

Five common mistakes in fluvial morphodynamic modeling

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1 FIVE COMMON MISTAKES IN FLUVIAL MORPHODYNAMIC MODELLING

2

3 by

4

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11

12 Keywords

13

14 River morphodynamics, numerical modelling, alternate bars

15

16 Abstract

17

18 Recent years have seen a marked increase in the availability of morphodynamic models and a

19 proliferation of new morphodynamic codes. As a consequence, morphodynamic models are

20 increasingly developed, used and evaluated by non-experts, possibly leading to mistakes. This paper

21 draws attention to five types of common mistakes. First, new morphodynamic codes are developed

22 as extensions of existing hydrodynamic codes without including all essential physical processes.

23 Second, model inputs are specified in a way that imposes morphodynamic patterns beforehand

24 rather than letting them evolve freely. Third, detailed processes are parameterized inadequately for

25 application to larger spatial and temporal scales. Fourth, physical and numerical phenomena are

26 confused when interpreting model results. Fifth, the selection of modelling approaches is driven by

27 the belief that complete data are a prerequisite for modelling and that the application of 2D and 3D
28 models requires more data than the application of 1D models. Examples from fluvial
29 morphodynamics are presented to illustrate these mistakes.

30

31 1. INTRODUCTION

32

33 Fast technological developments have fuelled impressive advances in two-dimensional depth-
34 averaged (2DH) numerical models of river morphodynamics over the past eighty years. Van
35 Bendegom's (1947) numerical code was solved by hand in the 1930s, when a calculator was still a
36 profession instead of a machine. Today, river engineers visit a river in a far-away country, collect
37 elementary data on the spot, set up a computational grid based on Google Earth in their Wi-Fi-
38 equipped hotel room in the evening, run a morphodynamic simulation, and present plots and
39 animations of the morphodynamic evolution to the client or stakeholders the next morning.

40

41 The technological developments have also increased the number, the availability and the user-
42 friendliness of morphodynamic codes. As a consequence, morphodynamic models are increasingly
43 developed, used and evaluated by non-experts. Mosselman (2012) and Sloff & Mosselman (2012)
44 argue, after Van Zuylen et al (1994), that modelling of river morphodynamics requires teams or
45 communities with specialists in (i) domain knowledge based on experience with real rivers; (ii)
46 knowledge about model concepts such as the underlying mathematical equations; (iii) knowledge
47 about model constructs such as grids, time steps, morphological acceleration factors and spin-up
48 times; and (iv) knowledge about model artefacts such as user interfaces and file formats. Mistakes
49 are possible if the modelling team does not cover this full range of expertise. Our objective is to
50 share our experiences on five common mistakes from over 25 years of involvement in executing,
51 supervising and reviewing modelling of river morphodynamics. This has been inspired by Salt's (2008)

52 similar but broader paper on mistakes in simulation modelling that bears relevance for river
53 morphodynamic modelling too.

54

55 Our approach in this paper is as follows. We set up a simple numerical model for water flow in a
56 straight channel with a mobile bed. We run simulations with this model to illustrate two of the five
57 mistakes. The other three mistakes are explained without model simulations. We discuss a few
58 considerations behind the list of common mistakes, the use of a morphological acceleration factor,
59 and the implications for model validation. Finally, we provide recommendations for modellers as
60 well as supervisors and reviewers of numerical computations in fluvial morphodynamics.

61

62

63 2. SET-UP OF NUMERICAL COMPUTATIONS

64

65 We set up a Delft3D model, based loosely on the numerical model of Crosato et al (2011), for a
66 10 km long and 90 m wide straight channel (Figure 1). The gradient, i , was equal to 0.1 m/km, the
67 discharge, Q , was 180 m³/s and the Chézy coefficient for hydraulic roughness, C , was 42.84 m^{1/2}/s.
68 These values produced a reach-averaged flow depth, h_0 , of 2.793 m and a reach-averaged flow
69 velocity, u_0 , of 0.716 m/s. The median sediment grain size, D_{50} , was equal to 0.2 mm. At the
70 entrance of the channel, a 30 m long cross-dam protruded perpendicularly from the left bank into
71 the channel in order to generate the development of a pattern of steady alternate bars downstream
72 (Struiksma et al, 1985). We used the Engelund & Hansen (1967) formula to calculate sediment
73 transport, and the following formula to calculate the influence of transverse bed slopes on the
74 direction of sediment transport:

75

$$f(\theta) = 0.5\theta^{0.5} \quad (1)$$

76

77 where θ denotes the Shields parameter and $f(\theta)$ is a function weighing the influence of
78 transverse bed slopes, following the notation of Struiksma et al (1985) and Talmon et al (1995). We
79 did not attempt to calibrate the model on any particular channel in reality, because the purpose of
80 the computations was simply to demonstrate the effect of certain settings, representing mistakes,
81 on model results.

82

83 The computations were carried out with a morphological acceleration factor of 10. The
84 computations were terminated after simulation of 500 days. We computed a reference case, leading
85 to a longitudinal bed level profile along the right bank presented in Figure 2, and two cases
86 illustrating common mistakes. The first illustration regards the effect of omitting the dependence of
87 sediment transport direction on gravity pull along transverse bed slopes. The second effect regards
88 the effect of non-homogeneous distributions of hydraulic roughness.

89

90

91 3. THE FIVE COMMON MISTAKES

92

93 3.1 Codes with inadequate representation of physical processes

94

95 An important feature of sediment transport in rivers is that its direction can deviate from the depth-
96 average flow direction by two mechanisms. First, the interplay of centrifugal forces and pressure
97 gradients in curved flows gives rise to a helical motion by which flow velocity vectors exhibit an
98 inward deviation near the bed and an outward deviation near the water surface. Accordingly, the
99 direction of bedload differs from the depth-average flow direction. The same holds for the depth-
100 average vector of suspended sediment transport as long as the corresponding concentrations are
101 not distributed homogeneously over the vertical. The second mechanism for deviations between the

102 direction of sediment transport and depth-average flow is that sediment particles move by a
103 combination of flow forces and gravity. Particles moving over a transversely sloping bed thus
104 experience gravity pull in a direction perpendicular to the direction of the flow shear stresses,
105 producing a difference between the directions of flow and sediment transport.

106

107 Results of morphodynamic computations appear to depend sensitively on these differences in
108 direction. Well-established morphodynamic codes account for these differences through
109 parameterized representations of these mechanisms. In new codes, however, these effects are not
110 always accounted for, often because they are developed as simple extensions of 2D or 3D
111 hydrodynamic codes with sediment transport formulas and a sediment mass balance. Figure 3 shows
112 the effect of omitting the effect of transverse bed slopes on sediment transport direction from our
113 model. The resulting bed morphology is completely different, with a shorter wave length and less
114 downstream attenuation.

115

116 Apparently the bed slope effect has a damping or stabilizing influence on morphodynamic evolution
117 of the river bed. This can be understood by considering the 2D depth-averaged sediment balance for
118 flow in x direction (cf. Mosselman, 2005):

119

$$\frac{\partial z_b}{\partial t} + \frac{\partial q_{sx}}{\partial x} + \frac{\partial q_{sx} \tan \alpha}{\partial y} = 0 \quad (2)$$

120

121 with

122

$$\tan \alpha = -\frac{1}{f(\theta)} \frac{\partial z_b}{\partial y} \quad (3)$$

123

124 in which z_b denotes bed level, q_{sx} is the sediment transport rate per unit width in flow direction, α
 125 is the angle between the directions of flow and sediment transport, t is time, and x and y are co-
 126 ordinates in flow direction and transverse direction, respectively. Substitution of the latter equation
 127 into the sediment balance yields

128

$$\frac{\partial z_b}{\partial t} - \frac{q_{sx}}{f(\theta)} \frac{\partial^2 z_b}{\partial y^2} = \frac{\partial z_b}{\partial y} \frac{\partial}{\partial y} \left(\frac{q_{sx}}{f(\theta)} \right) - \frac{\partial q_{sx}}{\partial x} \quad (4)$$

129

130 This is a diffusion equation for bed level, forced by gradients in sediment transport. The diffusive
 131 second term is responsible for the damping or stabilization. This explains the reduced attenuation of
 132 alternate bars when omitting the effect of transverse bed slopes.

133

134 Similar diffusion terms, however, arise from truncation errors in the numerical discretization. For
 135 instance, a simple upwind discretization of the transverse bed gradient could be

136

$$\frac{\partial z_b}{\partial y} = \frac{z_b^n - z_b^{n-1}}{\Delta y} \quad (5)$$

137

138 Taylor series expansion results in

139

$$z_b^{n-1} = z_b^n - \Delta y \frac{\partial z_b}{\partial y} + \frac{(-\Delta y)^2}{2} \frac{\partial^2 z_b}{\partial y^2} + \text{higher order terms} \quad (6)$$

140

141 This means that the true representation of the discretized transverse bed level gradient reads

142

$$\frac{z_b^n - z_b^{n-1}}{\Delta y} = \frac{\partial z_b}{\partial y} - \frac{\Delta y}{2} \frac{\partial^2 z_b}{\partial y^2} + \text{higher order terms} \quad (7)$$

143

144 Grid dependent truncation errors can hence have the same effect as inclusion of the physics-based
 145 effect of transverse bed slopes. This may hide the effect of omitting this mechanism in the sense
 146 that model results could be plausible for the wrong reasons. This renders correct calibration,
 147 verification and interpretation challenging.

148

149 A closely related, frequently occurring case of inadequate representation of physical processes is the
 150 application of sediment transport adaptation lengths to cases where in reality such lengths are
 151 negligible. The adaptation of non-equilibrium sediment transport can be described by a relaxation
 152 equation

153

$$q_{sx} + L \frac{\partial q_{sx}}{\partial x} = q_{se} \quad (8)$$

154

155 where L is the adaptation length and q_{se} is the equilibrium sediment transport rate per unit width
 156 predicted by a sediment transport capacity formula. Substitution into the 1D sediment balance (i.e.
 157 eq. 2 without the third term) results in

158

$$\frac{\partial z_b}{\partial t} + \frac{\partial q_{se}}{\partial x} - L \frac{\partial^2 q_{sx}}{\partial x^2} = 0 \quad (9)$$

159

160 The adaptation term appears to have a diffusive effect too. Some modellers use L to make their
 161 model stable while claiming that this parameter represents the real physical effect of retarded
 162 adaptation of non-equilibrium sediment transport, even if the Rouse number is too large to support

163 this claim. It would be better if they would state L to be a numerical stability parameter right away,
164 to avoid erroneous conclusions about the nature of the sediment transport in the system.

165

166 A final example of inadequate representation of physical processes is the confusion between
167 capacity-limited and supply-limited sediment transport. Models based on sediment transport
168 capacity formulas (with or without adaptation lengths for non-equilibrium transport) are sometimes
169 calibrated on measured suspended sediment concentrations that represent a mixture of bed-
170 material load and washload. Only the bed-material load is capacity-limited; washload is supply-
171 limited. In certain codes, sediment transport formulas for capacity-limited transport are erroneously
172 used to calculate the entrainment of sediment from the bed in convection-diffusion approaches that
173 are essentially supply-limited.

174

175 3.2 Inputs that impose morphodynamic patterns

176

177 A second common mistake occurs when model inputs impose morphodynamic solutions that
178 suppress the real morphodynamic behaviour. A widespread practice, for instance, is so-called “fine-
179 tuning” in which a model is calibrated by adjusting the hydraulic roughness on a point-by-point basis.
180 The resulting spatial roughness distribution generates a morphodynamic response (cf. Sloff &
181 Mosselman, 2012). To illustrate this, we applied a pattern of 416 m long and 45 m wide rectangular
182 roughness patches to the channel in our model (Figure 4). The Chézy roughness values of the
183 patches alternated between 37.49 and 51.41 $\text{m}^{1/2}/\text{s}$. The equivalent uniform Chézy value with the
184 same average roughness is hence equal to $[0.5(37.49^2+51.41^2)]^{-1/2} = 42.84 \text{ m}^{1/2}/\text{s}$, as in the
185 reference case. Figure 5 shows the results of computations with this configuration. The imposed
186 hydraulic roughness pattern produces higher alternate bars than the cross-dam, with a different
187 wave length. Calibration by local adjustment of field parameters can prevent the model river bed
188 from evolving freely and it reduces the predictive power of the model. Spatial variations of field

189 parameter values can be meaningful if they result from physical processes, for instance described by
190 an alluvial roughness predictor. They are not meaningful if they are imposed by fixed values.

191

192 Erroneous morphodynamic solutions can be imposed not only by spatial variations in field
193 parameter values but also by boundary conditions if the boundaries are too close to the area of
194 interest. The required distance to boundaries with uncertain conditions depends on the simulation
195 period, because the influence of boundaries reaches further as the period becomes longer. The
196 effect of sediment entry errors propagates into the model at a celerity, c , given by (De Vries, 1965)

197

$$c = \frac{bq_{sx}}{h} \quad (10)$$

198

199 where h denotes flow depth and b is defined by

200

$$b = \frac{u}{q_{sx}} \frac{dq_{sx}}{du} \quad (11)$$

201

202 in which u is the depth-averaged flow velocity. Ideally, the upstream boundary is selected at such a
203 distance, L_b , that sediment entry errors do not reach the area of interest within the simulation
204 period, T_s :

205

$$L_b > cT_s \quad (12)$$

206

207 assuming that these errors are a main source of uncertainty. Similarly, a minimum required distance
208 can be derived from the condition that morphological developments due to interventions in the area
209 of interest should not reach the upstream boundary within the simulation period, as this would

210 compromise the morphological condition imposed at the boundary. The relative effect at the
211 upstream boundary should be smaller than a prescribed tolerance, ε , e.g. $\varepsilon = 0.05$ or $\varepsilon = 0.1$.
212 According to the theory of De Vries (1975) this can be expressed as

213

$$\operatorname{erfc}\left(L_b \sqrt{\frac{3i}{4bq_{se}T_s}}\right) < \varepsilon \quad (13)$$

214

215 where i is the longitudinal river gradient and 'erfc' stands for the complementary error function.
216 Equations 12 and 13 imply that long simulation times might require long distances between the area
217 of interest and the upstream boundary, impractical not only for reasons of computation time but
218 also for reasons of including reaches with unknown water and sediment inflows from tributaries. In
219 practice shorter models are chosen in which, hence, the morphodynamic development is forced by
220 the boundary conditions. Such models have lower predictive power, but can still be meaningful for
221 sensitivity and scenario analyses. They are hence not necessarily mistaken. Ignoring the forcing by
222 boundary conditions when interpreting the results, however, does form a mistake.

223

224 Erroneous morphodynamic solutions can also arise from errors in the initial conditions. The effects
225 disappear after some spin-up time if the sediment is uniform and the banks are fixed. In case of non-
226 uniform sediment or erodible banks, however, the effects may last throughout the simulation.

227

228 3.3 Inadequate upscaling

229

230 Numerical models for fluvial morphodynamics solve equations that result from the integration of
231 small-scale processes over time and space. New concepts or phenomena may emerge from this
232 "parameterization" or "upscaling". For instance, exchange processes due to turbulent fluctuations
233 can be represented on larger time scales by employing eddy viscosities in Reynolds-Averaged Navier-

234 Stokes (RANS) models. The proper value of the eddy viscosity to be applied in a particular case
235 depends on the dimensions of the flow considered. Selecting a wrong value can be seen as
236 inadequate upscaling of the effects of turbulence.

237

238 Another example of this third common mistake occurs in the modelling of mixed-sediment
239 morphodynamics. Here complex processes of grain sorting (cf. Blom et al, 2003) can be scaled up to
240 the Saint-Venant-Hirano model, with an active bed layer in which the changes in bed sediment
241 composition take place. The latter emergent feature has a dominant effect on model results. Under
242 certain conditions it even leads to an elliptic set of equations in time and space, which is physically
243 unrealistic (Ribberink, 1987; Stecca et al, 2014). Outside conditions of ellipticity, the thickness of the
244 active layer governs the competition between two types of morphodynamic adjustment: bed level
245 change and change in bed sediment composition. Mosselman & Sloff (2007) and Sloff & Mosselman
246 (2012) characterize this competition by the ratio of the time scales for adjustment of bed levels, T_{bed} ,
247 and adjustment for bed sediment composition, T_{mix} :

248

$$\frac{T_{mix}}{T_{bed}} \propto \frac{\delta}{h} \quad (14)$$

249

250 in which δ represents the active-layer thickness. When modelling laboratory experiments with
251 constant uniform flow, this thickness corresponds typically to the height of bedforms. When
252 modelling real rivers, however, the active-layer thickness represents also the effect of other factors
253 reworking the bed within a morphological time step, such as the variation of cross-sectional bed
254 tilting in river bends under varying discharges and the generation of erosion and deposition waves at
255 locations where water enters or leaves the floodplains during floods. The thickness can thus be
256 much larger than the height of bedforms. Inadequate upscaling by taking the active-layer thickness
257 equal to bedform height can make this layer too thin and hence the time for adjustment of bed

258 sediment composition too short compared to the time for adjustment of bed levels. This leads to
259 erroneous suppression of bed level changes (Sloff & Mosselman, 2012).

260

261 3.4 Confusion of physical and numerical phenomena

262

263 The fourth common mistake is the confusion of physical and numerical phenomena. The truncation
264 errors of numerical schemes can produce phenomena such as oscillations (“wiggles”), growth
265 (“instability”) and attenuation (“smearing”, “diffusion”). These numerical artifacts can dominate the
266 results or simply alter the physics-based oscillations, growth and attenuation. The examples of
267 transverse-bed slope effects, sediment transport adaptation lengths and numerical truncation errors
268 in Section 3.1 showed that distinguishing numerical effects from physical phenomena can be difficult.
269 Analytical solutions can help in making this distinction. Sometimes numerical diffusion is accepted
270 on purpose when model stability is considered more important than model accuracy. Users of
271 Delft3D, for instance, can choose using an accurate central scheme or a more robust upwind scheme.
272 The choice should be reported when presenting model results.

273

274 The effects of truncation errors can be assessed and minimized by reducing the sizes of
275 computational grid cells. Numerical errors also arise, however, from the schematized representation
276 of river geometry. This type of errors is often compensated by modifying model parameters in the
277 calibration. These parameters then lose their strict physical meaning and can no longer be calculated
278 straightforwardly from fundamental considerations. Hydraulic resistance, for instance, becomes a
279 bulk parameter that depends not only on physics-based drag but also on the deviations between the
280 river geometries in the model and in the prototype. The same holds for bank erodibility parameters
281 in morphodynamic models for river planform evolution. A commonly used formula for river bank
282 erosion reads

283

$$\frac{\partial n}{\partial t} = E(\tau - \tau_c) \quad (15)$$

284

285 where $\partial n / \partial t$ denotes the rate of bank retreat, E is the bank erodibility, τ is the bank shear stress
286 exerted by the flow and τ_c is the critical bank shear stress for erosion. In theory, values of E and τ_c
287 could be derived from material properties of the bank soil. Crosato (2007) demonstrates, however,
288 that values derived in this way are erroneous because the parameters account also for the numerical
289 effects of bankline smoothing and regridding. Proper values for E and τ_c hence require calibration.
290 Assigning values based on soil properties is a mistake in morphodynamic models for river planform
291 evolution.

292

293 3.5 Belief that 2D and 3D models require more data than 1D models

294

295 The fifth common mistake regards a misconception *about* approaches to modelling rather than an
296 actual mistake *within* approaches to modelling. This regards the belief that 2D and 3D models
297 require more data than 1D models and hence often cannot be used due to a lack of data. This is
298 tenable for neither initial condition data nor boundary condition data. A main initial condition for
299 morphodynamic models is the bed topography, for which all models can use a set of river cross-
300 sections. One-dimensional models incorporate these cross-sections directly. Two- and three-
301 dimensional models use these cross-sections for an initial calibration of bed levels, but this does not
302 present any particular difficulties. On the contrary, it is easier to set up and calibrate a 2D or 3D
303 model than a 1D model because the latter requires an additional step of data schematization. For
304 instance, the flow path between two consecutive river stations can be longer along a sinuous main
305 channel at low discharge than along the more straight floodplains at high discharge. Two- and three-
306 dimensional models reproduce this feature automatically. One-dimensional models require

307 manipulation of stage-dependent hydraulic roughness parameters to translate all distances to the
308 same length in the model.

309

310 Boundary conditions for 2D and 3D models must be specified in the form of distributions over the
311 inflow and outflow sections, whereas single values are sufficient for the boundary conditions of 1D
312 models. Reasonable estimates, however, can be made for these distributions, without the need of
313 more field data. The upstream discharge can be distributed in proportion to the conveyance of each
314 part of the inflow section. The supply of sediment to each computational cell at the upstream
315 boundary can be assumed equal to the local transport capacity of the flow to avoid the generation of
316 spurious erosion and sedimentation. Sediment overloading and underloading can be specified as a
317 constant percentage of the supply to each cell. The downstream water level can be assumed
318 horizontal in the outflow section. In 3D models, the vertical distributions of discharges can be
319 specified in accordance with logarithmic flow velocity profiles.

320

321 A 1D approach may be sufficient for large-scale sediment budgets and the overall development of
322 longitudinal river profiles. Many morphological problems, however, such as navigability
323 improvement, ask for 2D spatial distributions of channels and bars. The appropriate approach
324 depends on the purposes of the modelling, not on data availability. The false belief that 2D and 3D
325 numerical models require a lot of data often leads to abandoning these options, for the wrong
326 reasons, in favour of 1D numerical models, physical models, or even no model at all.

327

328 Assertions that modelling is not possible because of a lack of data are often a fallacy. They could be
329 parried with the assertion that data collection is not possible if there is not any model. Initial
330 modelling helps in identifying data gaps and defining an effective measurement campaign. In reality,
331 of course, data collection and modelling are complementary and go hand-in-hand in successive steps
332 of improvement.

333

334

335 4. DISCUSSION

336

337 One of the reviewers suggested our criticism of modellers of fluvial morphodynamics could be seen
338 as a disguised advertisement of our own modelling capabilities. This is not our intention, because we
339 make mistakes too. Rather, by sharing our experiences, we seek to empower the growing
340 community of both executers and users of morphodynamic modelling, academic and applied. We
341 focus on experiences that recur frequently and are specific for fluvial morphodynamics, without
342 detracting from Salt's (2008) more general warnings that are equally relevant for fluvial
343 morphodynamics but not repeated in this paper. The same reviewer also suspected we criticize river
344 engineers who carry out simulations in their Wi-Fi-equipped hotel room in the evening and present
345 animations of the morphodynamic evolution to the client the next morning. On the contrary, we find
346 the technological progress that made this possible a great achievement. Even without full calibration
347 and validation, such simulations can be powerful for a diagnosis of morphological problems and a
348 first assessment of the effectiveness of interventions.

349

350 We ran the model with a morphological acceleration factor of 10. This does not affect the results in
351 this case of a constant discharge, uniform sediment and fixed banks. In other cases, however, such
352 factors may introduce errors by distorting the relation between the time scales of different
353 processes (cf. Vanzo et al, 2015). A morphological factor of 2, for instance, implies that a sequence of
354 two identical discharge hydrographs would be merged into a single discharge hydrograph with
355 double duration. Each discharge level would retain the same frequency of occurrence, but the
356 dynamics of the emptying and filling of storage areas would change as the volumes of excess
357 discharges in a single flood would be doubled. The storage dynamics could be corrected by splitting
358 the original two hydrographs into four hydrographs with halved duration each. The morphological

359 factor of 2 would then restore the original two hydrographs. Short sharply peaked flood waves,
360 however, experience stronger attenuation as they travel downstream than longer flood waves with a
361 broader peak, so that this correction of storage dynamics could distort the dynamics of flood wave
362 propagation. Although we do not experience careless use of morphological factors as a common
363 mistake, the possible adverse effects do represent an important caveat.

364

365 The common mistakes presented here have a bearing on validation. Mosselman (2012) argues that
366 acceptance criteria for validation should not be limited to metrics for the differences between
367 computed and observed values. Validation methods correcting spatial offsets (Bosboom & Reniers,
368 2014) may offer improvements but are not sufficient. Validation criteria should also address the
369 reproduction of characteristic features such as wave length and amplitude attenuation. Mosselman
370 (2012) advocates the development of a set of internationally agreed validation cases with
371 corresponding criteria for acceptance. Considering the present paper, these criteria should support
372 the detection of inadequate representation of physical processes, forcing of morphodynamic
373 patterns by manipulated inputs, inadequate upscaling, and confusion of physical and numerical
374 phenomena.

375

376

377 5. CONCLUSIONS AND RECOMMENDATIONS

378

379 We have drawn attention to five types of common mistakes in fluvial morphodynamic modelling.
380 First, physical processes can be represented inadequately, especially if new morphodynamic codes
381 are developed as extensions of existing hydrodynamic codes. Second, model inputs can be specified
382 in a way that imposes morphodynamic patterns beforehand rather than letting them evolve freely.
383 Third, detailed processes can be parameterized inadequately for application to larger spatial and
384 temporal scales. Fourth, physical and numerical phenomena can be confused. Fifth, the selection of

385 modelling approaches can be driven by the erroneous belief that complete data are a prerequisite
386 for modelling and that applying 2D and 3D models requires more data than the application of 1D
387 models.

388

389 We recommend to all stakeholders of fluvial morphodynamic modelling that they recognize the full
390 range of expertise needed, often requiring team work. We recommend to modellers that they study
391 the background of the processes represented by the mathematical equations, including the pitfalls
392 of common mistakes. Our advice to supervisors and reviewers is that they verify in particular the
393 inputs and modelling settings that correspond to the common mistakes presented in this paper. This
394 involves inquiring about the representation of bed slope effects and helical flow, having maps
395 plotted of hydraulic roughness values and bed sediment grain sizes, evaluating the distances to
396 model boundaries in relation to simulation times, and checking results against estimates from
397 analytical solutions.

398

399

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401

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404

405

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478 LIST OF FIGURES

479

480 Figure 1. Basic set-up of numerical model for water flow in a straight-channel with a mobile bed.

481

482 Figure 2. Reference bed level profile along the right bank, associated with a pattern of steady
483 alternate bars attenuating in downstream direction.

484

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486 slopes on sediment transport direction (solid line), compared to the reference profile of Figure 2
487 (dashed line).

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489 Figure 4. Rectangular roughness patches in model set-up to demonstrate the forcing effect of fixed
490 spatially varying input parameter values.

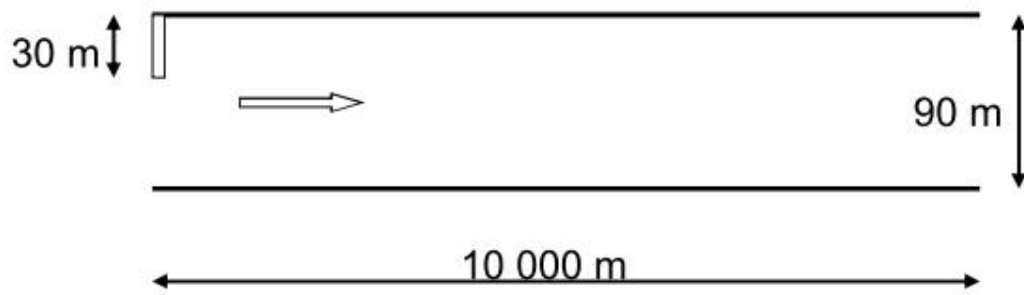
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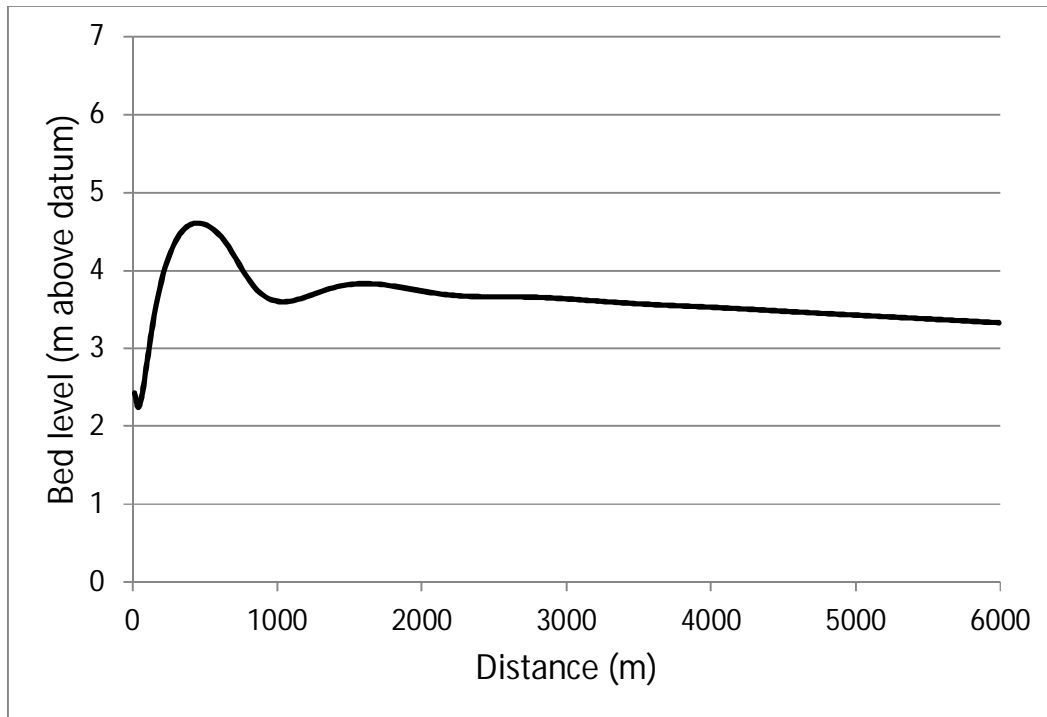
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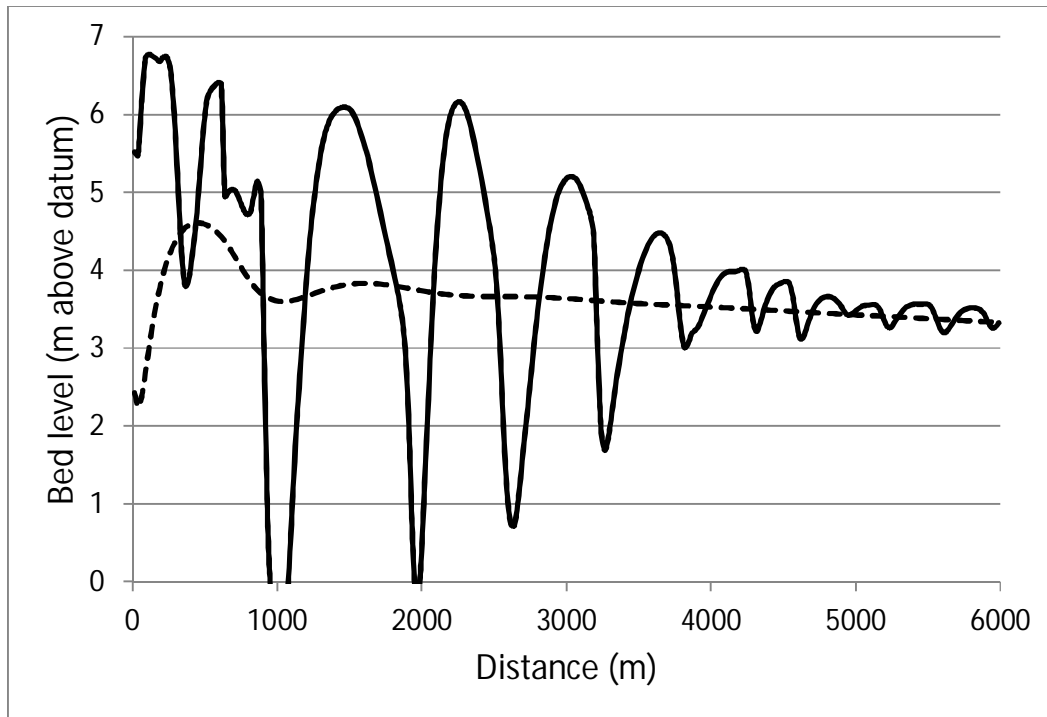
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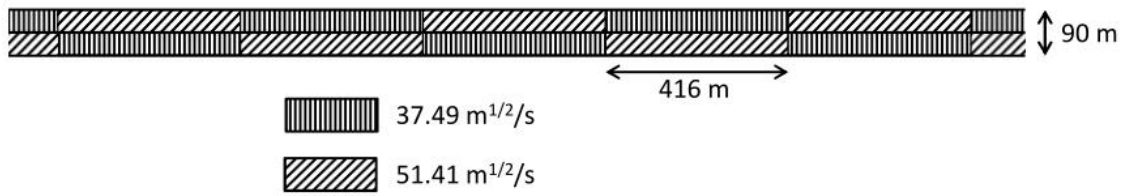
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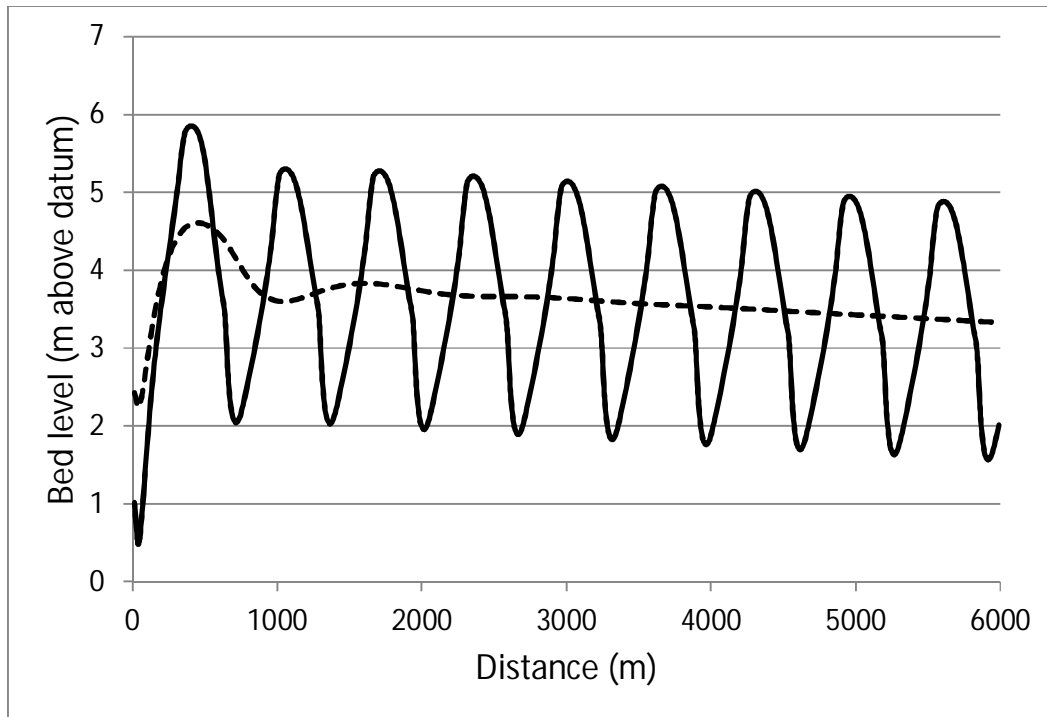
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