2007:

SOME CHALLENGES IN NUMERICAL MODELLING

UNSA – Hydro-Europe – 2007 challenges in modelling

A. Modify the paradigm of good practice in modelling.

B. Explain the reality on models towards non specialists.

C. Decision making processes and models.

D. Extension of the state of the art in mathematical and numerical analysis.

E. Understanding and mathematical formulation of sediment movement and bed-bank deformation in rivers.

F. Modelling of river morphology and sediment movement.

G. Turbulence modelling and applications.

A. Modify the paradigm of good practice in modelling.

Current paradigm:

a) Instantiation or set up or 'construction'.

b) Calibration = executing a number of simulations of past observed events and varying parameters

c) Validation= executing with a calibrated model a number of simulations of past-observed events (different from those used for calibration)

d) Exploitation runs (studies) with the model recognised as a validated tool.

These four stages historically come from hydrological correlative or black box modelling practice. They are a natural and indisputable approach when data-driven 'models' are concerned

CALIBRATION SHOULD BE ABANDONNED IN MECHANISTIC-DETERMINISTIC MODELS

Calibration must be limited to the model parameters that are *invariant* between the instantiation and exploitation stages

To calibrate parameters that will subsequently be modified during the exploitation runs used for simulating the impact of future projects is most often a useless, as well as costly

Calibration of 'global' head loss coefficients along a river stretch including features the characteristics of which vary between calibrated situation and exploitation runs (structures, sills, narrowing or widening of the river bed, etc.), may lead to a non predictive black box model

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<u>Example</u>: Strickler – Manning coefficient is invariant for a uniform flat gravel bed

<u>Counter example</u>: if the river is alluvial, with sand bed and if the exploitation runs involve water discharges and stages such that the dunes or other bed-forms appear, Strickler coefficient calibrated for the flat bed is not invariant.

<u>Counter example</u>: if during exploitation runs the stretch is affected by backwater (due to structures, confluences, etc;) Strickler coefficient calibrated for the situation of non affected flow is not invariant.

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Example: a natural river stretch of length of few kilometres, with vegetation, variation of bed sediments; global Manning coefficient calibrated for a stretch is useless if the works are planned and the model is supposed to be used to study their effect

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Indeed: there is no difference in concept between such calibrated model and calibrated black box: the results are valid only within the range of the sample used to calibration

In practice, is a ***meaningful calibration possible?***

The answer is negative for most cases, because of:

- impossibility to isolate invariant parameters
- lack of appropriate data
  or
- cost of the data acquisition.

'obvious' applications of a paradigm including calibration may well lead to serious errors because of the belief that calibration is meaningful or because of a wrong choice of calibrated parameter

Calibration is still a common practice because it makes both sides happy: the modeller and the end-user/client.

Their satisfaction is most often related to a formal coincidence **and not to any** understanding of physical problems**,**

while this last criterion is the most important point for projects and future developments, and the very reason for commissioning the model at all.

New modified paradigm of modelling:

a) *Instantiation* of the model: construction *and* definition of the methodology necessary to define the range of uncertainty in the results of the computations.

b) *Validation* : simulation of a number of past-observed events with the model, computing or otherwise finding the range of uncertainty for the results, and finding physically logical reasons for differences between the simulated and observed results. Analysis of the impact of the differences as well as of the uncertainties upon the results.

c) *Exploitation runs* *(studies)*: supplying the results *and* impacts *and* their range of uncertainty to the end-user or client under an intelligible interpretation form.

B. Explain the reality on models towards non specialists:

- **A model is not the reality and, hence, it is not a panacea for engineering problems.**
- **A model ("calibrated" and "validated") cannot be trusted for all situations (e.g.: river morphology).**
- **Any model is limited in its applications by our knowledge, numerical techniques, available budget.**
- **3D model may not be an improvement over 2D model or 1D model.**

C. DECISION-MAKING CANNOT BE BASED ON THE RESULTS OF MODELLING ALONE *UNLESS* DECISION-MAKERS ARE CONVINCED AND SURE THAT THE MODEL IS RELIABLE FOR THE PROBLEM AT HAND.

OTHERWISE A COMBINATION OF FOUR TECHNOLOGIES SHOULD BE USED:

- **NUMERICAL SIMULATION**
- **SURVEYING AND MEASURMENTS**
- **SCALE MODELLING**
- **EXPERTISE**

Example: alluvial estuaries and rivers (viz. Prof Peters)

D. Extension of the state of the art in mathematical and numerical analysis (1):

Even for linear equations the following problems are not solved for 3D systems:

- ***Existence*** **of solutions, dependence upon boundary and initial conditions, for both differential and difference equations;**
- ***Consistency*** **of discretisation, boundary conditions (number and form) included;**
- ***Convergence*** **of solutions of discretised systems solutions to analytical solutions.**

D. Extension of the state of the art in mathematical and numerical analysis (2):

- For 2D systems appropriate formulation and understanding of boundary conditions has been achieved only 3 years ago (viz. Prof. Guinot).
- Most of existing and market available 2D modelling systems for rivers and estuaries use wrong or inadequate boundary conditions.
- ***All*** **existing and market available 3D modelling systems for rivers and estuaries use wrong or inadequate boundary conditions.**

E. UNDERSTANDING OF PHYSICS AND DEVELOPMENT OF MATHEMATICAL FORMULATION OF SEDIMENT MOVEMENT AND BED-BANK DEFORMATION IN RIVERS

CURRENTLY NO CONSENSUAL HYPOTHESES, THEORY OR FORMULATION EXIST

N.B.:* *This is not strictly speaking modelling challenge but so many people model these phenomena in absence of understanding them that…

F. **Modelling of sediment erosion, deposition, movement.**

Lack of understanding of physics and absence of reliable mathematical formulation leads to the "modelling" results of which are often coarse, sometimes false, always to be interpreted & compared with other approaches.

G. **Modelling of river plan morphology and bed forms**

Same comment as above

G. Turbulence:

- Consensual Mathematical formulation does not exist
- Consensual formulations of links with
  - turbulent diffusion,
  - sediment suspension,
  - shear stresses and erosion/deposition

do not exist

ABOVE COULD SUFFICE FOR A LIFE TIME…..

GIVES AN IDEA WHY NUMERICAL MODELS ARE NOT PANACEA, WHY MODELS MUST NOT BE USED ALONE FOR COMPLEX PROBLEMS,

WHY ENGINEERING EXPERTISE, SURVEYS, SCALE MODELS, KNOWLEDGE OF PHYSICS(HYDRAULICS) AND EVEN INTUITION

MUST NOT BE DISCARDED FROM DECISION MAKING PROCESSES.