Erosion control by water management

G. Pottecher

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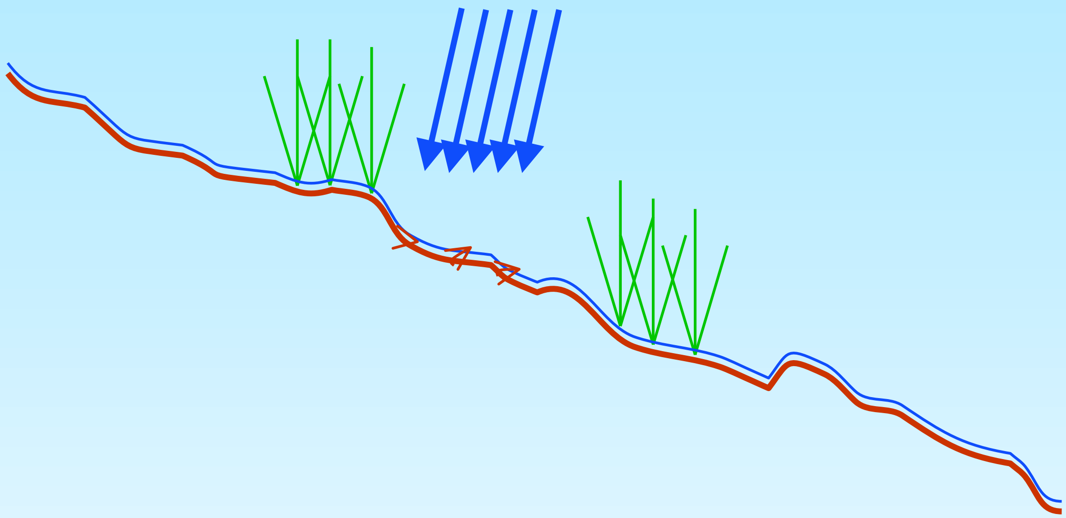
Content of the presentation

- Erosion phenomena
- Erosion control methods and engineering
- Flow modelling strategy for erosion control
- Application to the Salsigne case

Why erosion control ?

- Source of impacts
  - Mining and metallurgy contaminate surface soils by dust fallout and solids spills
  - Runoff erodes the contaminated surface soils
  - Rivers and sediments are impacted
- Remediation approach
  - Containment is unfeasible at the km^2 scale
  - Erosion control enables **flux reduction**

Impact erosion (splash erosion)



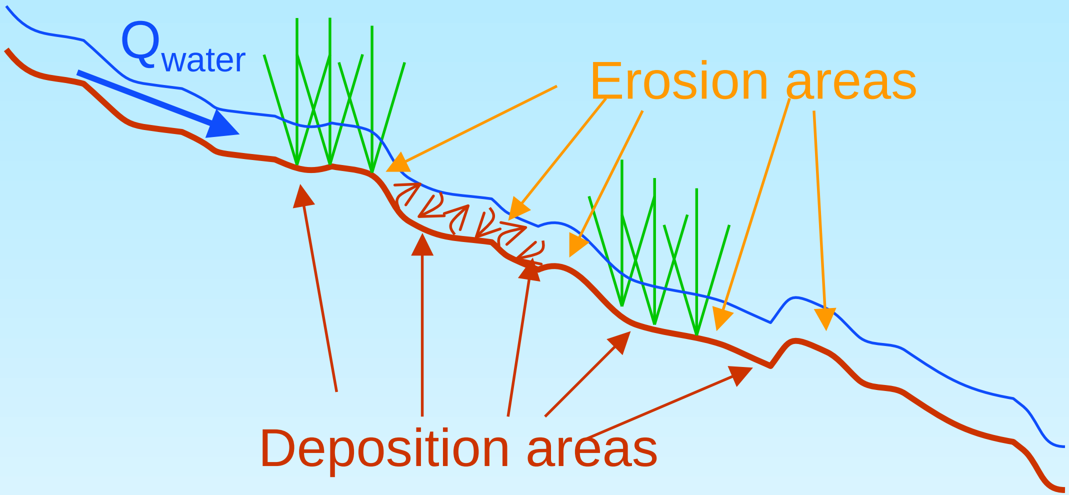
- According to the Universal Soil Loss Equation

  Solids detachment ≈

  (drop energy) x (soil texture) x (vegetation coverage)

- Mitigation by
  - vegetation coverage
  - coarse topsoil

Channelled flow erosion



- According to the Meunier formula
  - Solids transport capacity of flow ≈ (flow rate) x (slope^2)
- Rills appear where the slope increases
- Solutions
  - Minimise flow rate
  - Protect convex ditches

Sheet flow erosion

- Same concept as channelled flow erosion but for a thin water layer flowing on flat slopes
- Importance of:
  - water flow rate across the sheet
  - soil retention by vegetation
  - slope angle (pull strength of water flow)
- Sheet flow tends to convert into channelled flow when going downhill
- A Meunier type formula can be used, cf. channelled flow erosion

Basic methods for erosion control

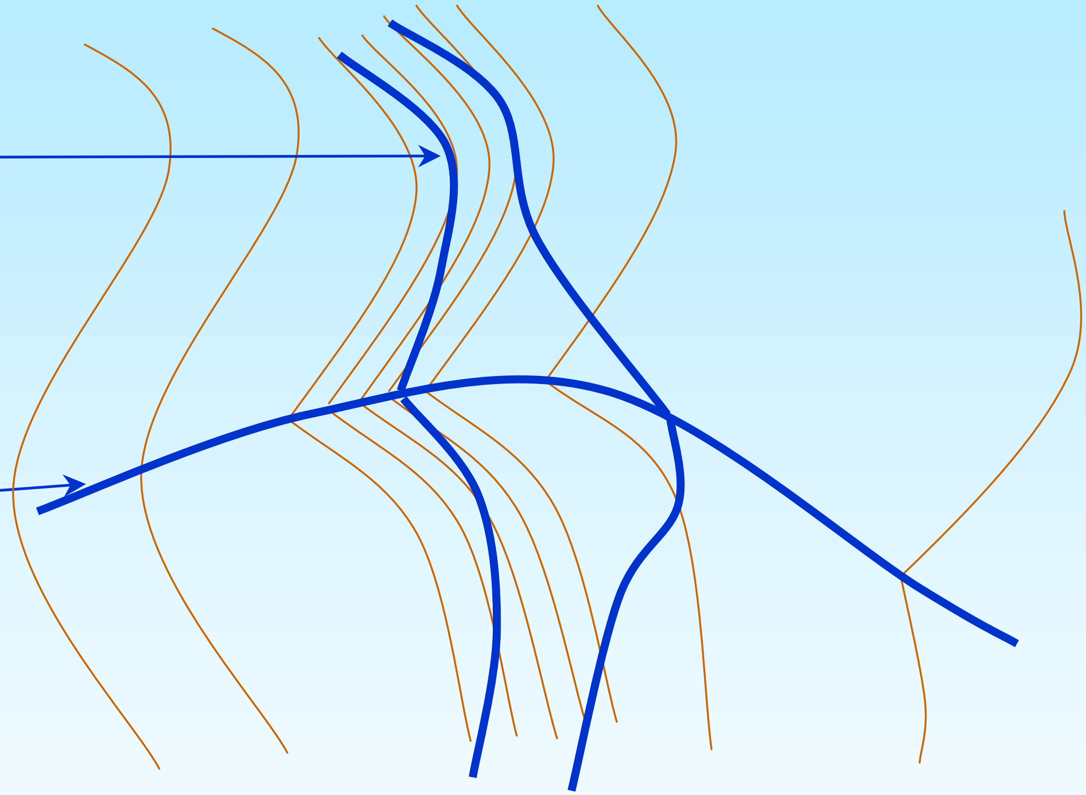
- Vegetalisation
  - Reduces rain impact energy
  - Dramatically increases topsoil permeability
  - Holds topsoil
- Collection of runoff by non-erodible ditches
  - Avoids the build-up of excessive flow rate runoff on loose soil
- Settling system for particles abatement
  - Prevention of ditch filling
  - Ultimate protection of surface water against contaminated solids
- Separate handling of unpolluted runoff
  - Reduced dimensions for pollution control systems

Engineering issues for erosion control

- The engineer must determine the following
  - Layout of ditches, berms, and settling systems
  - Dimensions of hydraulic systems
  - Identification of key vegetalisation zones
  - Mixing or separation of “clean” runoff with polluted flow

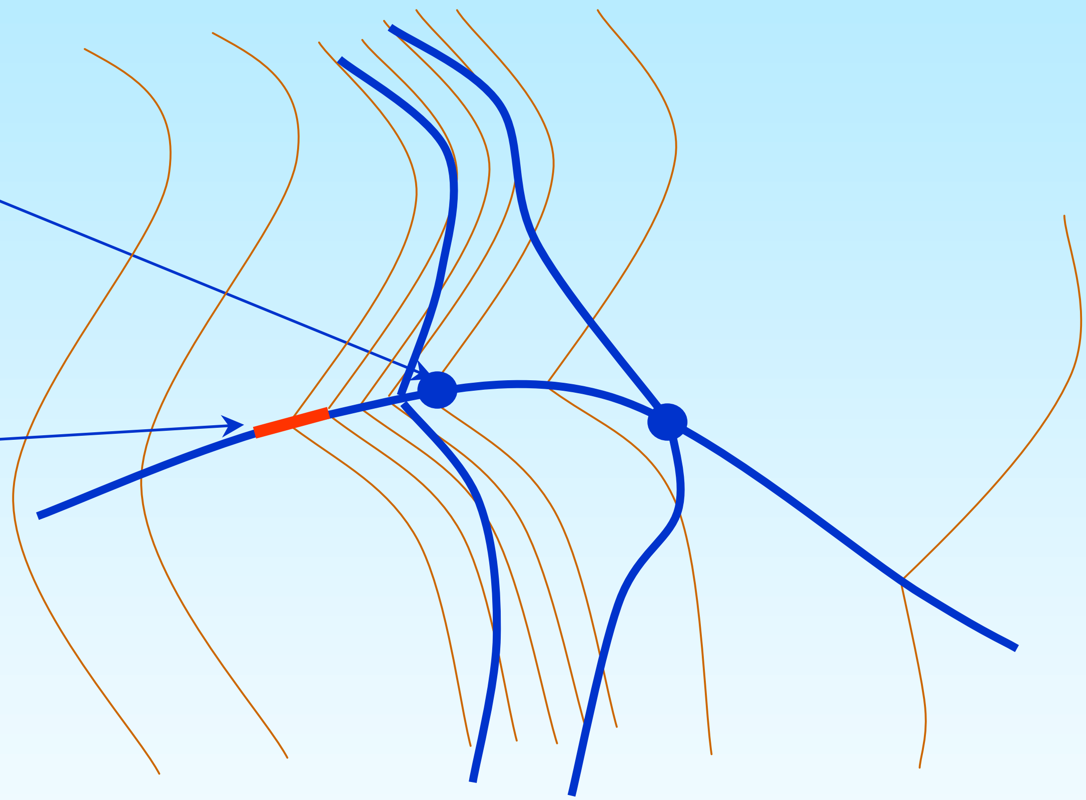
Layout of ditches

- Convex zones
  - Constant slope of ditch or berm
- Concave zones
  - Ditch along the talweg line



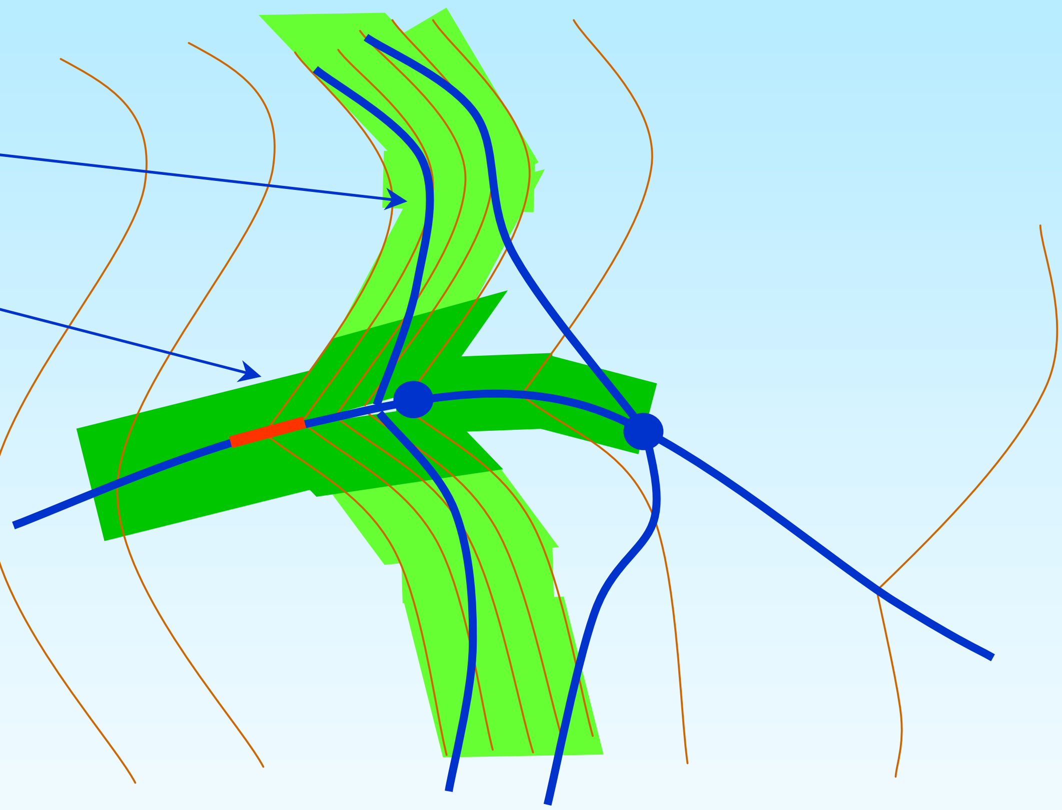
Layout of specific protections

- Settling systems (e.g. ponds)
  - at slope decrease points
- Anti-erosive protections
  - at slope increase points



Key areas for vegetalisation

- Reinforced
  - On steep slopes
  - In talwegs (flow concentration zones)



- Everywhere
  - For minimizing runoff generation and splash erosion

Hydraulic dimensions

- Define a reference rain event (e.g. decennial)
  - duration, maximum intensity, total rainfall
- Design the hydraulic section of ditches on the basis of flow rate modelling
  - **Linear yield model**, In Salsigne the design value can be 2 $(m^3/h) / ((mm/h).ha)$
    This approach is very conservative, does not consider the beneficial effect of vegetation
  - **Modelling** of local vegetation effect: useful but demanding
- Design the settling systems
  - Possible basis for ponds:
    - flow velocity reduction (e.g. divide by 3 or 5)
    - sand storage capacity without significant efficiency reduction during the projected maintenance interval (e.g. 1 year)

Separation of clean and polluted flows

- Separating flows is the result of a balance between:
  - duplicate discharge lines (increased costs)
  - size reduction for settling and treatment systems (savings)
- Water quality forecasts are required for such decisions
- Approximate assumptions can be made for water quality forecast:
  - the suspended solids content is constant (e.g. 1 g/l)
  - the pollution is bound to suspended solids, which are representative of topsoil quality in each sub-catchment

Flow modelling strategy for erosion control

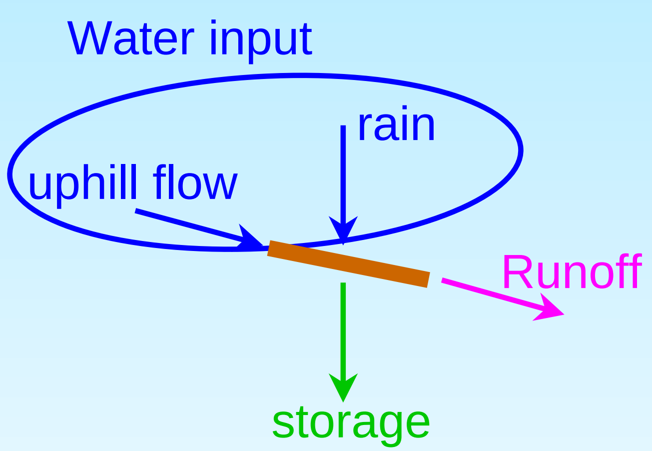
- Possible actions on the system are:
  - modification of runoff source (vegetalisation)
  - modification of flow transfer (drainage network)
- Aim of simulation:
  - prevision of local flow rates and discharge volume
- Key model features are:
  - the simulation has to be event based
  - the generation of runoff water has to be described by parameters with local values
  - accurate peak flow forecasts are required

Runoff model used in Salsigne

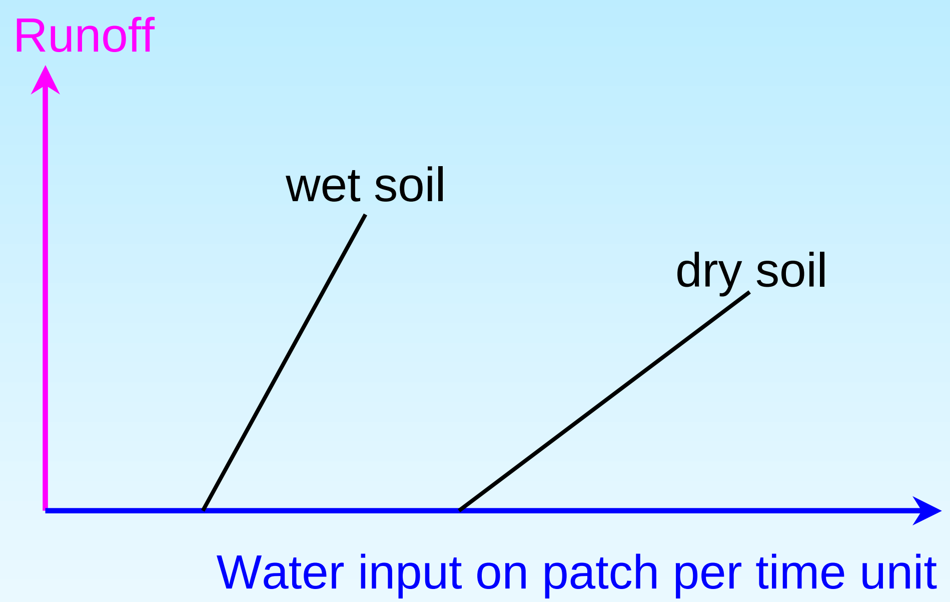
- A **specific model** has been developed, because available ones (e.g. Eurosem) require too much data
- It has been adapted from an original approach developed by Cerdan at **INRA** (French Agronomy Research Institute) for fields with moderate slopes
- The Salsigne model is based on a 5 m mesh Digital Terrain Model
- It is a distributed dynamic model: flow equations are calculated at the mesh level

Modelling the local generation of runoff

Water balance for a patch of soil surface



Runoff production by a patch of soil surface



- Runoff is negligible when rain begins
- Later runoff production varies according to:
  - soil saturation (cf. figure above)
  - soil type

Mathematical description of runoff source term

- Parameters in the equations describing each patch
  - At least one parameter mapped in the field, e.g. maximum infiltration rate on dry soil
  - 2 or 3 parameters valid at catchment scale for describing the infiltration behaviour according to rainfall
    - during the event
    - according to evaporation and draining history (past rainfall)
- **Calibration** of catchment scale parameters is done against flow measurement data

Peak flow estimate

- The transfer across patches is not instantaneous
  - results computed with instantaneous transfer must be smoothed
- Approach
  - the smoothing depends on the local slope: the water flow velocity is slope-dependent (e.g. proportional to slope angle)
  - 1 smoothing parameter is fitted for the whole catchment

Salsigne model calibration area (30 ha)

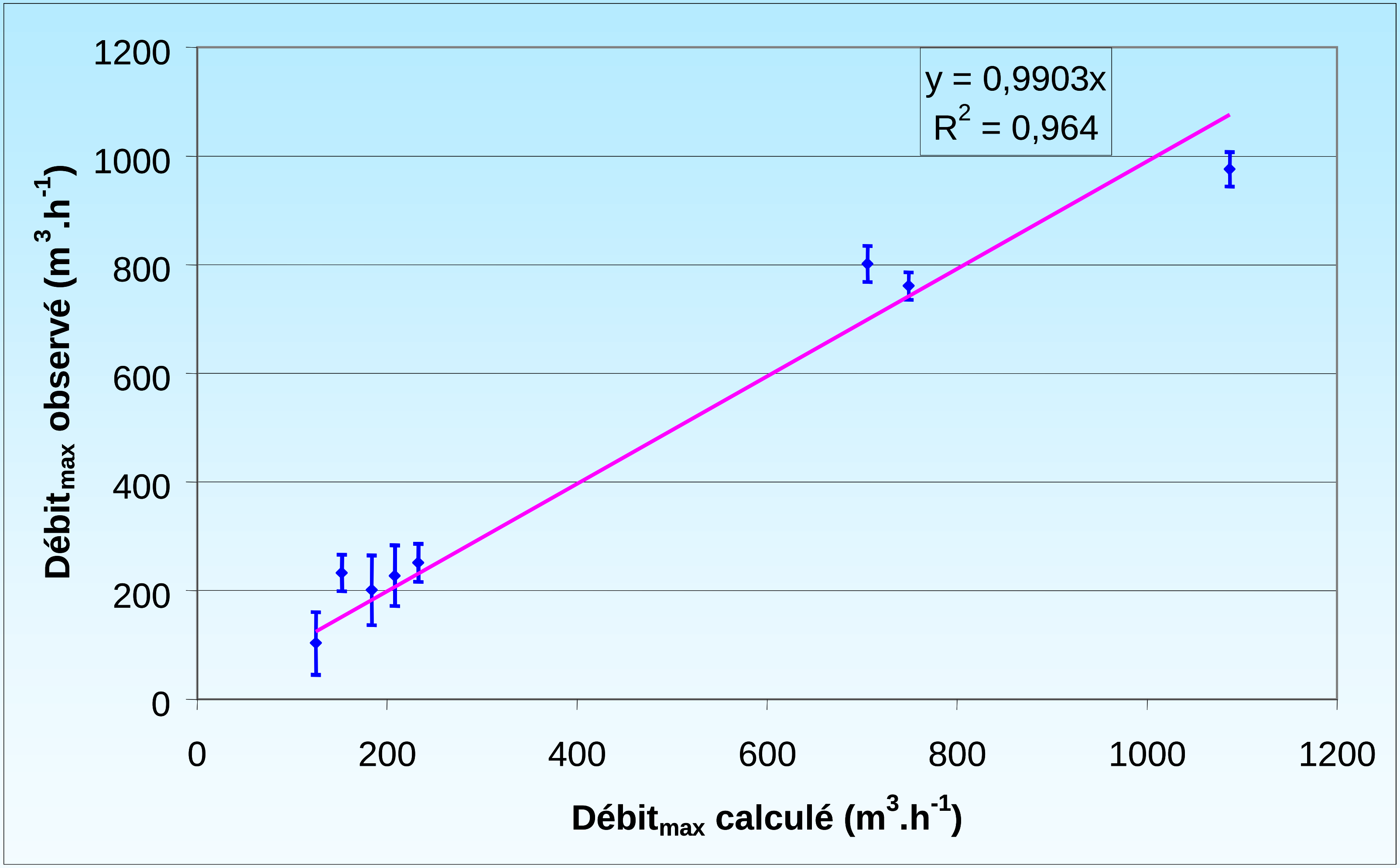
Water sampling
7 events

Sand settling
20 events

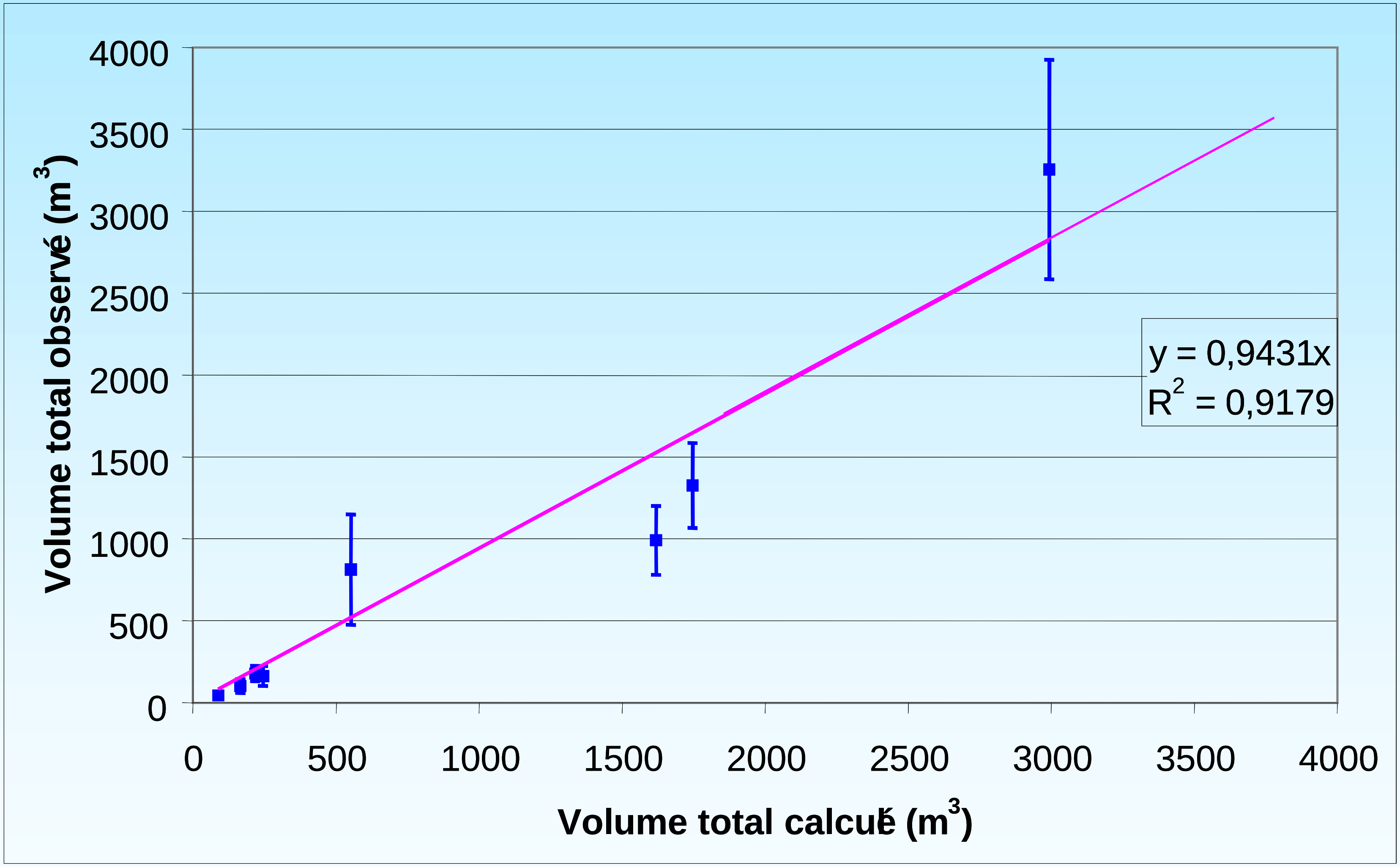
Flow rate recording
40 events

Rainfall gauge
150 events

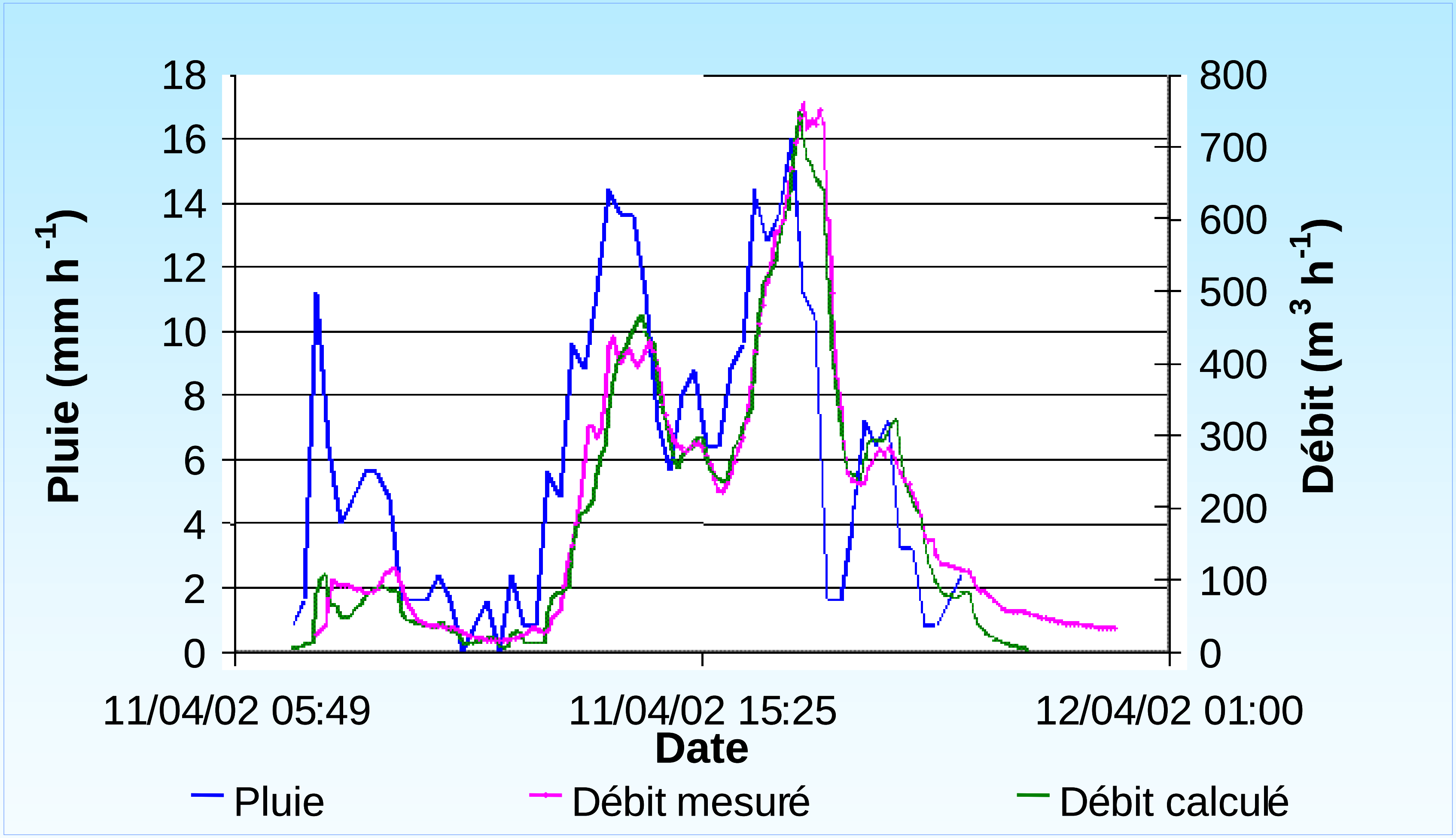
Peak flow rates fitting with the calibrated model



Flow volumes fitting with the calibrated model

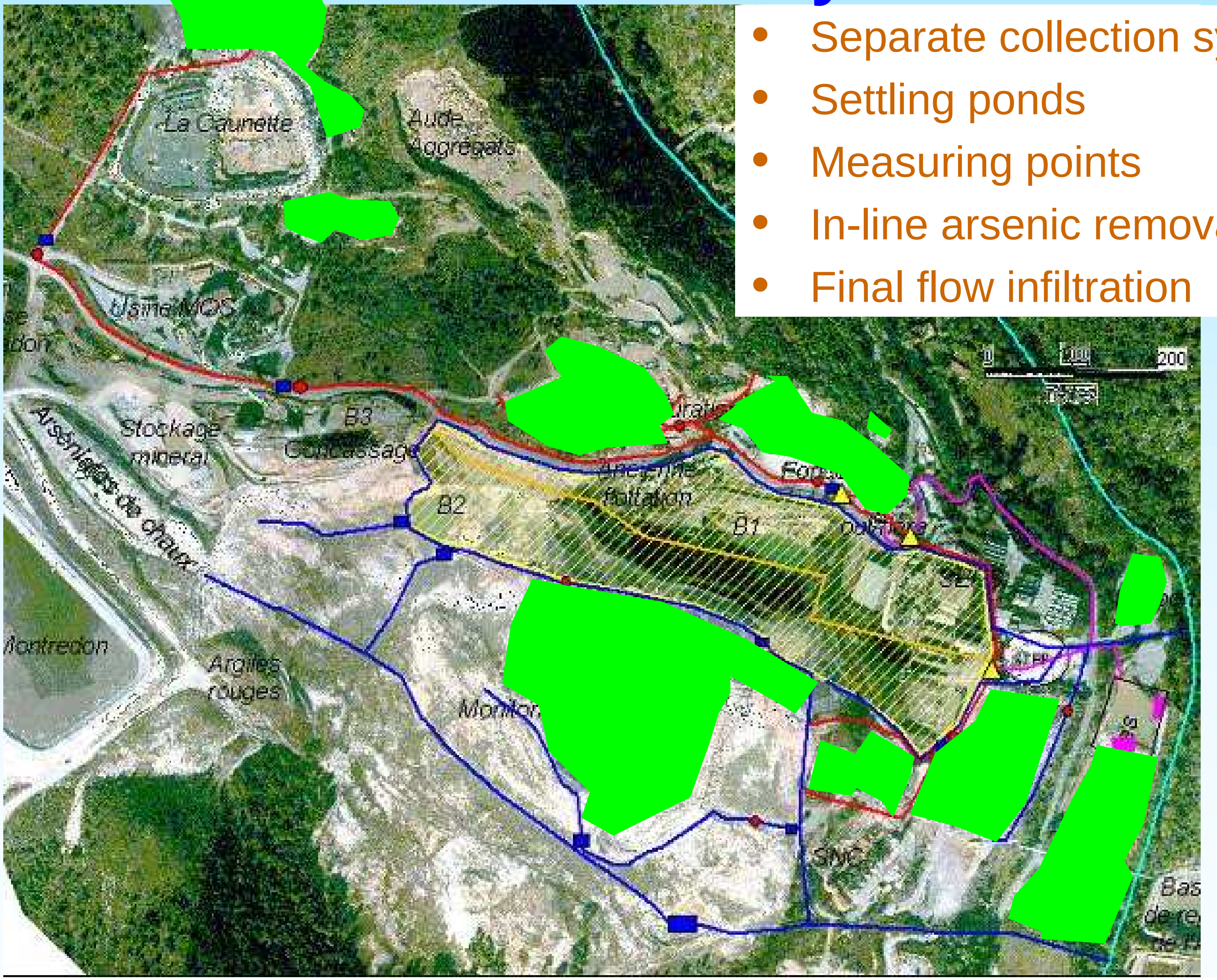


Hydrogram fitting
with the calibrated model



Salsigne case: result of water system design

- Separate collection systems
- Settling ponds
- Measuring points
- In-line arsenic removal treatment
- Final flow infiltration



Conclusion

- Joint design of vegetalisation and hydraulic system is recommended for project optimisation.
- The major effect of vegetation is through the reduction of runoff.
- Other applications of this approach are:
  - agriculture (runoff of pesticides, cf. Life SWAP CPP by IRH)
  - urban drainage