m.

Study area

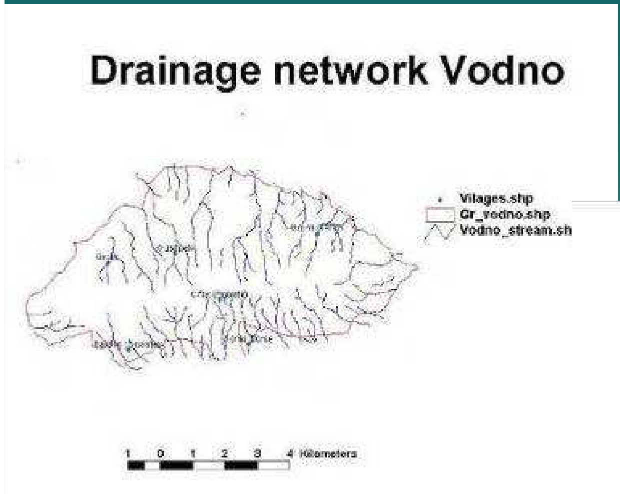


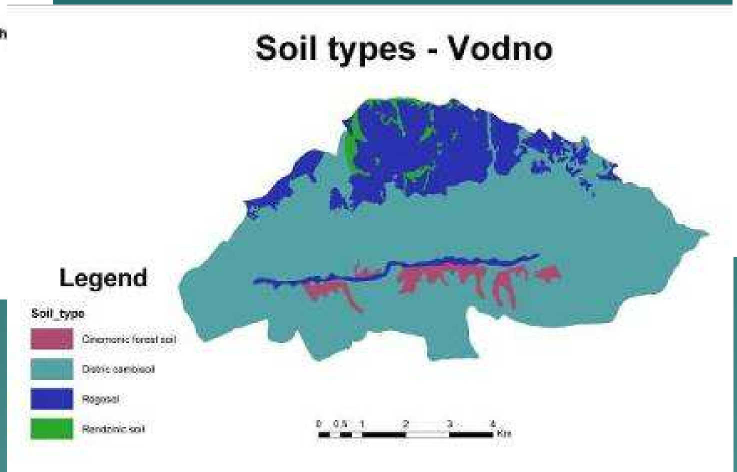
GORNOVODNJANSKI POROJ

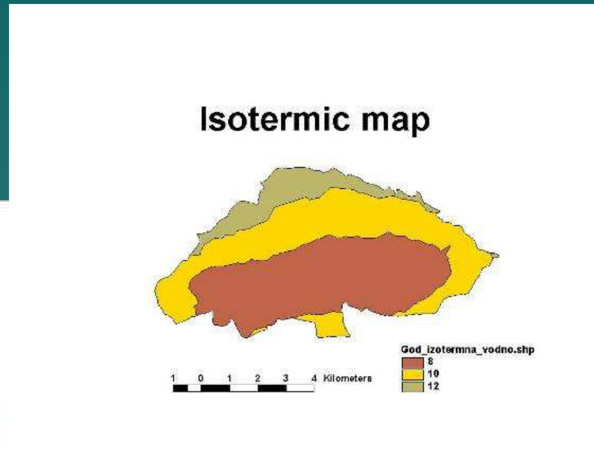
Why this torrent ?

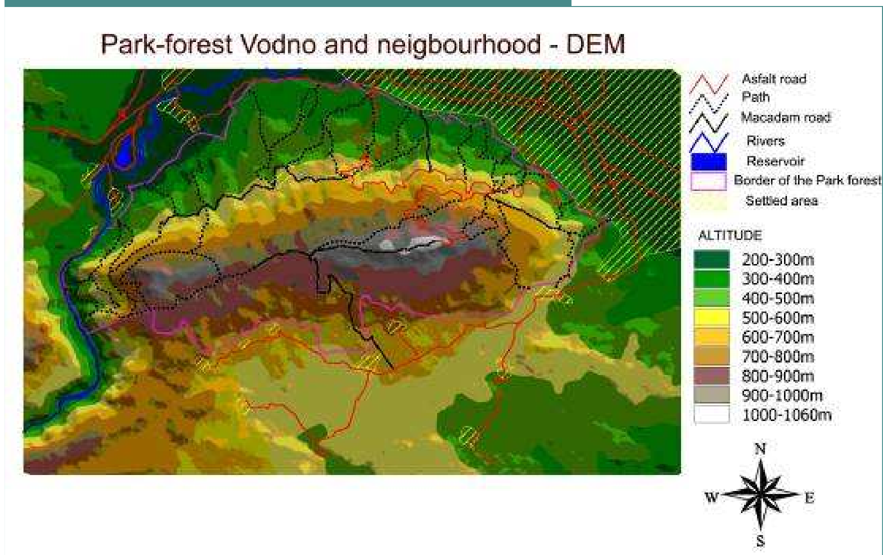
- **Date : 1.06.1951 – time: about 17.oo**
- **High intensity precipitation result in catastrophic disaster - flash flood**
- **1 guilty, large number of injured**
- **25 000 m^3 sedimented material around "Stara rampa" (Old gate) ,**
- **Damaged infrastructure and houses**
- **Flooded and covered with sediment yards**

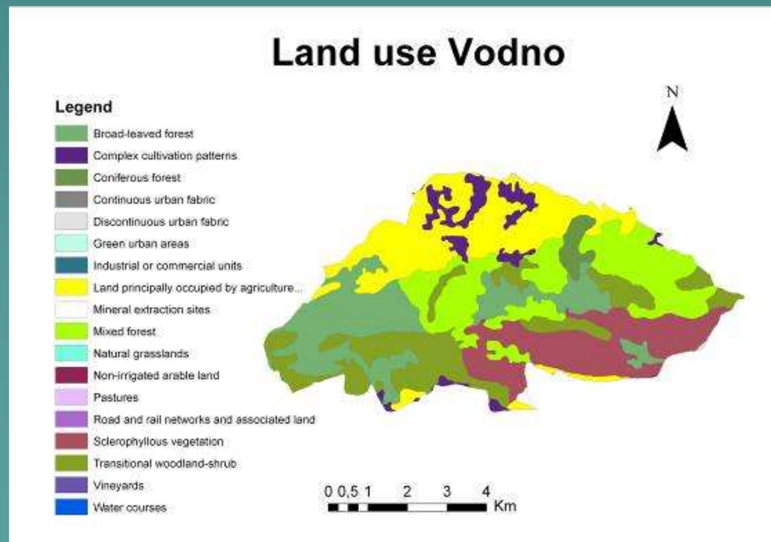
Basic dataset











The main hydrographical characteristics are as follows:

- catchment area - F = 3.27 km^2,
- Highest altitude - Niz = 1066 m. a.s.l.,
- Profile altitude – Nvl = 295 m.a.s.l.,
- mean catchment altitude – Nsr = 604 masl.
- stream length - L = 3.137 km,
- catchment perimeter - O (S) = 7.621km,
- mean bed inclination - Isr = 6.2%.

Climatic data

- Period 1951- 2000
- Average values
- t = 12.1 ^oC
- H (P) = 488 mm
- Transformed according to the mean catchment altitude

- For estimation water discharge with different probability were used previously estimated values for extreme precipitation with different duration and probability for HMS Skopje – Zajcev Rid (Blinkov 1993).

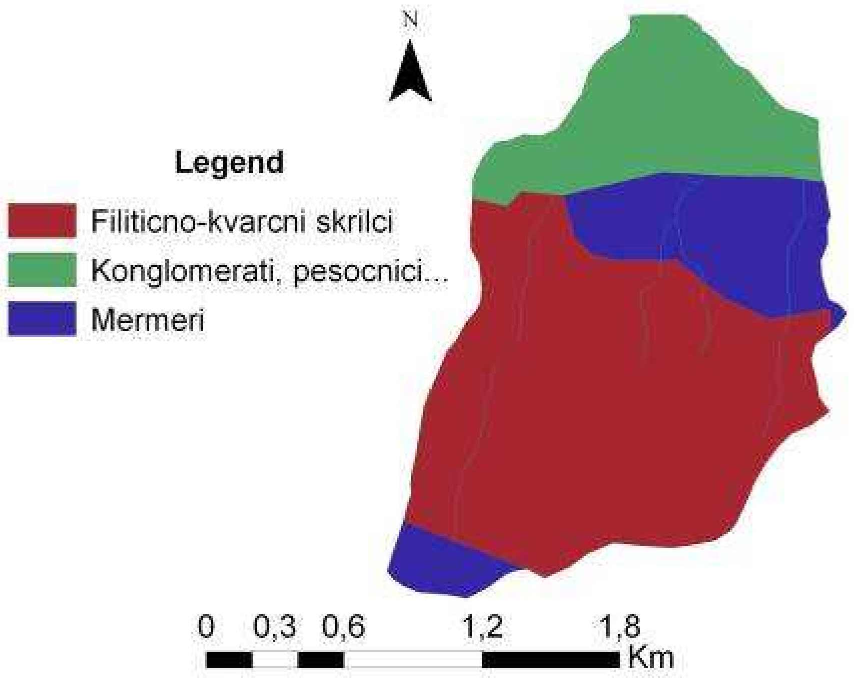
- Duration of effective precipitation (Tk = 0,66’) was estimated by the time of concentration (Tc) based on stream length and bed slope.

Precipitation with different duration and probability

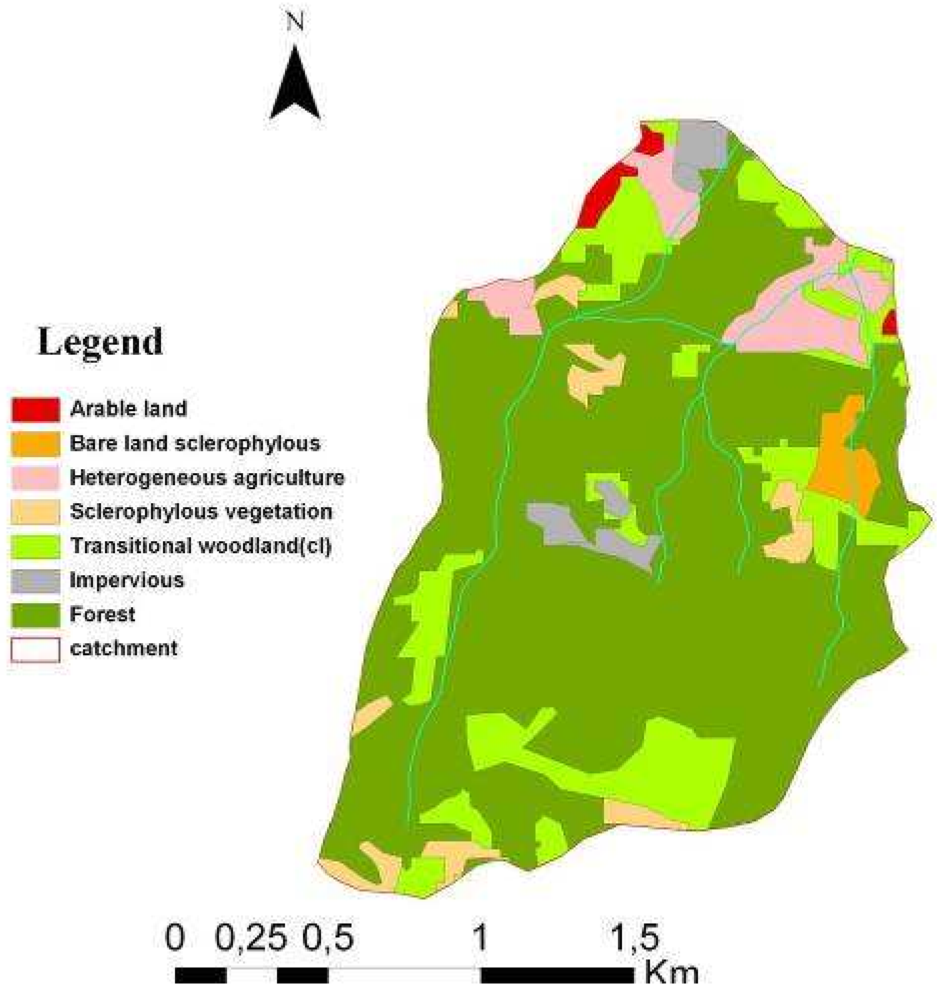
pojava	element	5`	10`	20`	40`	60`	90`	150`	300`	720`	1440`	24 h
	mm	23.04	39.16	53.21	65.04	69.53	71.61	75.19	84.07	109.76	125.19	104.29
0,1%	mm/min	4.61	3.92	2.66	1.63	1.16	0.80	0.50	0.28	0.15	0.09	0.07
	l/sec.ha	767.90	652.63	443.39	270.99	193.13	132.61	83.54	46.71	25.41	14.49	12.07
	mm	17.25	28.94	39.49	48.27	51.71	53.49	56.70	63.40	81.63	93.30	82.90
1 %	mm/min	3.45	2.89	1.97	1.21	0.86	0.59	0.38	0.21	0.11	0.06	0.06
	l/sec.ha	574.90	482.38	329.05	201.11	143.63	99.05	63.00	35.22	18.90	10.80	9.59
	mm	15.50	25.85	35.33	43.19	46.31	48.01	51.10	57.14	73.12	83.65	74.56
2 %	mm/min	3.10	2.59	1.77	1.08	0.77	0.53	0.34	0.19	0.10	0.06	0.05
	l/sec.ha	516.50	430.87	294.45	179.96	128.64	88.90	56.78	31.75	16.93	9.68	8.63
	mm	13.73	22.74	31.15	38.08	40.88	42.48	45.47	50.84	64.54	73.93	66.15
4 %	mm/min	2.75	2.27	1.56	0.95	0.68	0.47	0.30	0.17	0.09	0.05	0.05
	l/sec.ha	457.63	378.95	259.59	158.66	113.55	78.67	50.52	28.24	14.94	8.56	7.66
	mm	11.35	18.54	25.51	31.19	33.56	35.03	37.87	42.34	52.98	60.83	54.82
10 %	mm/min	2.27	1.85	1.28	0.78	0.56	0.39	0.25	0.14	0.07	0.04	0.04
	l/sec.ha	378.33	308.98	212.60	129.94	93.21	64.88	42.08	23.52	12.26	7.04	6.34
	mm	9.47	15.22	21.05	25.73	27.76	29.14	31.86	35.62	43.83	50.46	45.85
20 %	mm/min	1.89	1.52	1.05	0.64	0.46	0.32	0.21	0.12	0.06	0.04	0.03
	l/sec.ha	315.53	253.62	175.41	107.21	77.11	53.96	35.40	19.79	10.14	5.84	5.31
	mm	6.62	10.20	14.31	17.49	19.01	20.24	22.27	25.47	30.00	34.79	32.31
50 %	mm/min	1.32	1.02	0.72	0.44	0.32	0.22	0.15	0.08	0.04	0.02	0.02
	l/sec.ha	220.73	169.97	119.24	72.88	52.79	37.48	24.75	14.15	6.95	4.03	3.74

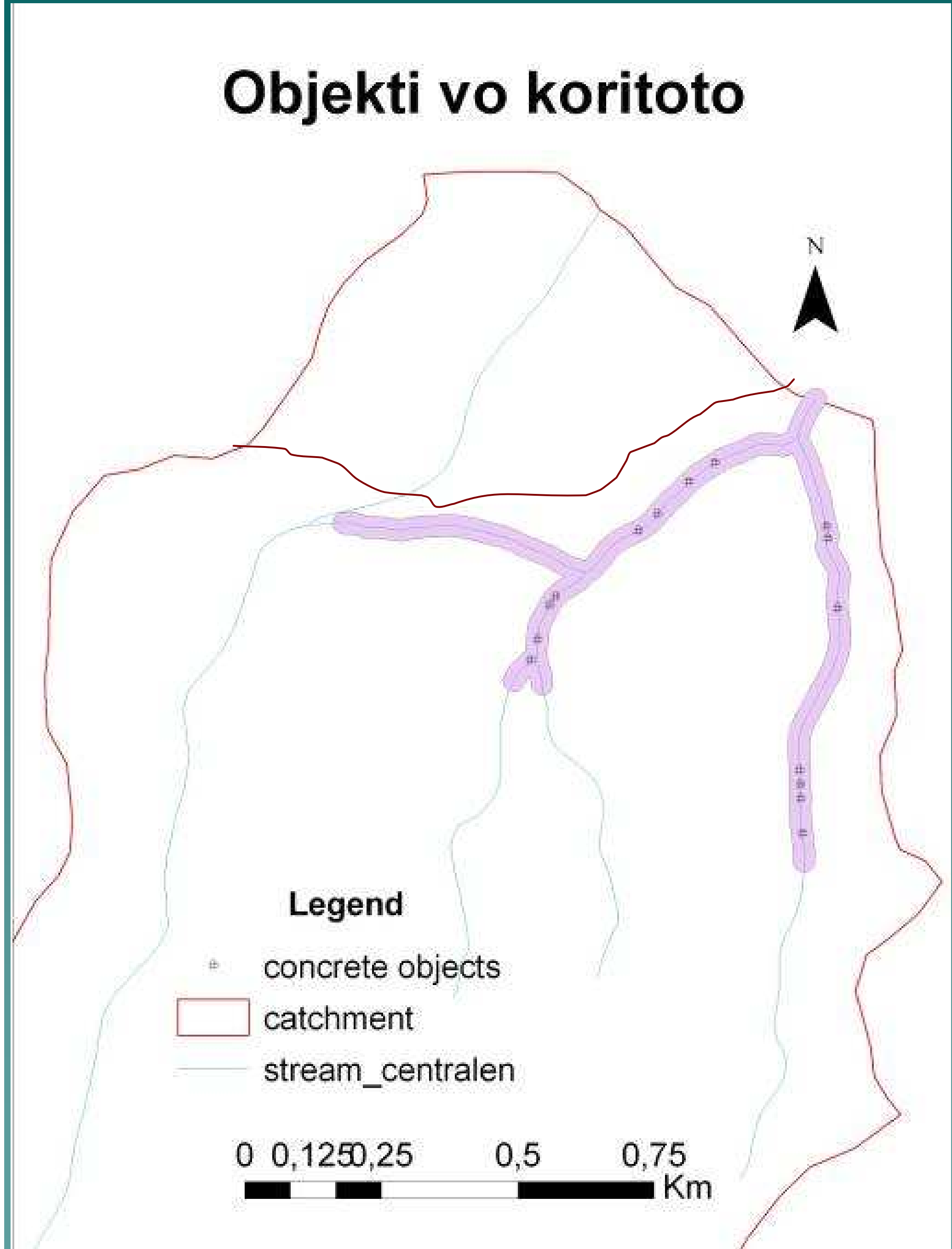
Reclassification of basic dataset

Geology



Land cover/use





Hydraulic structures

Channels,

cross constructions

Necessary for estimation

Of parameter - x a -

Actual situation

Hypothetic situation

Vodno 1920

RESULT: Erosion risk analyses

	Z	Rn	E	W	Gsp	G
			$m^3/km^2.y$	m^3/y	$m^3/km^2.y$	m^3/y
actual	0.21	0.47	167.07	552.86	78.79	267.63
potential	0.94	0.47	1601.15	5235.75	746.13	2439.86

Z – erosion coefficient by Gavrilovic

E – total annual erosion production

G – total annual transported sediment

Z – 4.5 times higher risk

W, G – 9.5 times larger quantities of sediment

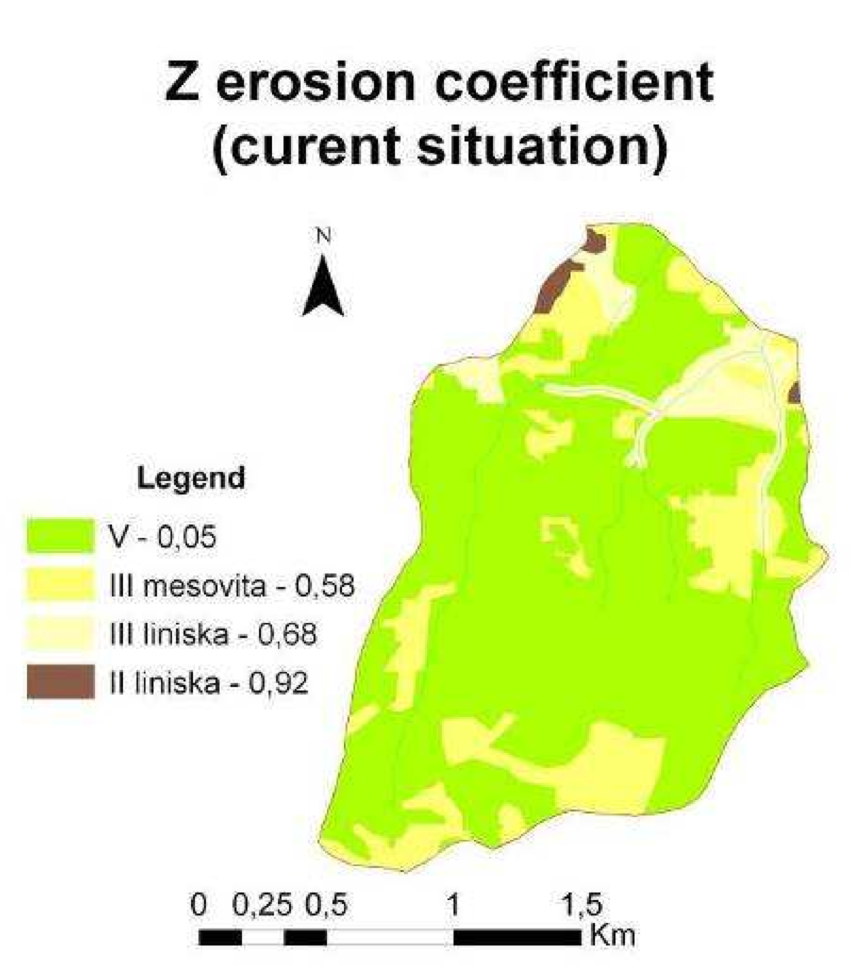
V - very low risk

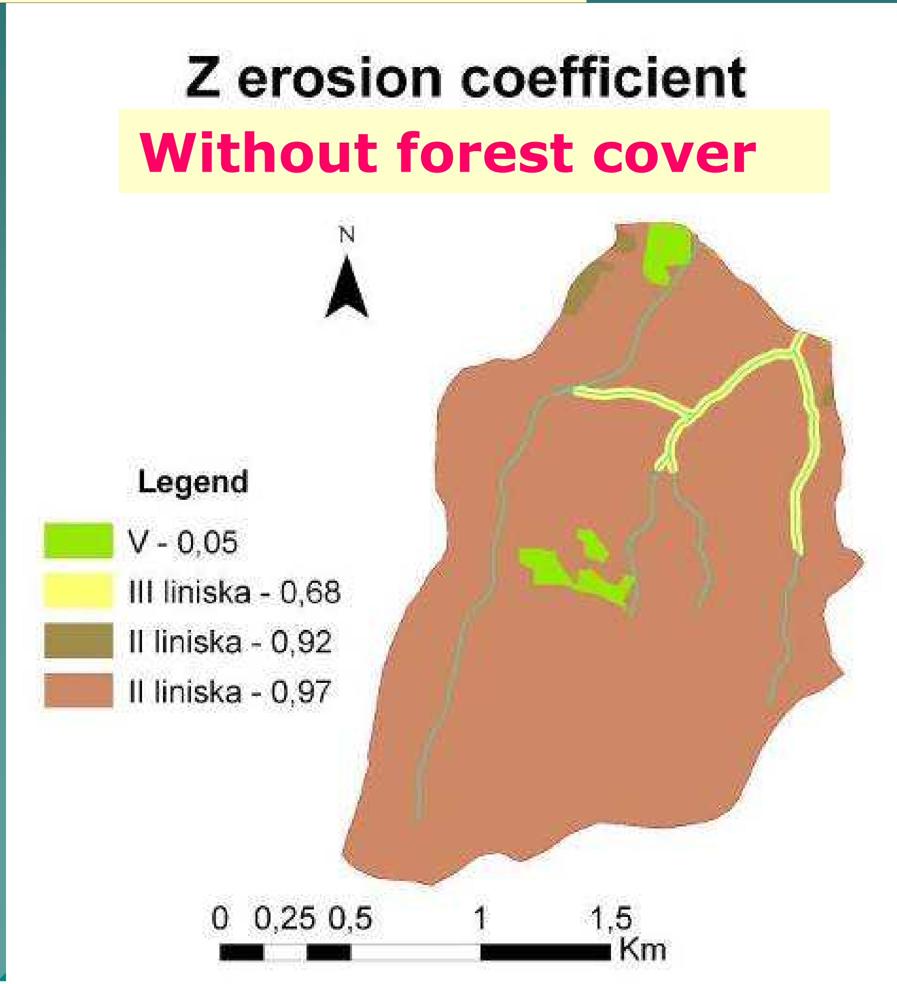
IV – low risk

III – medium risk

II – high erosion risk

I – extreme erosion risk





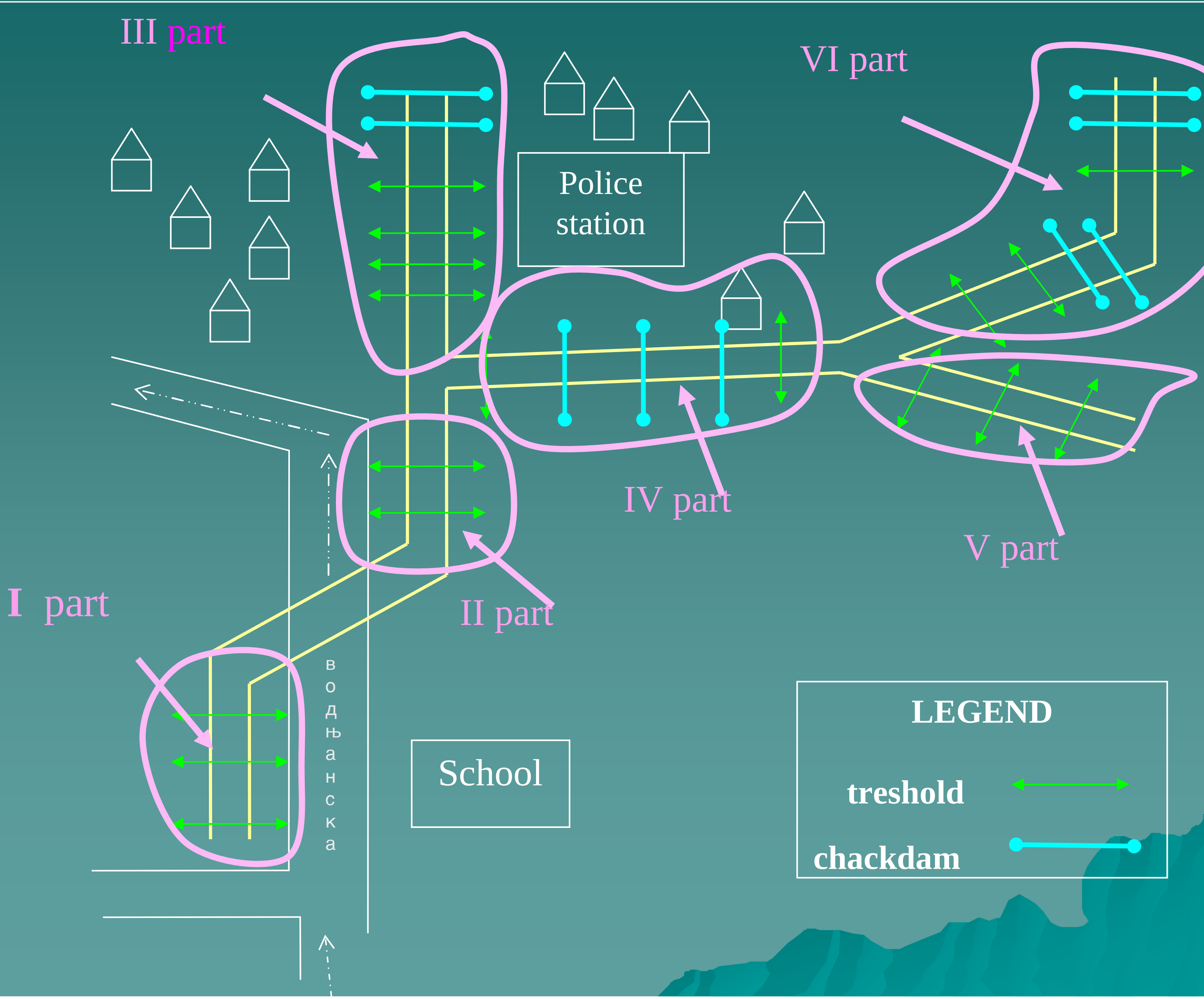
Water discharge estimation – current and hypothetic situation

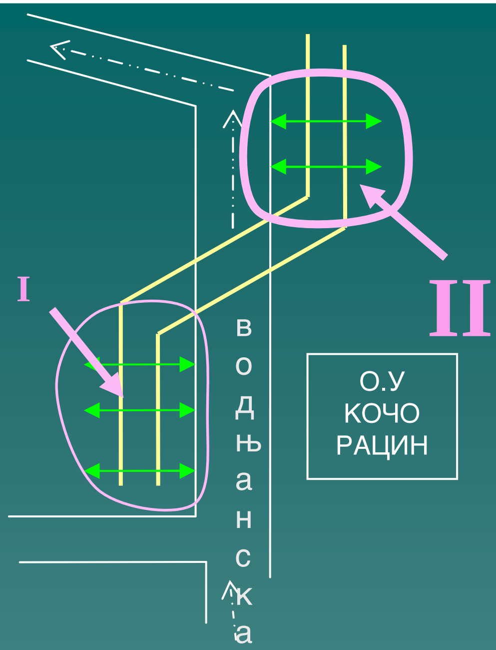
probability	2	10	5	4	2	1	0.5	0.1
return per	**5**	**10**	**20**	**25**	**50**	**100**	**500**	**1000**
h	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
K	0.4	0.5	0.67	0.75	0.85	1	1.5	1.7
hn	0.021	0.026	0.035	0.039	0.044	0.052	0.078	0.088
W	0.291	0.361	0.477	0.531	0.597	0.693	0.995	1.107
A	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
S1	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
2gDF	140	140	140	140	140	140	140	140
S2	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Q	**8.10**	**10.04**	**13.27**	**14.75**	**16.58**	**19.26**	**27.65**	**30.77**
S2 – hyp.	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Q – hyp.	**11.54**	**14.30**	**18.90**	**21.01**	**23.61**	**27.43**	**39.38**	**43.83**

Current hydraulic structures

- Channel made of stone somewhere concrete with check-dams, thresholds, cascades

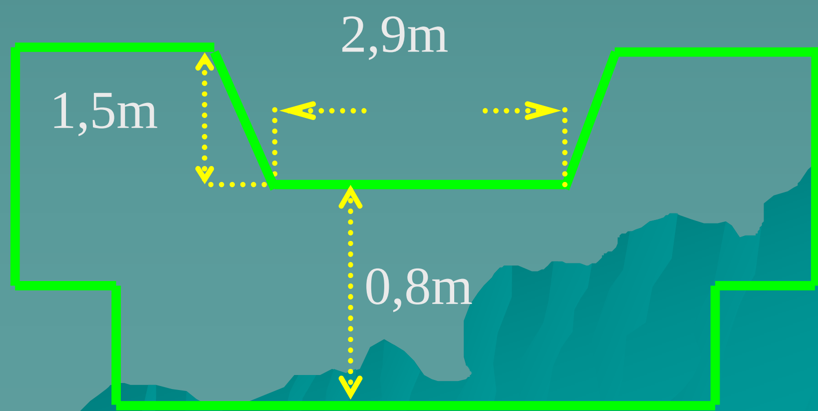
Sheme of Hydraulic structures in Gornovodnjanski poroj





$A = 5\ m^2$ - $V = 5.8 m/s$

$Q = 22\ (30)\ m^3/s$



Possible flow resistance

In downstream sections

Not more then 18 m^3

Not more then 10 m^3


Illegal constructions

Conclusions

- Current erosion risk is low - Z=0.21
- Current estimated erosion intensity is W=552 m3, out of them quantities of sediments are very low G =257 m^3

- Potential erosion risk is high Z = 0.94
- Estimated erosion intensity according to the scenario is W = 5235 m3 and transported sediments G = 2439 $m^{3,}$
  or 9.5 times higher.

- Estimation of water discharge and estimated capacities of the channels show that in normal situation channels can accept even discharge with 1-2% probability by the hypothetic scenario

- Solid waste and legal and illegal construction could cause flow resistance so the channels wouldn't can accept discharge with probability over 5-10% (current situation) or 20% (hypothetic situation).

Do we Like it!

Bareland on southern side of Vodno

Waste and Illegal bans >>> flow resistance


СНИМАТЕЛ—ЃОРЃЕ МИЛЕНКОВИЌ

Recommendations

- We are obliged to :

- Protect the forest
- Clean up the channels
- Extract illegal bans

FINAL AIM

protection of the environment and citizens of Skopje

VODNO MOUNTAIN IN AUTUMN

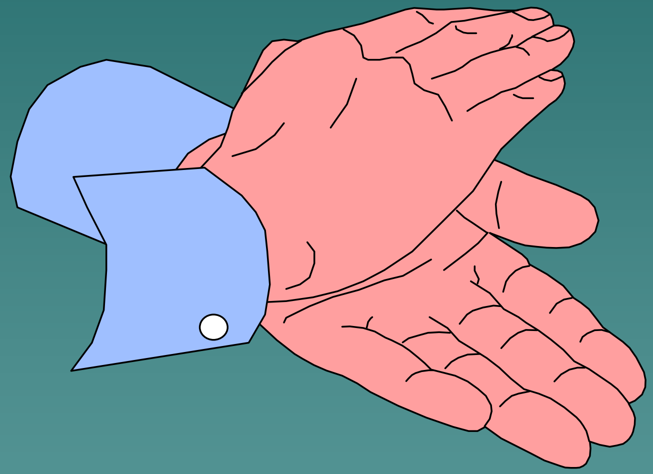
RimaDima
RISK MANAGEMENT • DISASTER MANAGEMENT

INTERREG IIIB CADSES
An EU-funded project managed by the European Agency for Reconstruction

RIMADIMA
Risk-, Disaster-Management & prevention of natural hazards in mountainous and/or forested regions

Ref.nr.: 5D102 RIMADIMA

Благодарам на вниманието



Thank you for your attention