Development of Design Methods for In-Stream Flow Control Structures (NCHRP 24-33)

30 August 2016

Today's Presenters

- **Moderator**
  Michael Fazio, P.E., City Engineer, Bluffdale, Utah – *Former member of ASHTO Technical Committee on Hydrology and Hydraulics.*

- **Presenter**
  Dr. Ali Khosronejad, New York State University at Stony Brook

NCHRP is...

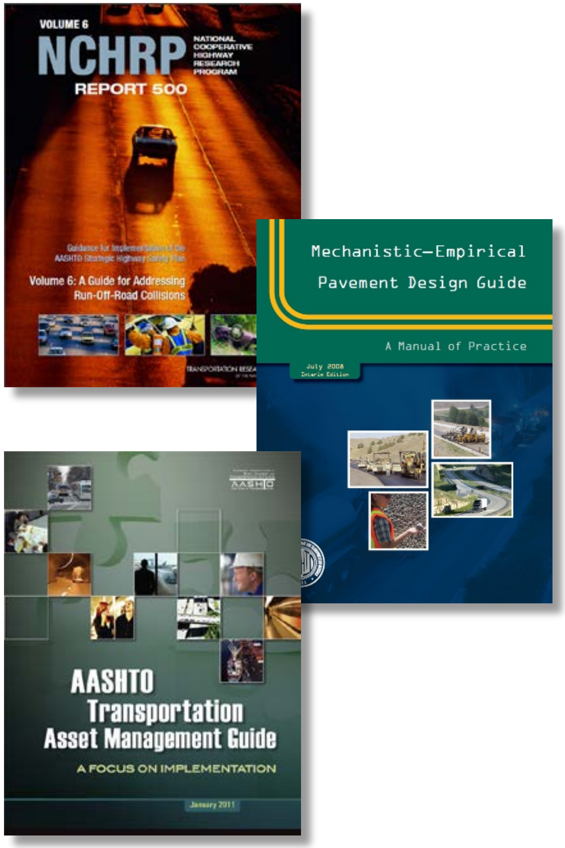
A state-driven national program

- The state DOTs, through AASHTO’s Standing Committee on Research...
  - Are core sponsors of NCHRP
  - Suggest research topics and select final projects
  - Help select investigators and guide their work through oversight panels

NCHRP delivers...

Practical, ready-to-use results

- Applied research aimed at state DOT practitioners
- Often become AASHTO standards, specifications, guides, manuals
- Can be directly applied across the spectrum of highway concerns: planning, design, construction, operation, maintenance, safety

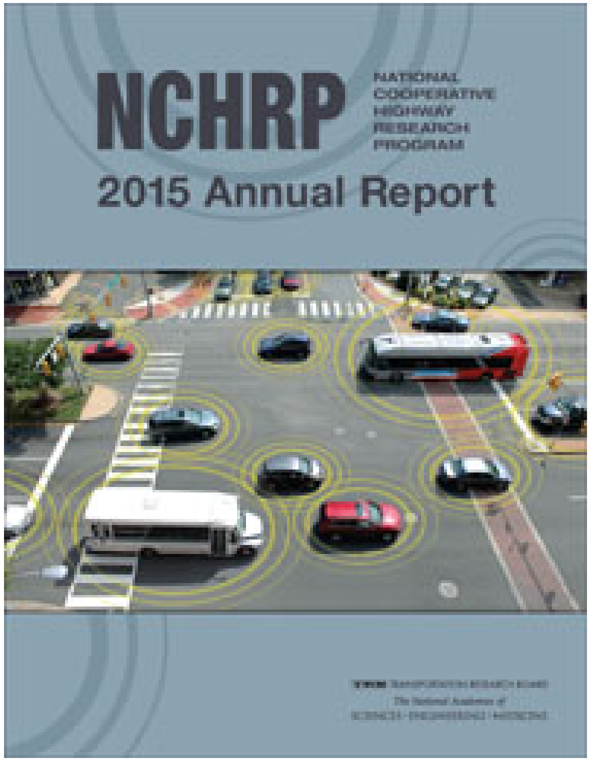


A range of approaches and products

- Traditional NCHRP reports
- Syntheses of highway practice
- IDEA Program
- Domestic Scan Program
- Quick-Response Research for AASHTO
- Other products to foster implementation:
  - *Research Results Digests*
  - *Legal Research Digests*
  - *Web-Only Documents and CD-ROMs*

NCHRP Webinar Series

- Part of TRB’s larger webinar program
- Opportunity to interact with investigators and apply research findings.



Today's First Presenter

- **Development of design guidelines for in-stream restoration structures via high-resolution numerical simulations**
  Ali Khosronejad, Department of Civil Engineering, State University of New York at Stony Brook

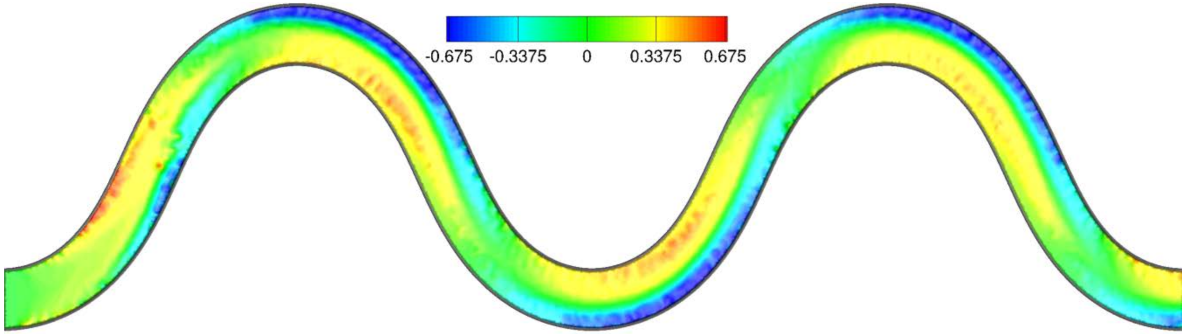
High fidelity numerical simulation of field-scale rivers: Development of design methods for in-stream flow control structures (NCHRP 24-33)

Ali Khosronejad & Fotis Sotiropoulos
Civil Engineering Department
College of Engineering & Applied Science
State University of New York at Stony Brook

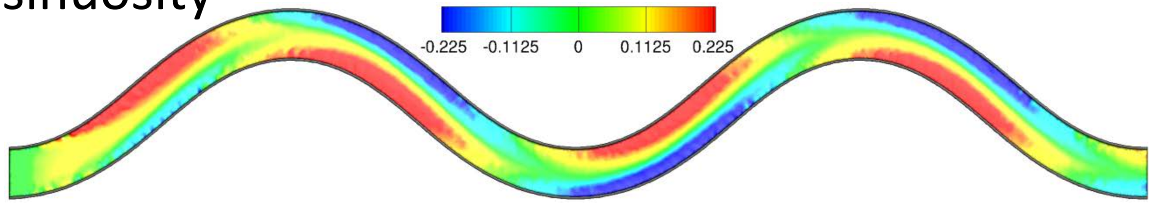
NCHRP

Developing design guidelines for in-stream restoration structures$^{\psi}$ for two common rivers:

1) **Sand-bed rivers→** higher sinuosity and other typical characteristics



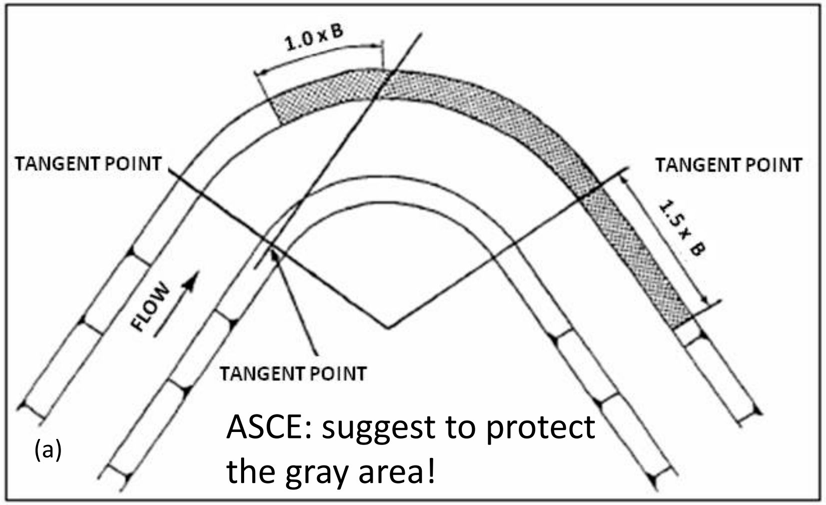
2) **Grave-bed rivers→** less sinuosity



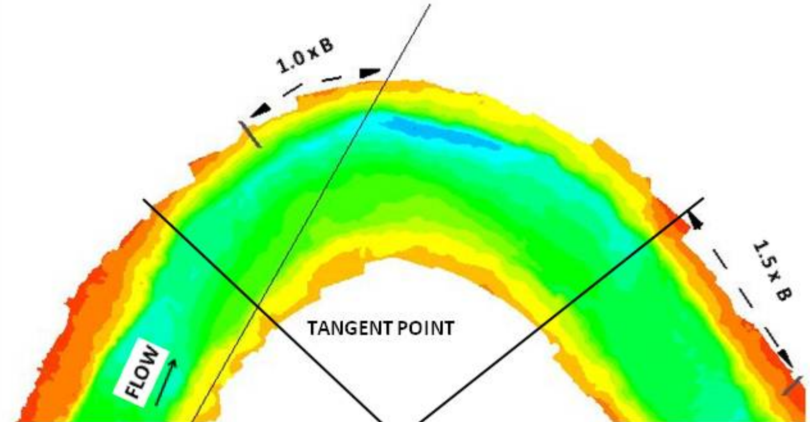
$^{\psi}$ Stream restoration structures include:

a) Rock-vane;
b) J-hook;
c) Bend Way weir;
d) Cross-vane;
e) Step Cross-vane;
f) W-weir

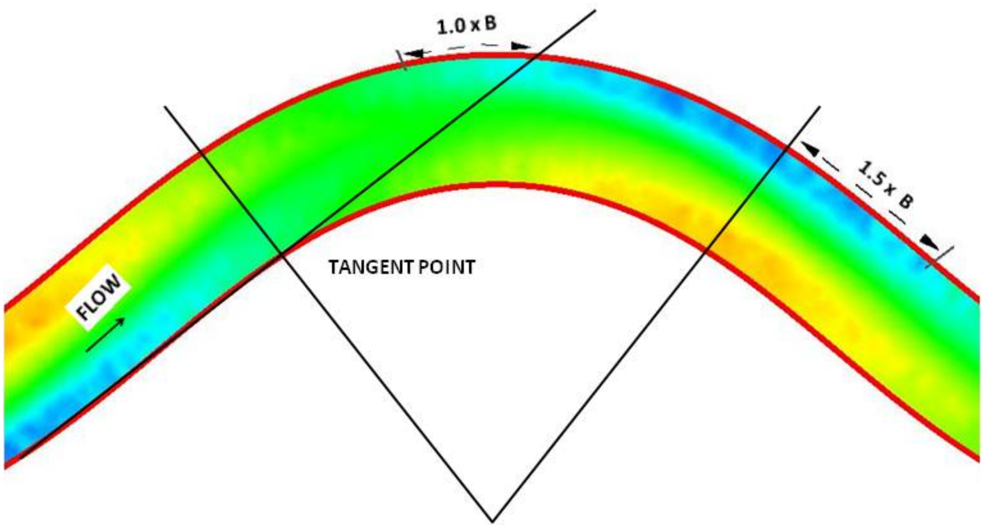
Problem description: scour at the apex of meandering rivers



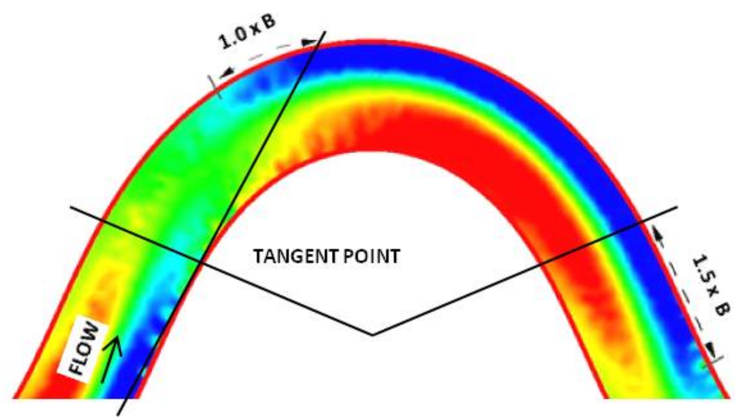
ASCE: suggest to protect the gray area!



OSL experiment confirms ASCE's suggestion



VSL3D confirms ASCE's suggestion for gravel-bed rivers

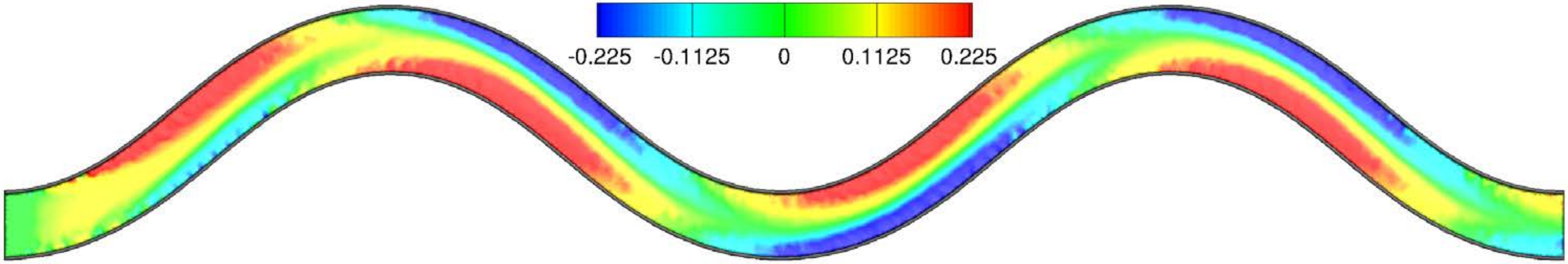


VSL3D confirms ASCE's suggestion for sand-bed rivers

What criteria one need to consider for simulation-based optimization of in-stream rock structure design:

- The more bank protection provided, the better;
- The less interference to the point bar near the inner bank, the better;
- The less rock-material is needed, the better.

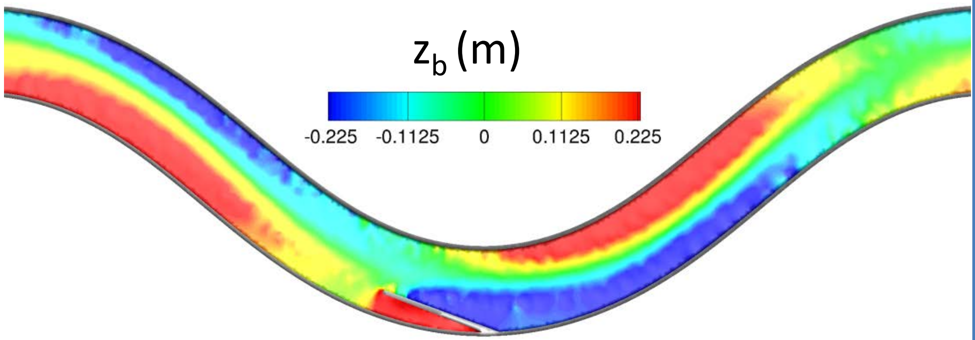
Let’s Start with a gravel river

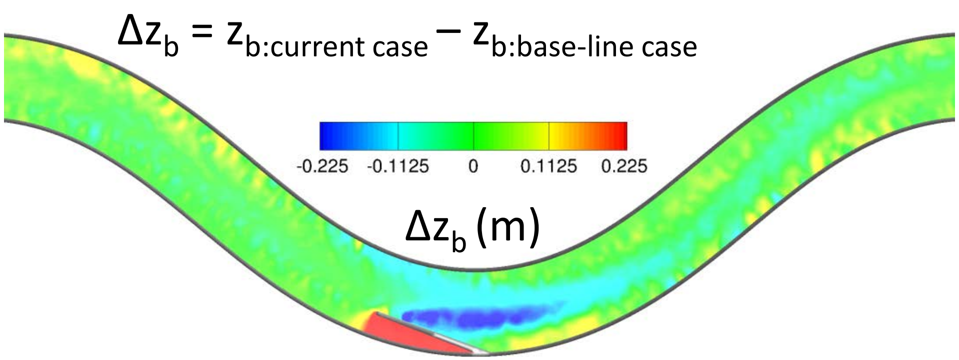


$Q=36\ m^3/s$
Width = 27 m
Mean flow depth = 0.9 m
D_{50} = 3.2 cm
Meander length = 3 × 328.1 m

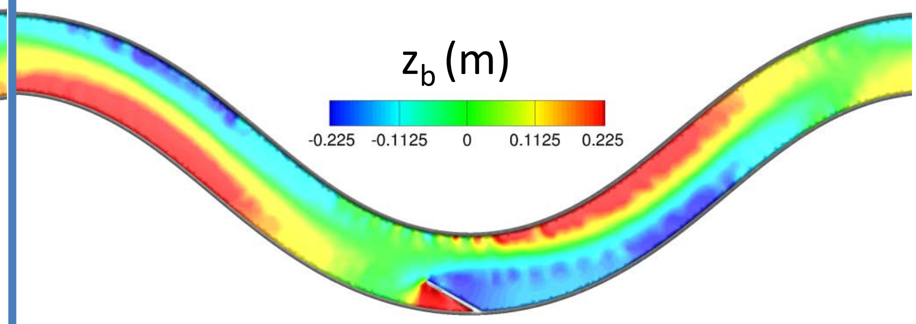
Rock-vane: gravel river

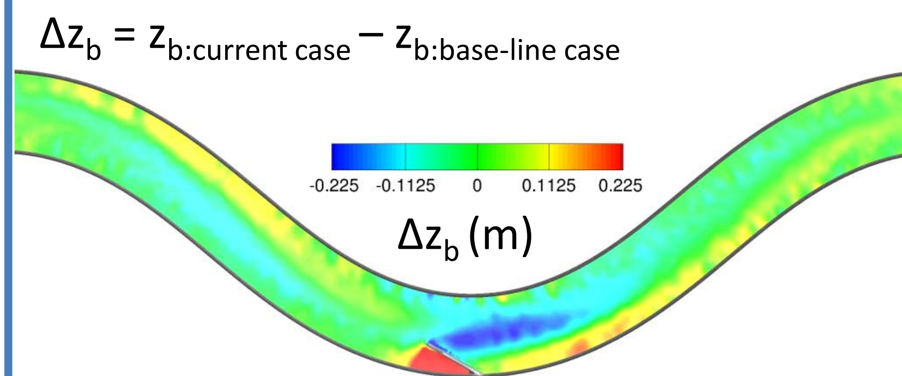
20° rock-vane



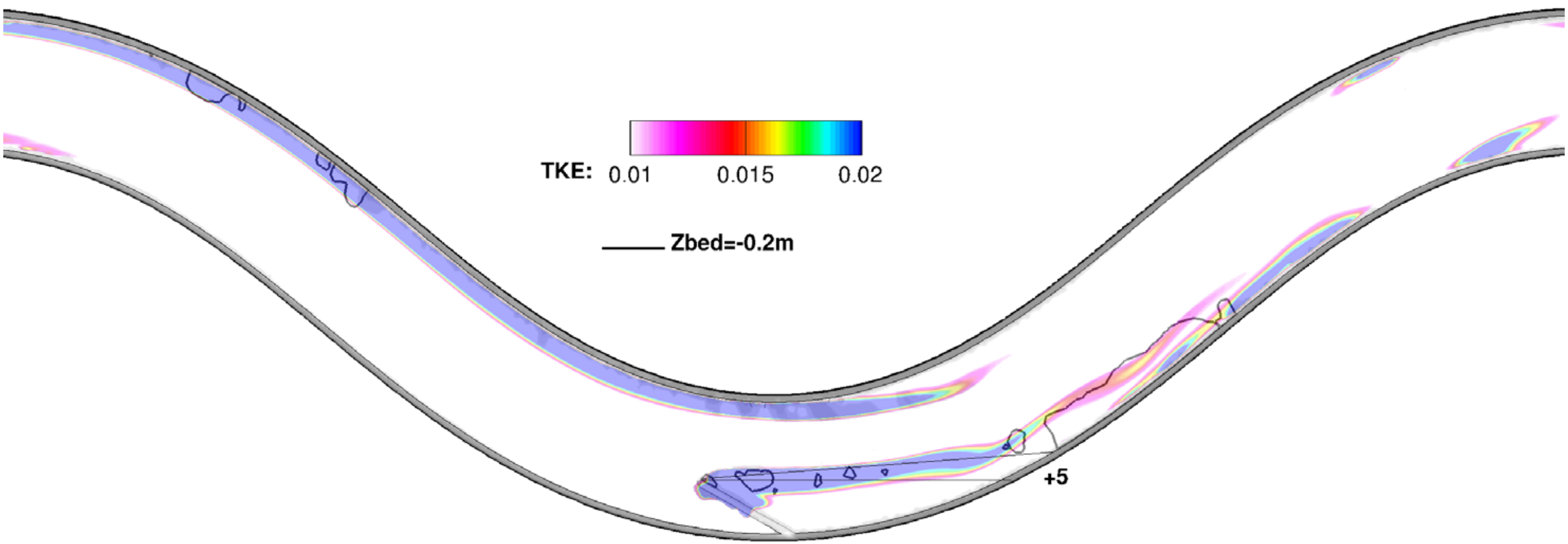


30° rock-vane

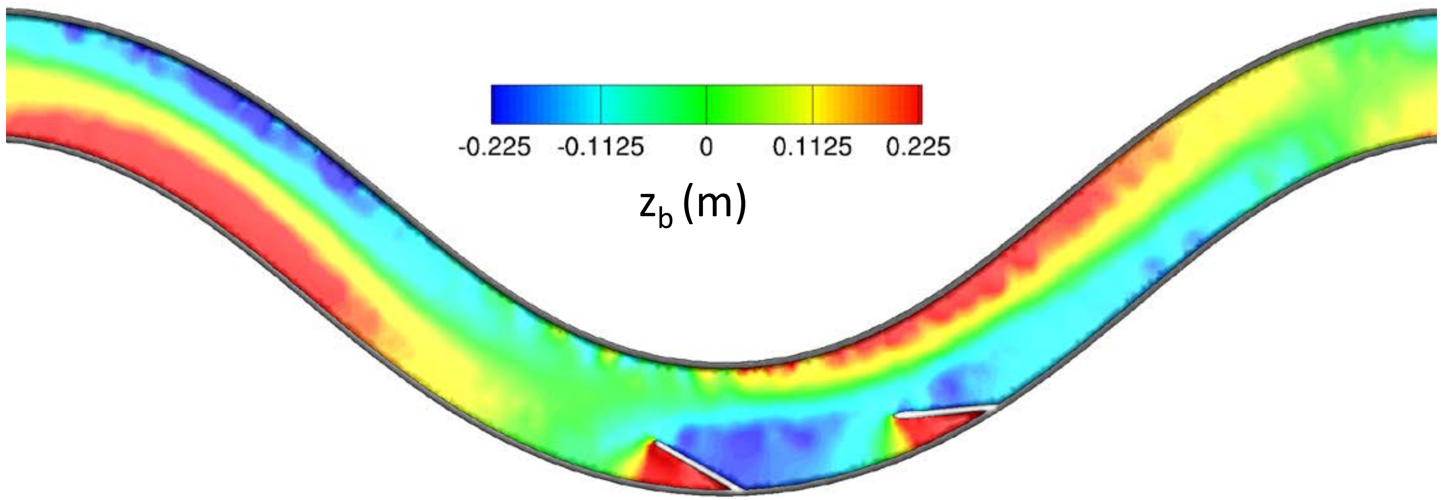


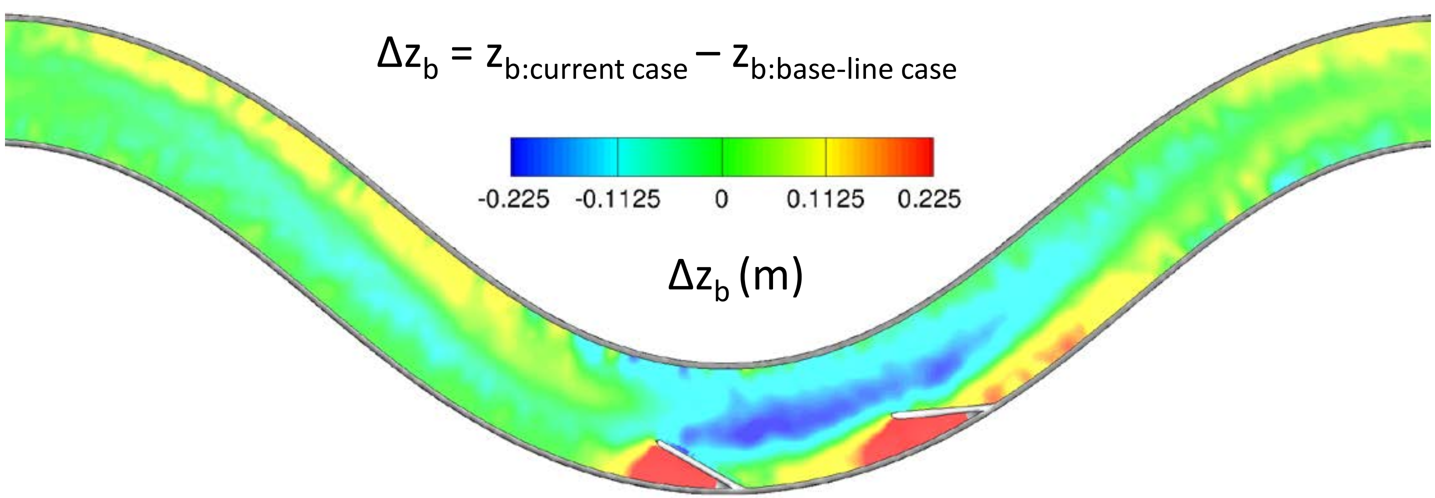


Now that the 30^o rock-vane is better but one more rock-vane is needed, where should one install the second structure?

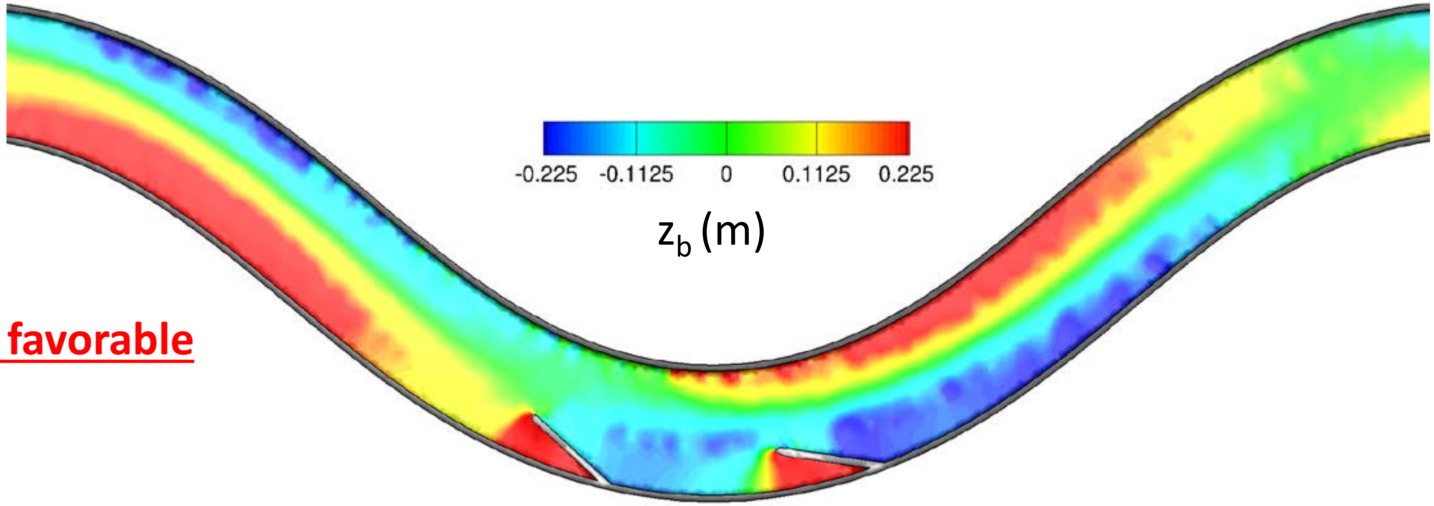


Double 30^o Rock-vanes in gravel river satisfy all design-requirements;

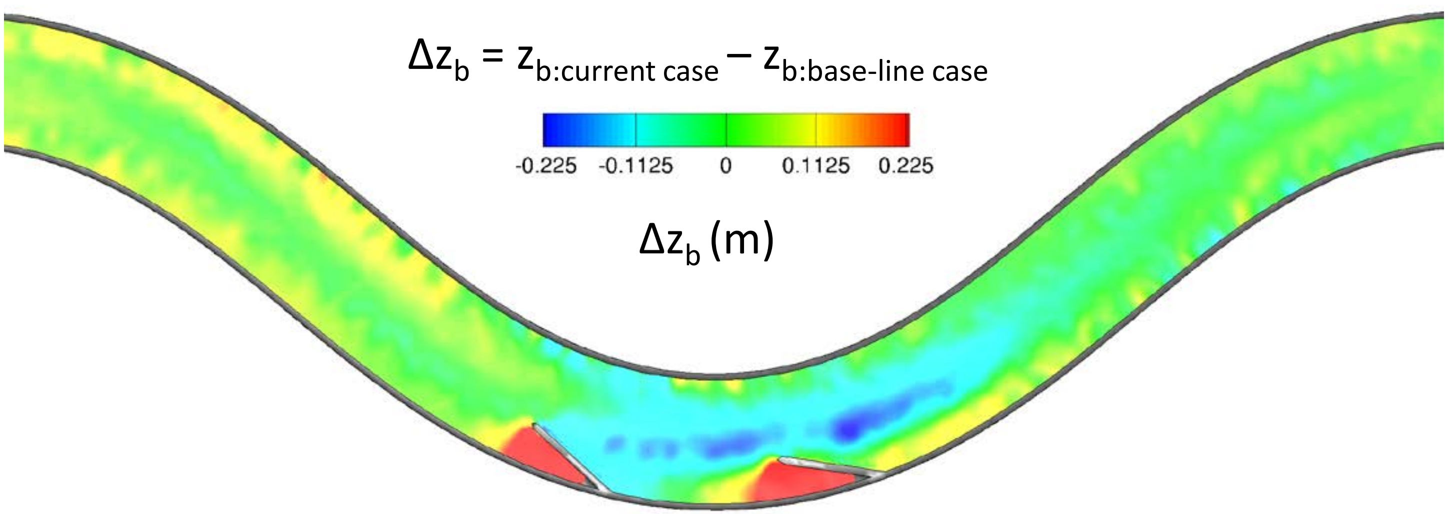




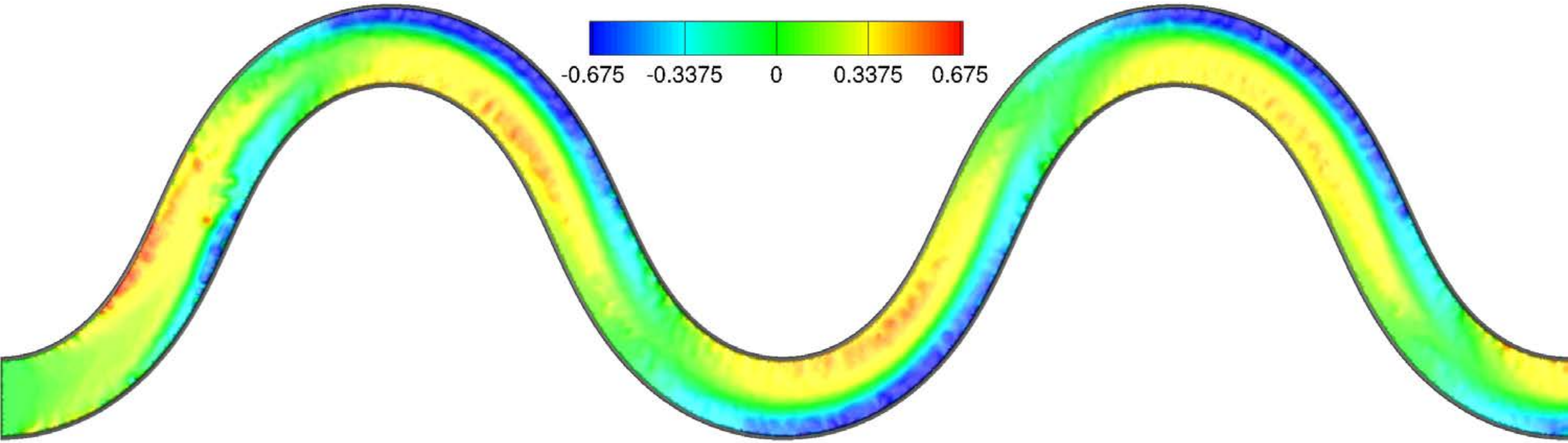
Let's now check an *offset* of the double 30° rock vanes in gravel river:



Less favorable



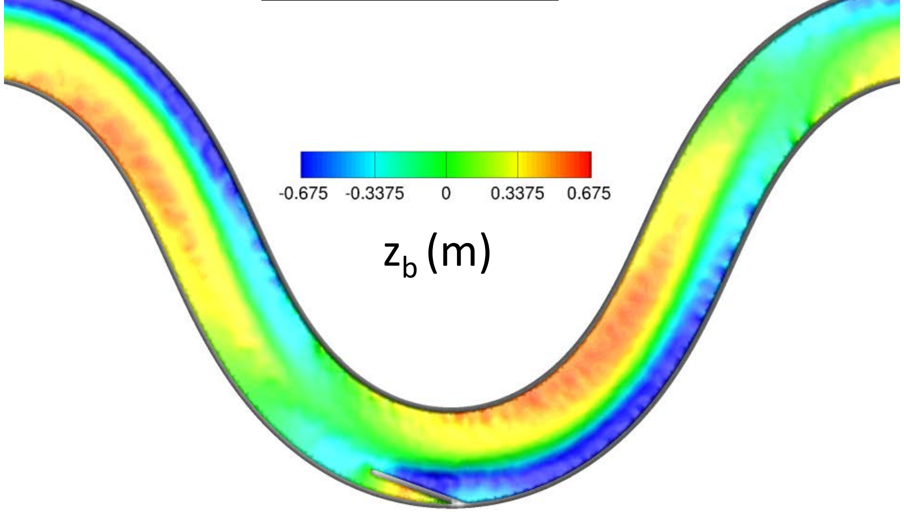
Let's continue with a sand river

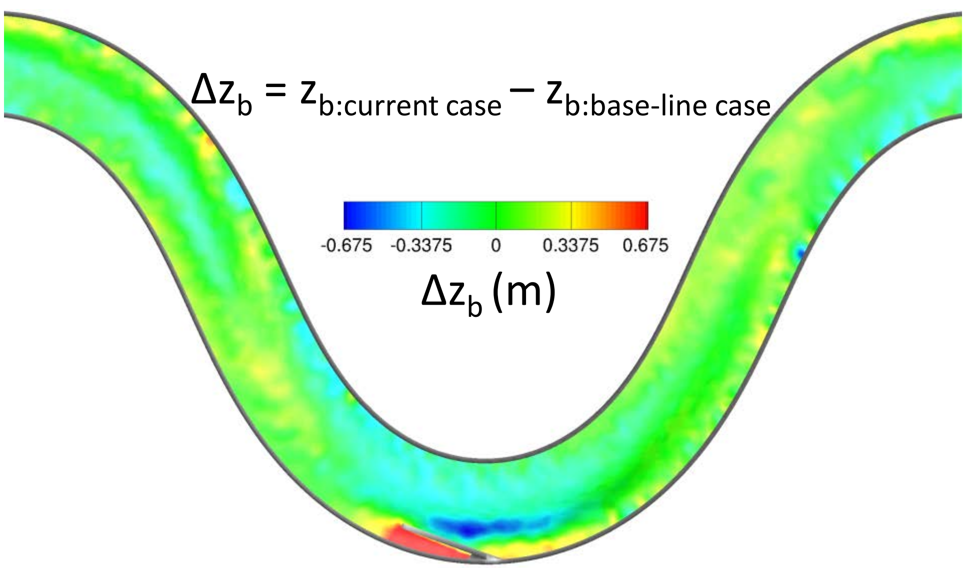


Q=48.4 m^3/s
Width = 27 m
Mean flow depth = 1.35 m
D_{50} = 0.5 cm
Meander length = 3 × 266.7 m

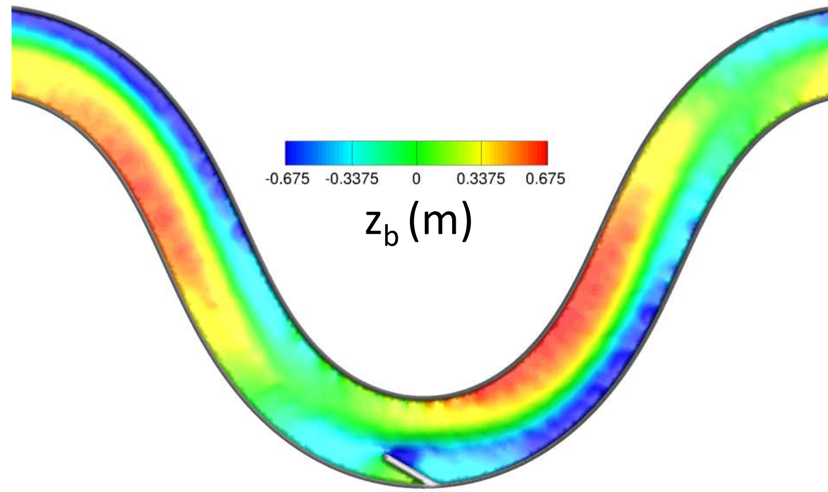
Rock-vane: sand river

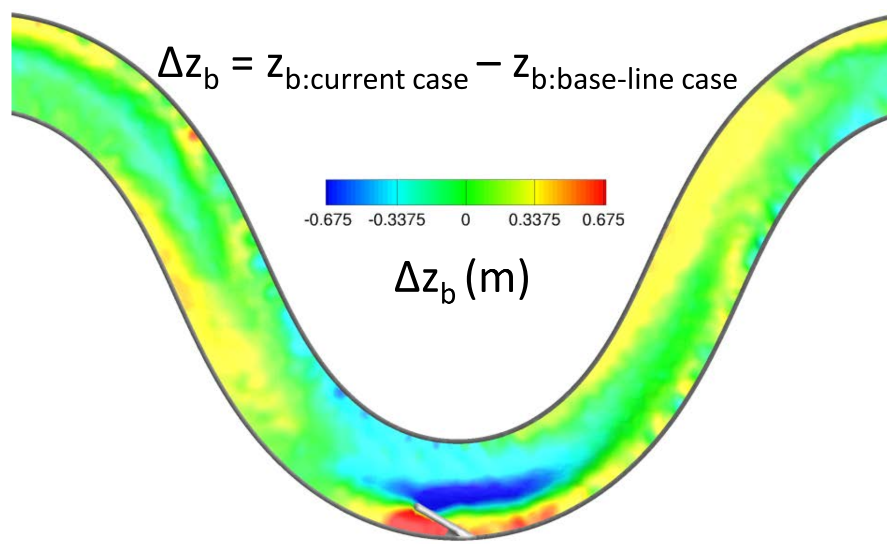
20^o rock-vane



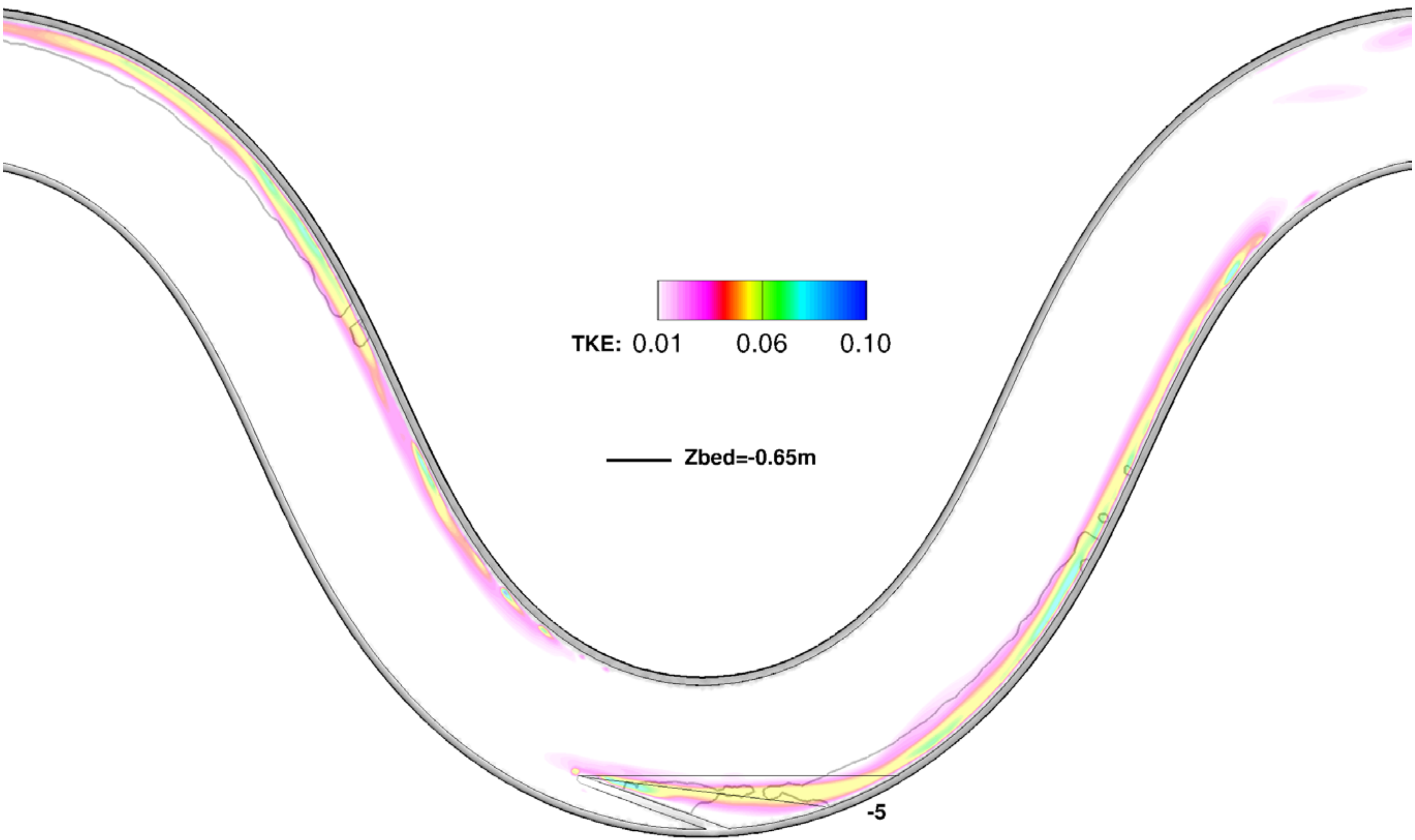


30^o rock-vane

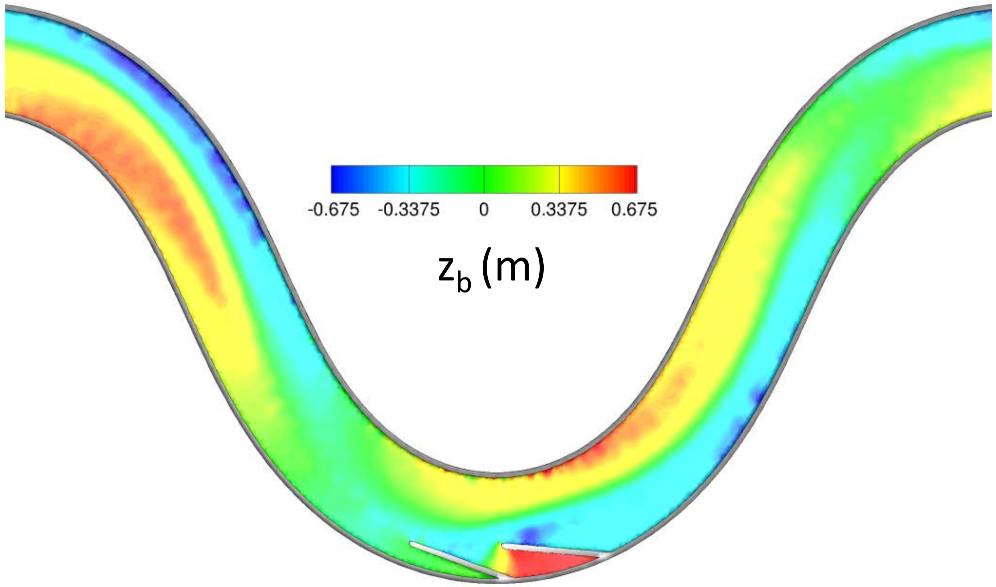


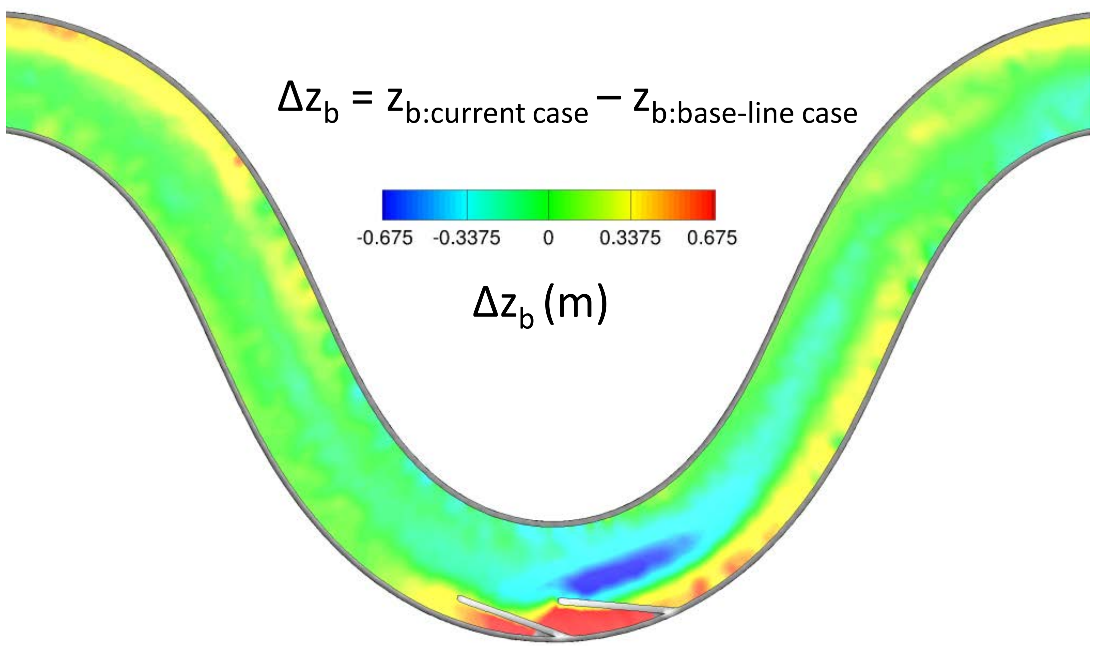


Now that the 20º rock-vane is better but one more rock-vane is needed, where should one install the second structure?

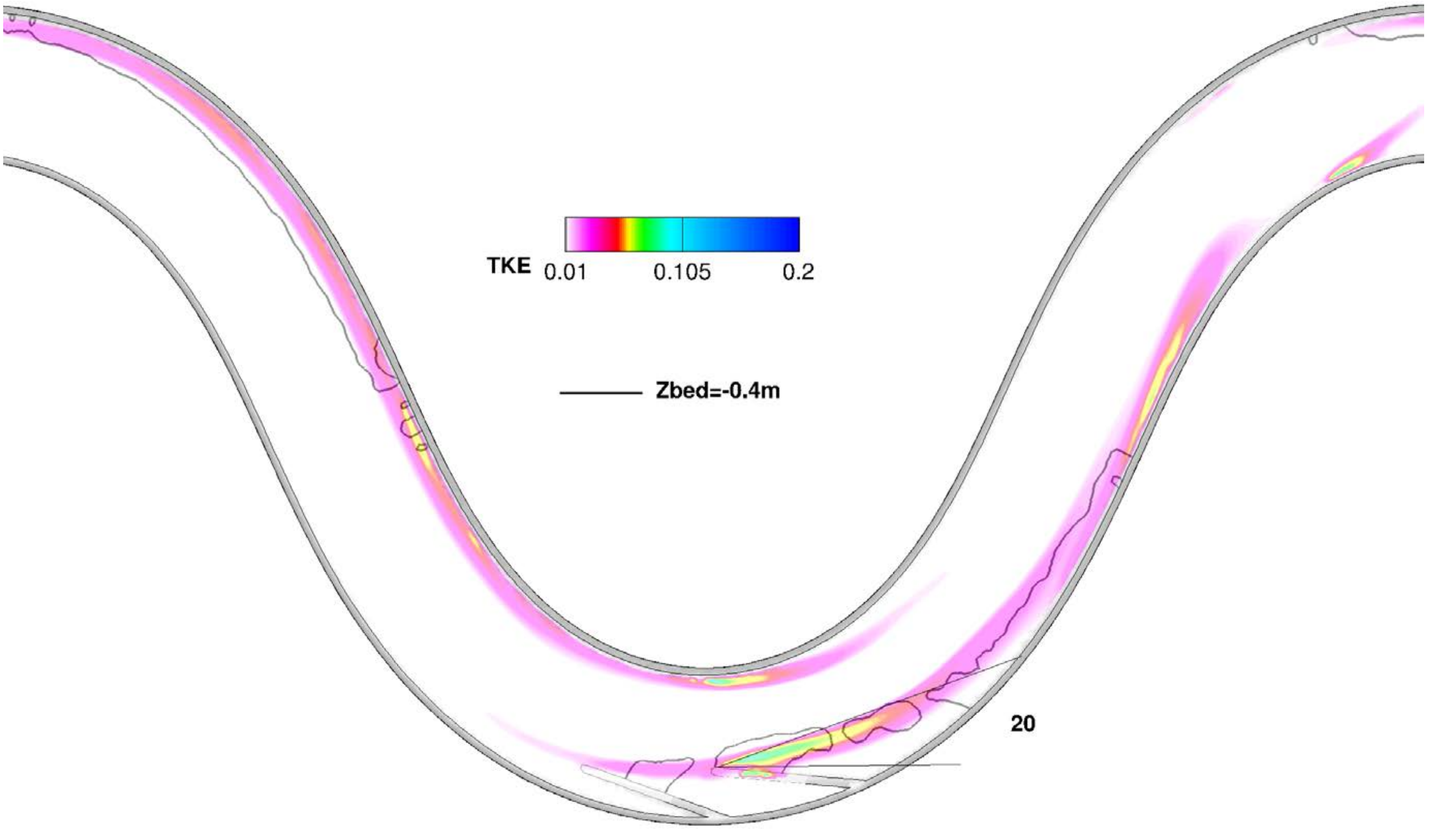


Double 20^o Rock-vanes in sand river do not satisfy all design-requirements: a third one is needed.

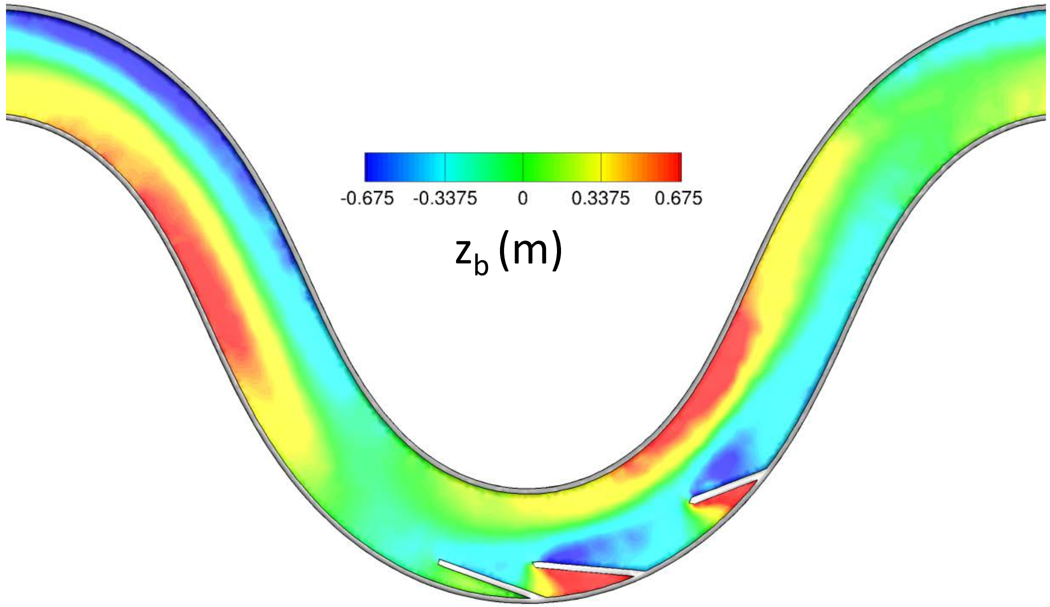


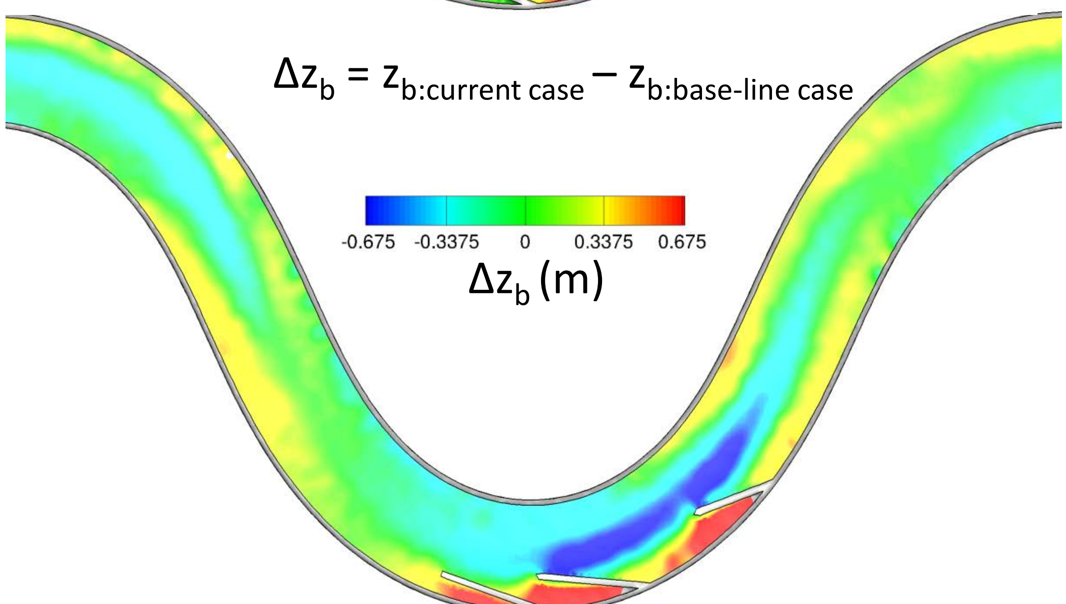


Where to install the *third* structure?

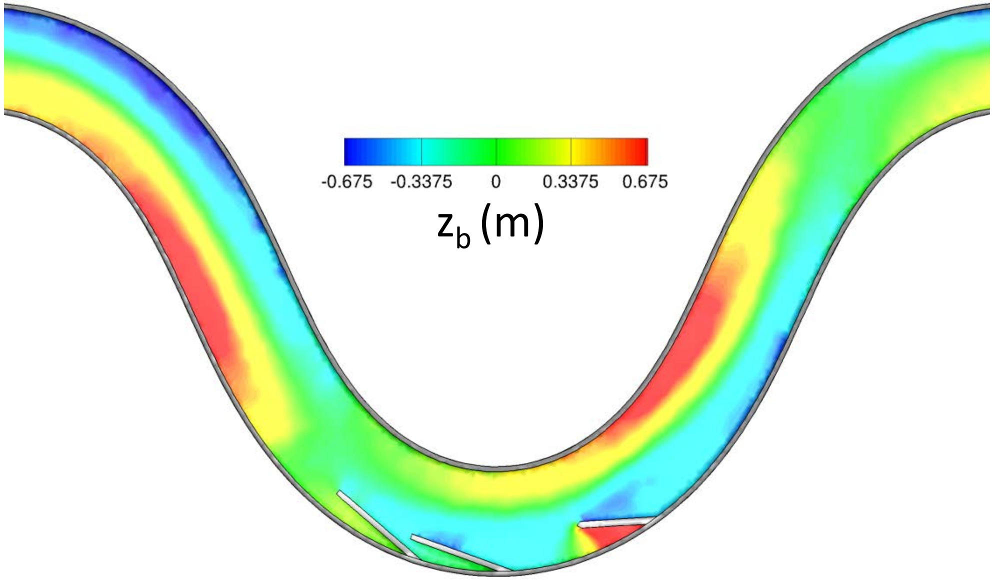


Triple 20^o Rock-vanes in sand river satisfy all design-requirements.



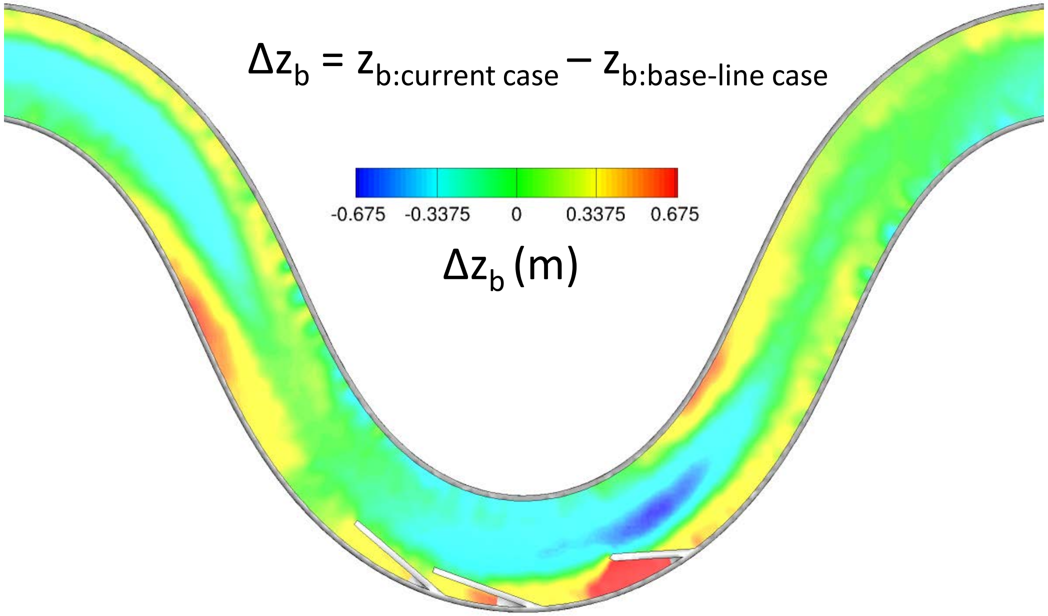


Let's now check an *offset* of the triple 20^o rock vanes in the sand river:

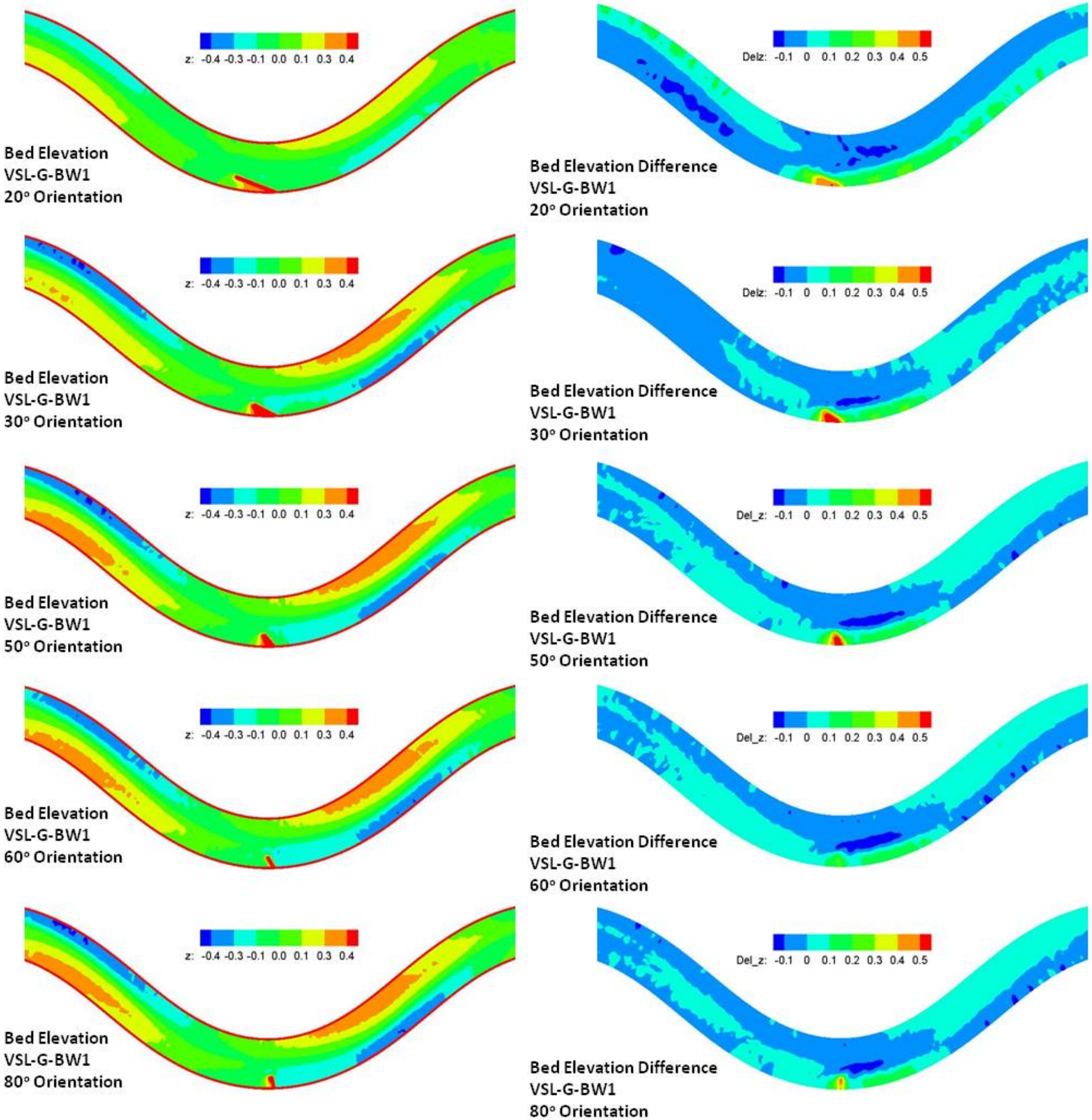


Offset *is* **More favorable:**

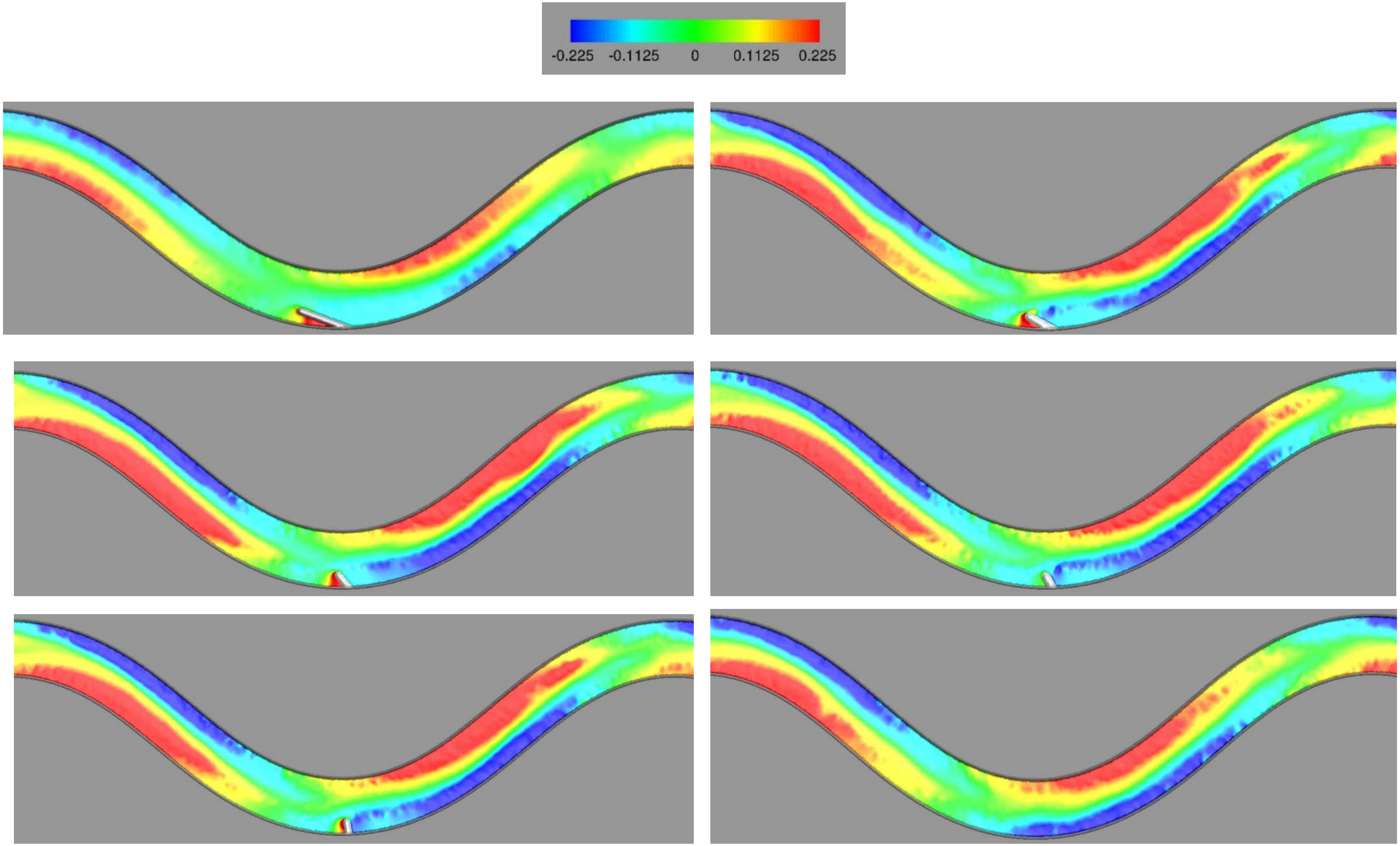
- ✓ Less deposition of sediment at the upstream corner of each rock vane;
- ✓ the maximum thalweg scour depth is less than non-shifted case;
- ✓ the protected length of the outer bank is extended farther upstream



Barbs: gravel river

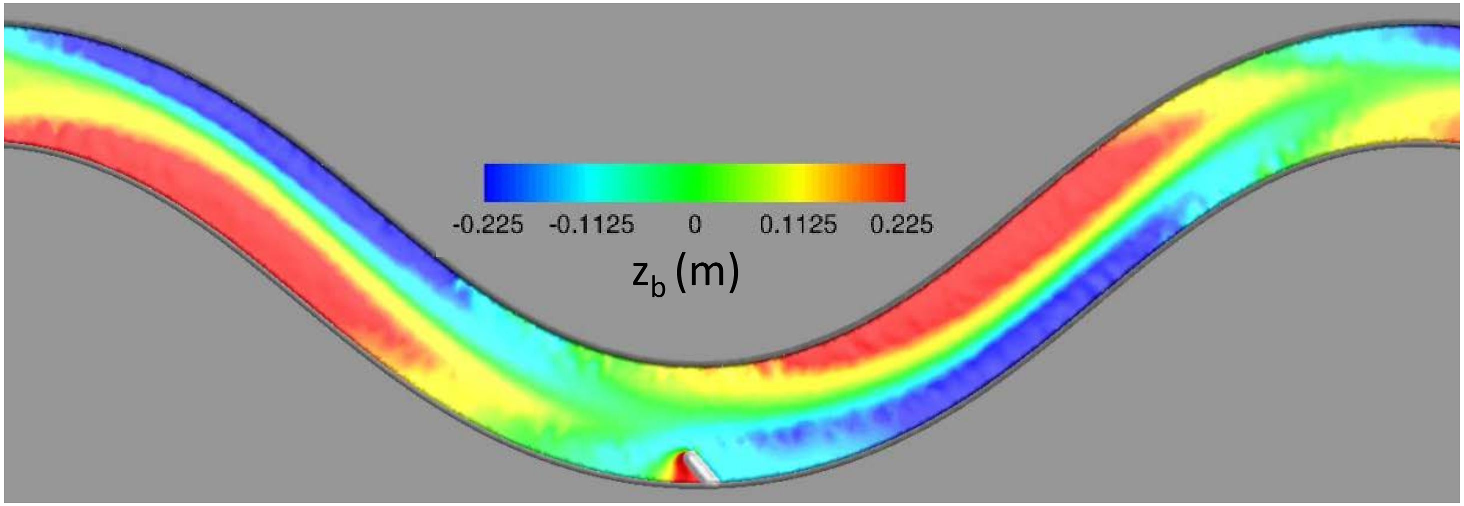


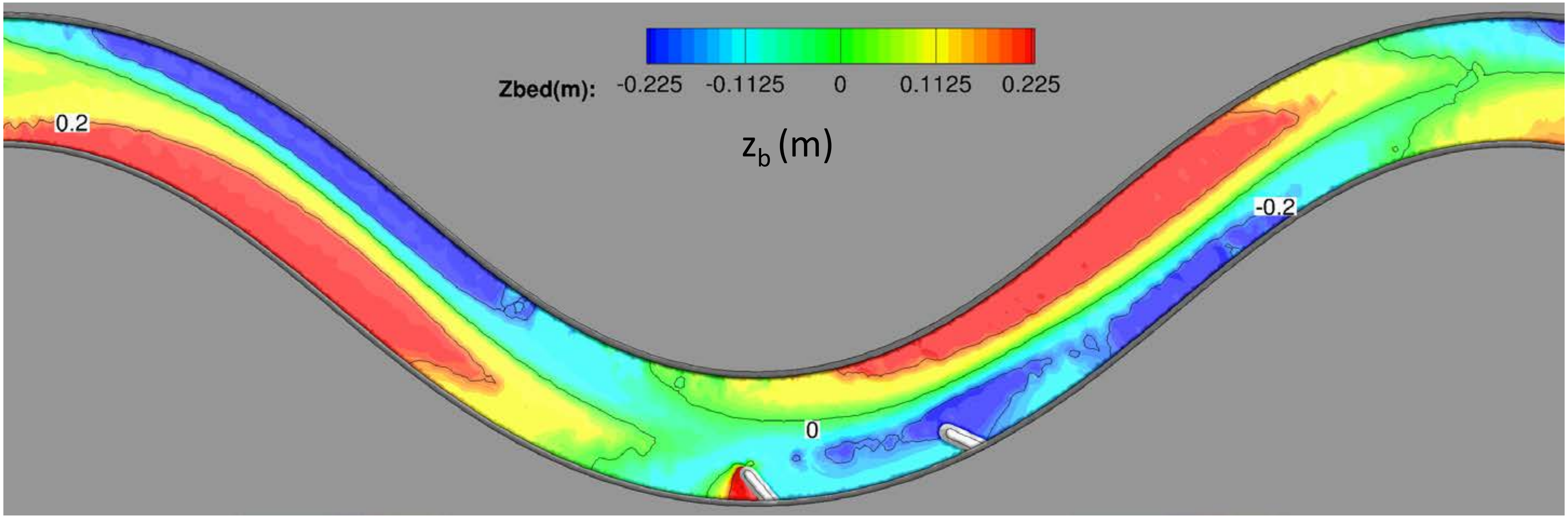
- Five installation angles studied;
- Optimum angle is selected based on cost (material) and bank protection;
- 50^{o} barb is selected;
- Number and spacing is optimized—see next slides.



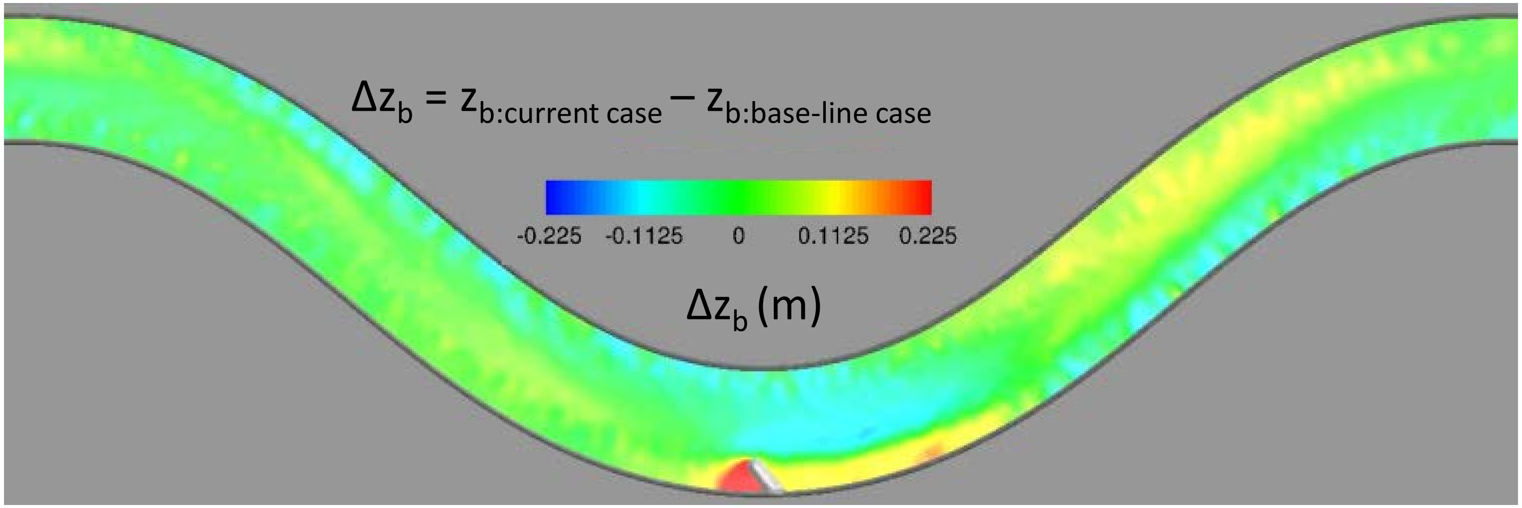
Barbs: gravel river

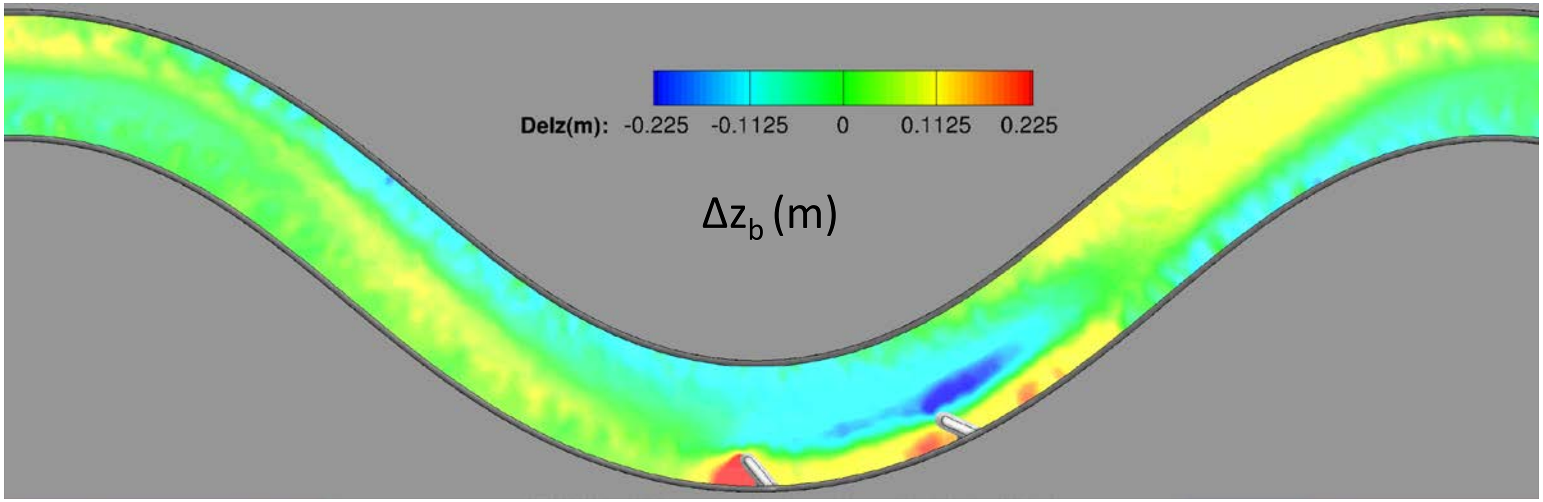
Single & double 50^o Barb: gravel river



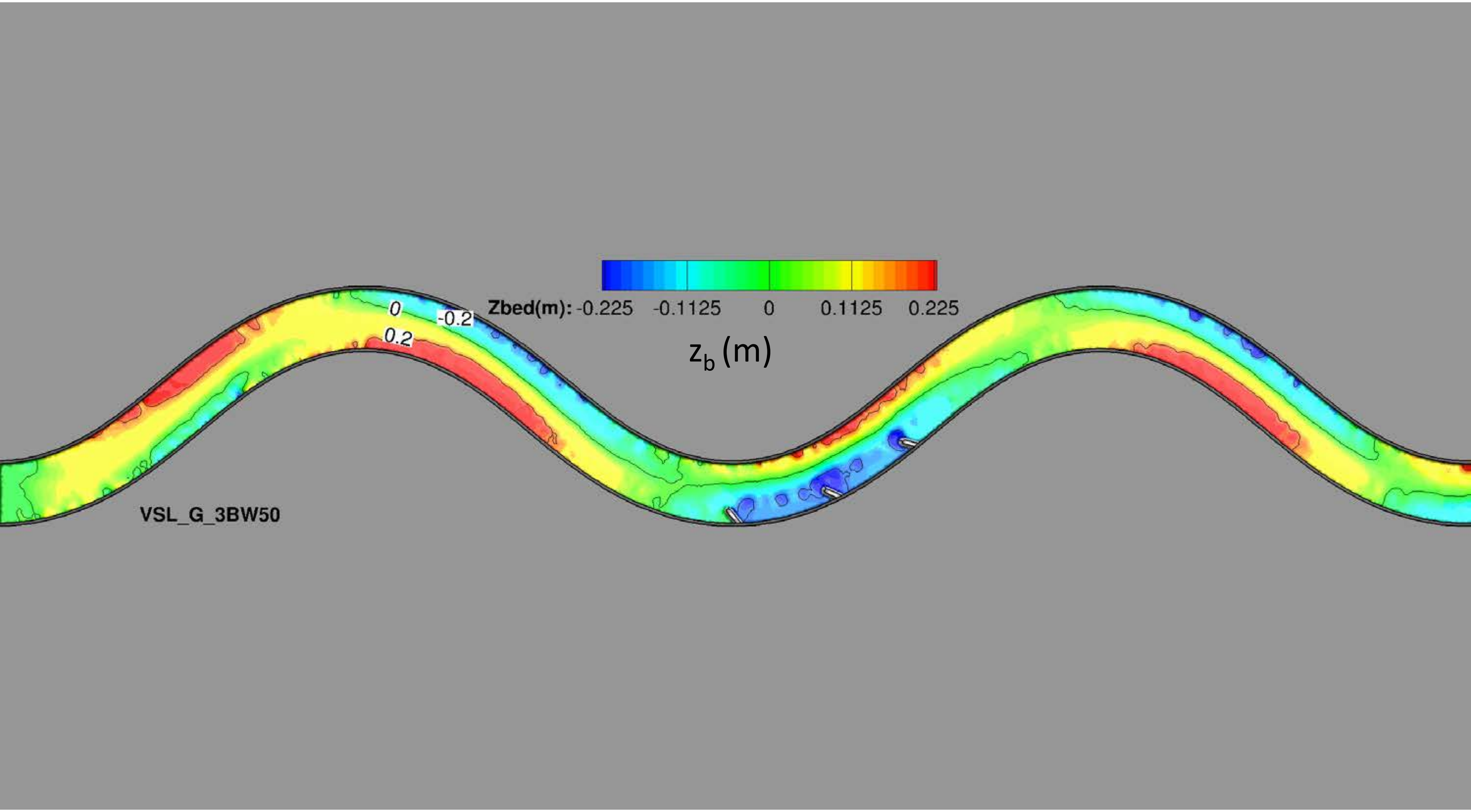


Single & double 50° Barb: gravel river

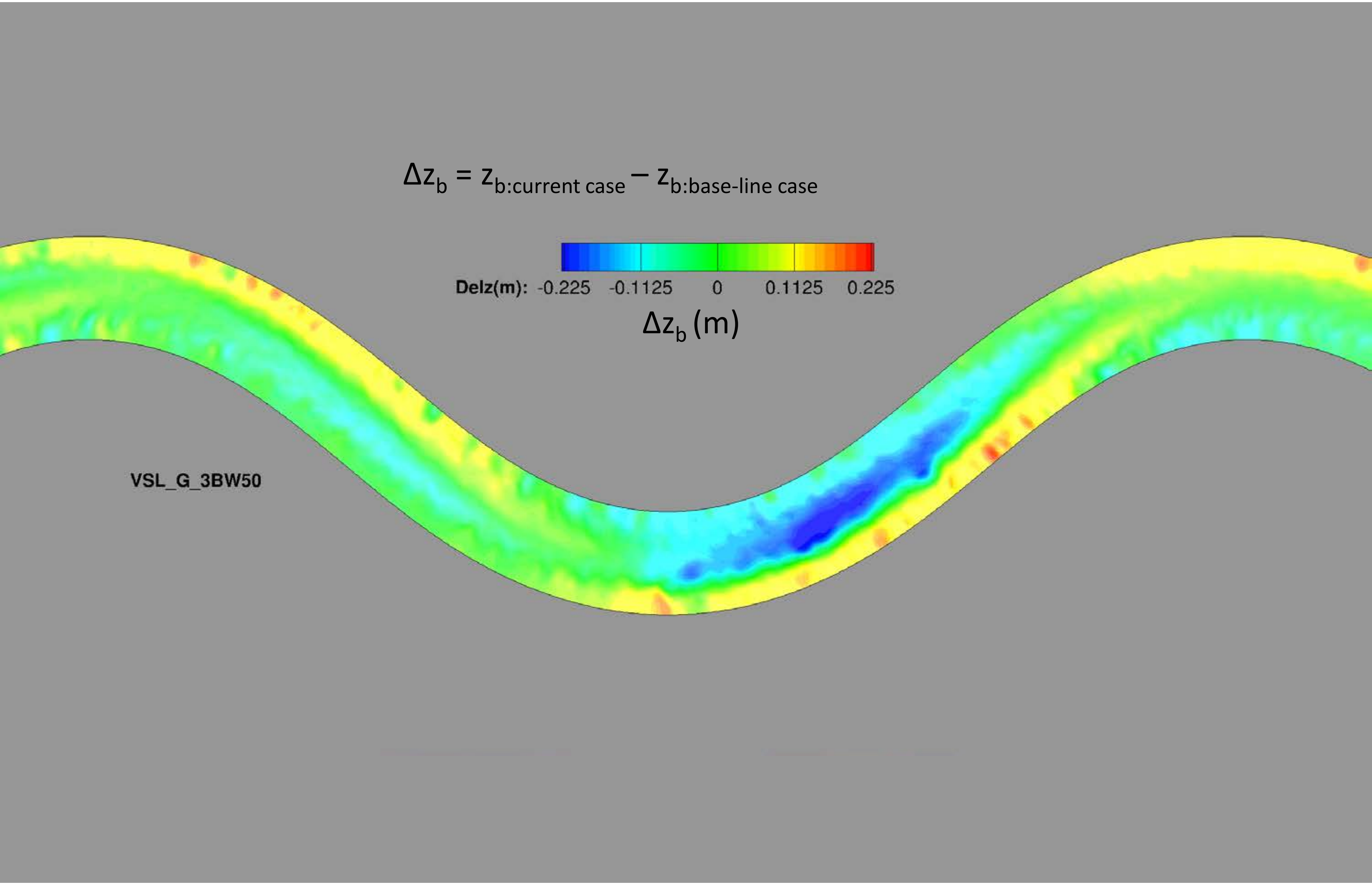




Triple 50^o Barb: gravel river



Triple 50° Barb: gravel river

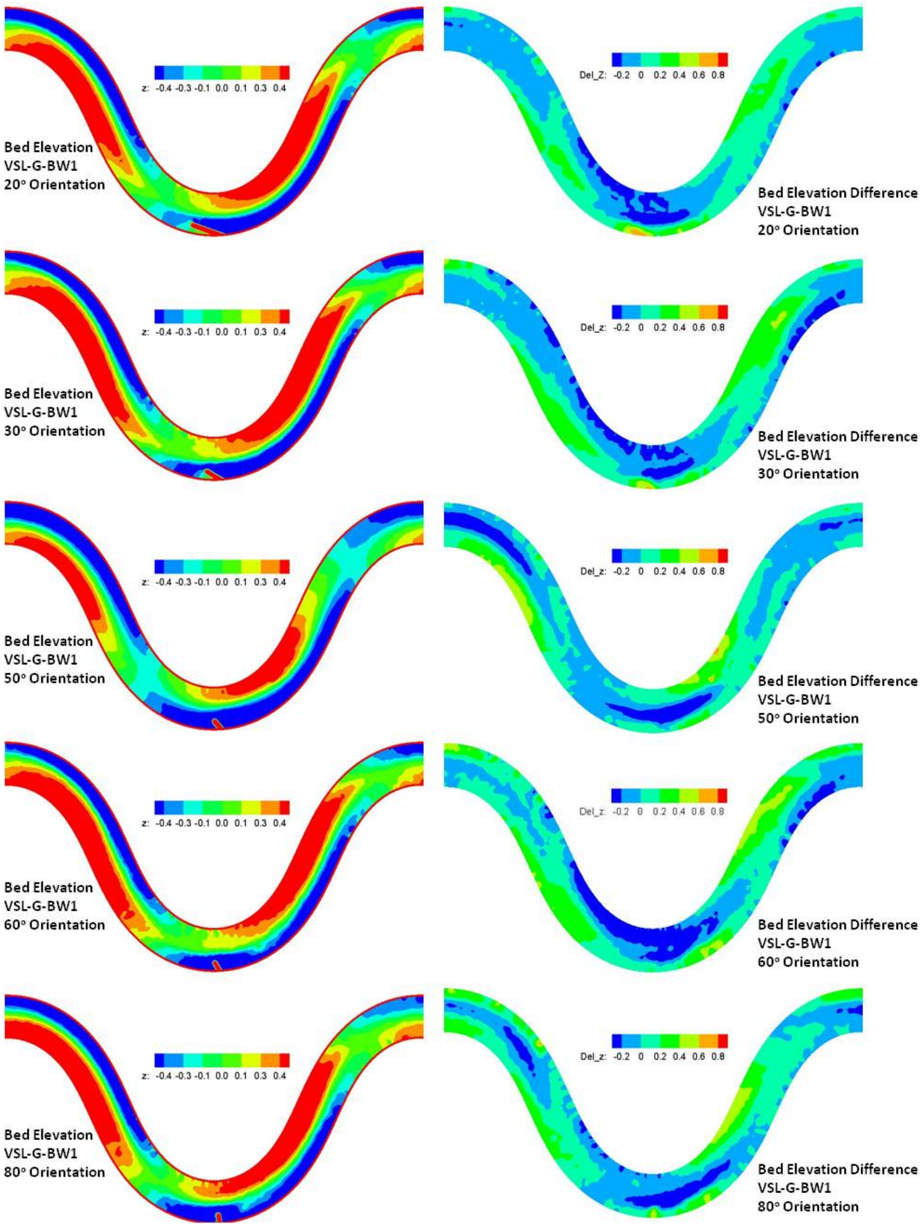


Simulation results for flow & sediment transport in a field-scale meander with 3 Bendway weirs

0 < t < 3 months

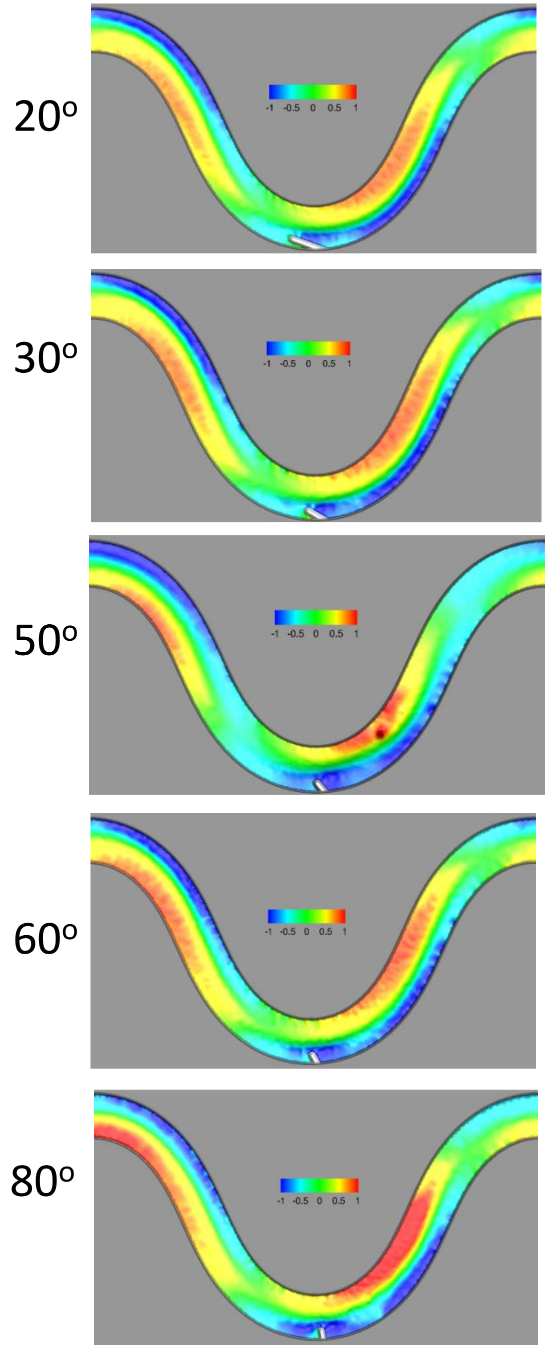
Width ~30 m
Length ~ 1.5 km long
h = 0.9 m
Re > 10^6

Barbs: sand river

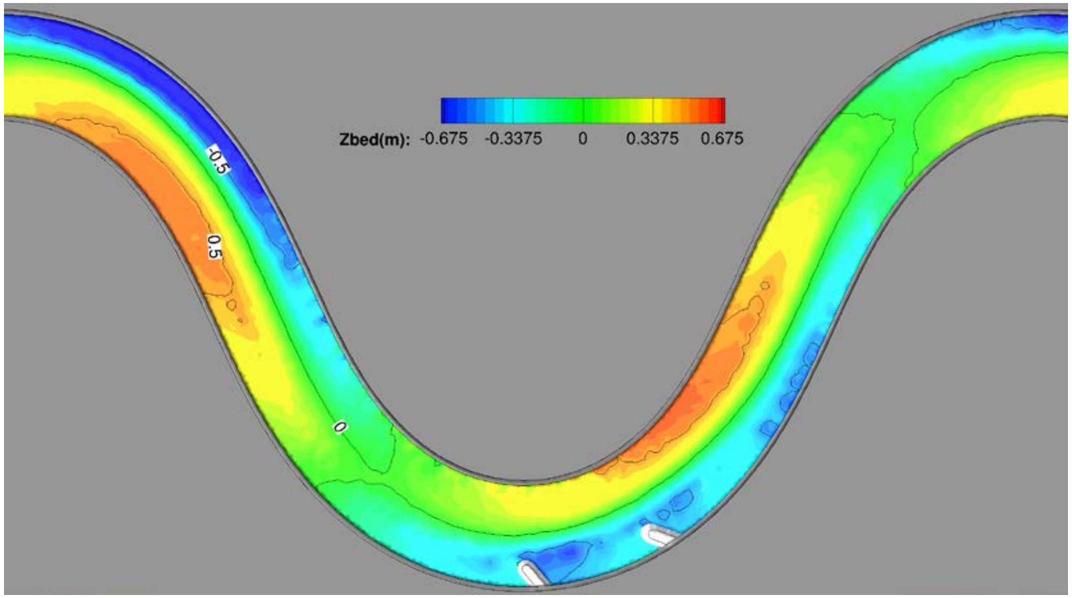


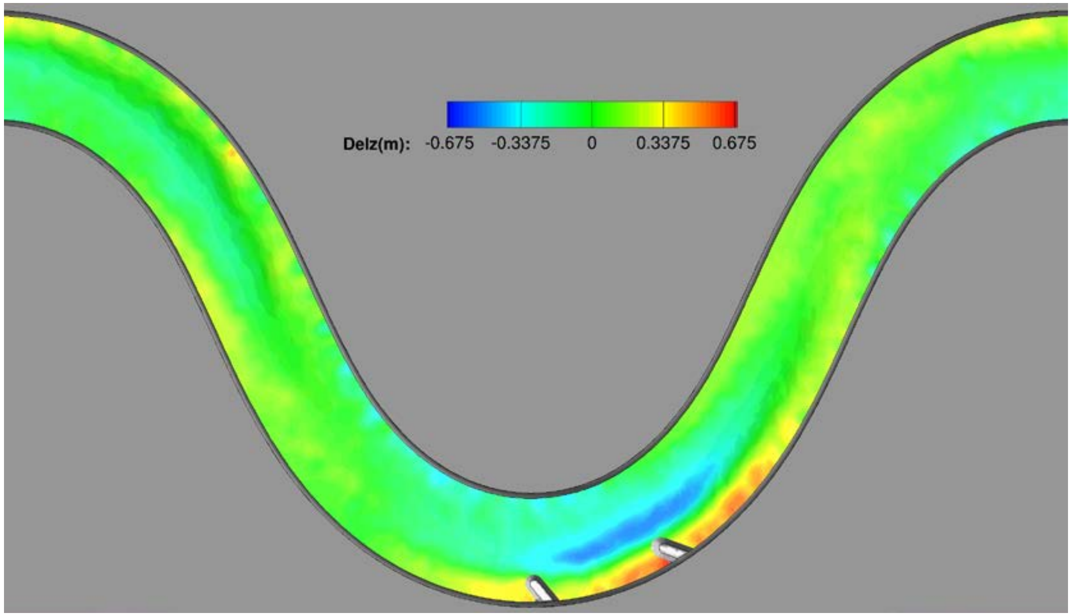
- Five installation angles studied;
- Optimum angle is selected based on cost (material) and bank protection;
- 50° barb is selected;
- Number and spacing is optimized—see next slides.

Barbs: sand river

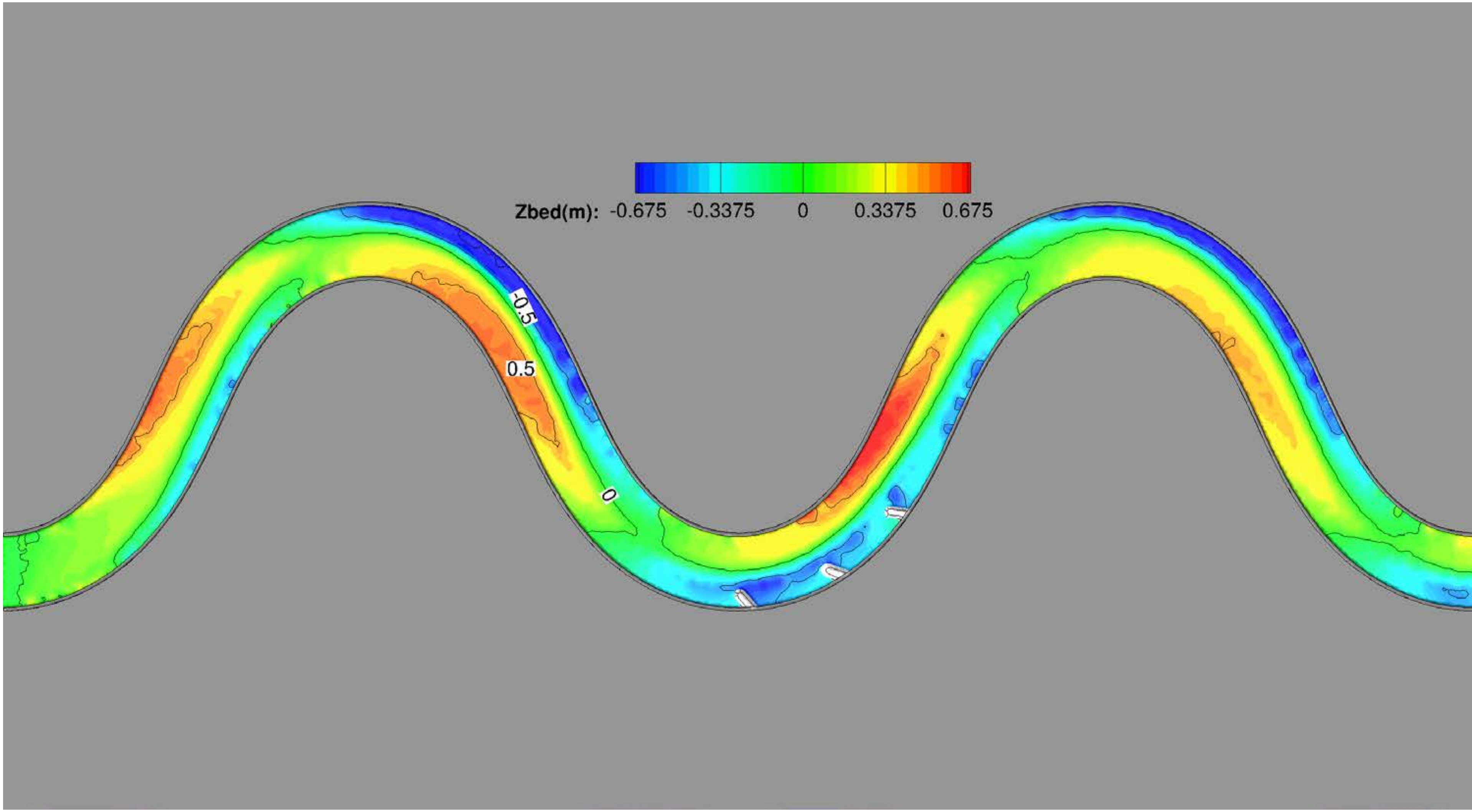


Barbs: sand river

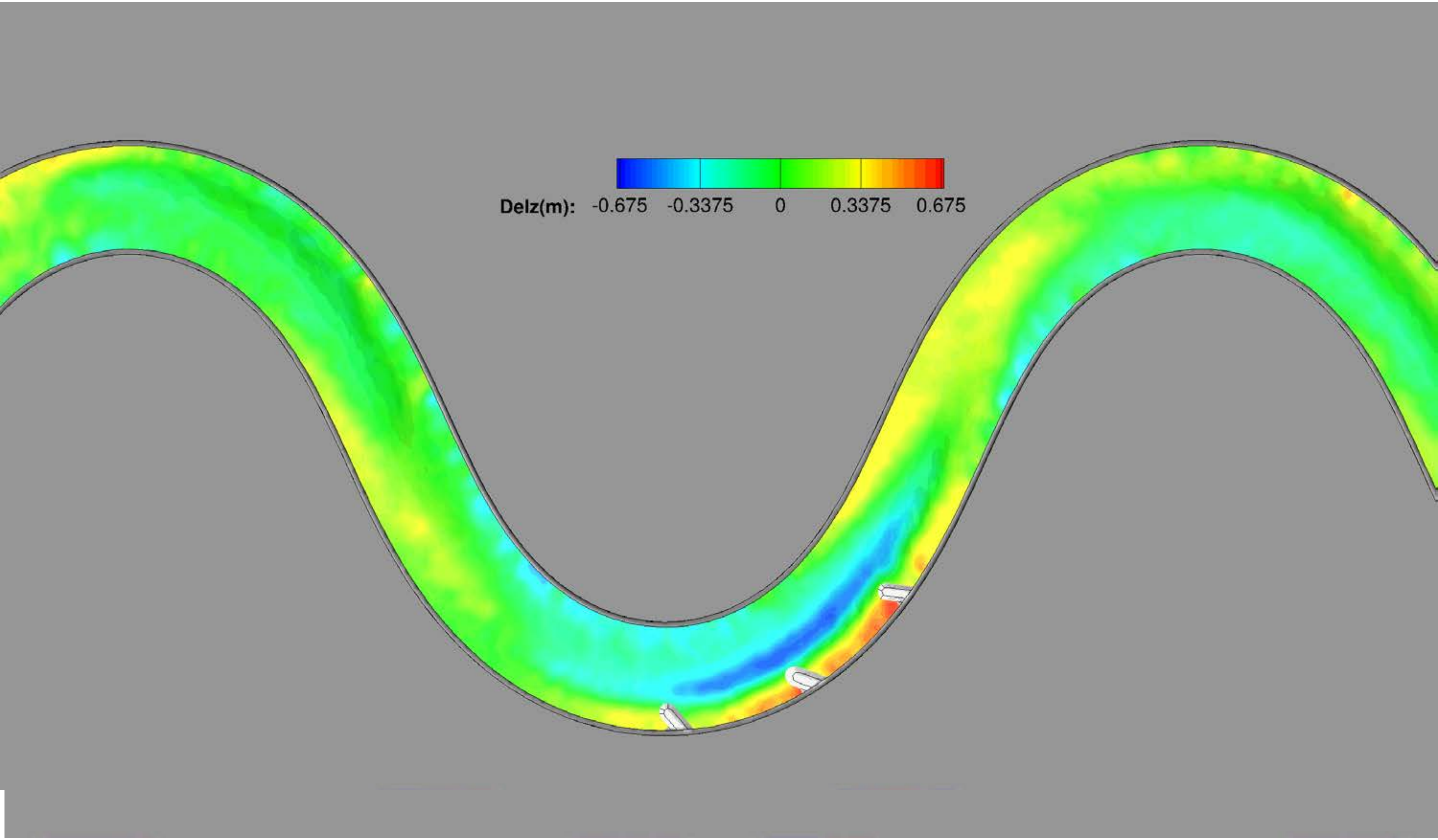




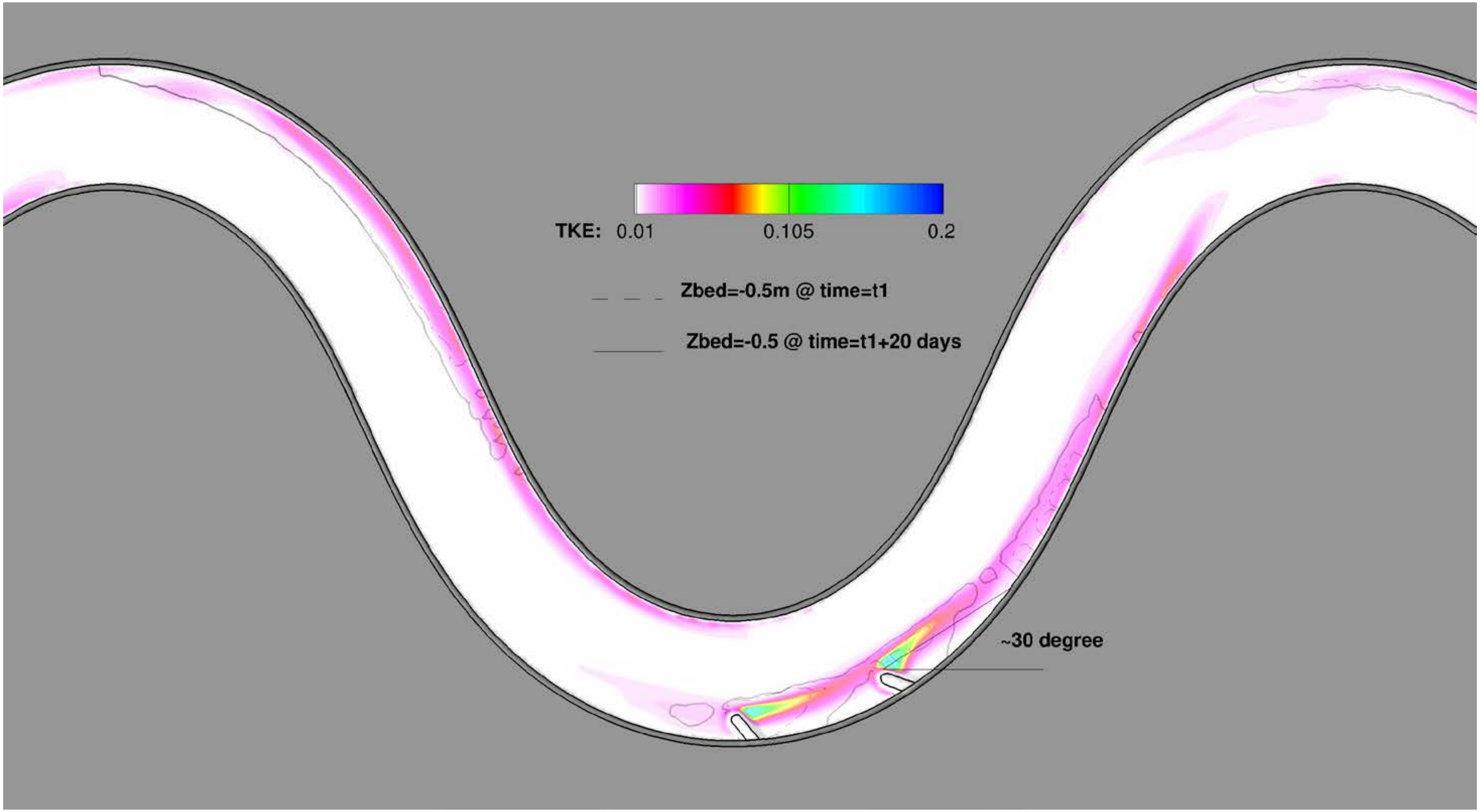
Barbs: sand river



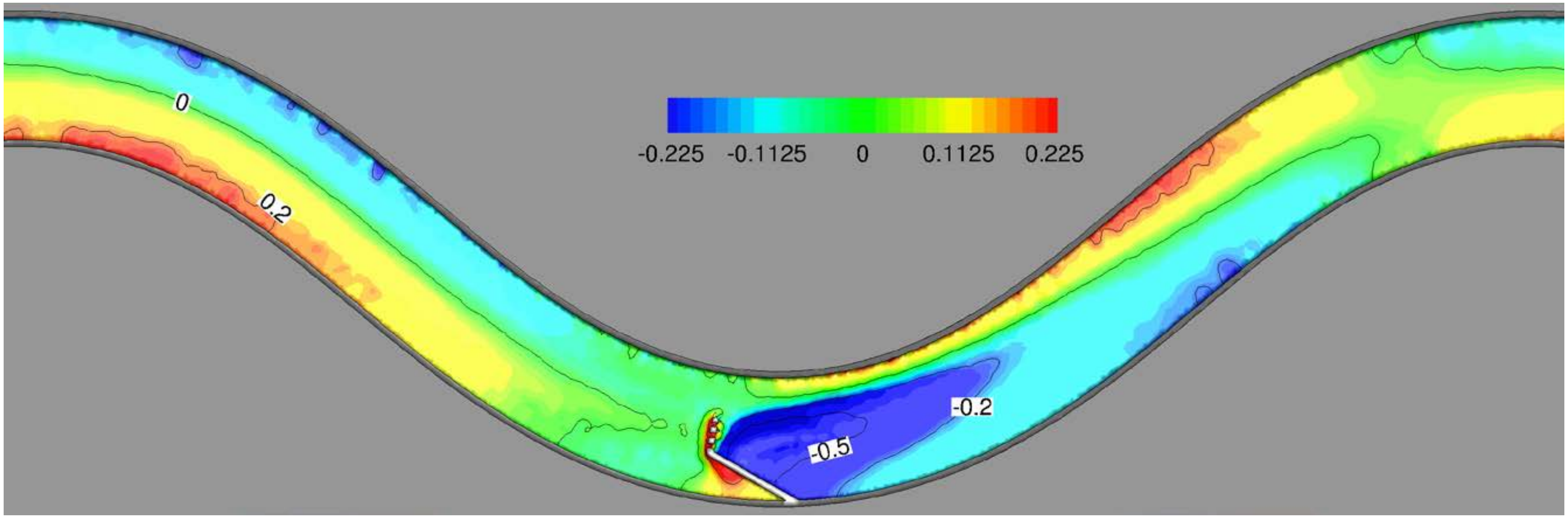
Barbs: sand river

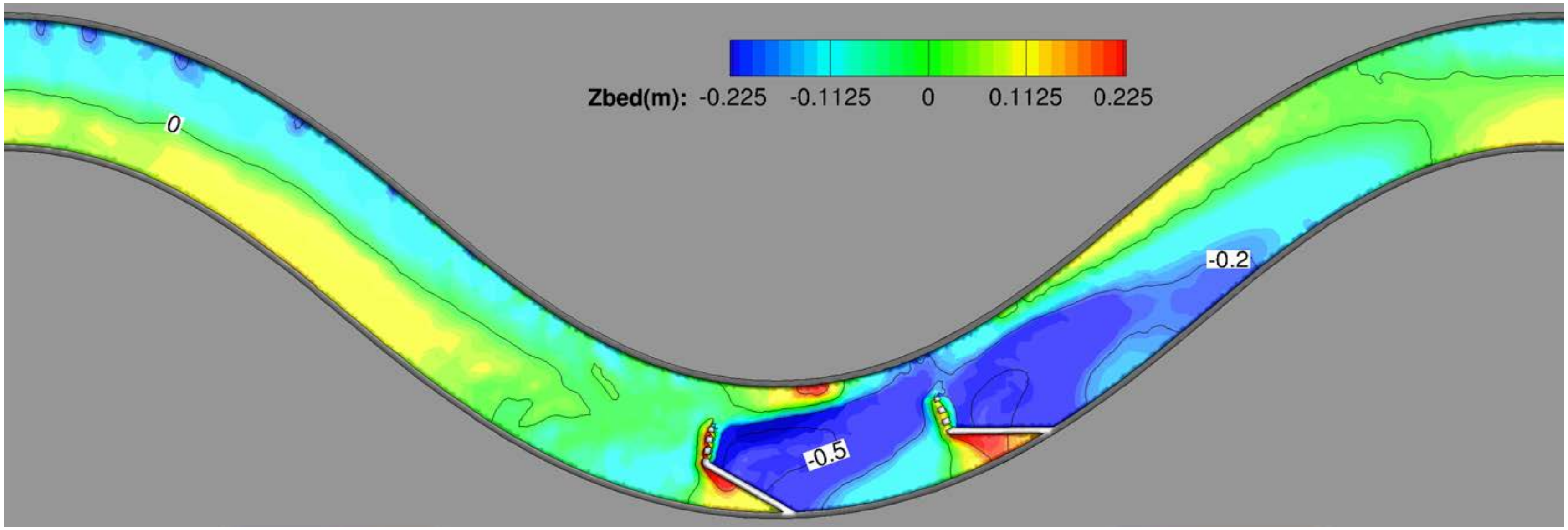


Two rock-vanes: Sand river

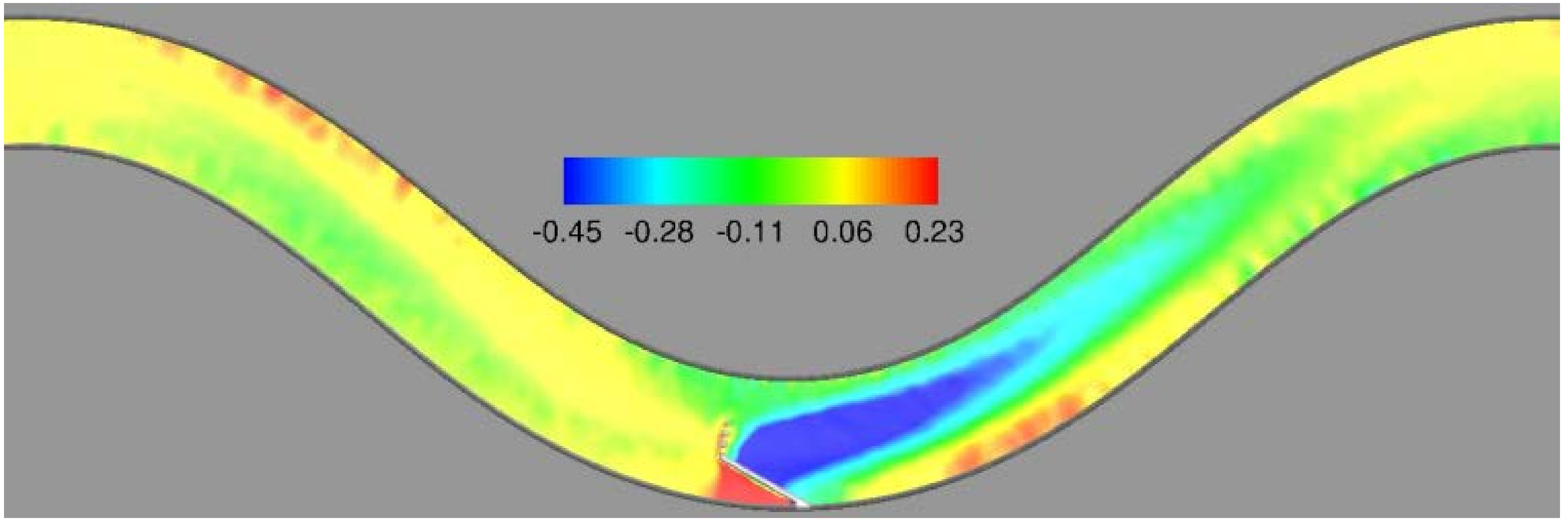


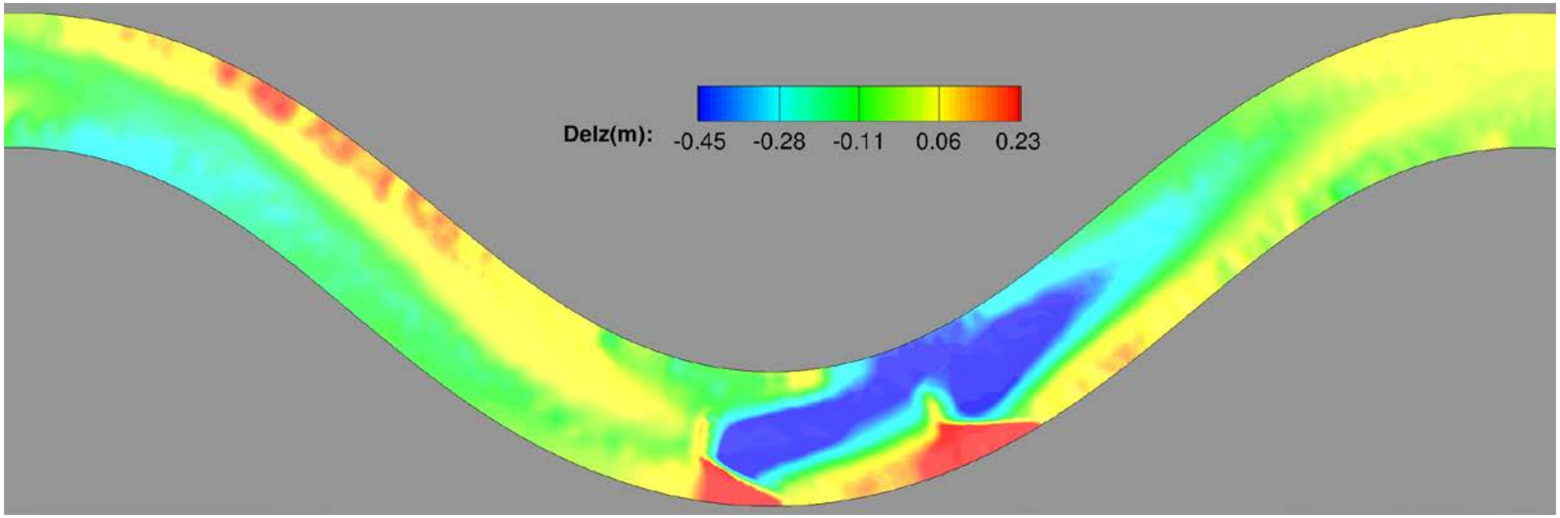
J-hook 30 degree: gravel river



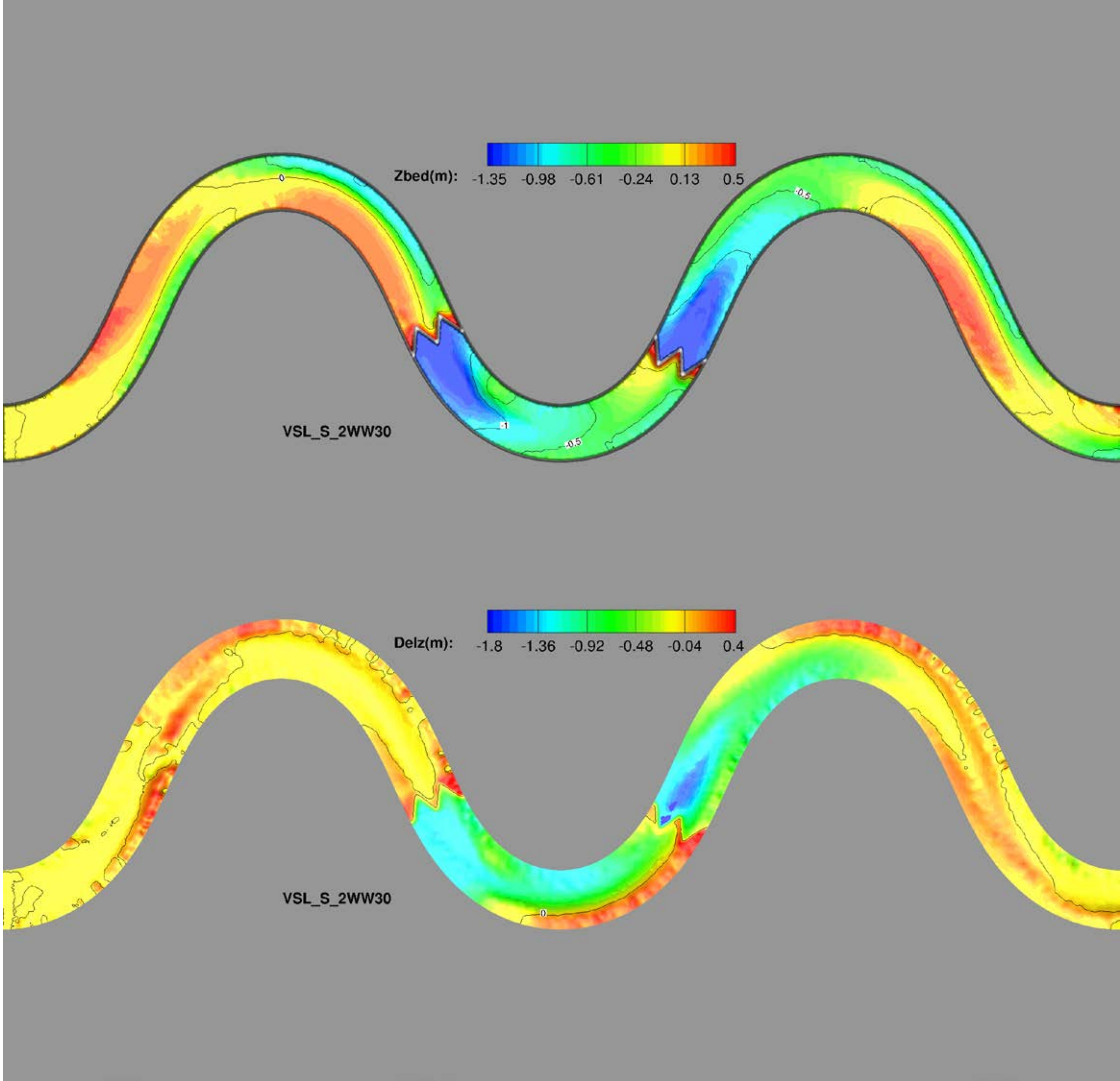


G_JH30



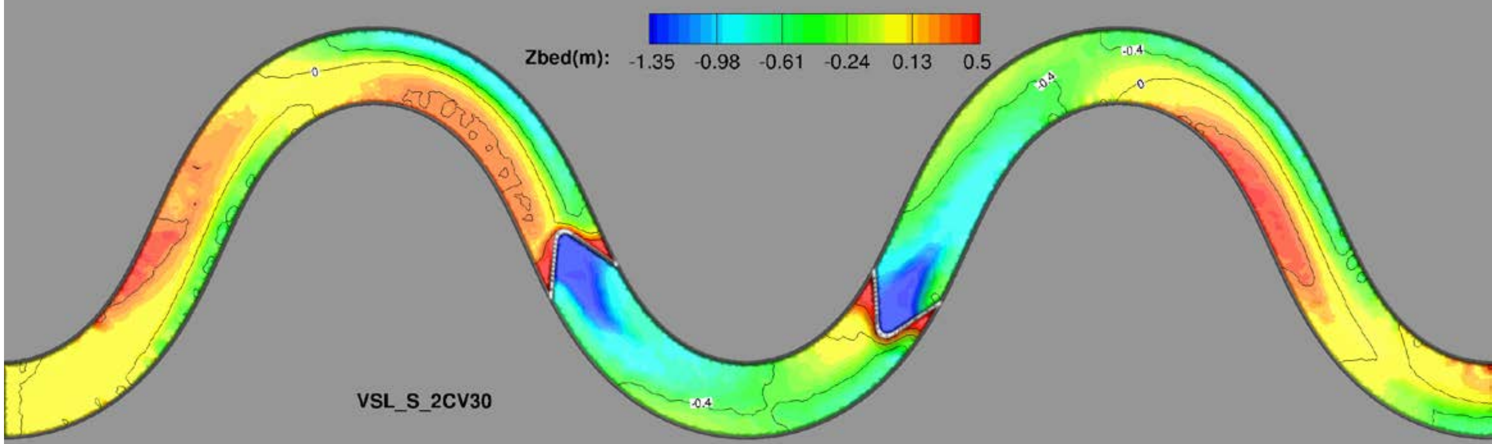


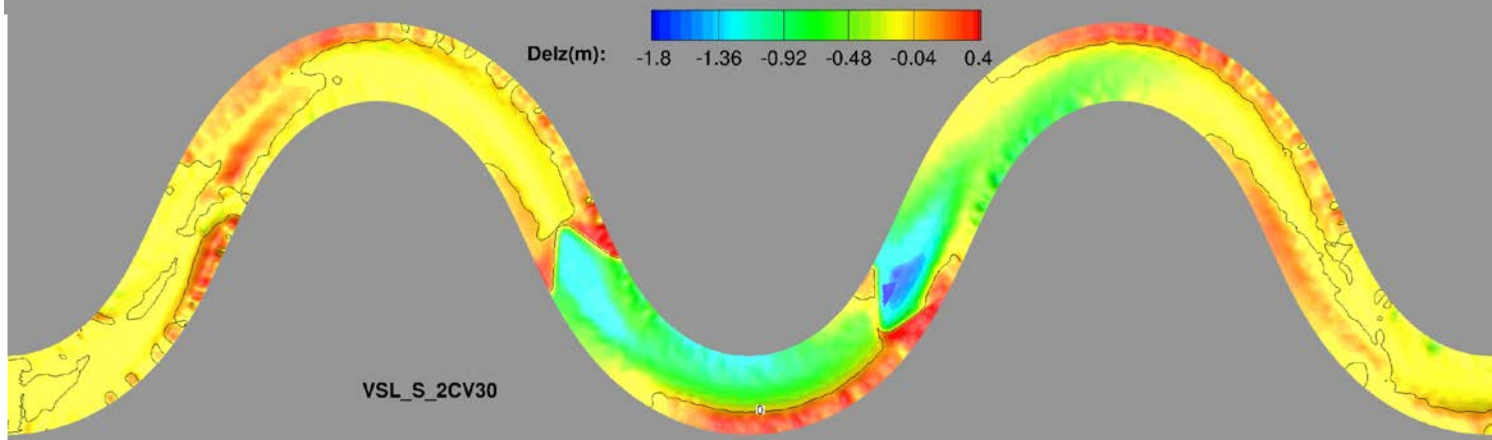
Phase B3:



S_WW_30

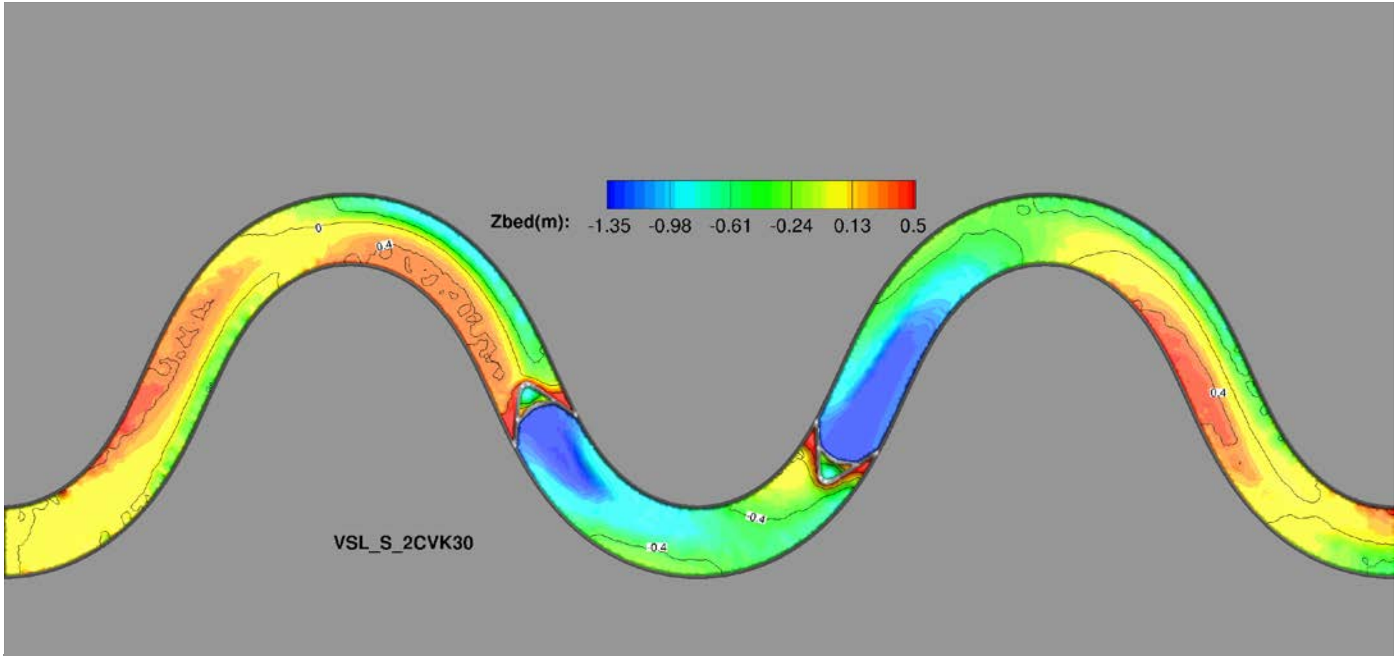
Phase B3:

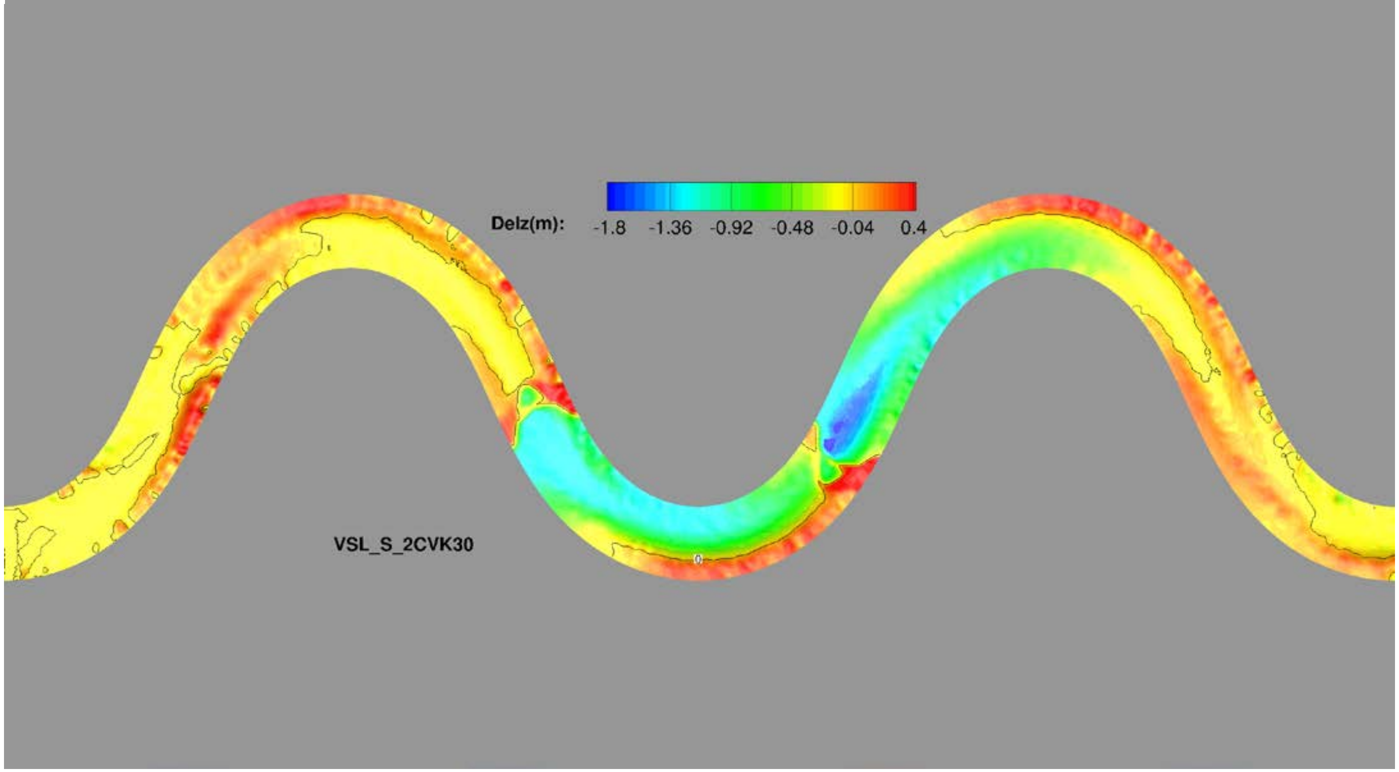




S_CV_30

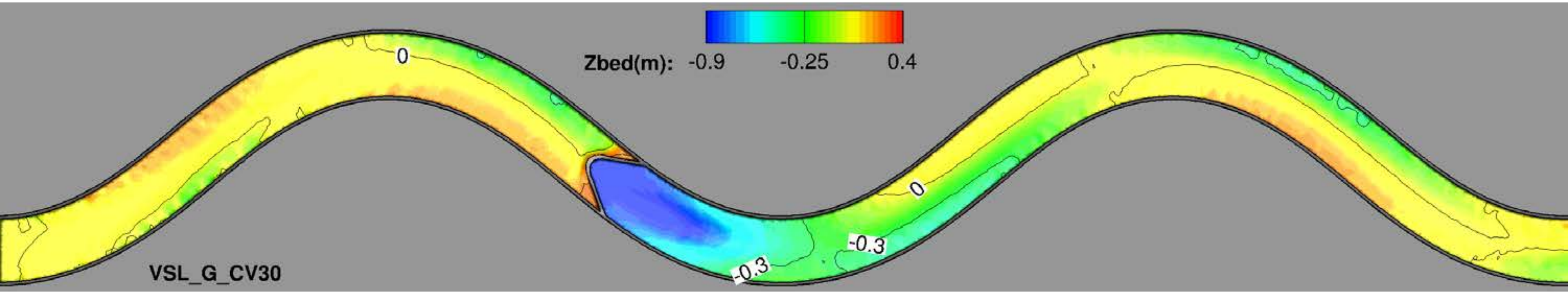
Phase B3:

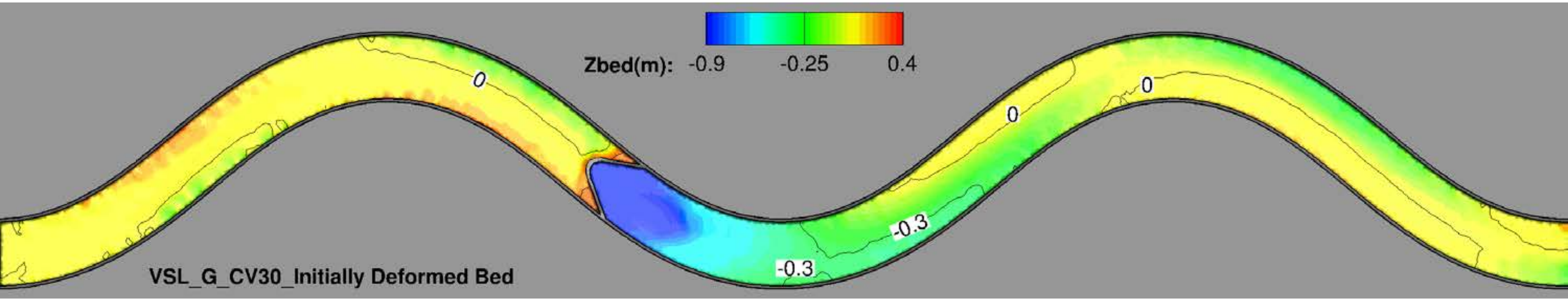




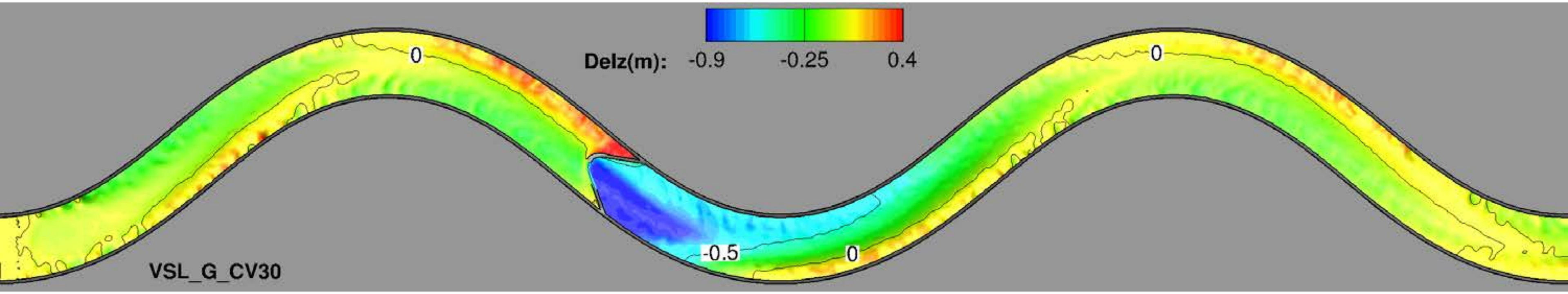
S_CVK_30

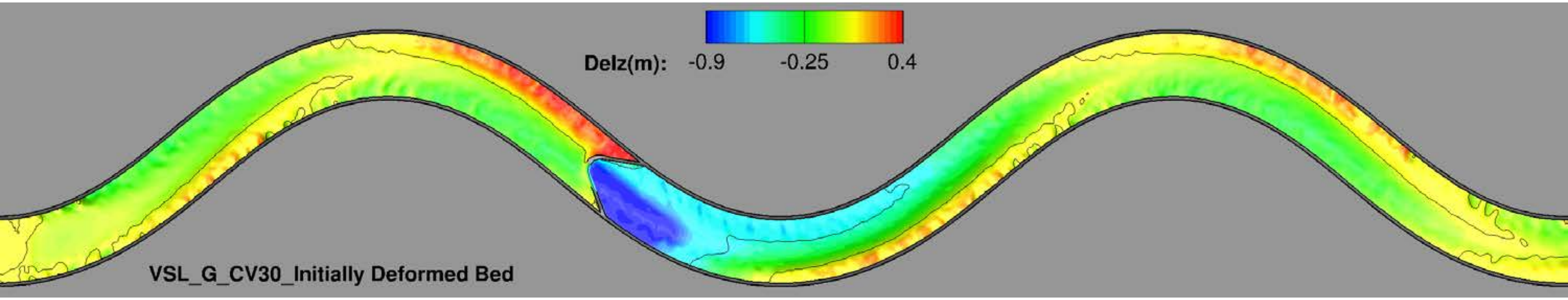
G_CV_30





Starts from deformed equilibrium bed



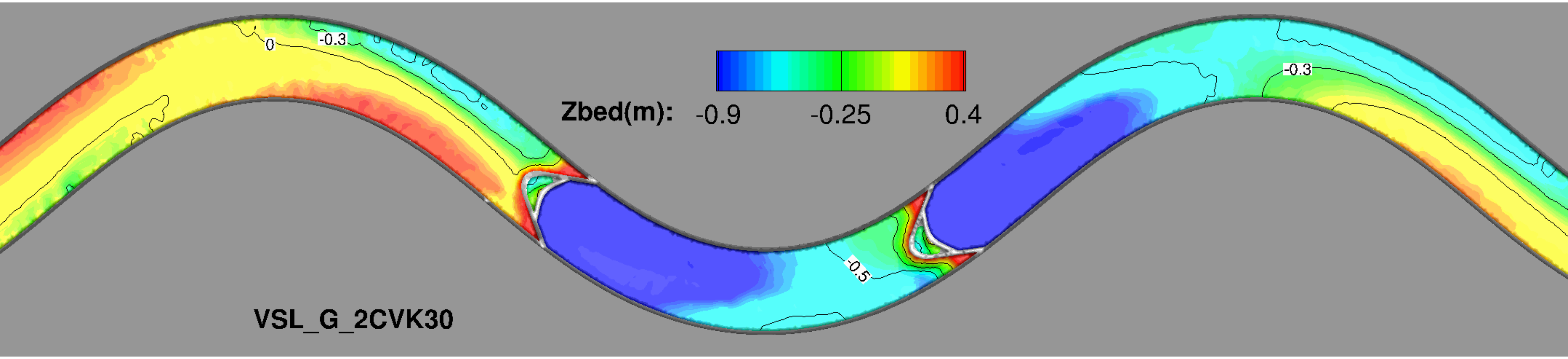


Starts from deformed equilibrium bed

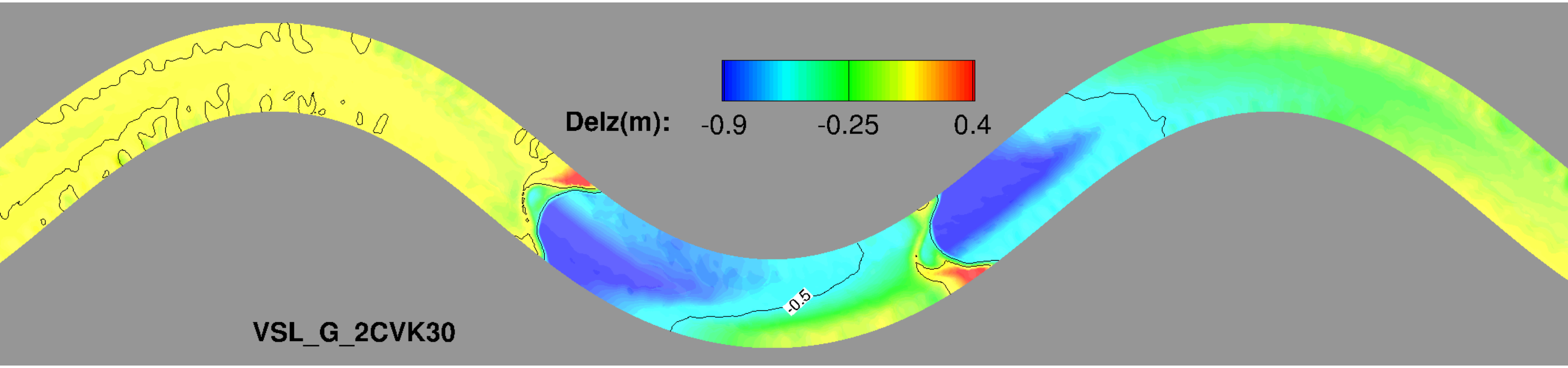
G_CV_30

Phase B3:

Mean bed elevations



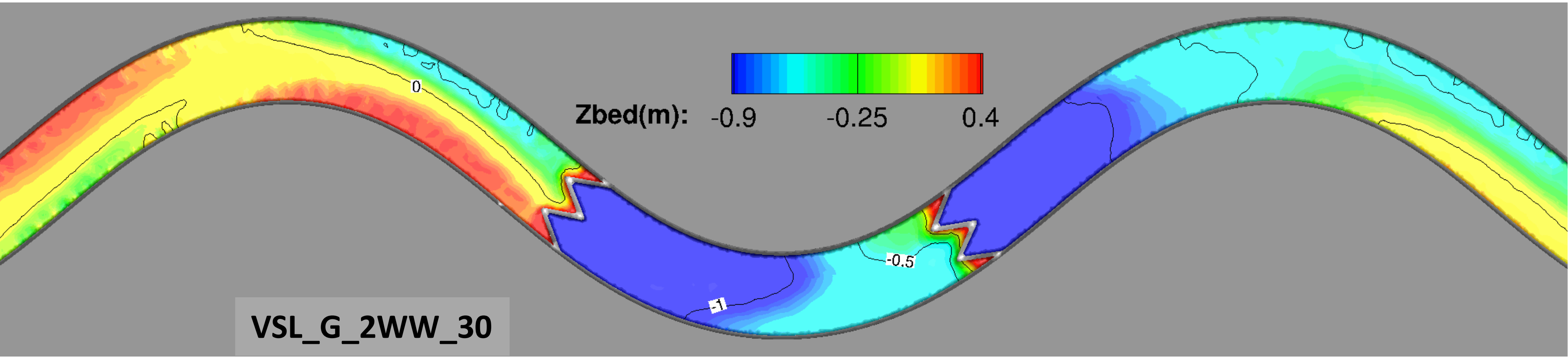
Difference with the base-line



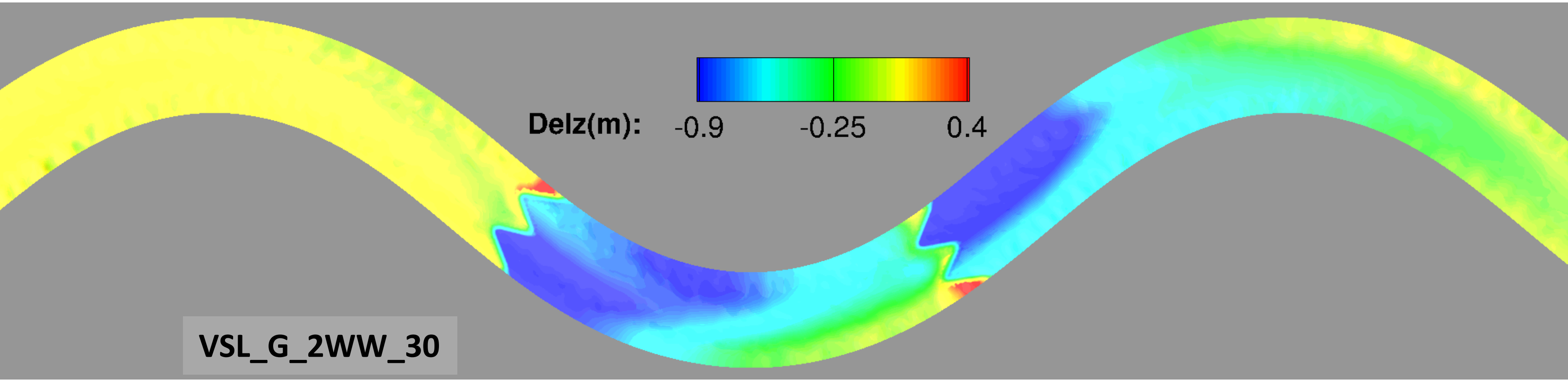
G_CVK_30

Phase B3:

Mean bed elevations



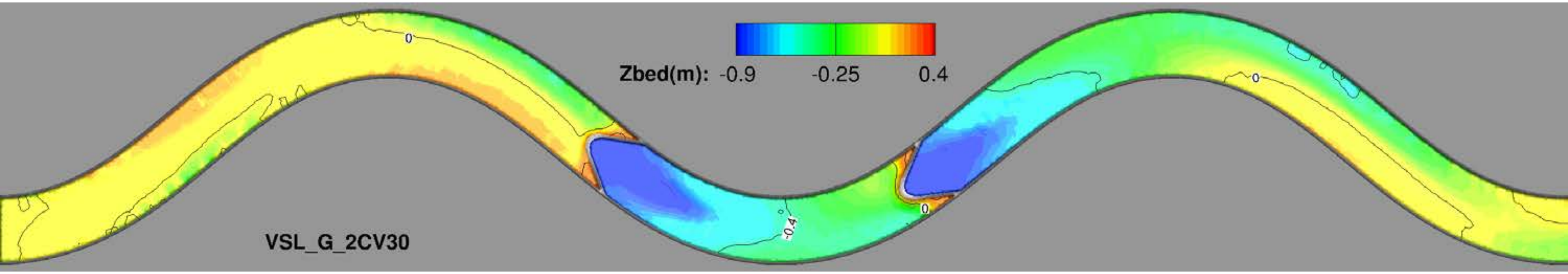
Difference with the base-line



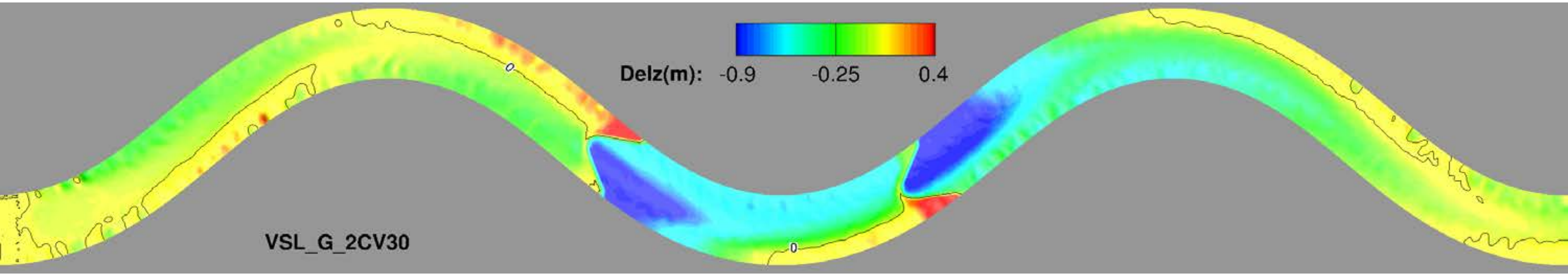
G_WW_30

Phase B3:

Mean bed elevations



Difference with the base-line



G_CV_30