MODELLING SURFACE RUNOFF TO MITIGATE IMPACT ON SOIL EROSION

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HydroPredict Conference 2012
Vienna, September 24 to 27, 2012

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INTRODUCTION

Solving Problems Related to Water Erosion

- Empirical models:
  - **USLE/MUSLE** (Modified/Universal Soil Loss Equation, Delivery Ratio)
- Simulation models:
  - CN-based models (**EPIC**, **CREAMS**, **AGNPS**, ...)
  - Surface Runoff and Erosion Processes (**KINEROS2 …**)
- Advanced simulation models:
  - **EUROSEM** (European Erosion Model, http://www.cranfield.ac.uk/eurosem/Eurosem.htm)
  - **WEPP** (Water Erosion Prediction Project, http://milford.nserl.purdue.edu/weppdocs/)
  - **EROSION 2D/3D** Model (http://tu-freiberg.de/faklut3/bodenschutz/)

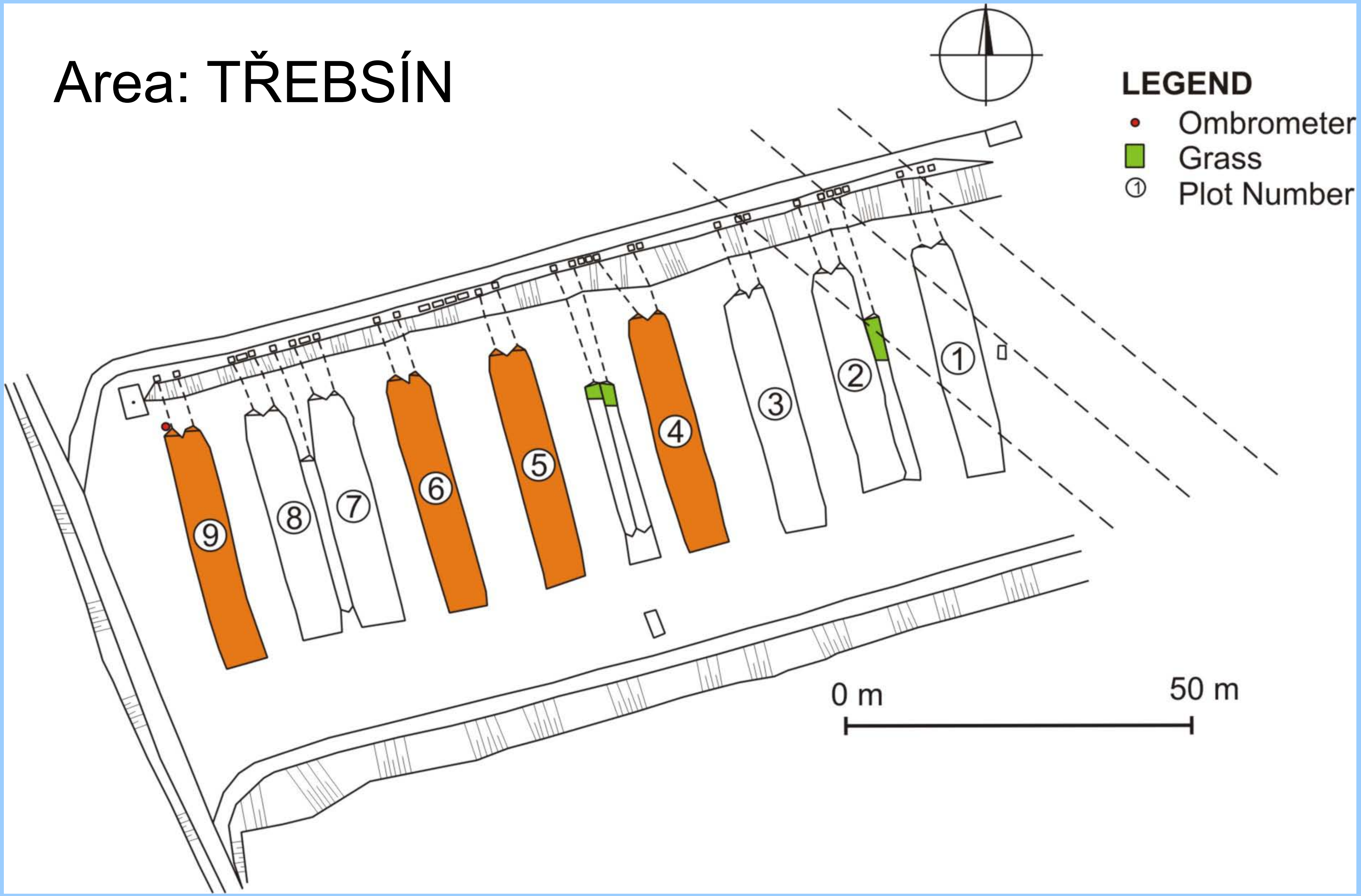
INTRODUCTION

CAN WATER EROSION BE PREDICTED USING A MODIFIED HYDROLOGIC MODEL?

Trying to determine the common principles of surface runoff and soil erosion simulation:

- Physically-based models
- Natural rainfall-runoff events data
- Simulated rainfall-runoff data (using rain simulator)
- Design rainfall data (for biotechnical measures)
- Observed and computed rain erosivity data assessment
- Soil loss analysis based on soil erodibility (incl. rill and interrill erosion assessment)

EXPERIMENTAL RUNOFF PLOTS



EXPERIMENTAL SITES DESCRIPTION

Soil characteristics:

- Brown soil “Eutric Cambisol” on weathered eluvials and deluvials
- Field capacity (average): 33.5%
- Porosity (average): 48.3%

Plot parameters and crops

Plot No.	Length (m)	Wide (m)	Slope (%)	Area (m^2)	Crop 2007	Crop 2008	Crop 2009	Crop 2010
9	37.7	6.6	11.2	248.8	sunflower	maize	sunflower	maize
6	37.8	6.7	12.8	253.3	sunflower	maize	sunflower	maize
5	??	??	13.5	253.5	sunflower	maize	sunflower	maize
4	37.4	6.8	14.3	254.3	sunflower	maize	sunflower	maize
Average	37.6	6.7	12.8	250.0				

Soil hydraulic parameters

$$SF = (So)^2 / 2K_s$$

Plot No.	Satur. hydraulic conductivity K_s ($mm \cdot min^{-1}$)	Sorptivity at FC So ($mm \cdot min^{-0.5}$)	Storage suction factor SF (mm)
9	0.214	1.06	2.63
6	0.177	1.20	4.07
5	1.650	4.13	5.17
4	4.360	4.64	2.47

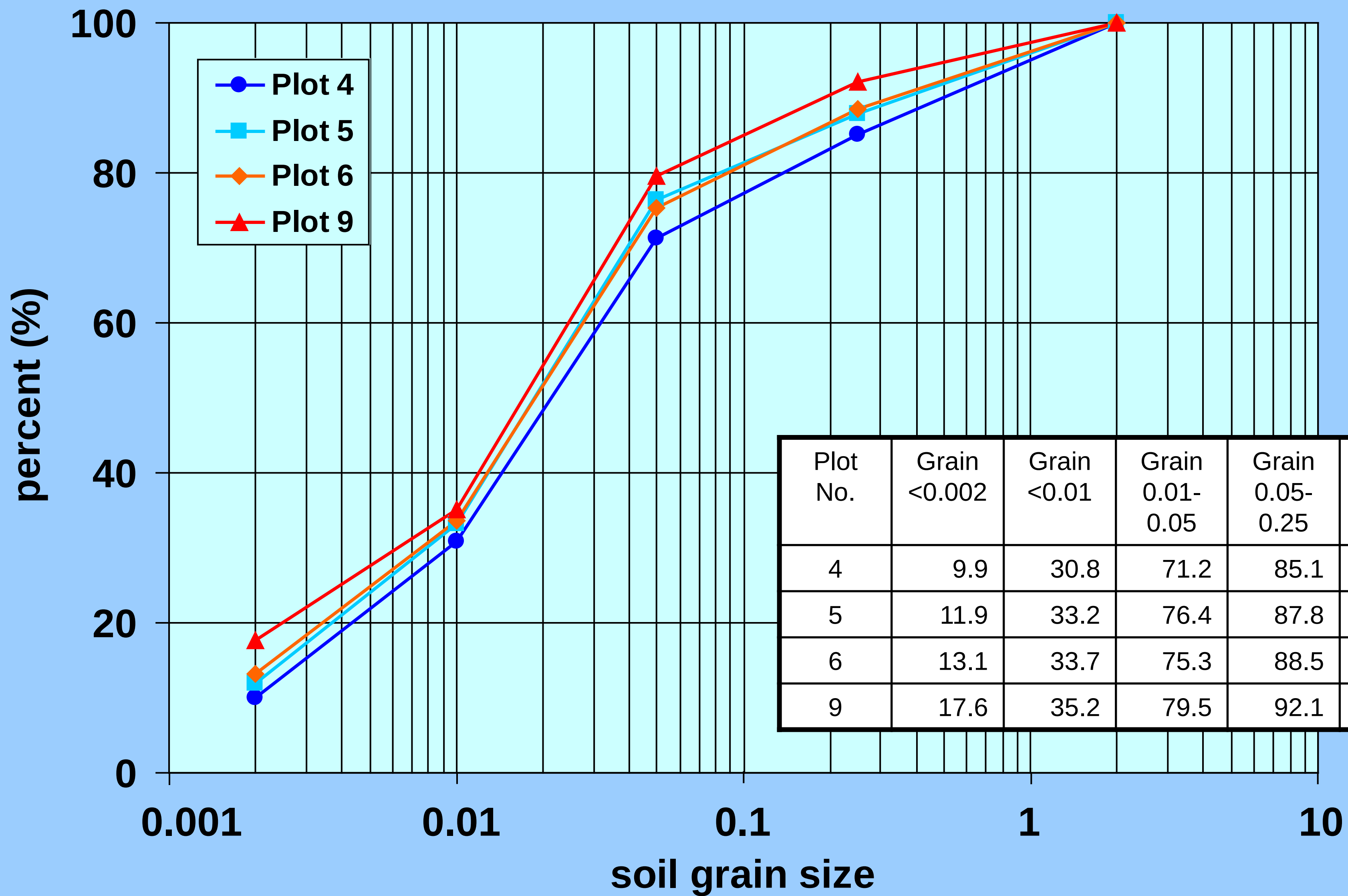
RAIN SIMULATOR

RAIN SIMULATOR

DISCHARGE/LOAD MEASUREMENT DEVICE

GRANULARITY CURVE

FOR EXPERIMENTAL RUNOFF AREAS AT TŘEBSÍN



Plot No.	Grain <0.002	Grain <0.01	Grain 0.01-0.05	Grain 0.05-0.25	Grain 0.25-2.0
4	9.9	30.8	71.2	85.1	100.0
5	11.9	33.2	76.4	87.8	100.0
6	13.1	33.7	75.3	88.5	100.0
9	17.6	35.2	79.5	92.1	100.0

MODEL KINFIL – PRINCIPLES

EINFIL Part

- Infiltration computation:
  - Green Ampt (and Morel-Seytoux)

$$i = K_s\left(1 + \frac{(\theta_s - \theta_i)\cdot H_f}{i \cdot t_p}\right)$$

- Storage suction factor:

$$S_f = (\theta_s - \theta_i)\cdot H_f = \frac{(So)^2}{2K_s}$$

- Ponding time:

$$t_p = \frac{S_f}{i\cdot\left(\frac{i}{K_s} - 1\right)}$$

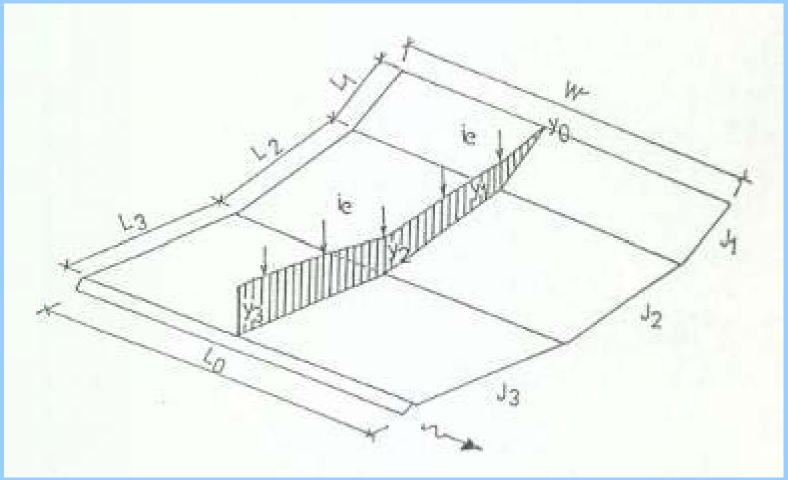
KINFIL Part

- Computation of flow on slopes using kinematic wave computation:
  - (Lax-Wendroff numerical scheme)

$$\frac{\partial y}{\partial t} + \alpha m y^{m-1}\frac{\partial y}{\partial x} = i_e(t)$$

THE KINFIL PARAMETERS

ROOT	depth of root zone (m)
KS	saturated hydraulic conductivity ($m \cdot s^{-1}$)
SO	sorptivity at field capacity ($m \cdot s^{-0.5}$)
POR	porosity (–)
FC	field capacity (–)
SMC	(or API) soil moisture content (mm)
JJ	number of planes in cascade (–)
SLO	slope of plane (–)
LEN	length of plane (m)
WID	width of plane (m)
NM	Manning roughness
DS	mean soil particle diameter (mm)
D(i)	soil particle category diameters (mm)
RO	soil particle density ($kg \cdot m^{-3}$)



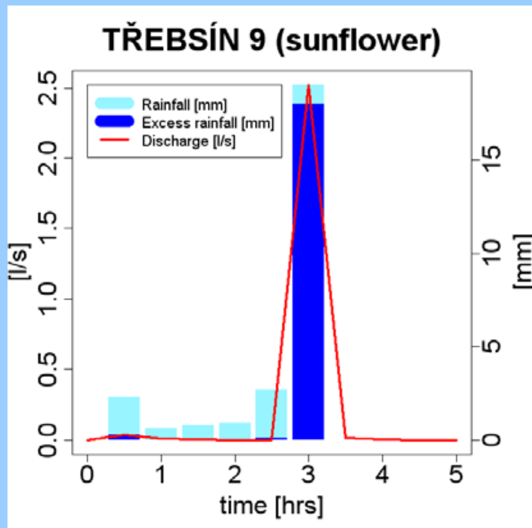
$$\frac{\Delta t}{\Delta x} \leq \frac{1}{\alpha m y^{m-1}}$$

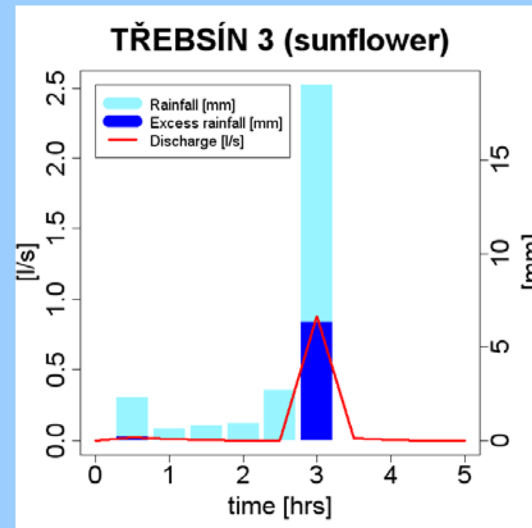
– cascade of planes
– cascade of segments

NATURAL RAINFALL-RUNOFF OBSERVATION

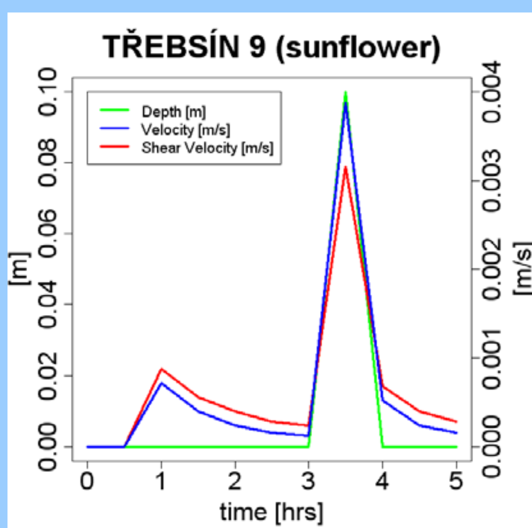
DT = 30 min, area 250 m^2 (36.0   7.0 m), 10 August 2007

Rainfall-runoff events

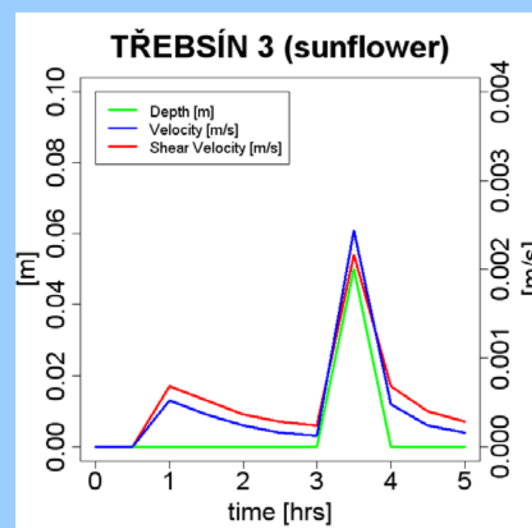




Depths, velocity and shear velocity

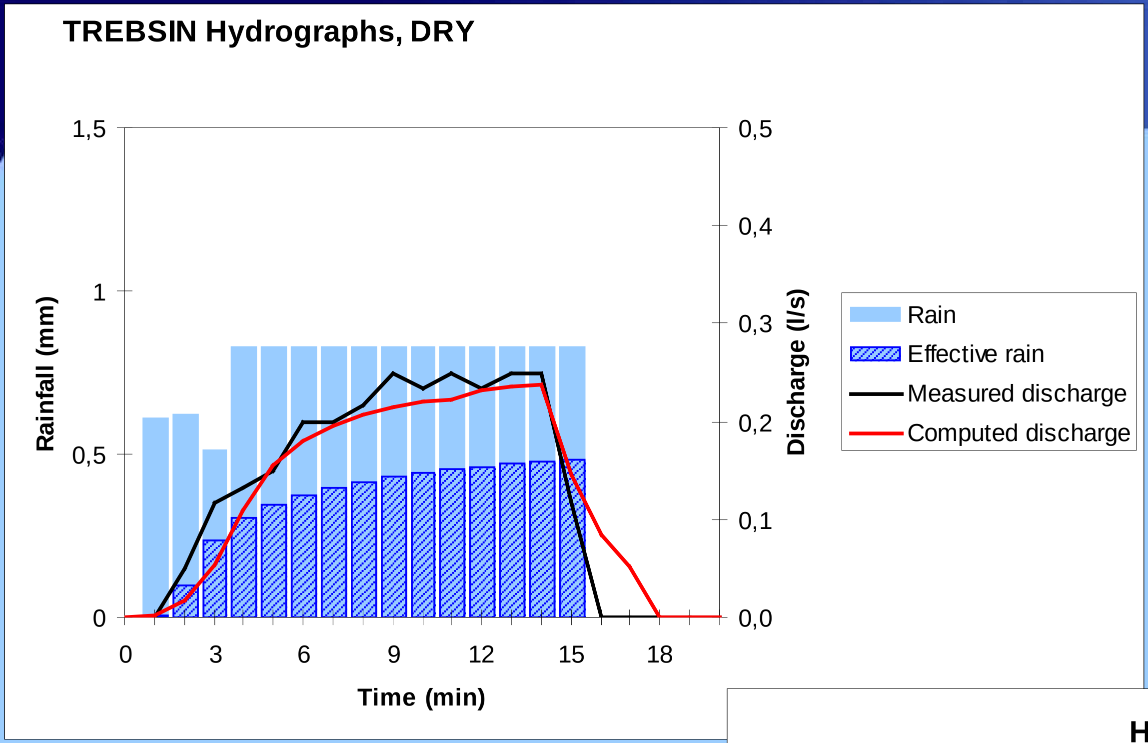


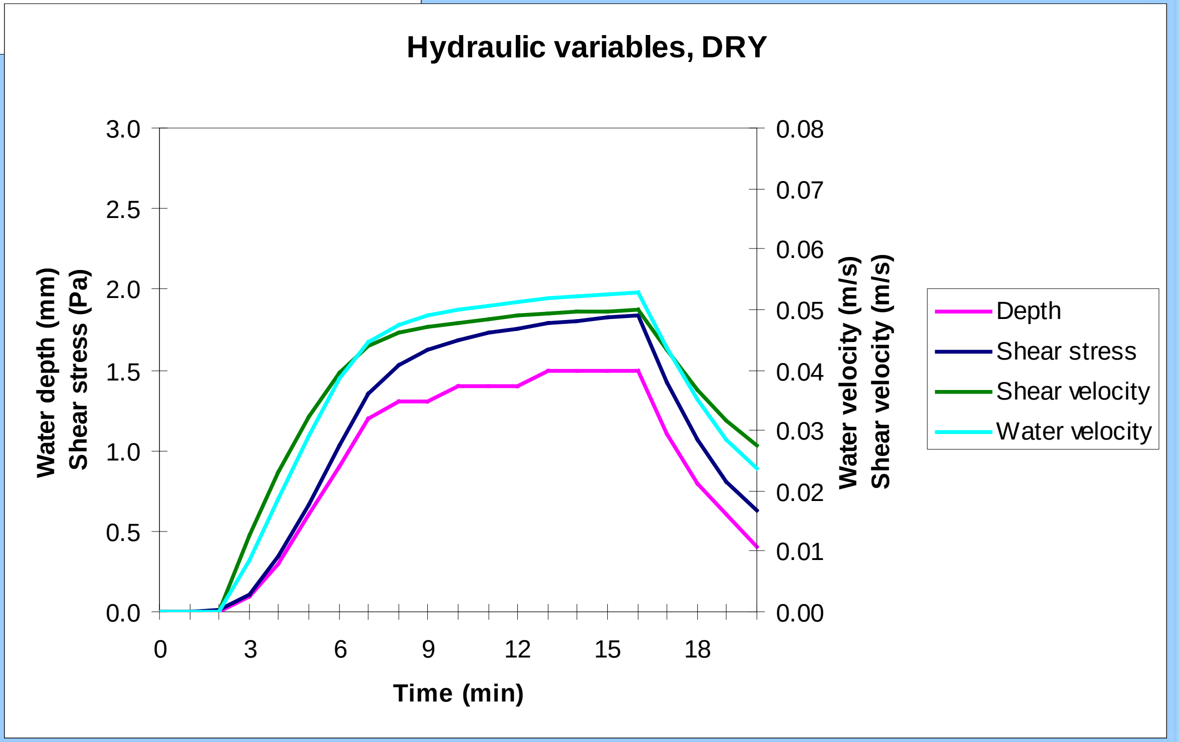
Soil loss:
5330 kg · ha^{-1}



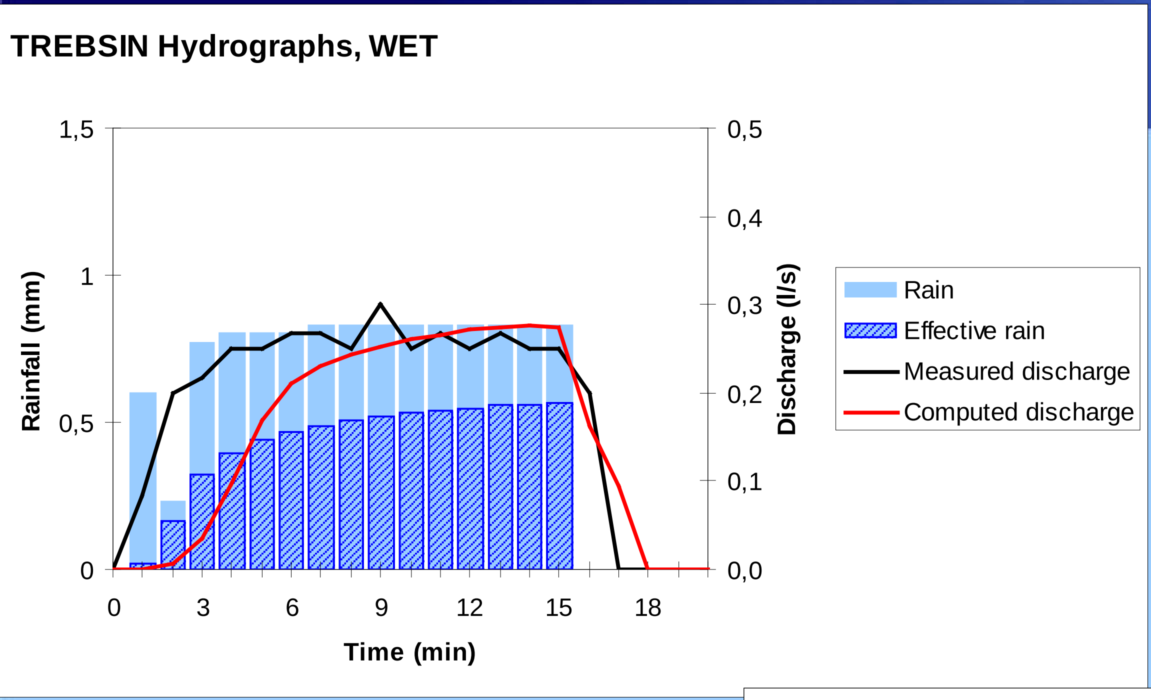
Soil loss:
281 kg · ha^{-1}

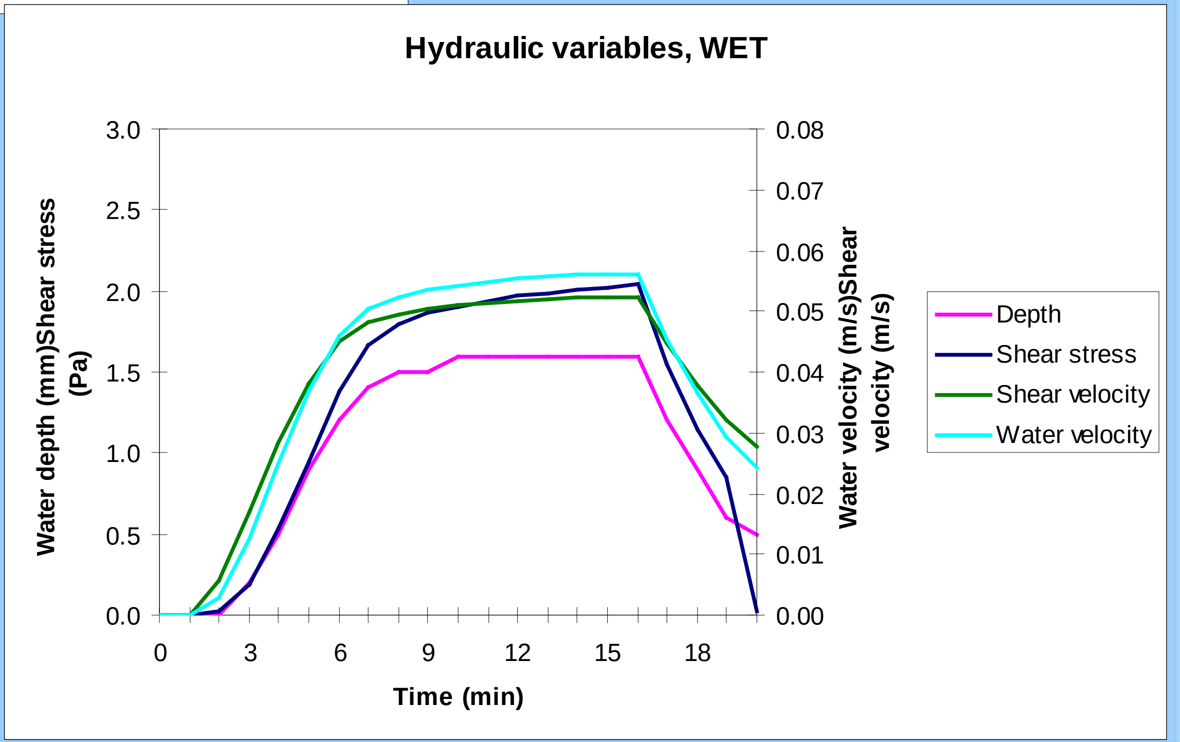
Plot 9, 26 August 2009
Rainfall/Runoff
event simulation

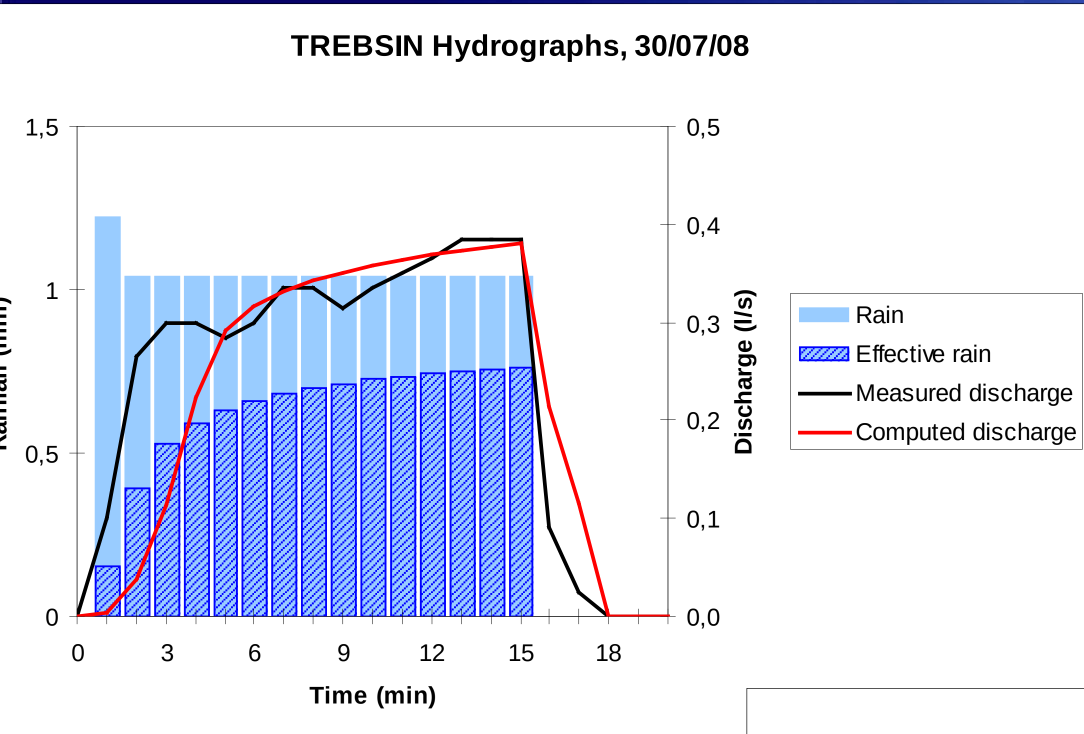




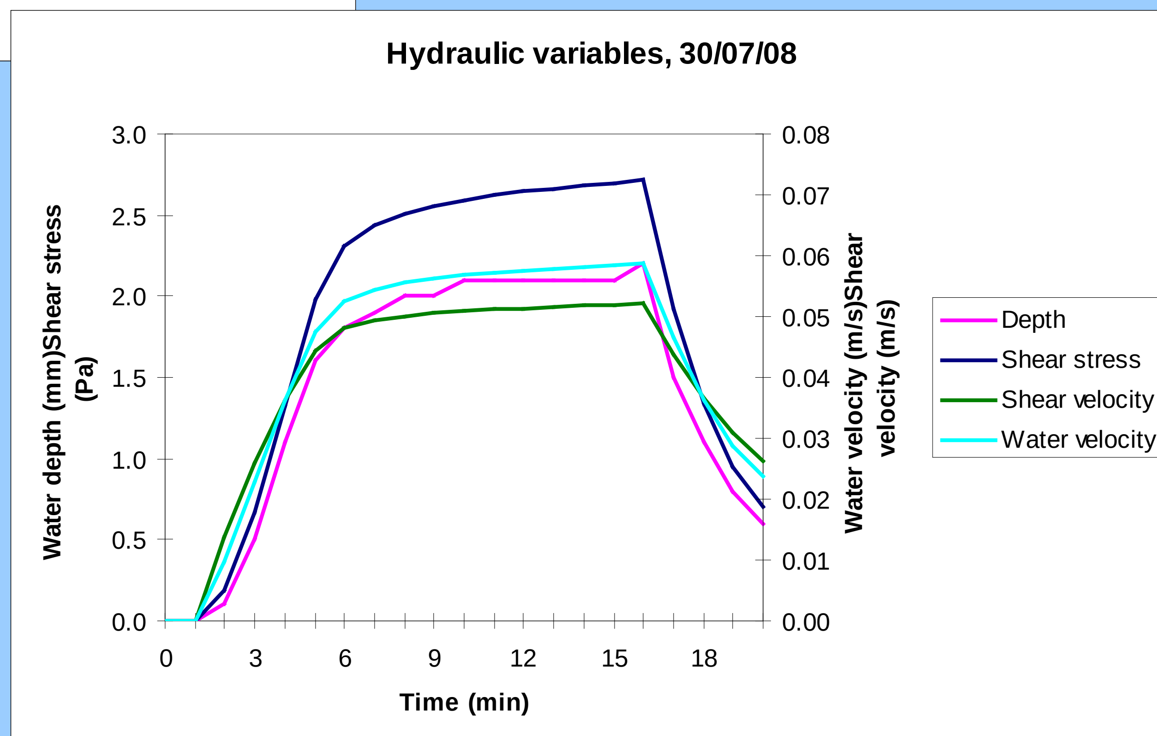
Plot 9, 26 August 2009 Rainfall/Runoff event simulation



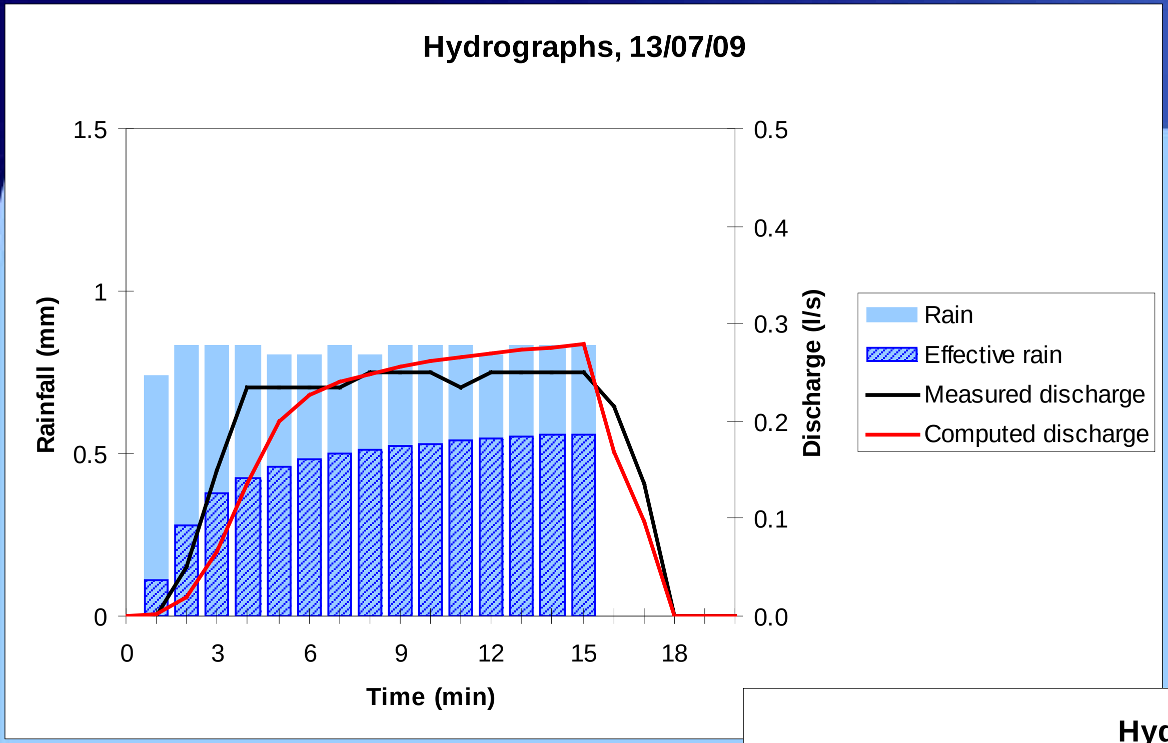


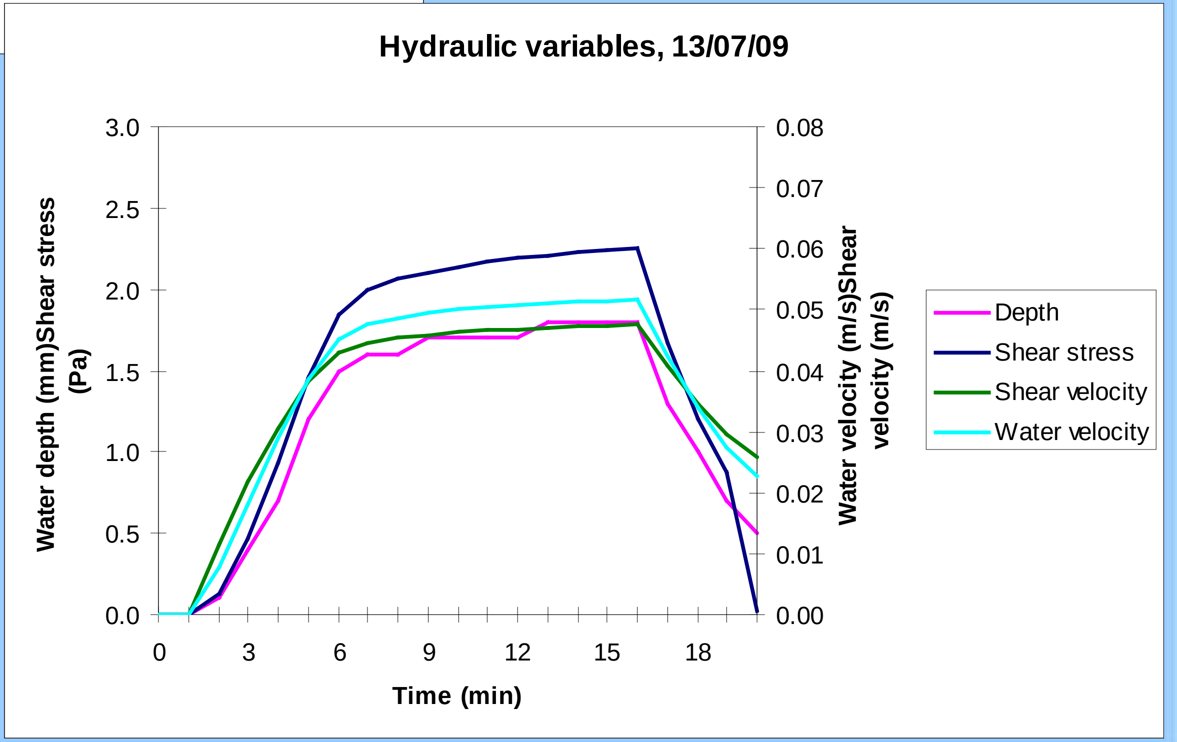


Plot 6, 30 July 2008 Rainfall/Runoff event simulation (wet initial condotions)



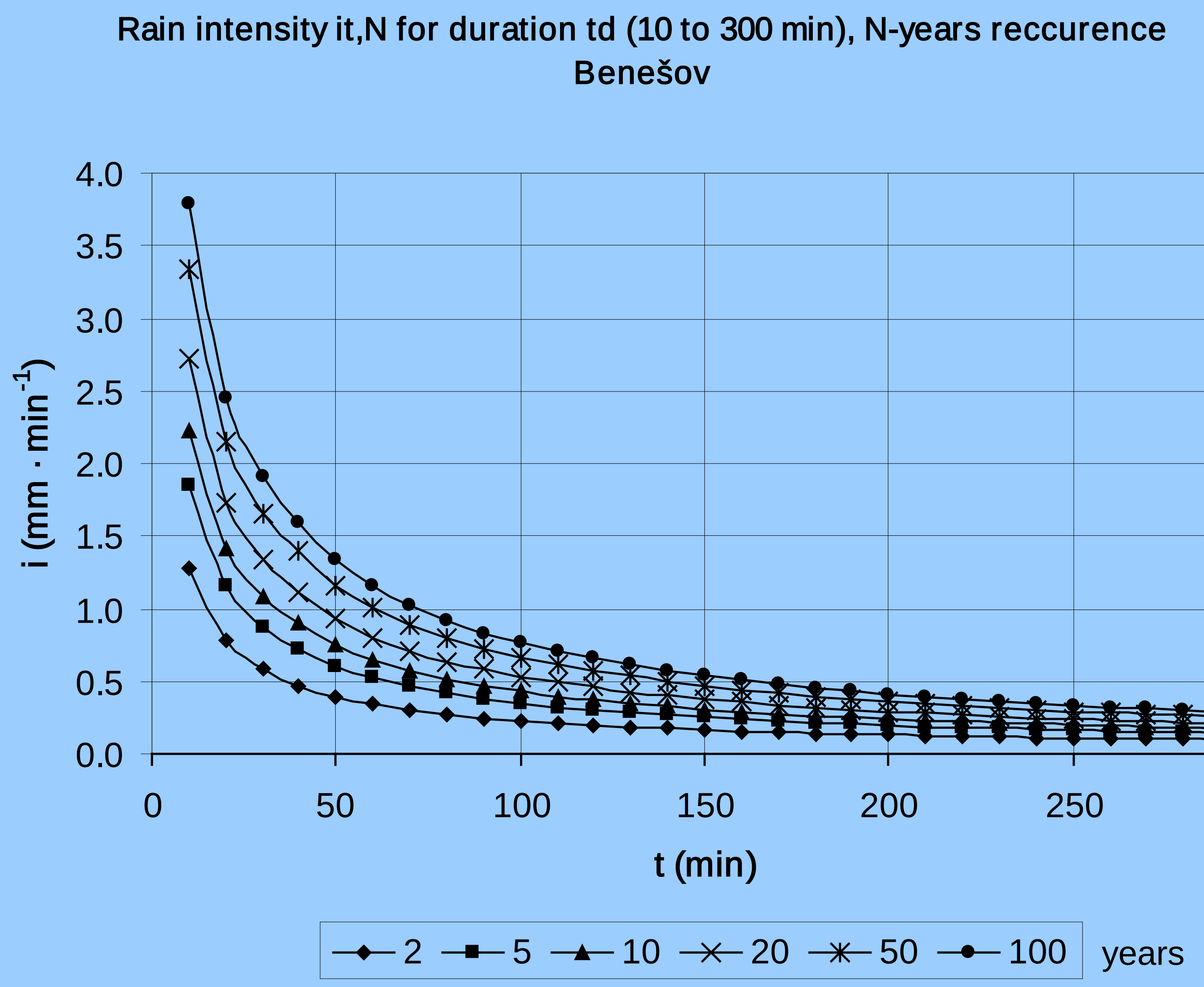
Plot 6, 13 July 2009 Rainfall/Runoff event simulation (wet initial conditions)





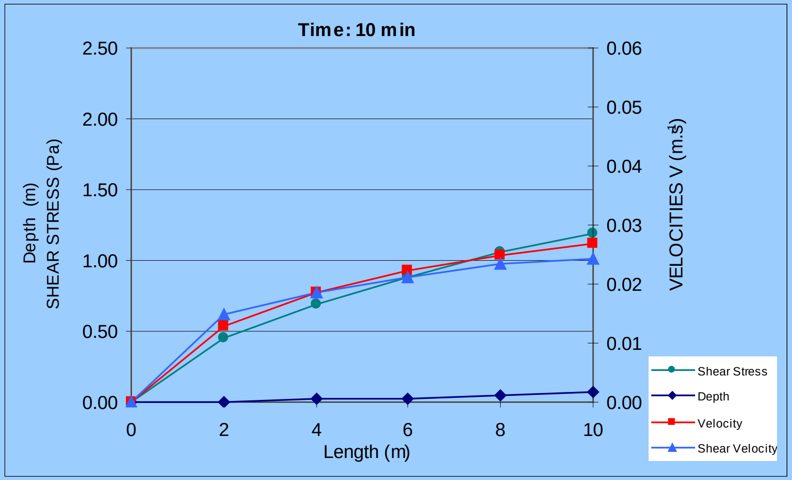
DESIGN RAIN INTENSITIES

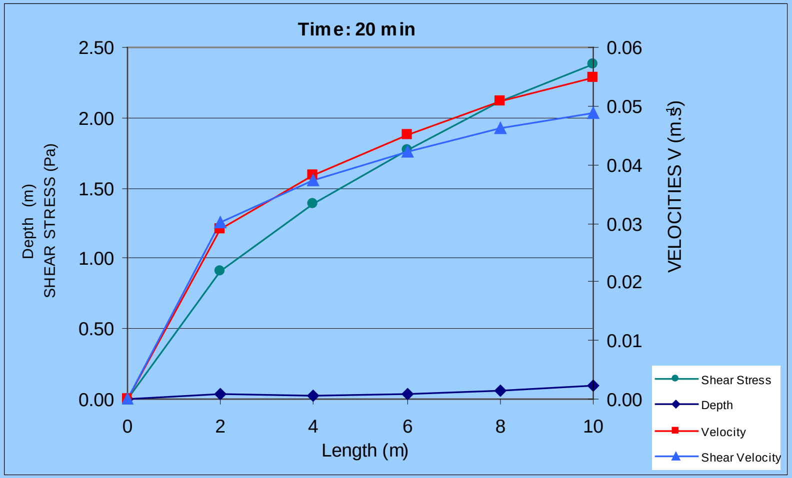
Design rain intensities $i_{t,N}$ (mm · min^{-1}):

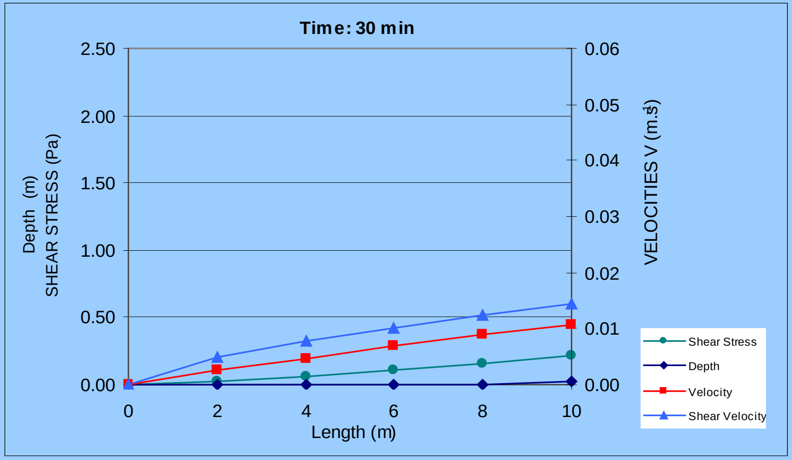


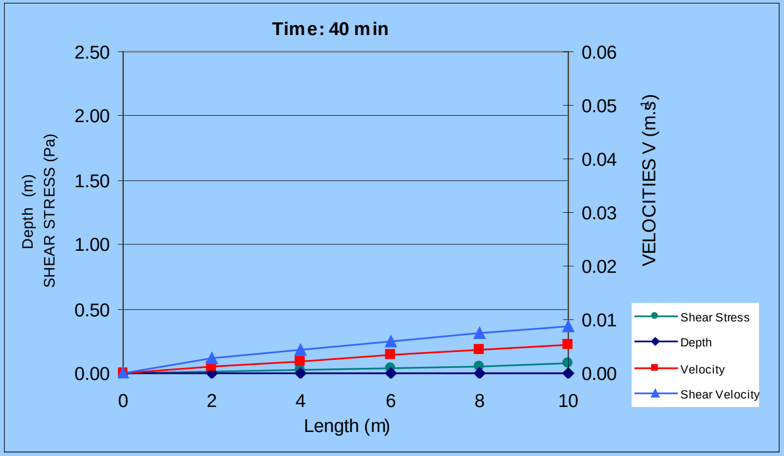
DESIGN RUNOFF: DEPTH, VELOCITIES AND SHEAR STRESS VALUES AT DIFFERENT TIME

Locality: TŘEBSÍN 9, N = 2 years









DESIGN RUNOFF: POTENTIAL SOIL LOSS

Locality: TŘEBSÍN 9, N = 2 years, TD = 10 min

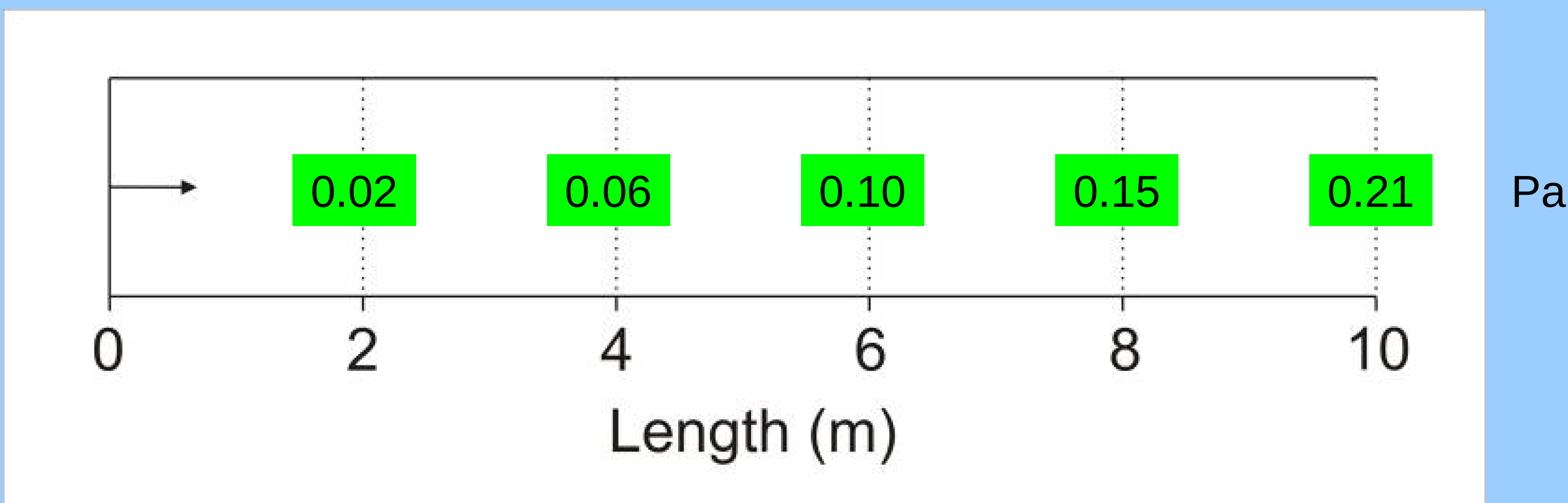
Grain size categories and their critical shear stress:

Category (mm)	< 0.01	0.01–0.05	0.05–0.25	0.25–2.00
τ_c (Pa)	0.0076	0.0380	0.1900	1.6700

Effective medium grain size D_s = 0.030 mm, τ_c = 0.5 Pa

Experimental runoff area:

Potential soil loss (for D_s) at 20’



CONCLUSIONS (1)

THE KINFIL MODEL (advantages)

- provides results from the physically-based scheme.
- provides possibilities to calibrate model parameters for natural rainfall-runoff event reconstructions.
- simulates surface runoff discharges, depths, velocities and shear stress accurately enough to be compared with measured discharges and soil losses measured by rain simulator equipment and with other models.
- can be used for the validation of broader spectra of natural conditions to identify potential water erosion (also by simplifying K_s and So computation using their relations with Runoff Curve Numbers).
- simulates also the change of land use and farming management.

CONCLUSIONS (2)

THE KINFIL MODEL (bottlenecks)

- is sensitive to uncertainty in scaling, significant rill-systems, sudden change of hydraulic roughness (vegetation), geomorphologically complicated system of planes and segments.
- has difficulties to simulate an effective impact on biotechnical measures.

Thank you for your attention