



**HAL**  
open science

## How 2D Hydraulic Modelling Can Improve Landscape Analysis in Tectonic Geomorphology?

Thomas Bernard, Philippe Davy, Dimitri Lague

► **To cite this version:**

Thomas Bernard, Philippe Davy, Dimitri Lague. How 2D Hydraulic Modelling Can Improve Landscape Analysis in Tectonic Geomorphology?. American Geophysical Union Fall Meeting 2019, Dec 2019, San Francisco, United States. , pp.EP31C-2301, 2019. <insu-02402513>

**HAL Id: insu-02402513**

**<https://insu.hal.science/insu-02402513v1>**

Submitted on 17 Jan 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

## 1 TECTONIC INFORMATION FROM CHANNEL NETWORK AND ISSUES

**Theoretical background** → **Channel extraction from High Resolution DEM** → **Slope-area relationship**

In a variety of natural landscapes, fluvial channels tend to follow:

$$S = k_s A^{-\theta}$$

(Hack, 1957; Flint, 1974)

Assuming  $U=E$  and that a stream power incision model applies, one predict that :

$$k_s = (U/K)^{1/n}$$

(Howard, 1994; Wobus et al., 2006; Lague, 2014)

→ Tectonic information could theoretically be extracted from channel morphology

$k_s$  : channel steepness index,  $\theta$ : concavity index,  $S$ : Topographic slope,  $A$ : drainage area,  $U$ : uplift rate,  $E$ : Erosion rate,  $K$ : Erodability coefficient

Issue when channel width > 1 pixel

**NEED FOR A NEW METHOD ACCOUNTING FOR CHANNEL WIDTH**

## 2 METHODOLOGY: SOLVING 2D HYDRODYNAMICS TO DESCRIBE CHANNEL WIDTH

**The 2D shallow water equations**      **Eros/Flodos: a particle method for solving hydrodynamics** (Davy et al., 2017)

**Water mass balance equation**

$$\frac{\partial h}{\partial t} + \frac{\partial U h}{\partial x} = 0$$

Flow depth      Flow velocity

**Hypothesis**

Inertial terms are negligible  
Basal friction >> other frictional terms

precipiton : water volume

**Fill depressions**      **Account for channel morphology**

**Conservation of flow momentum**

$$\rho h \left( \frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} \right) = \rho g h \left( \frac{\partial h}{\partial x_i} + \frac{\partial Z}{\partial x_i} \right) - \tau_i$$

Acceleration      gravity      Flow resistance

## NEW HYDRO-GEOMORPHIC DESCRIPTORS

**The drainage area per unit width**

$$A_w = \frac{q}{r}$$

$A_w$ : drainage area per unit width (m)  
 $q$ : unit discharge (m²/s)  
 $r$ : rainfall rate (m/s)

deviation from 1/1 line

**The hydraulic slope**

## 3 APPLICATION EXAMPLE TO THE MULE FORK CATCHMENT, CALIFORNIA

**The hydraulic slope - drainage area per unit width relationship**

**Input parameters**

Precipitation rate: 10 mm/h  
Resolution: 1m  
Manning's coefficient: 0.04

**Drainage Area per unit width**

**Sensitivity of fluvial extent to runoff intensity**

**Sensitivity to the grid resolution**

2D hydrodynamics model

Insensitive to grid resolution when pixel width < flow width

**Combined analysis at various runoff yield new insights into landscape organisation**

Area: 3 Km²  
Lithology: granite  
MAP: 685 (mm/h)

**D-infinity flow routing**

## 4 TAKE HOME MESSAGE

**2D hydraulics model have several benefits:**

- Directly account for channel width in the calculation of fluvial hydraulic variables (unit discharge, hydraulic slope, shear stress etc..)
- Richer description of landscape organization for various runoff intensities
- A sharper transition between colluvial and channelized domain
- A much clearer expression of the concavity and steepness index than the traditional slope-area analysis
- Reduced sensitivity to DEM resolution compared to slope-area analysis

## REFERENCES

Davy, P., Croissant, T., Lague, D., 2017. A precipitation method to calculate river hydrodynamics, with applications to flood prediction, landscape evolution models, and braiding instabilities. *Journal of geophysical research: earth surface*, 122(8), 1491-1512

Flint, J.J., 1974. Stream gradient as a function of order, magnitude, and discharge. *Water Resour. Res.* 10, 969-973.

Hack, J.T., 1957. Studies of longitudinal stream profiles in Virginia and Maryland. U.S. Geological Survey Professional Paper, vol. 294-B, p. 97.

Lague, D., 2014. The stream power river incision model: evidence, theory and beyond. *Earth Surface Processes and Landforms*, 39(1), 38-61.

Wobus, C., Whipple, K.X., Kirby, E., Snyder, N., Johnson, J., Spyropoulos, K., Crosby, B., Sheehan, D., 2006. Tectonics from topography: procedures, promise, and pitfalls. *Geol. Soc. Am. Spec.* 398, 55-74.