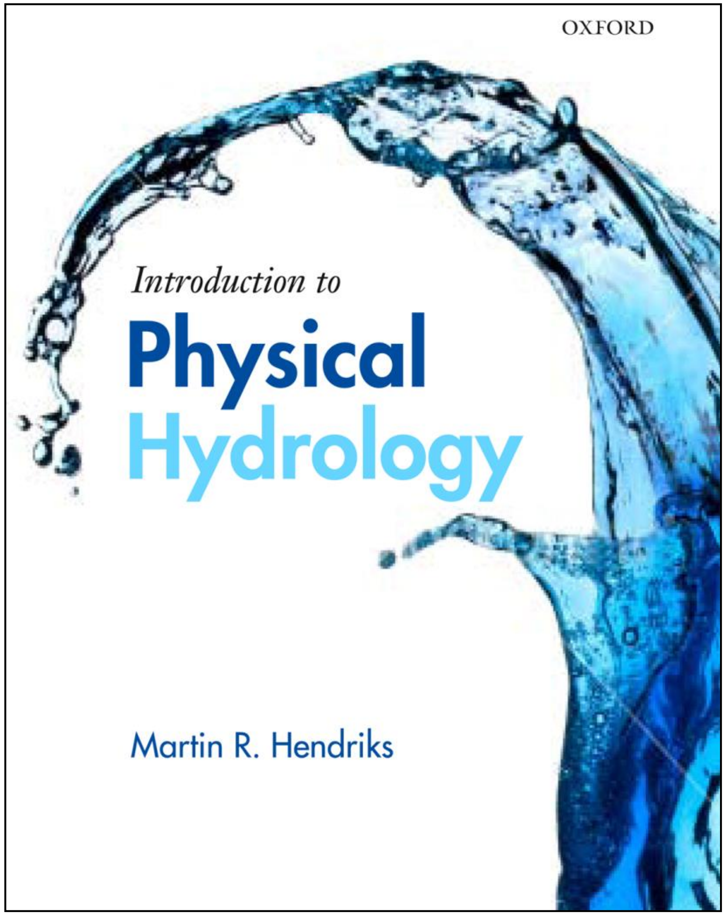
Surface water



Paperback | 351 pages
Follow the book's didactic concept!

Part 1

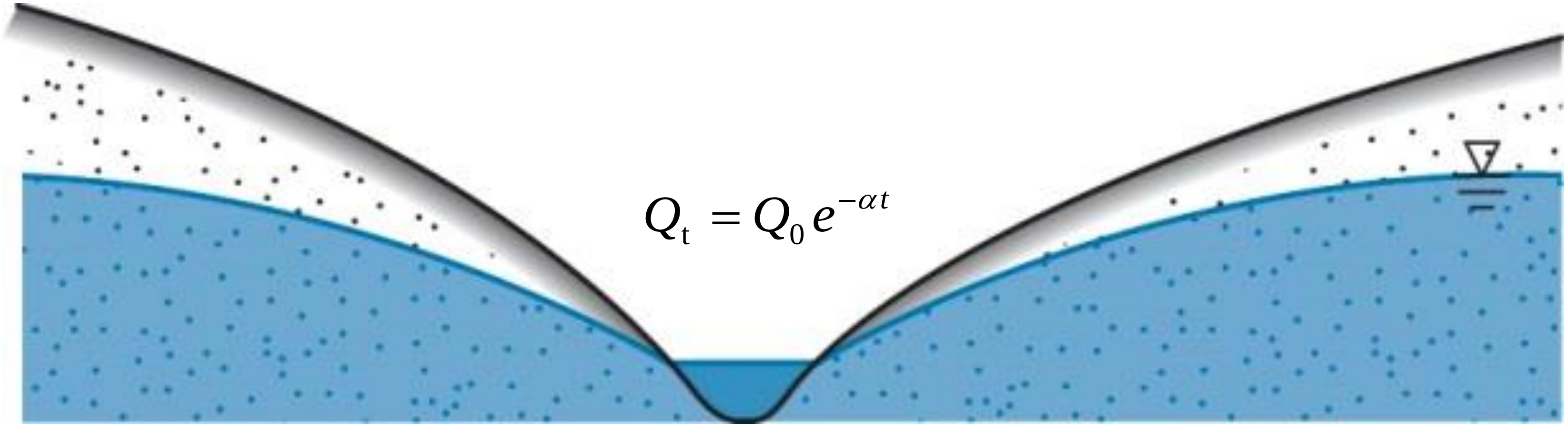
- Processes:
  - quickflow
- Hydrograph:
  - recession analysis
  - separation

Part 2

- Simulation models:
  - linear reservoir
  - exponential reservoir

Linear reservoir model

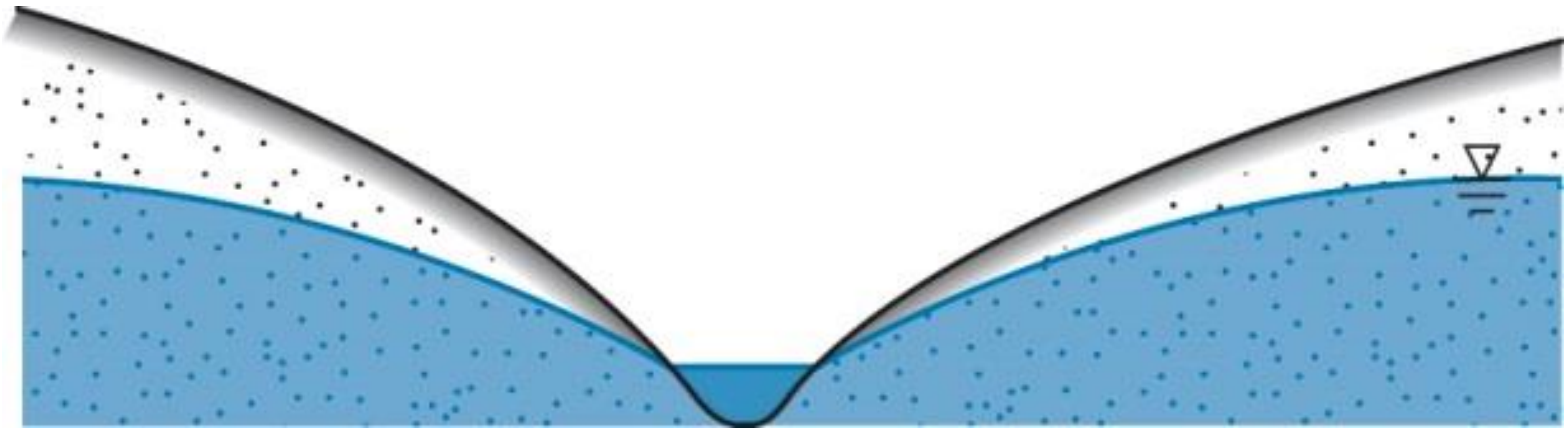
$$S_t = \int_t^{\infty} Q_t \, dt$$



$$Q_t = Q_0 e^{-\alpha t}$$

$$S_t = \int_t^{\infty} Q_0 e^{-\alpha t} dt = Q_0 \int_t^{\infty} e^{-\alpha t} dt = Q_0 \left[\frac{e^{-\alpha t}}{-\alpha} \right]_t^{\infty} = Q_0 \left(0 - \frac{e^{-\alpha t}}{-\alpha} \right) = \frac{Q_0 e^{-\alpha t}}{\alpha} = \frac{Q_t}{\alpha}$$

Linear reservoir model



$$S = \frac{Q^n}{\alpha} \qquad n = 1$$

Rainfall - groundwater runoff model

How to build a simulation model!

$$\frac{dS}{dt} = I - Q \qquad dS = \frac{dQ}{\alpha} \qquad \frac{dQ}{\alpha} = \left(I - Q\right) dt$$

$$dt \longrightarrow \Delta t$$

$$dQ \longrightarrow \Delta Q = Q_{\mathrm{t+\Delta t}} - Q_{\mathrm{t}}$$

$$Q \longrightarrow \frac{Q_{\mathrm{t}} + Q_{\mathrm{t+\Delta t}}}{2}$$

$$I \longrightarrow I_{\Delta \mathrm{t}}$$

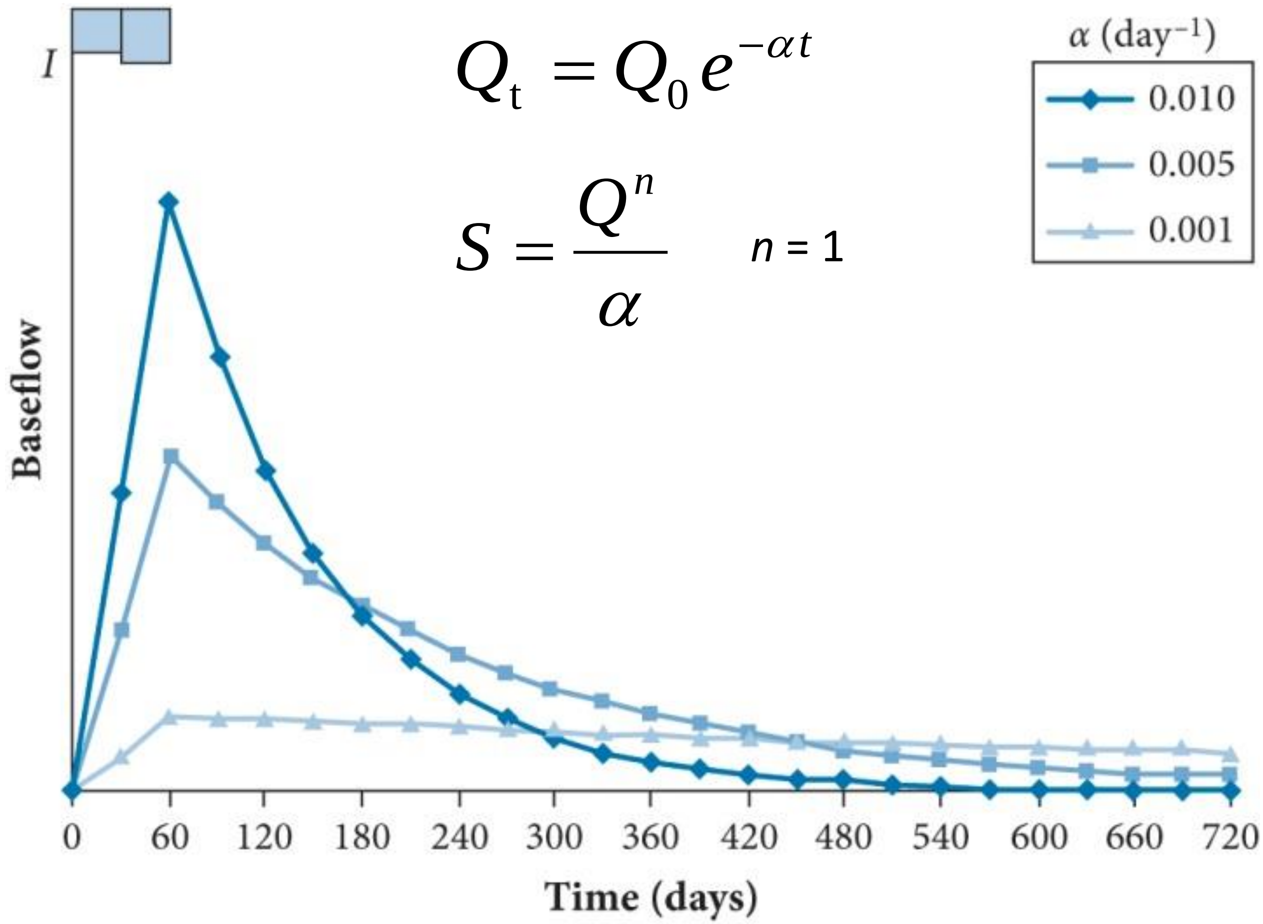
$$Q_{\mathrm{t+\Delta t}} = \frac{2 - \alpha \Delta t}{2 + \alpha \Delta t} Q_{\mathrm{t}} + \frac{2\alpha \Delta t}{2 + \alpha \Delta t} I_{\Delta \mathrm{t}}$$

$$Q_{\mathrm{t+\Delta t}} = \beta Q_{\mathrm{t}} + \left(1 - \beta\right) I_{\Delta \mathrm{t}}$$

Linear reservoir model

$$Q_t = Q_0 e^{-\alpha t}$$

$$S = \frac{Q^n}{\alpha} \qquad n = 1$$



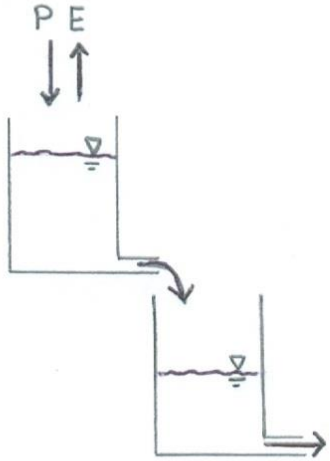
Hydrological triggering of landslides

French Alps, northwest of Gap

Two linear reservoirs in series:

upper reservoir = colluvial layer

lower reservoir = varved clays



varved clays

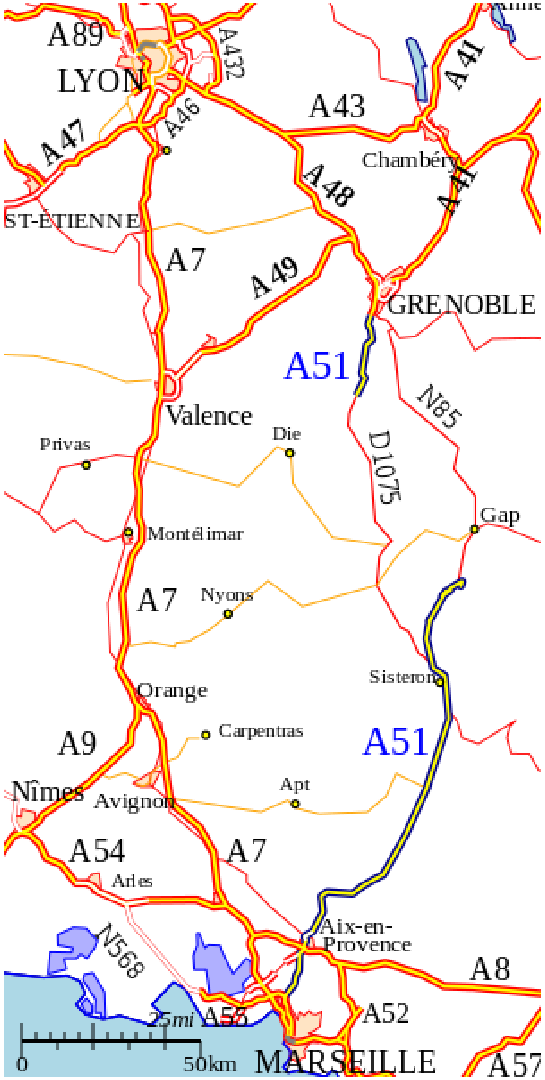
Source: Van Asch et al. (1996)

Hydrological triggering of landslides

Landslide movements in varved clay areas northwest of Gap in the French Alps are mainly triggered by a maximum rise of water in vertical fissures in the clays. Complete saturation of the clays is not necessary!

Drainage of the shallow, more permeable colluvial cover overlying the varved clays is a very effective measure to stabilize the deeper landslides.

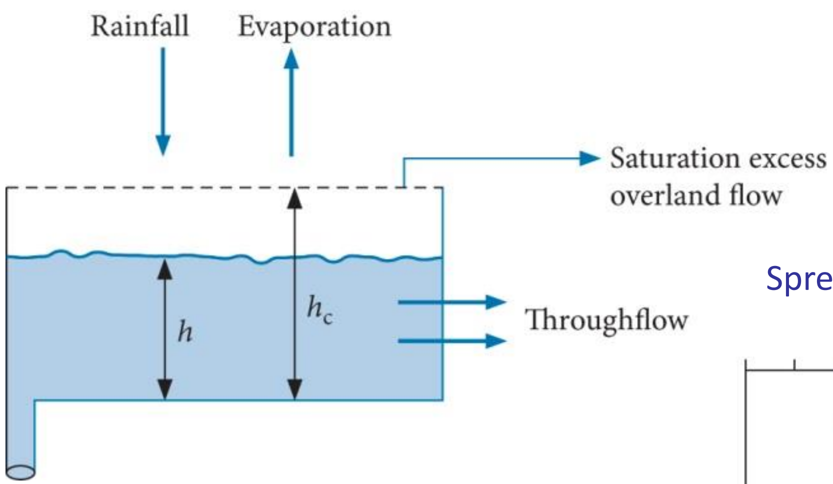
Source: Van Asch et al. (1996)



Exponential reservoir

STORFLO model (Kirkby et al., 1987)

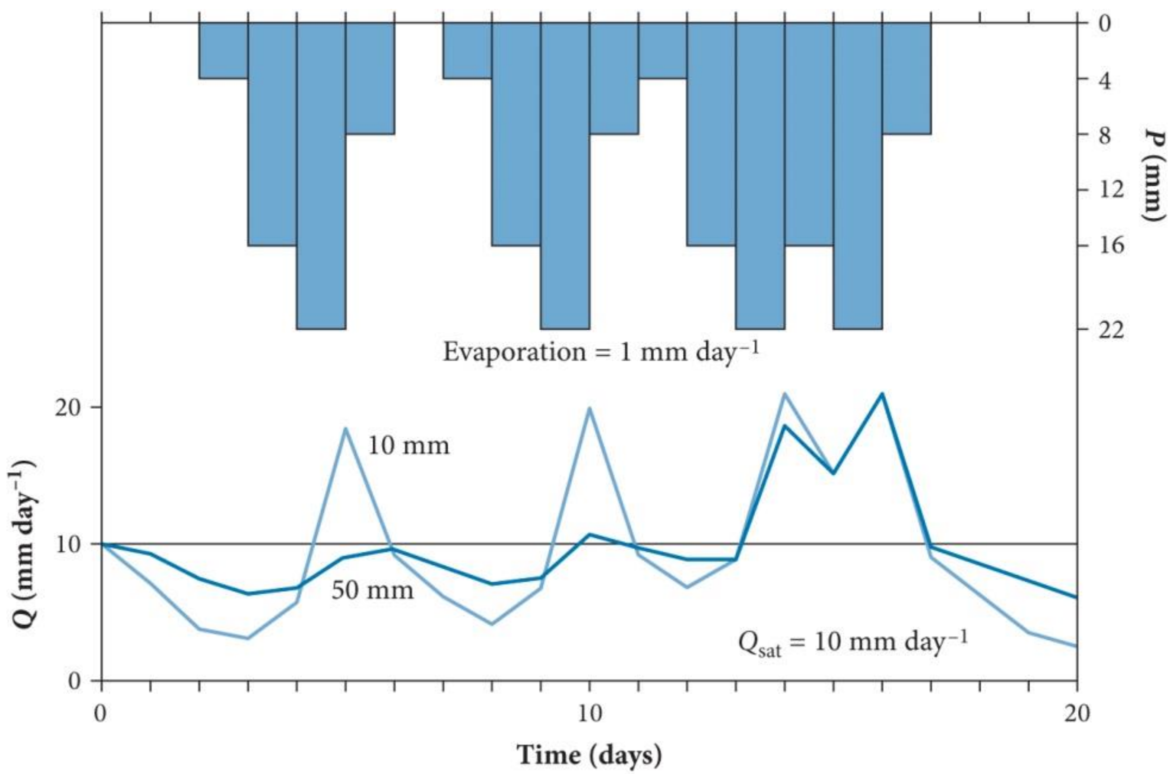
Spreadsheet: http://www.oxfordtextbooks.co.uk/orc/hendriks/



$$Q_t = Q_0 e^{\frac{S_t}{m}}$$

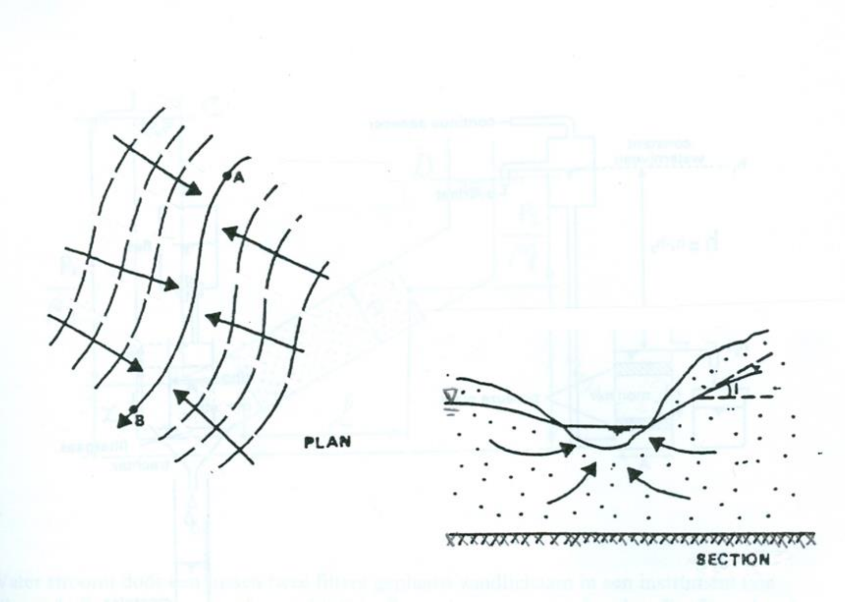
$$\frac{dS_t}{dt} = I - Q_t$$

$$Q_{t+\Delta t} = \frac{I_{\Delta t}}{1 - e^{\frac{-I_{\Delta t}}{m}} + \frac{I_{\Delta t}}{Q_t} e^{\frac{-I_{\Delta t}}{m}}}$$



Exercise 5.4.3

The discharge of a river at an upstream measuring station A equals 100 $m^3 s^{-1}$.
The discharge at a downstream measuring station B equals 120 $m^3 s^{-1}$.
In one hour, the storage in the river between these two stations reduces by 45000 m^3.
The discharge at the upstream station A after one hour is 110 $m^3 s^{-1}$.



Assuming a linear change of the discharge with time, determine the discharge in $m^3 s^{-1}$ at the downstream station B after one hour.

Vaison-la-Romaine

Hydrology is concerned with the occurrence, movement and composition of water below and at the earth's surface

Brothers in science: climatology, meteorology, fluid mechanics, sedimentology, hydrochemistry, land degradation, ecology

Water-related problems

Hydrology is a no-regrets study!

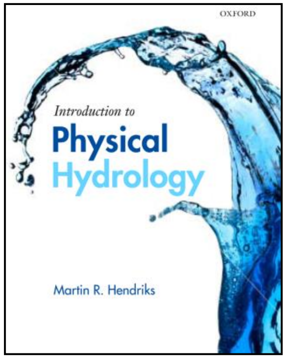
- floods and droughts
- greenhouse gas emissions
- plant and soil respiration
- the carbon cycle
- availability of fresh water for agricultural purposes
- intrusion of salt water
- water-related diseases
- sustainable access to safe drinking water
- adequate sanitation services
- deterioration of ecosystems
- declining groundwater quality
- soil loss by erosion
- pollution
- bioremediation
- preferential flow
- radioactive waste disposal
- natural gas transport in soil and groundwater systems
- water management

Climate change research

Hydrology at Utrecht University

BSc Earth Sciences, Hydrology courses:

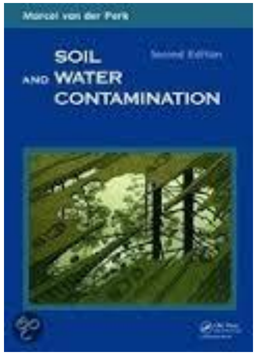
- GEO2-4203 Physical hydrology
- GEO3-1330 Water in GEO processes
- GEO3-4301 Soil and water contamination
- GEO3-4307 Fluid mechanics



Introduction to Physical Hydrology
in simplified Chinese characters

MSc Earth Sciences, Hydrology courses:

- GEO4-1434 Principles of groundwater flow
- GEO4-4404 Land surface hydrology
- GEO4-1433 Hydrogeological transport phenomena
- GEO4-4417 Unsaturated zone hydrology
- GEO4-4420 Stochastic hydrology
- GEO4-1432 Environmental hydrogeology
- GEO4-4423 Climate change, hydrology & cryosphere



Marcel van der Perk -
Soil and Water Contamination

MSc Water Science and Management course:

- GEO4-6001 Quantitative water management

References

Hendriks, M.R. (2010). Introduction to Physical Hydrology. Oxford University Press.

Kirkby, M.J., Naden, P.S., Burt, T.P., and Butcher, D.P. (1987). Computer Simulation in Physical Geography. Wiley, 227 pp.

Van Asch, Th.W.J., Hendriks, M.R., Hessel, R., and Rappange, F.E. (1996). Hydrological triggering conditions of landslides in varved clays in the French Alps. Engineering Geology, 42, 239-251.

GOOD LUCK WITH YOUR STUDIES!