

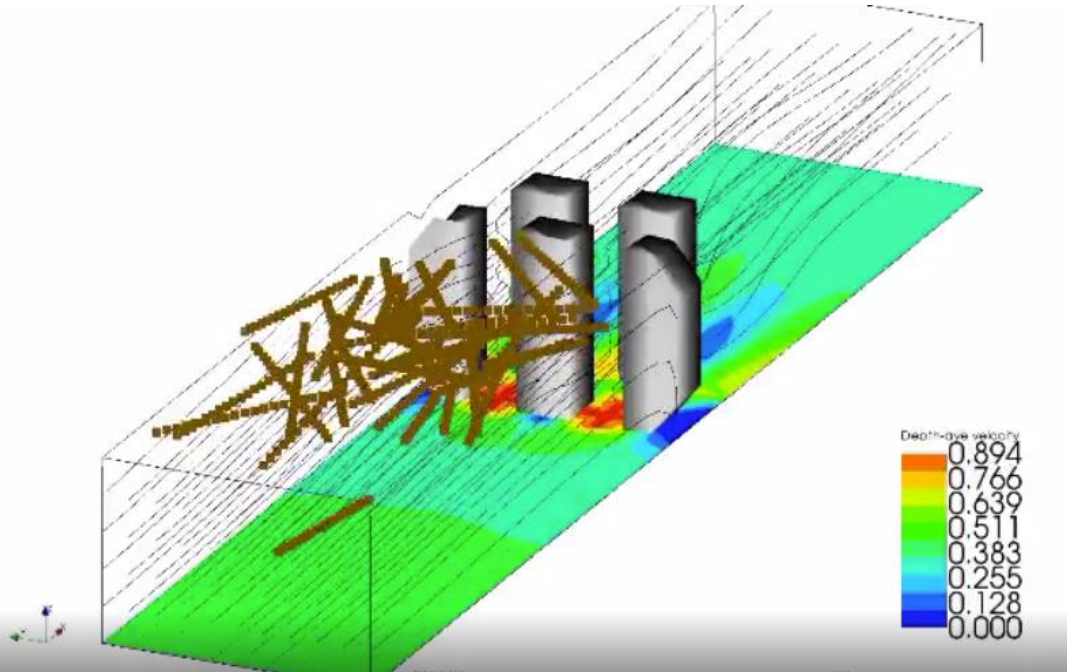
# Simulacija kretanja komada drveta kroz prepreke nalik mostovskim stubovima korišćenjem solvera NaysCUBE iRIC paketa



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UNIVERZITET U BEOGRADU  
GRAĐEVINSKI FAKULTET  
ODSEK ZA HIDROTEHNIKU I VODNO-EKOLOŠKO INŽENJERSTVO  
DOKTORSKE STUDIJE  
MEHANIKA FULUIDA – NAPREDNI KURS



Simulira se prostorno, turbulentno strujanje u prizmatičnom kanalu u kojem su postavljene tri vertikalne prepreke nalik mostovskim stubovima.

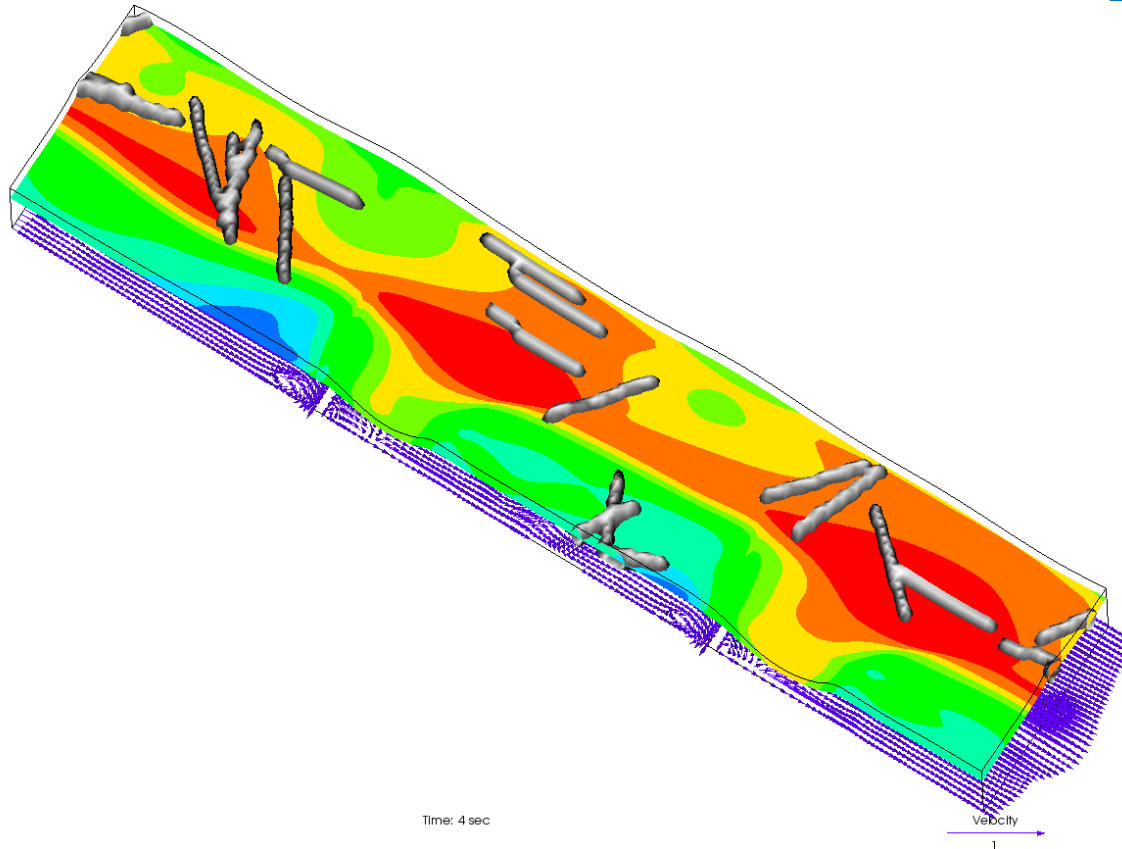
Posmatrati dva slučaja:

- Tečenje u kanalu bez prisustva plutajućih predmeta
- Tečenje u kanalu kada tok nosi plutajuće balvane

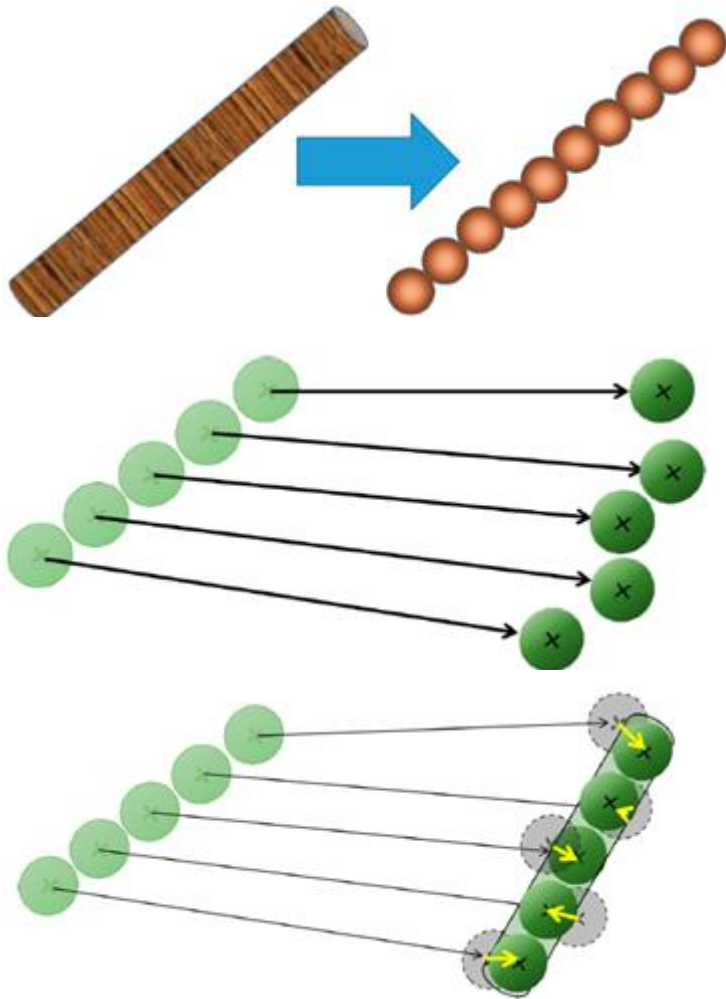


Poznavanjem osobina toka koji nosi plutajući materijal, moguće je predvideti preventivne mere i umanjiti negativne efekte:

- Gomilanje plivajućeg nanosa na suženjima u rečnom koritu
- Usporeno tečenje i podizanje nivoa vode
- Uzvodno plavljenje
- Oštećenje mostovskih stubova usled kolizije
- Rušenja mostovske konstrukcije

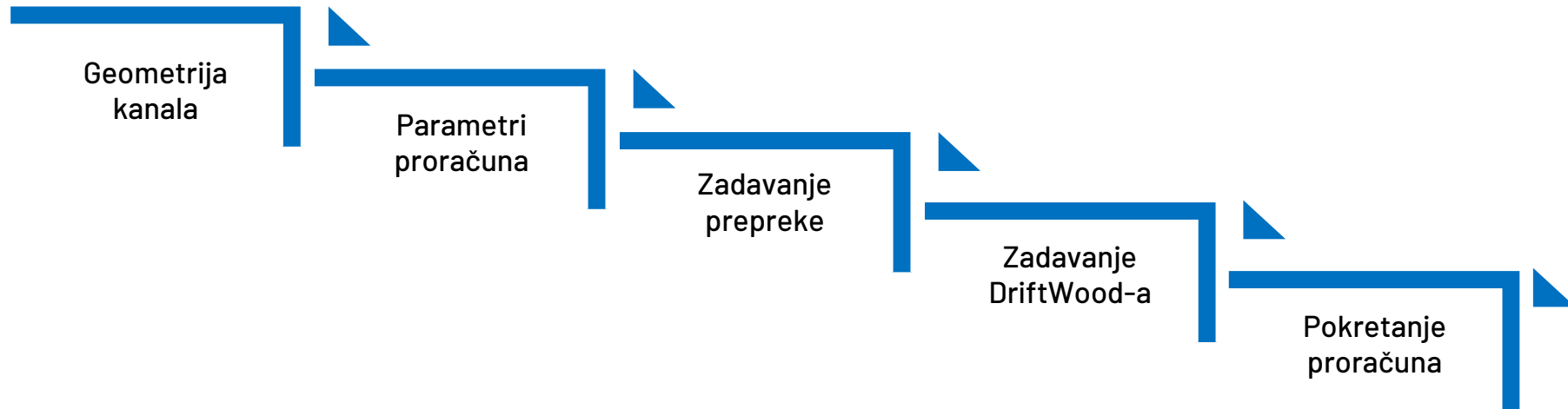


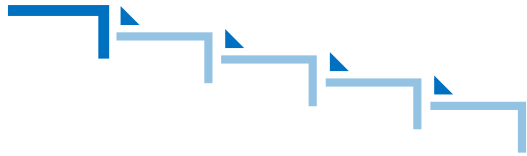
- Softver za proračun trodimenzionalnog tečenja u otvorenim tokovima i proračune defromacije rečnog korita
- Može da simulira sekundarna strujanja, opstrujavanje oko objekata u tokovima, tečenje u tokovima sa ili bez prepreka
- Nova funkcija proračuna kretnje drvenih komada, “driftwood”-a, je dodata u solver NaysCUBE softvera iRIC ver.3
- Verzijom 3.1 ova funkcija je proširena mogućnošću simulacije transporta objekta (krutog tela, bilo kog oblika) nošenog advektivnim strujanjem



- Komad drveta u modelu je prikazan preko sfera povezanih u niz
- Zanimaju se vezne sile između sfera i svaka od njih se pomera samostalno po zakonu koji je opisan Lagranžovom jednačinom kretanja
- Nakon pomeranja sfere se ne nalaze na istom pravcu
- U poslednjem koraku sfere se prilagođavaju i poravnavaju tako da ponovo postanu kolinearne

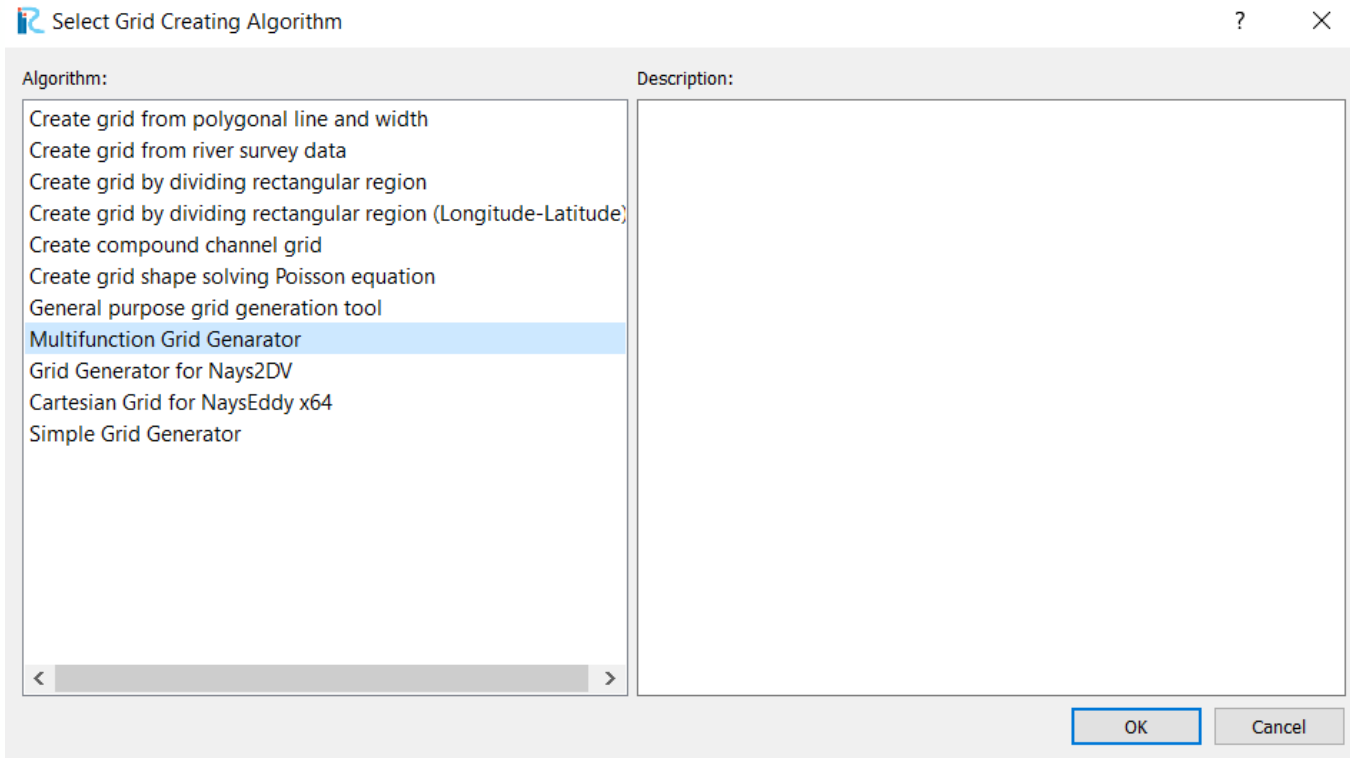
# METODOLOGIJE IZRADE MODELA

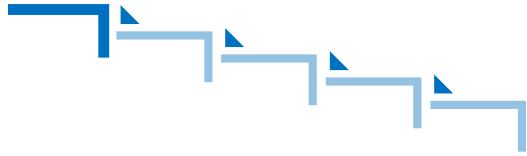




1

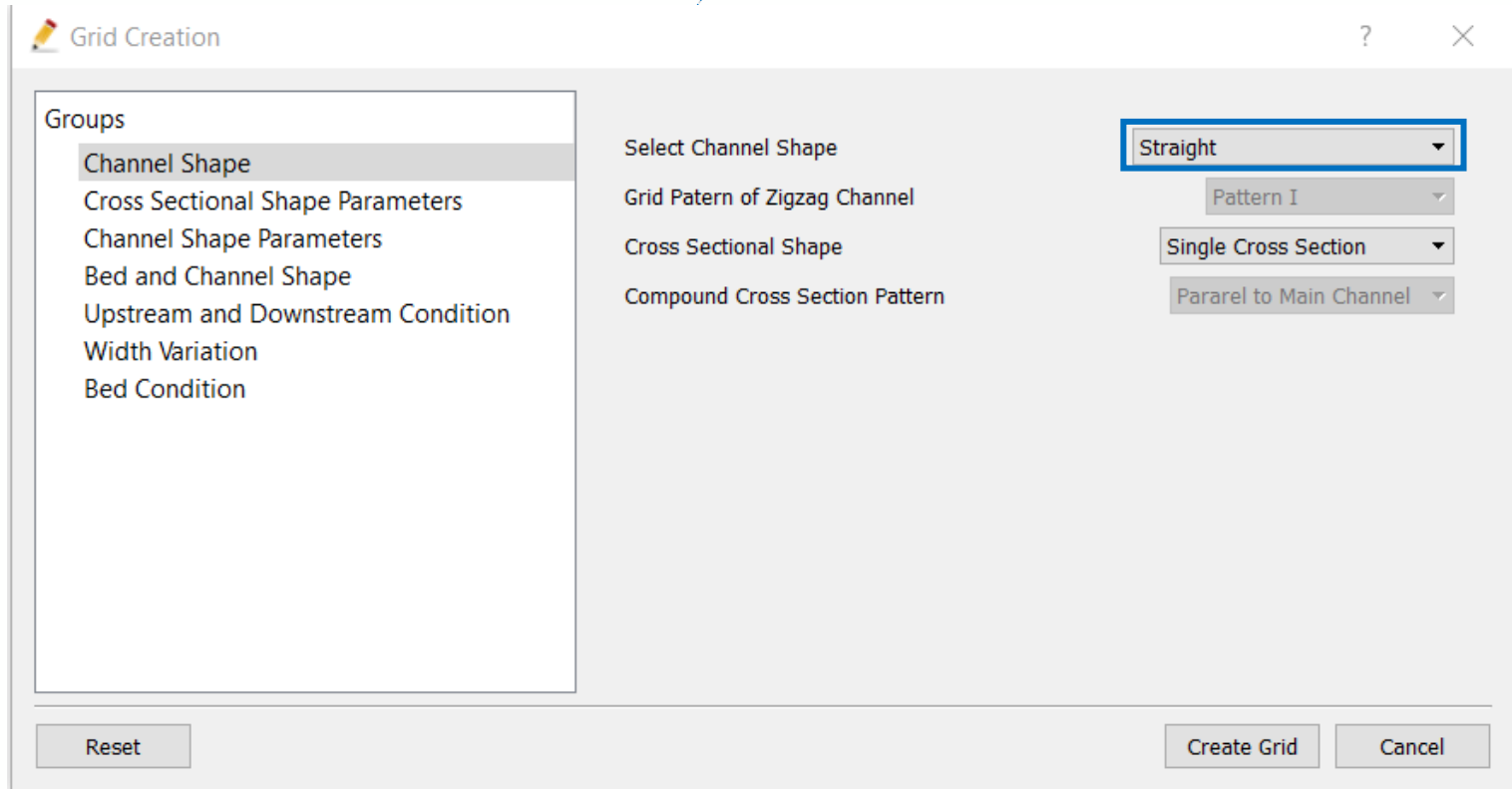
## Odabir načina zadavanja geometrije



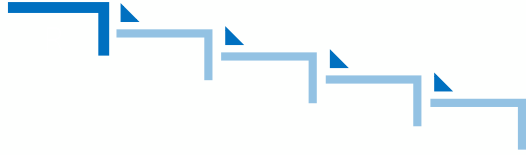


2

## Odabir oblika kanala - prizmatičan







3

Širina kanala: 0.5m  
Broj ćelija po širini: 10  
 $\Delta y = 0.05m$

Grid Creation ? X

Groups

- Channel Shape
- Cross Sectional Shape Parameters**
- Channel Shape Parameters
- Bed and Channel Shape
- Upstream and Downstream Condition
- Width Variation
- Bed Condition

Single Cross Section

Width(m)

Number of Grid in Lateral Direction

Compound Channel

Numbers of Grids

Left Floodplain

Low Water Channel

Right Floodplain

Low Water Channel Depth(m)

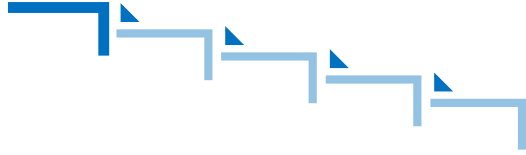
Bank Slope Raitio of Low Water Channel

Numbers of Grids in Low Water Channel Bank

Simple Compound Channel

Channel Width

Left Flood Channel Width(m)



4

Dužina kanala: 5m

Broj ćelija po dužini: 100

$\Delta x = 0.05m$

Groups

Channel Shape

Cross Sectional Shape Parameters

Channel Shape Parameters

Bed and Channel Shape

Upstream and Downstream Condition

Width Variation

Bed Condition

Wave Length of Meander(m)

Wave Number

Meander Angle(degree)

Number of Grids in One Wave Length

Levee Meander Parameters

Meander Angle(degree)

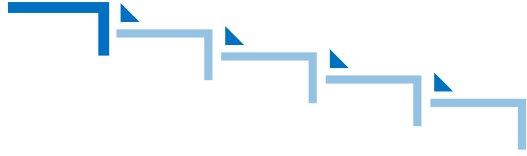
Meander Wave Length(m)

Phase Lag from LWC(m)

Kinoshita Meander Parameters

Additional Meander Angle(degree)

n1(Wave Number of the second term)



5

## Zadavanje nagiba

Groups

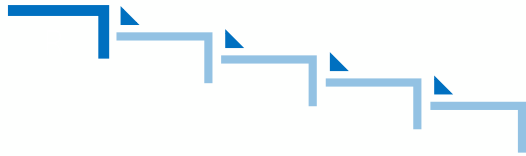
- Channel Shape
- Cross Sectional Shape Parameters
- Channel Shape Parameters
- Bed and Channel Shape**
- Upstream and Downstream Condition
- Width Variation
- Bed Condition

Initial Bed Shape

Bar Height or Amplitude of Parabolic Shape(m)

Lag Btween Bar and Plane Geometry(m)

Channel Slope



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## Nepokretno dno

Grid Creation

? X

## Groups

- Channel Shape
- Cross Sectional Shape Parameters
- Channel Shape Parameters
- Bed and Channel Shape
- Upstream and Downstream Condition
- Width Variation
- Bed Condition**

## Low Water Channel

Bed Condition

Fixed Bed

Roughness Definition

Not Specified

Roughness Value

0.02

## Floodplain

Bed Condition

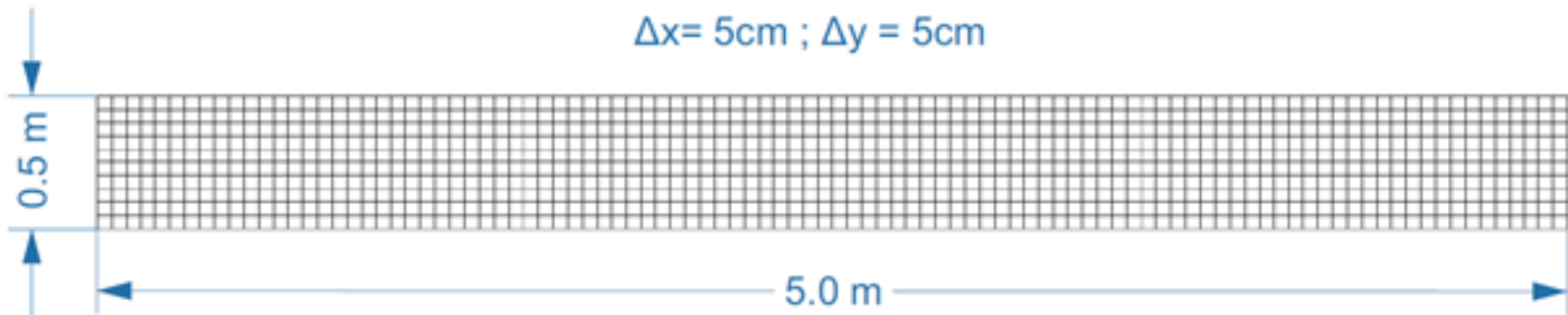
Moveable Bed

Roughness Definition

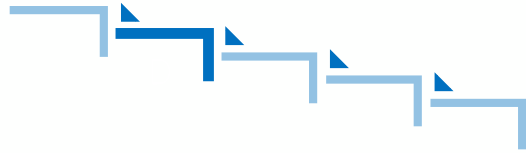
Not Specify

Roughness Value

0.05



Dobijena mreža



7

Broj ćelija po vertikali: 10

Nelinearni model

Calculation Condition

? X

Groups

Basic Parameters

Time Conditions

Inlet Discharge and Outlet WaterLe...

Depth and Wet-Dry Conditions

Roughness Conditions

Bed Conditions

Vegetation Conditions

Boundary conditions

Hot start conditions

Additional output files

Initial topography correction

DriftWood

Advanced settings

Number of Vertical Layers

10

Fixed or Movable Bed

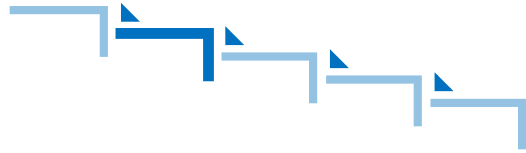
Fixed bed

Turbulence Model

Non-linear k-e model

Spatial Scheme for Advection Terms

TVD MUSCL



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# Odabir vremenskih parametara proračuna

Calculation Condition

Groups

- Basic Parameters
- Time Conditions**
- Inlet Discharge and Outlet WaterLe...
- Depth and Wet-Dry Conditions
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
- Boundary conditions
- Hot start conditions
- Additional output files
- Initial topography correction
- DriftWood
- Advanced settings

Start Time[s]

End Time[s]

File Output Time[s]

Start time of surface move[s]

Start time of bed move[s]

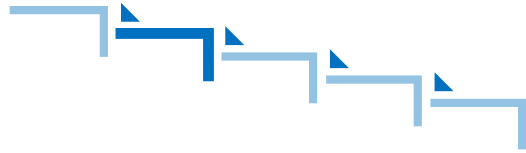
Variable DT with CFL condition

Coefficient for CFL condition

Time Step[s]

Display output interval

Reset Save and Close Cancel



## Konstantni proticaj

$$Q = 30\text{l/s}$$

Calculation Condition

?

×

Groups

- Basic Parameters
- Time Conditions
- Inlet Discharge and Outlet WaterLe...
- Depth and Wet-Dry Conditions
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
- Boundary conditions
- Hot start conditions
- Additional output files
- Initial topography correction
- DriftWood
- Advanced settings

Hydrograph Data Type: Constant discharge

Constant Discharge[m<sup>3</sup>/s]: 0.03

Outlet water level for fixed Q: set from uniform flow

Outlet water level for variable Q: set from uniform flow

Constant outlet water level[m]: 1

Unit of time for Q: second

Time series of Q at inlet: Edit

Time series of Q at inlet and WL at outlet: Edit

Q gradual increase: Q given directly

Initial Q rate: 0.1

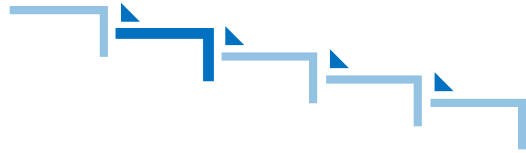
Time for Q slope[s]: 10

Reset

Save and Close

Cancel





10

Minimalna dubina: 0m

**Calculation Condition** [?] [X]

**Groups**

- Basic Parameters
- Time Conditions
- Inlet Discharge and Outlet WaterL...
- Depth and Wet-Dry Conditions**
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
- Boundary conditions
- Hot start conditions
- Additional output files
- Initial topography correction
- DriftWood
- Advanced settings

Wet and Dry Cells: Fixed wet and dry cells

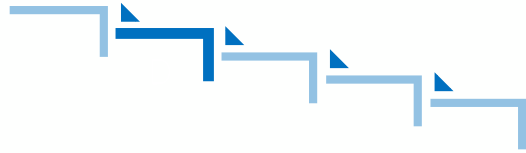
Minimum Depth[m]: 0

How to give initial surface slope?: Given by parabolic curve fit

Initial surface slope: 0.0001

Relaxation coefficient: 0.3

Buttons: Reset, Save and Close, Cancel



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## Osnovni parametri računanja DriftWood-a:

Calculation Condition

Groups

- Basic Parameters
- Time Conditions
- Inlet Discharge and O...
- Depth and Wet-Dry C...
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
- Boundary conditions
- Hot start conditions
- Additional output files
- Initial topography cor...
- DriftWood**
- Advanced settings

Calculate DriftWood?

Calculate wood motion in 2D or 3D?

Length of DriftWood[m]

Diameter of DriftWood[m]

Density of DriftWood[kg/m<sup>3</sup>]

How to set particle number?

Number of spheres for a wood

Impinging of driftwood

How to supply driftwood?

Supply driftwood periodically?

Start time of driftwood calculation[sec]

Period of driftwood supply[sec]

Stop driftwood supply during computation?

Stop time of driftwood supply[sec]

One-way or Two-way

Drag coefficient for driftwood

Grouped spheres

3-D computation

0.1

0.01

900

set arbitral number

5

No

Pack from the air

No

20

0

No

0

Two-Way model

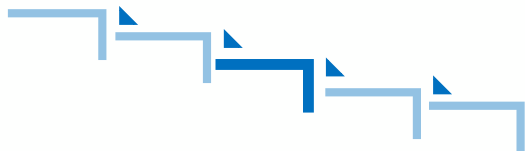
2

Reset

Save and Close

















Cancel

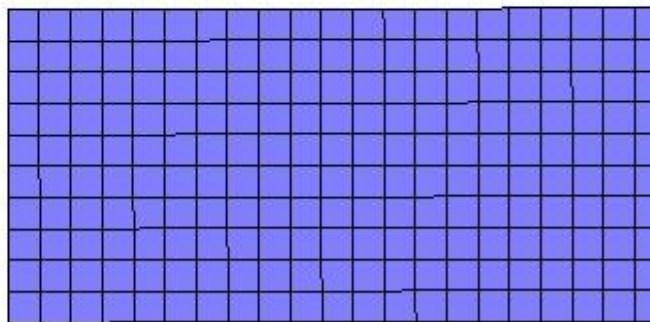
- Prostorni 3-D proračun
- Dužina komada drveta: 0.1m
- Prečnik drveta: 0.01m
- Gustina drvene mase: 900kg/m<sup>3</sup>
- Broj sfera koje formiraju strukturu: 5
- Opcija sudaranja: isključena
- Distribucija drvene strukture iz vazduha
- Vreme pokretanja simulacije drvene strukture: 20s
- Two-way model: Uticaj na protok se ne zanemaruje

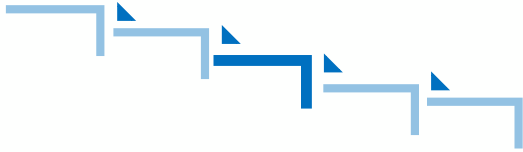


12

## Označavanje kartice Obstacle cell

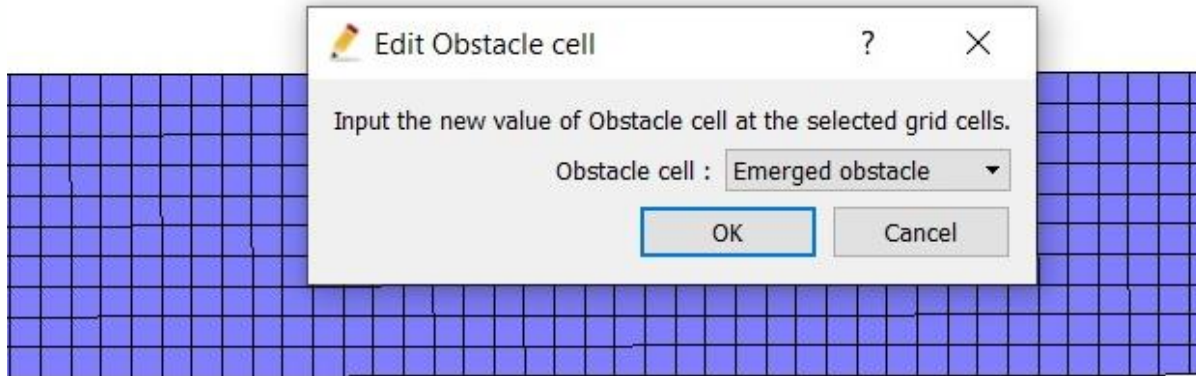
-  Obstacle height [m]
-  Underpass top heigh...
-  Underpass bottom h...
-  Reference Information
-  Grid Creating Condition
-  Grid (101 x 11 = 1111)
-  Grid shape
-  Node attributes
-  Cell attributes
  -  Obstacle cell
  -  Vegetation cell
  -  UnderPass Cell
  -  UnErodable cell
  -  Roughness
  -  DriftWood
  -  Obstacle height [...]

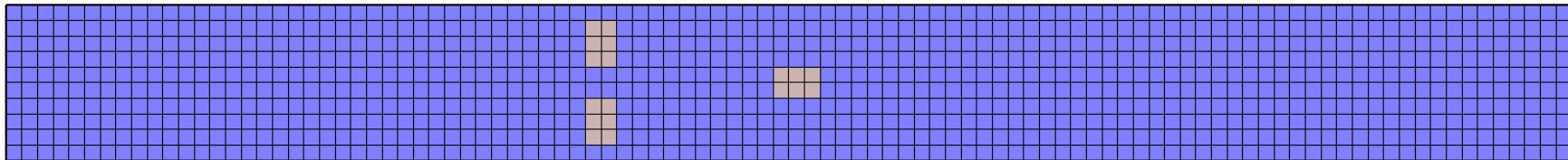




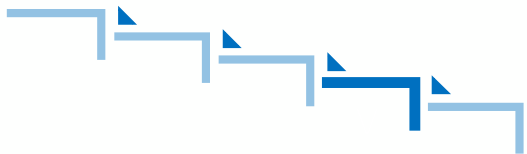
13

Postavljanje prepreke: Stub



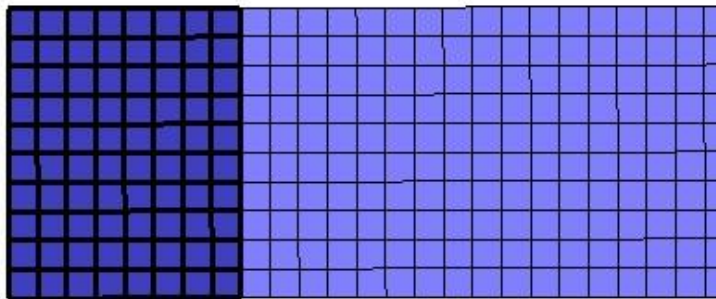
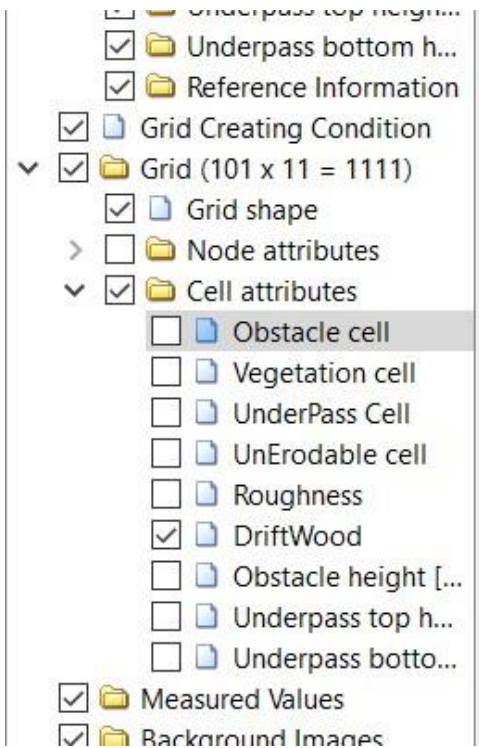


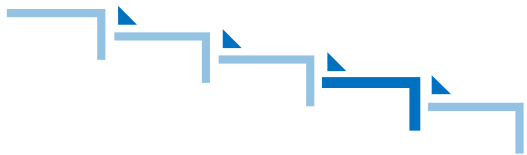
Prikaz mreže sa postavljenim preprekama



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## Označavanje kartice DriftWood

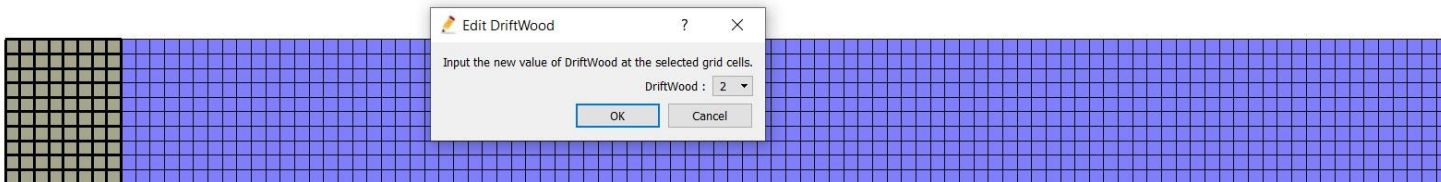


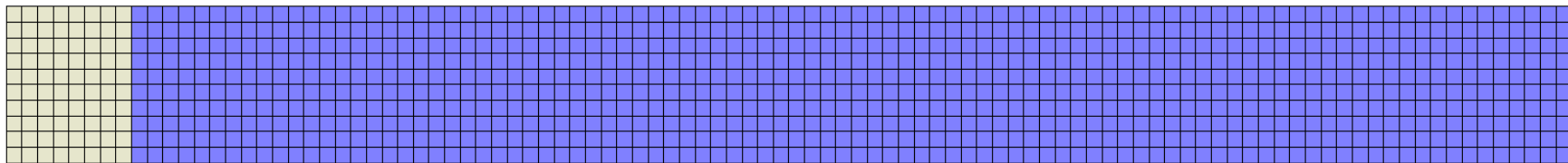


15

Lociranje polja koja će biti snabdevena komadima drveta:

80 označenih ćelija, 2 komada drveta po ćeliji, ukupno: 160 komada





Prikaz mreže sa postavljenim DriftWood-ovima



## Pokretanje proračuna Mogući razlozi obustavljanja proračuna:

- Neadekvatan zadati protok
- Neadekvatan vremenski korak
- Prevelik broj komada drveta(max 200)

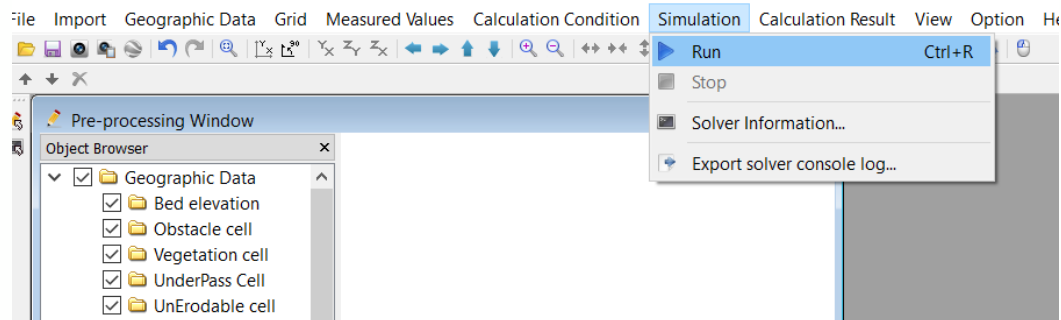
Simulacija.ipro - iRIC 3.0.19.6335 [CUBE3 v1.00.12] - [Solver Console [CUBE3 v1.00.12] (running)]

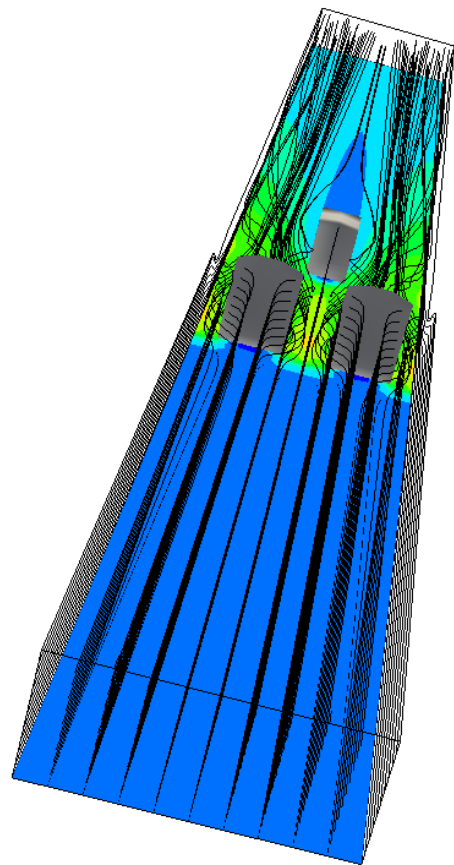
```

File Import Calculation Condition Simulation Calculation Result View Option Help
Q_hyd= 3.0000000000000000E-002 0
QIN_Q_hyd 2.9999999999999998E-002 3.0000000000000000E-002
NN_count = 50
Current-Q & Target-Q 2.98873068781625E-002 3.0000000000000000E-002
q= 1 2.9999999999999998E-002
q= 11 3.000255780580874E-002
q= 21 3.00025405077581E-002
q= 31 2.999118036834539E-002
q= 41 2.800889663058215E-002
q= 51 2.999326728368298E-002
q= 61 3.000253891118252E-002
q= 71 3.000254748219697E-002
q= 81 3.000254748267642E-002
q= 91 3.000254748267641E-002
q= 101 3.000254748267643E-002
KT= 8 T= 2.1000000000000000E-002 SLOPE=1/ 1000.0000000000007
SI_now= 9.99999999999999930E-004
Q_hyd= 3.0000000000000000E-002 2.1000000000000000E-002 0
QIN_Q_hyd 2.9999999999999998E-002 3.0000000000000000E-002
NN_count = 50
Current-Q & Target-Q 2.988712267309035E-002 3.0000000000000000E-002
q= 1 2.9999999999999998E-002
q= 11 3.000292497734180E-002
q= 21 3.00029006551630E-002
q= 31 2.999045186146135E-002
q= 41 2.791872952473754E-002
q= 51 2.999344201003618E-002
q= 61 3.000289768221000E-002
q= 71 3.000291261955418E-002
q= 81 3.000291262176547E-002
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q= 101 3.000291262176550E-002
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SI_now= 9.99999999999999930E-004
Q_hyd= 3.0000000000000000E-002 2.4000000000000000E-002 0
QIN_Q_hyd 2.9999999999999998E-002 3.0000000000000000E-002
NN_count = 50
Current-Q & Target-Q 2.988554116584678E-002 3.0000000000000000E-002
q= 1 2.9999999999999998E-002
q= 11 3.000329222321594E-002
q= 21 3.000325911557792E-002
q= 31 2.998997944888538E-002
q= 41 2.782161476460022E-002
q= 51 2.999395191928958E-002
q= 61 3.00032565462401E-002
q= 71 3.000327811739667E-002
q= 81 3.000327812427625E-002
q= 91 3.000327812427647E-002
q= 101 3.000327812427649E-002
KT= 10 T= 2.7000000000000000E-002 SLOPE=1/ 1000.0000000000007
SI_now= 9.99999999999999930E-004
Q_hyd= 3.0000000000000000E-002 2.7000000000000000E-002 0
QIN_Q_hyd 2.9999999999999998E-002 3.0000000000000000E-002

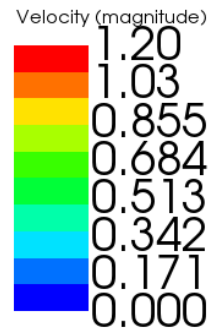
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Simulacija.ipro - iRIC 3.0.19.6335 [CUBE3 v1.00.12]



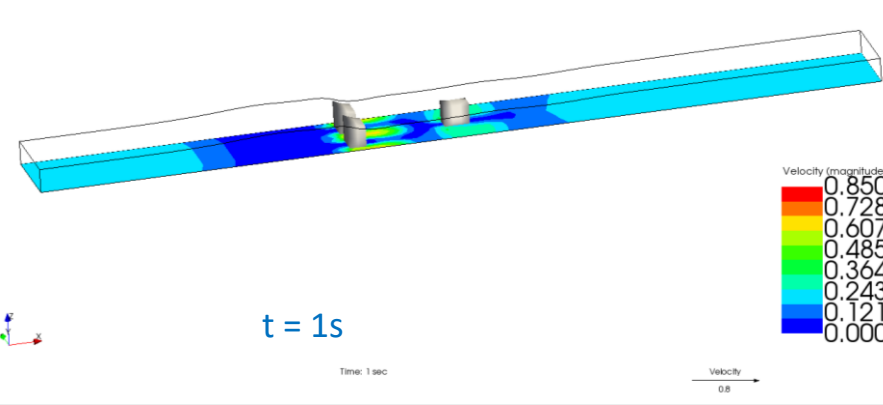


- Uspostavljanje neporemećenog tečenja
- Promena nivoa kroz vreme
- Promena brzine kroz vreme
- Karakteristične tačke:
  - Uzvodni neporemećen profil
  - Uzvodno od stubova
  - Nizvodno od stubova
  - Nizvodni neporemećen profil

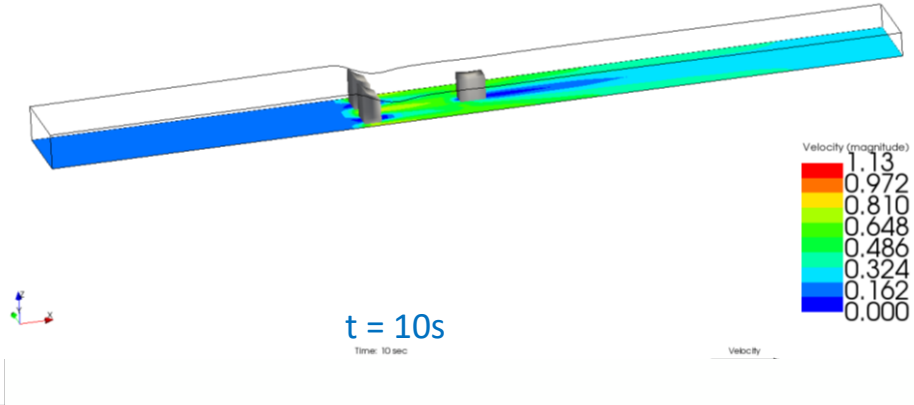


Time: 40 sec

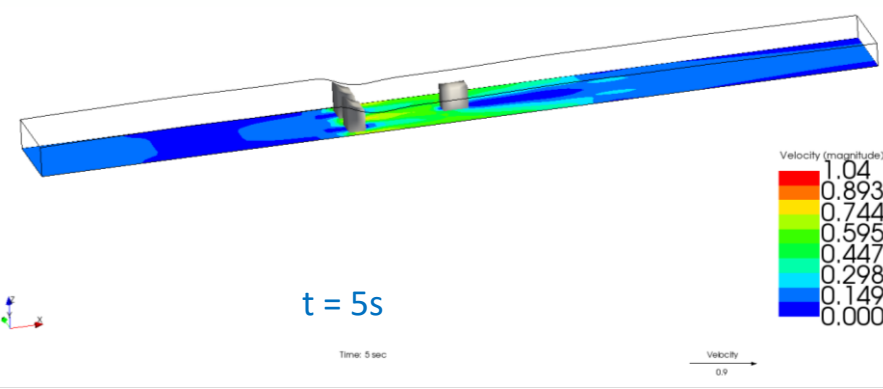
Velocity  
1



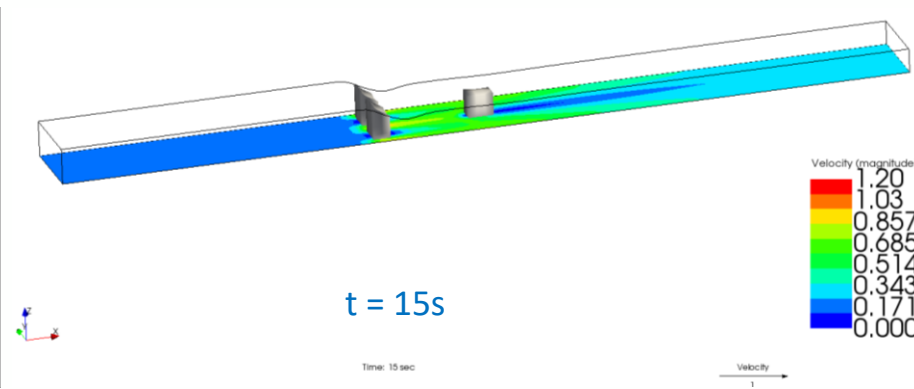
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t = 10s



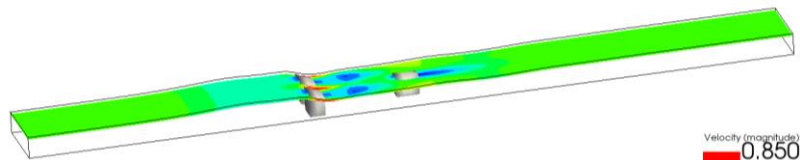
t = 5s



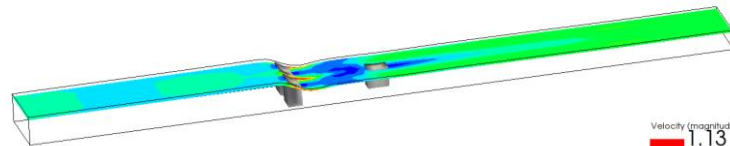
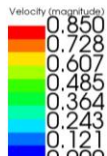
t = 15s

Uspostavljanje neporemećenog tečenja

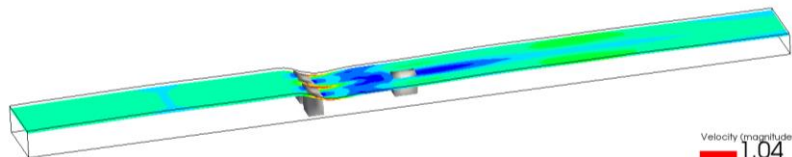
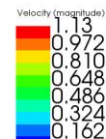
k = 1



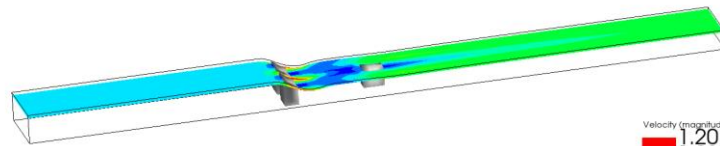
t = 1s



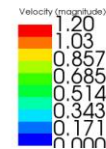
t = 10s



t = 5s

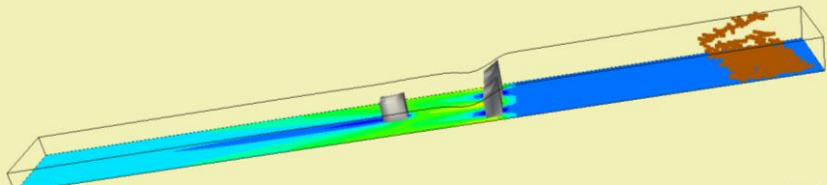


t = 15s

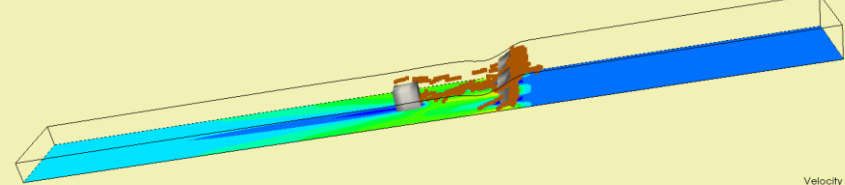


Uspostavljanje neporemećenog tečenja

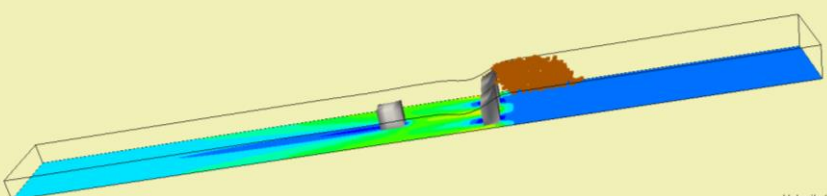
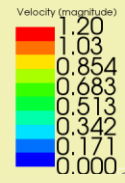
k = 10



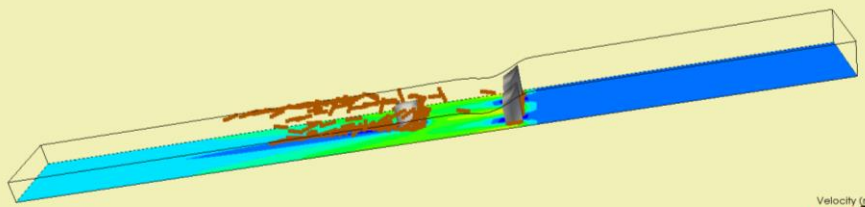
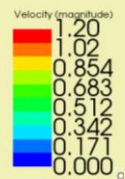
t = 21s



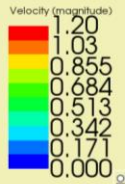
t = 26s



t = 25s



t = 28s



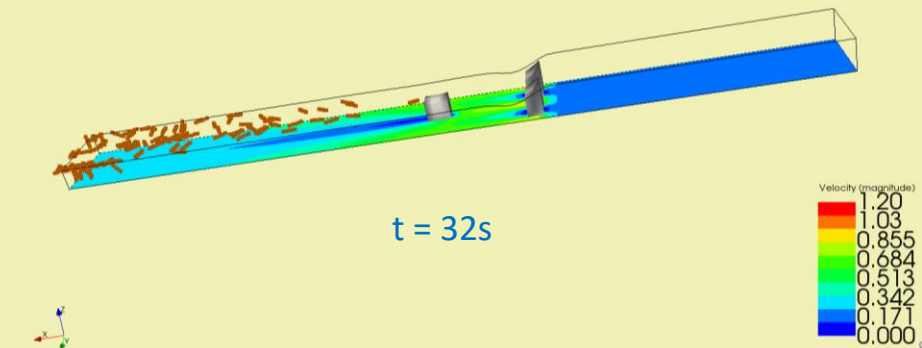
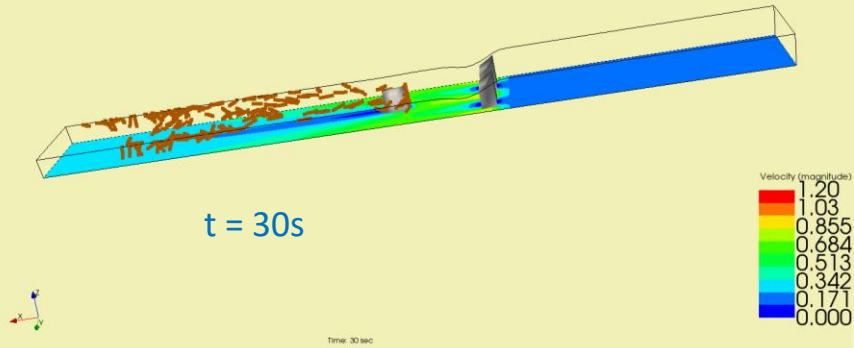
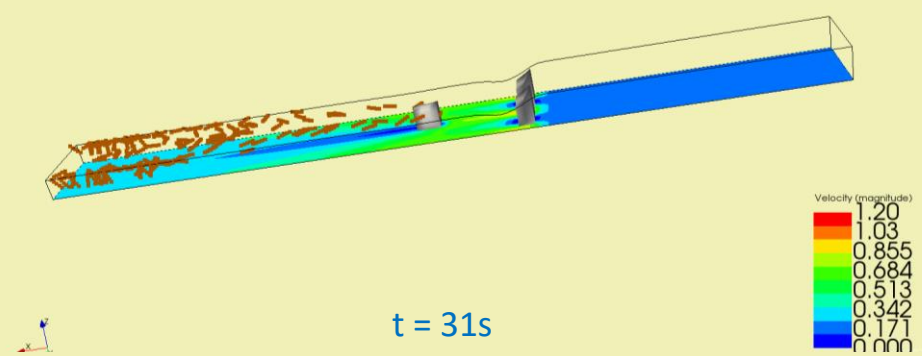
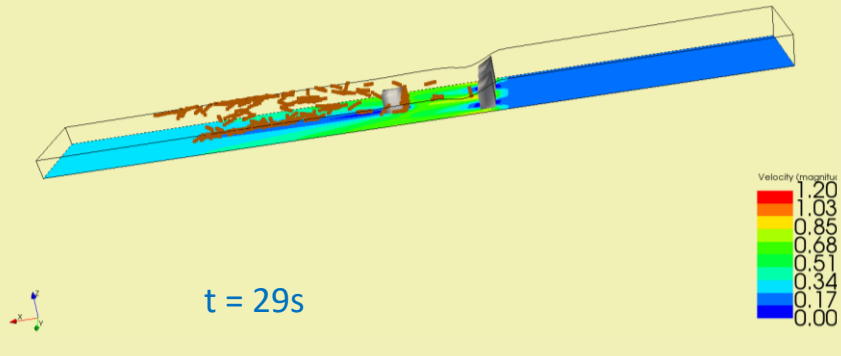
Time: 25 sec

Time: 28 sec



# Simuliranje kretanja DriftWood-ova

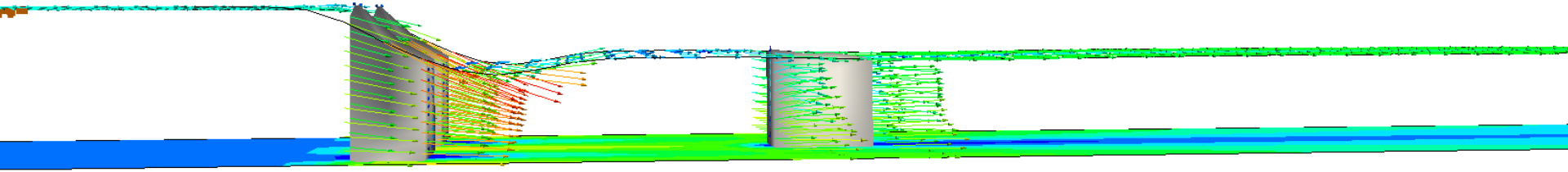
k=1



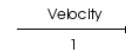
Simuliranje kretanja DriftWood-ova

k=1

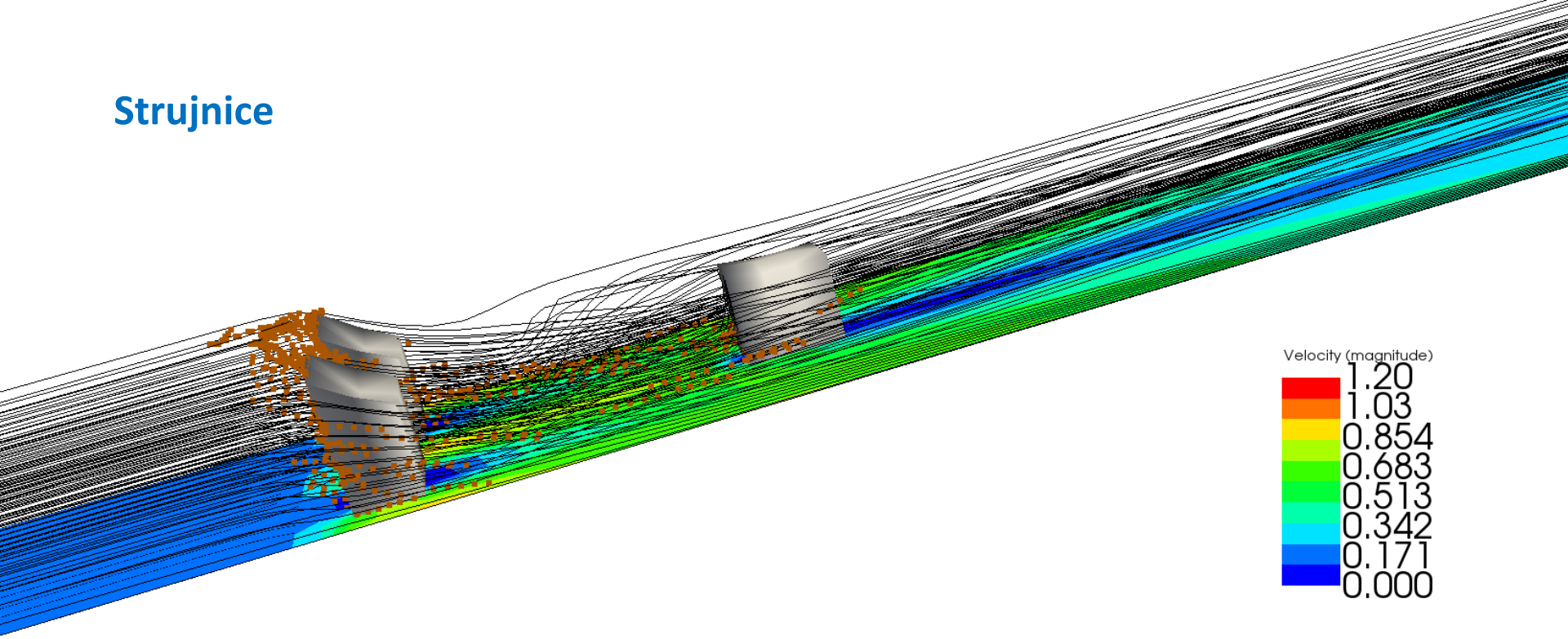
# Vektori brzina



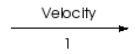
Time: 23.5 sec



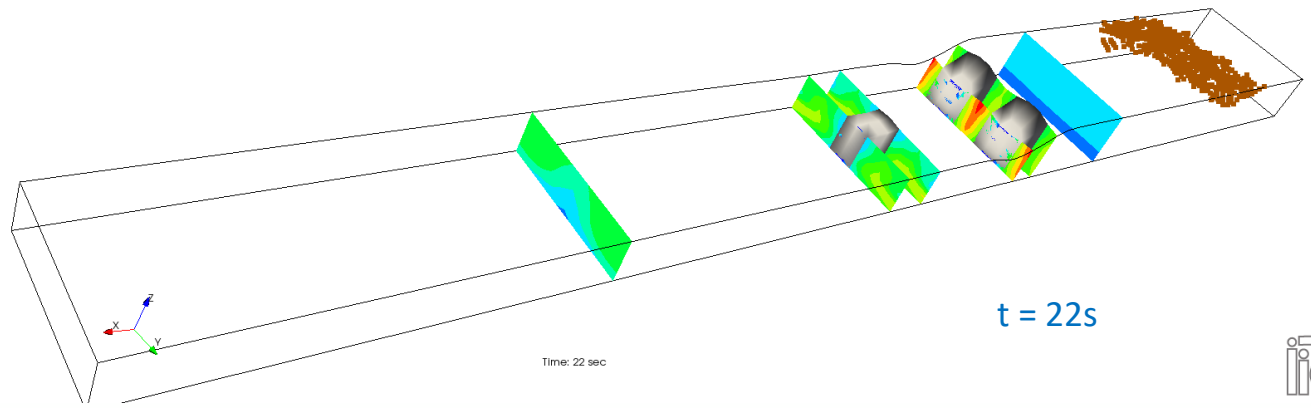
# Strujnice



Time: 26 sec



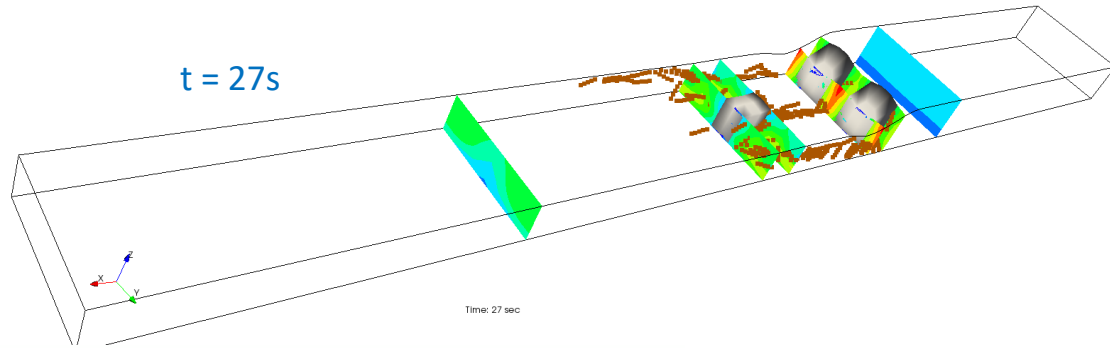




t = 22s

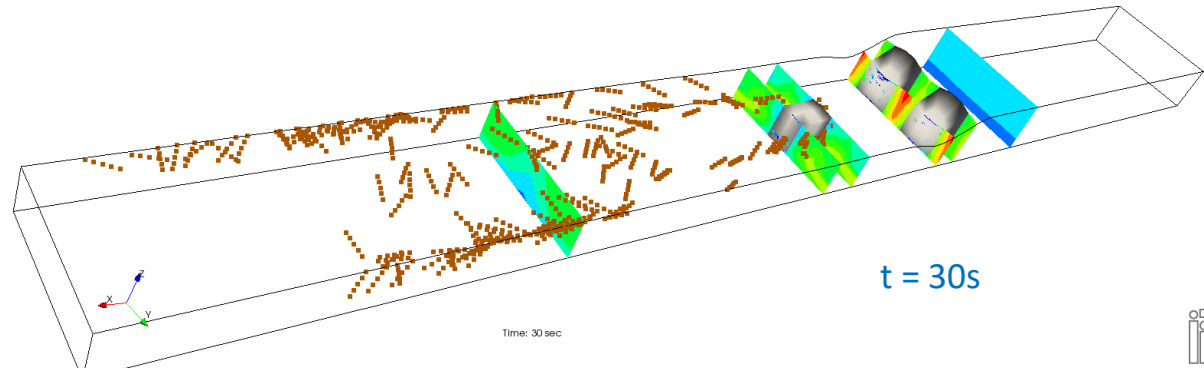


t = 27s



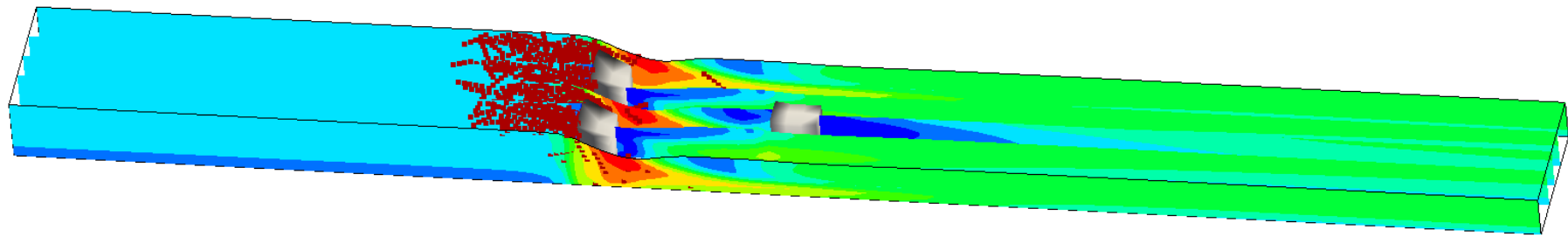
Brzine vode za konstantno x

$I = (30,38,40,50,53,75)$

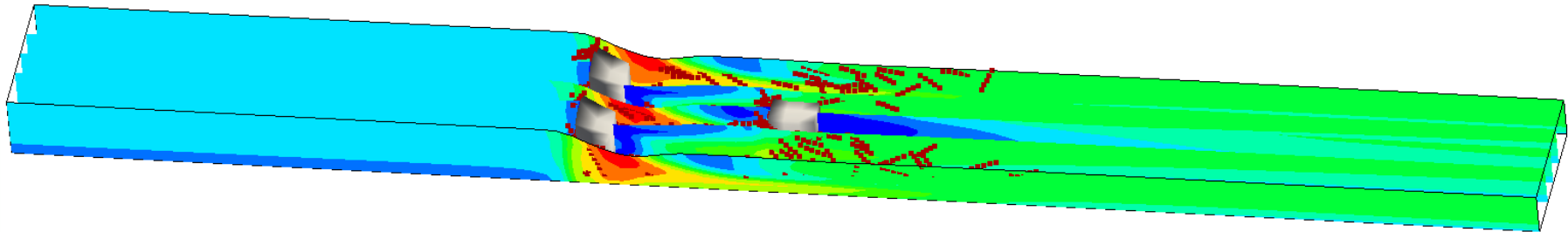
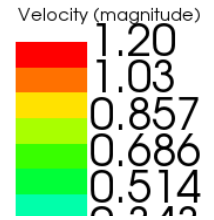


t = 30s



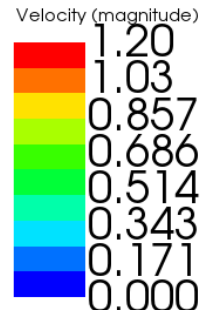


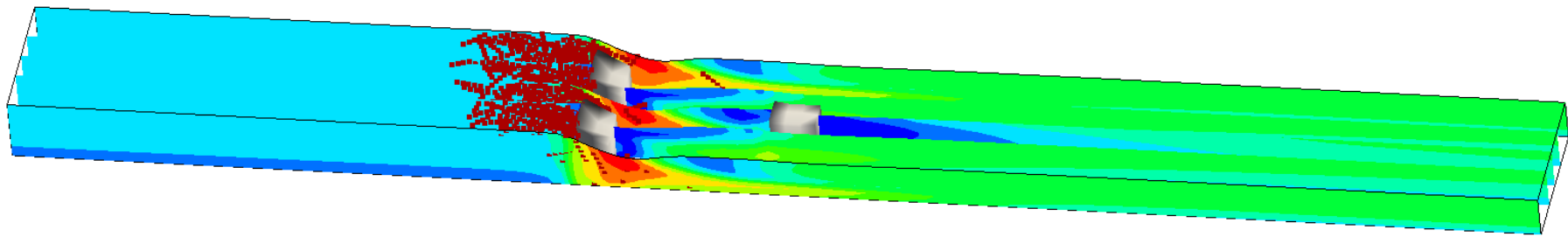
t = 25s



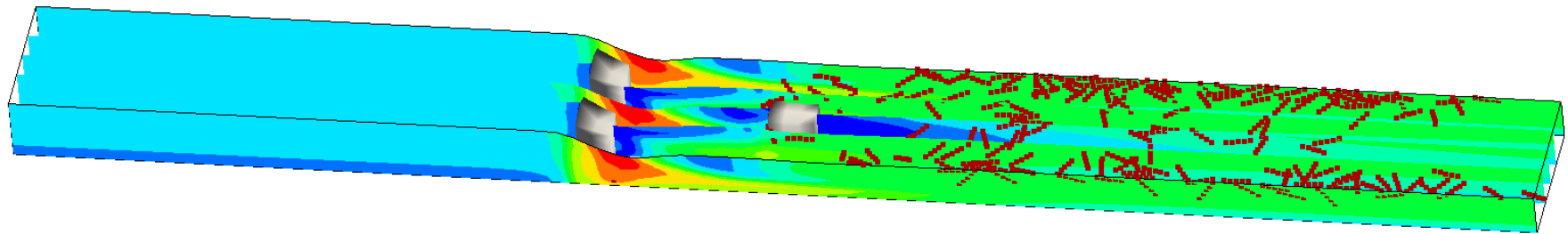
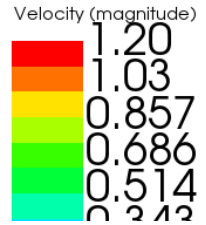
t = 27s

Brzine vode za konstantno y  
J = (1,4,6,8,11)





t = 25s



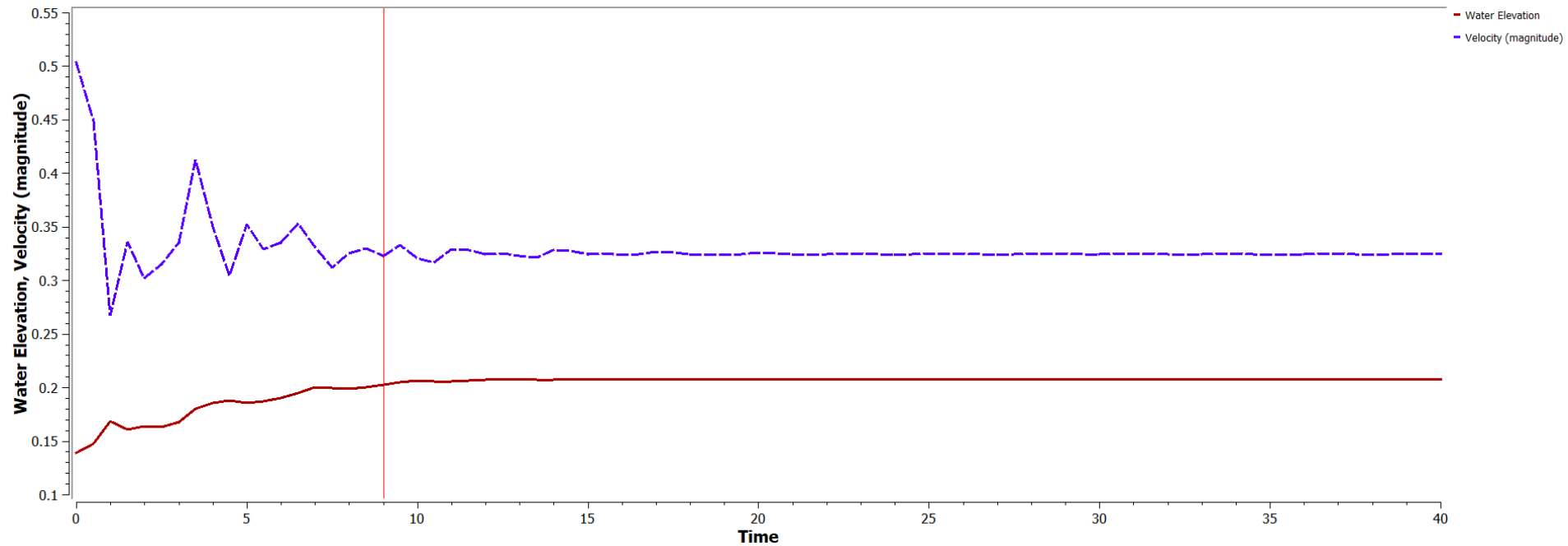
t = 30s

Brzine vode za konstantno y  
J = (1,4,6,8,11)



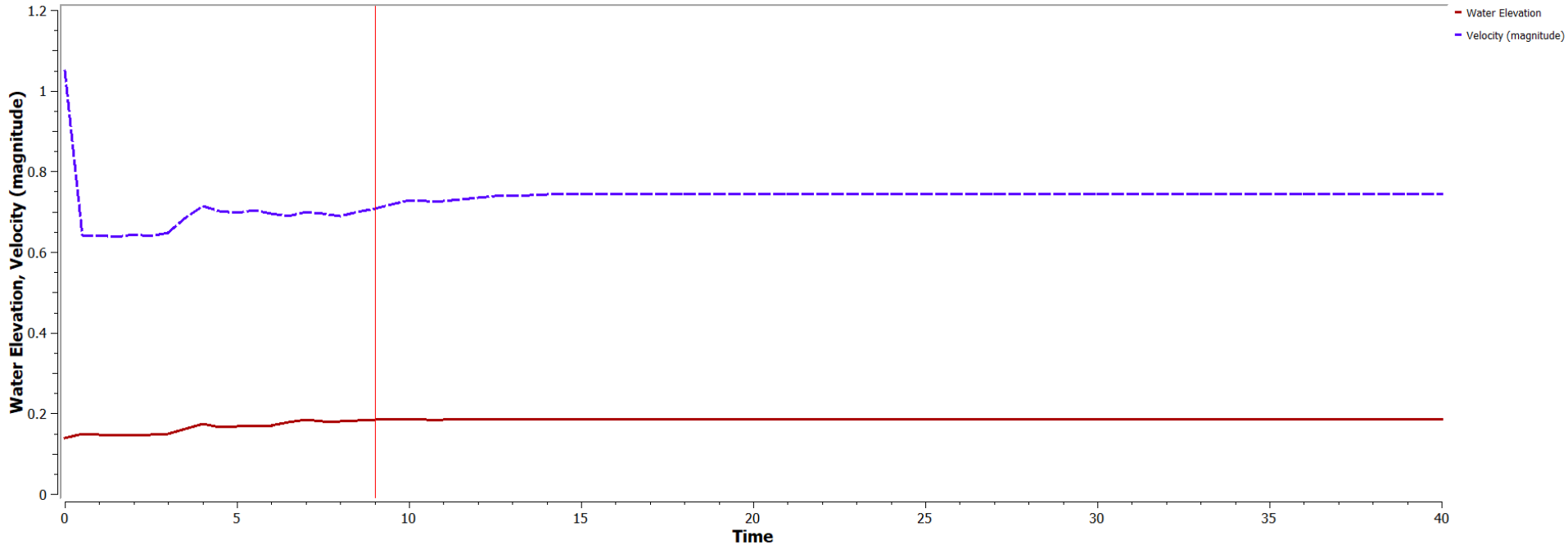
# Promena brzine i nivoa vode u vremenu

Posmatra se tačka u neporemećenom uzvodnom preseku  $l = 30$



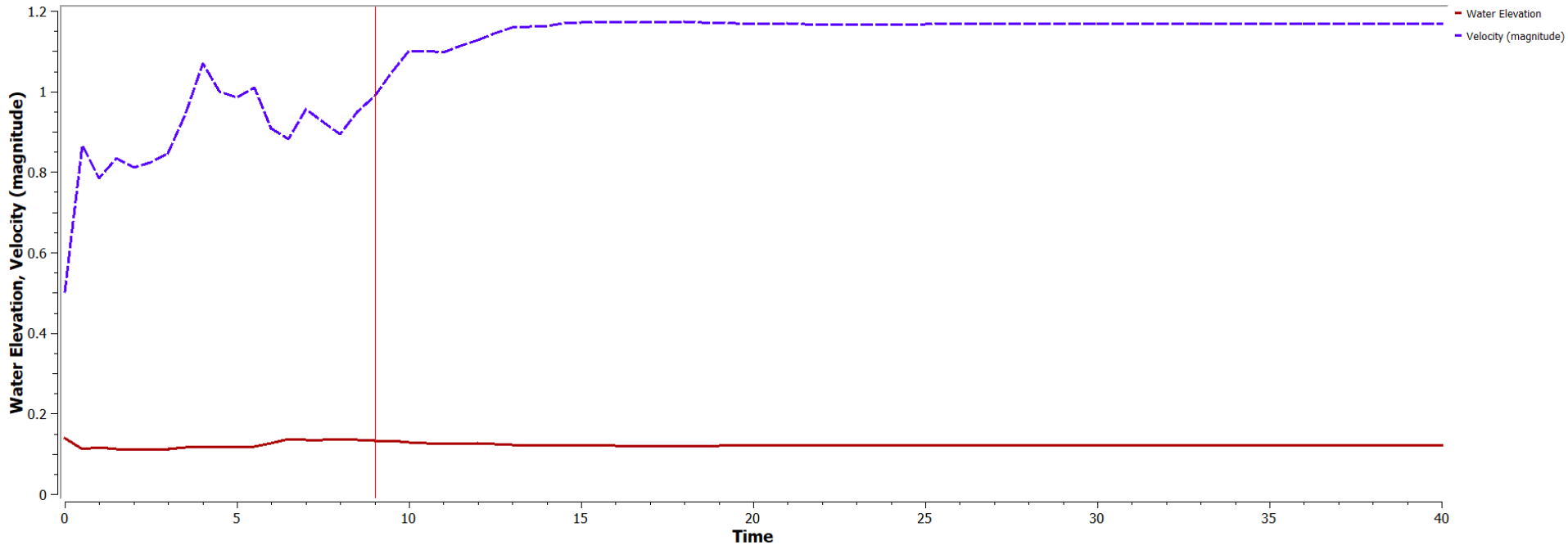
# Promena brzine i nivoa vode u vremenu

Posmatra se tačka uzvodno od stuba I = 38



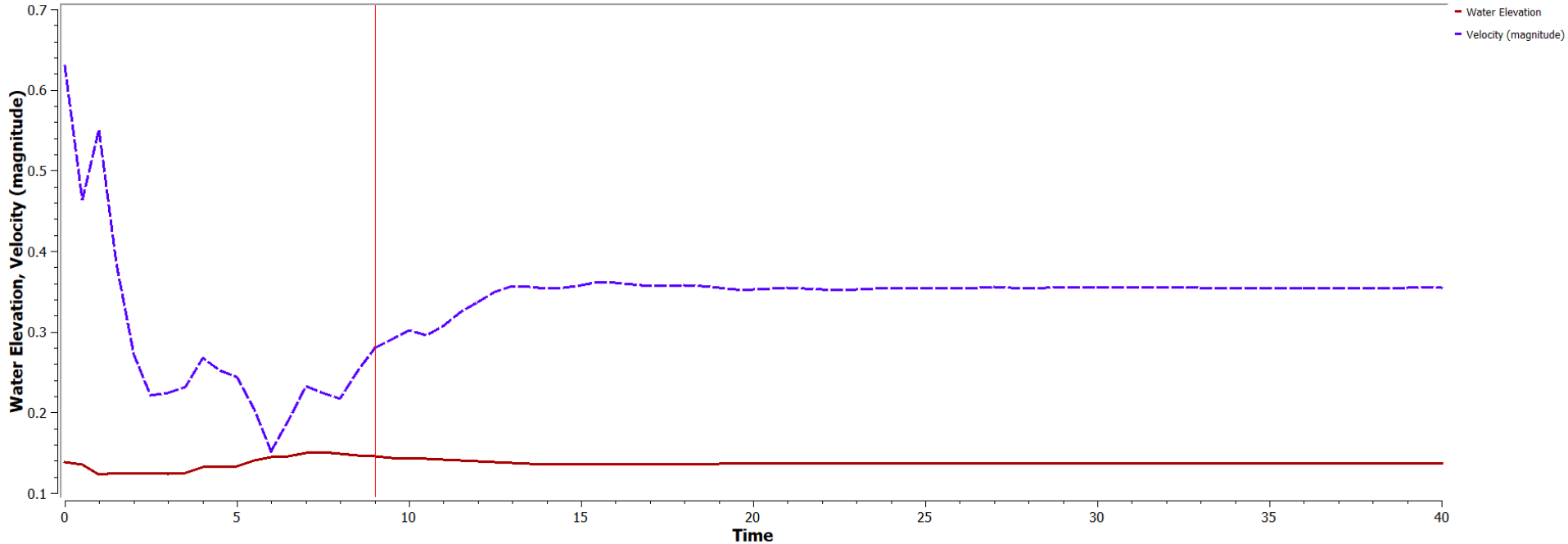
# Promena brzine i nivoa vode u vremenu

Posmatra se tačka nizvodno od stuba I = 41



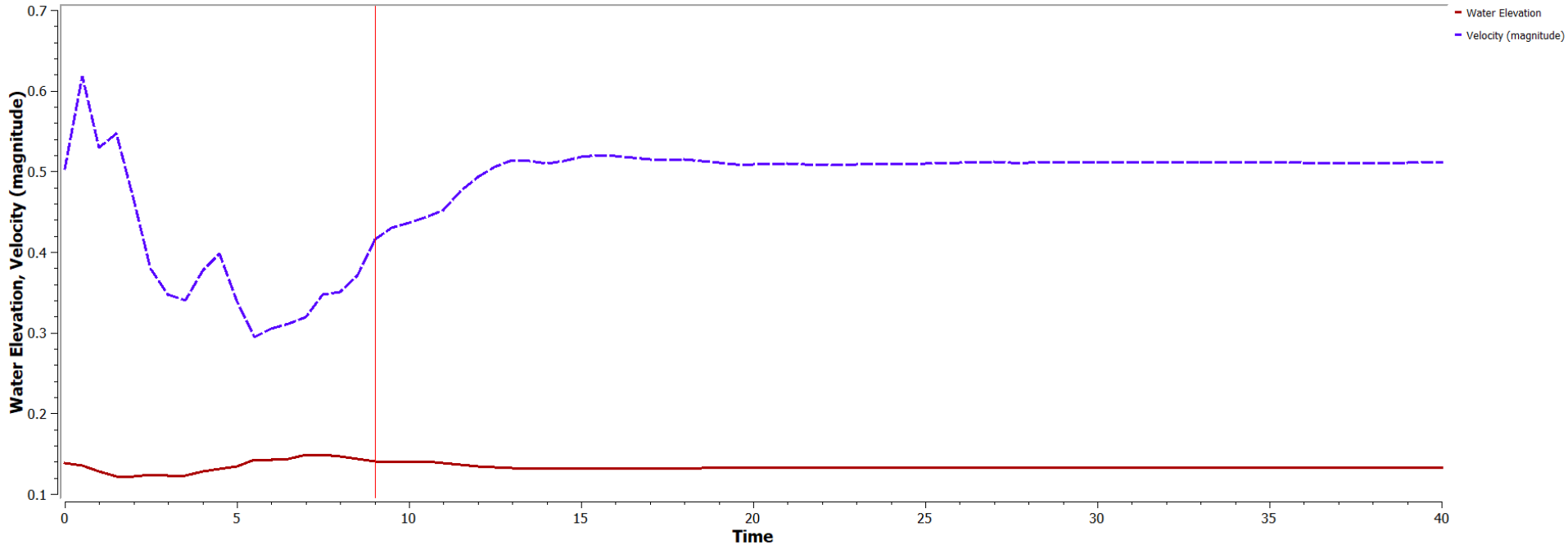
# Promena brzine i nivoa vode u vremenu

Posmatra se tačka uzvodno od stuba I = 50



# Promena brzine i nivoa vode u vremenu

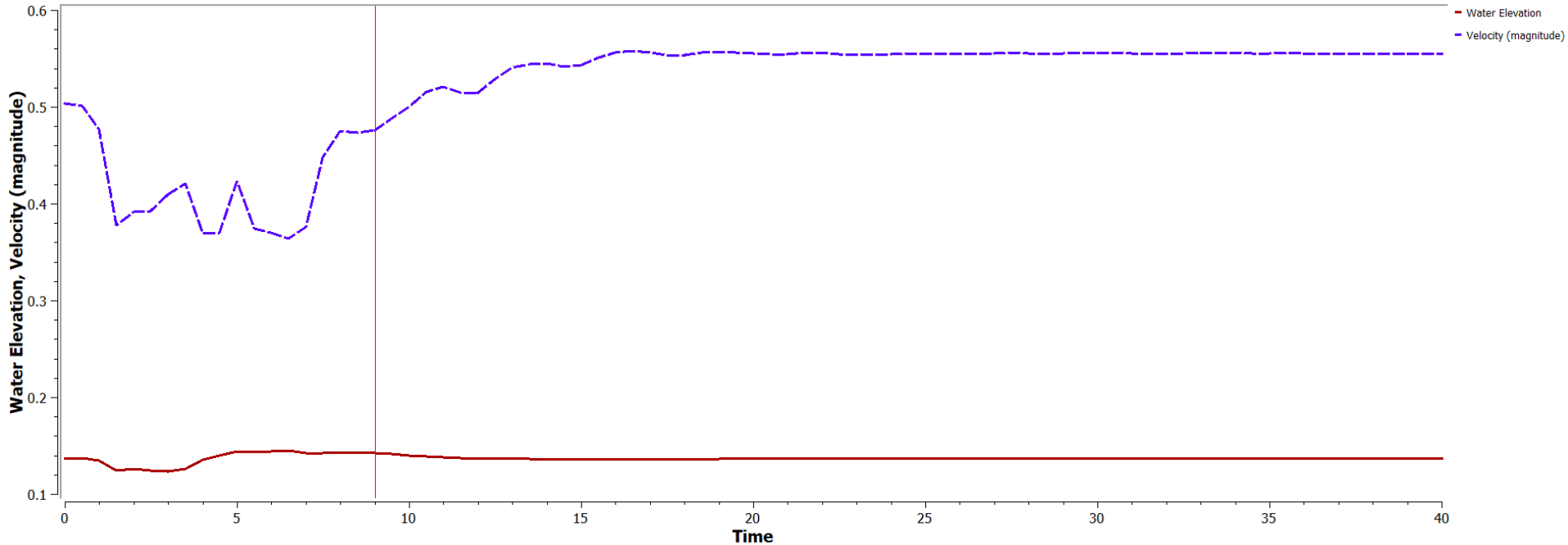
Posmatra se tačka nizvodno od stuba I = 54





# Promena brzine i nivoa vode u vremenu

Posmatra se tačka u neporemećenom nizvodnom preseku  $I = 75$



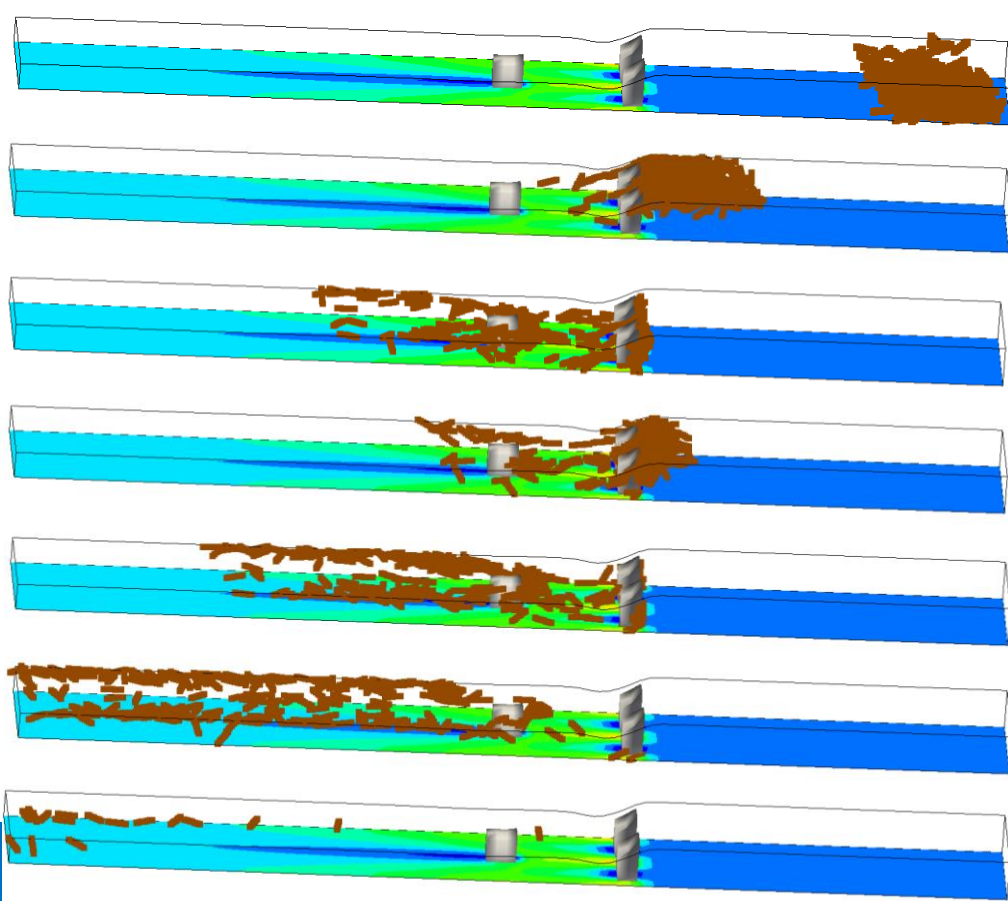
- Trajanje simulacije oko 60min
- Neporemećeno tečenje je ostvareno nakon 15s
- Nije došlo do zagušenja drvenih komada (Što je logično za ovakav raspored stubova i ovolike komade driftwooda)
- Nije primećen uticaj usporenog tečenja
- Vizuelnom metodom nisu opažene razlike u strujanju fluida bez drvenih komada i nakon ubacivanja drvenih komada u prizmatični kanal

Konstatacije nakon sprovedene simulacije osnovnog modela

Simulirana dodatna dva scenarija koja predstavljaju varijaciju podešavanja proračuna osnovnog modela sa ciljem ostvarenja uticaja na raspored brzina i dubina u kanalu:

- **Scenario 1:** Povećan broj drvenih komada na 200 i uključena opcija sudaranja
- **Scenario 2:** Povećan broj drvenih komada na 200, povećana je dužina komada na 0.2m, a prečnik na 0.05m

Dodatne simulacije modela



t = 21s

t = 25s

t = 26s

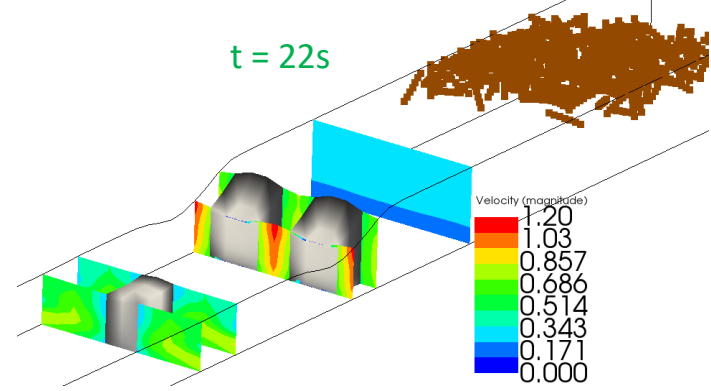
t = 27s

t = 28s

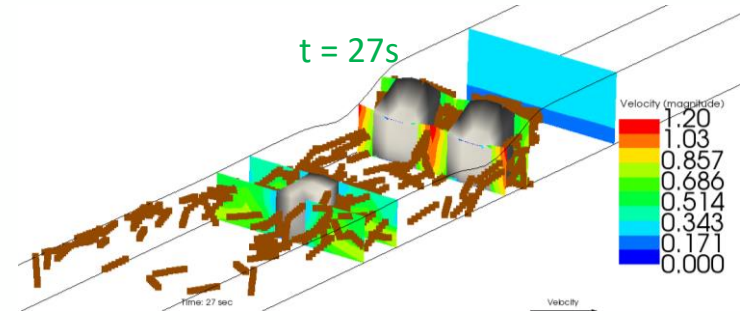
t = 30s

t = 35s

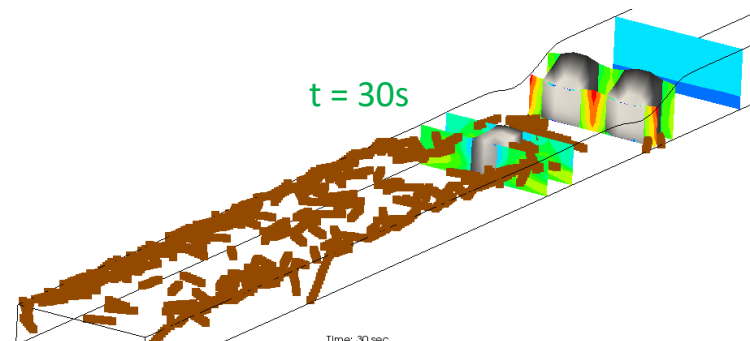
t = 22s



t = 27s

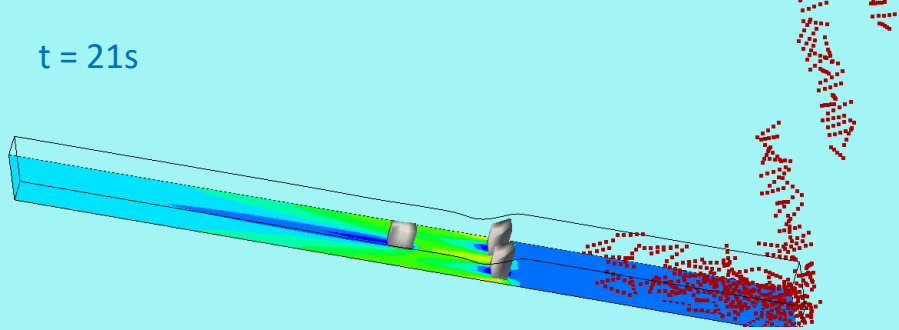


t = 30s

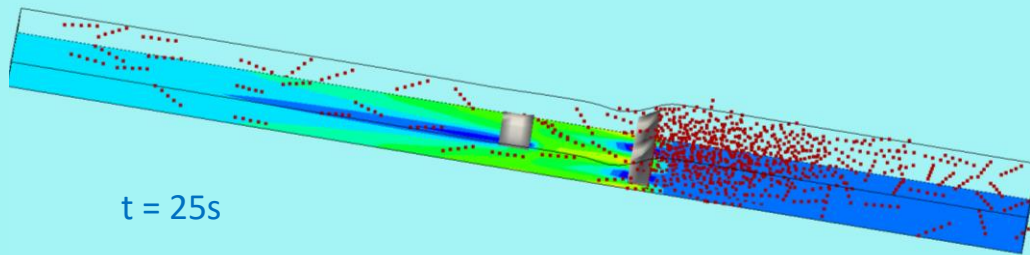


Scenario 1

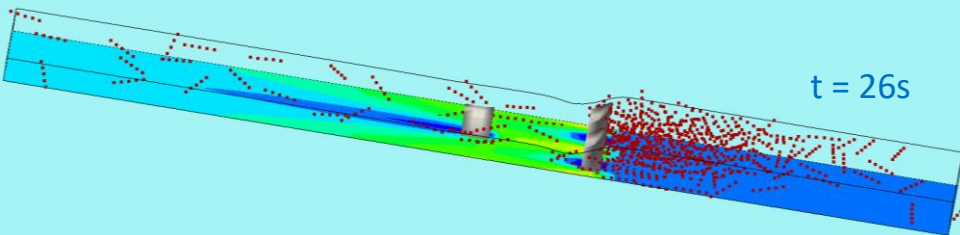
t = 21s



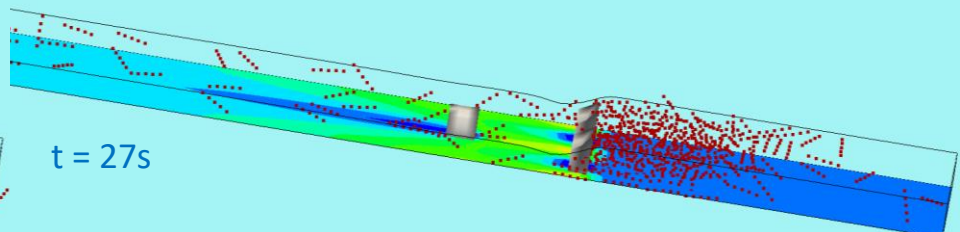
t = 25s



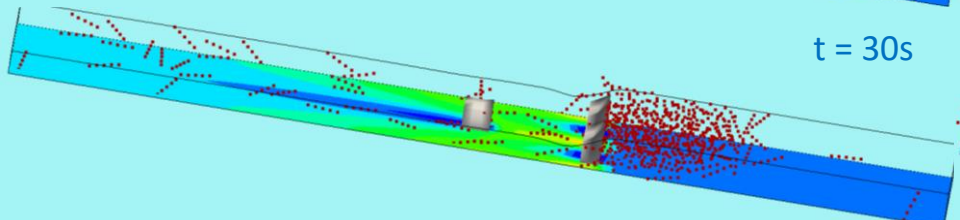
t = 26s



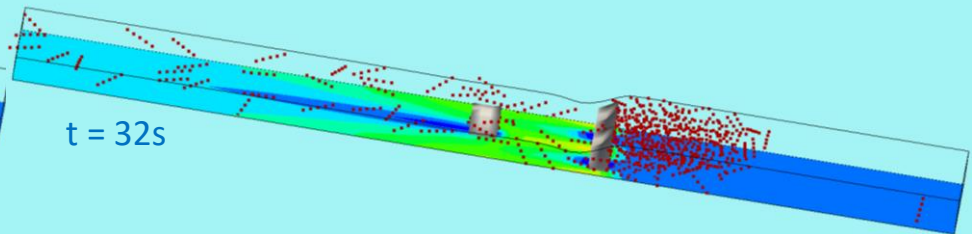
t = 27s



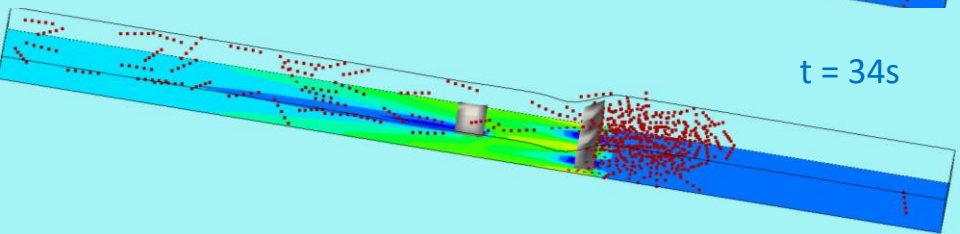
t = 30s



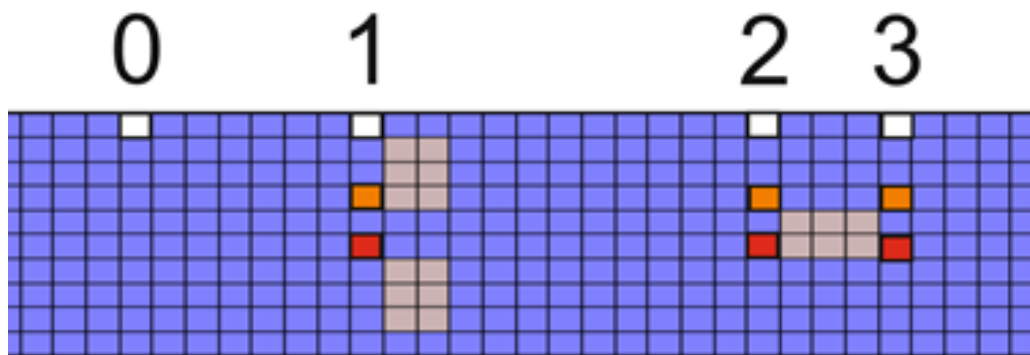
t = 32s



t = 34s



Scenario 2



Upoređivanje nivoa vode i brzina u deset karakterističnih tačaka

<i>Tačka</i>	<i>I</i>	<i>J</i>	<i>K</i>
0	30	1	11
1a	38	1	
1b		4	
1c		6	
2a	50	1	
2b		4	
2c		6	
3a	53	1	
3b		4	
3c		6	

# Vremenski preseki pre pojave i nakon pojave drvenih komada

<i>Lokacija</i>	<i>Pre pojave drvenih komada</i>		<i>Drveni komadi</i>		<i>Kraj simulacije</i>	
	<i>t=15s</i>		<i>t=30s</i>		<i>t=39s</i>	
	<i>Nivo vode</i>	<i>Brzina</i>	<i>Nivo vode</i>	<i>Brzina</i>	<i>Nivo vode</i>	<i>Brzina</i>
0	0.20809	0.32365	0.20808	0.32436	0.20808	0.32444
1a	0.18707	0.74608	0.18711	0.74534	0.18712	0.74529
1b	0.21106	0.11307	0.21107	0.11286	0.21108	0.11284
1c	0.18731	0.75341	0.18736	0.75296	0.18736	0.75292
2a	0.13632	0.35615	0.13682	0.35387	0.13685	0.35357
2b	0.13641	0.40693	0.13691	0.40372	0.13694	0.40341
2c	0.14394	0.00561	0.14430	0.00618	0.14433	0.00620
3a	0.13250	0.49850	0.13334	0.49242	0.13338	0.49204
3b	0.13024	0.51833	0.13118	0.51226	0.13121	0.51195
3c	0.12986	0.00056	0.13092	0.00011	0.13095	0.00014

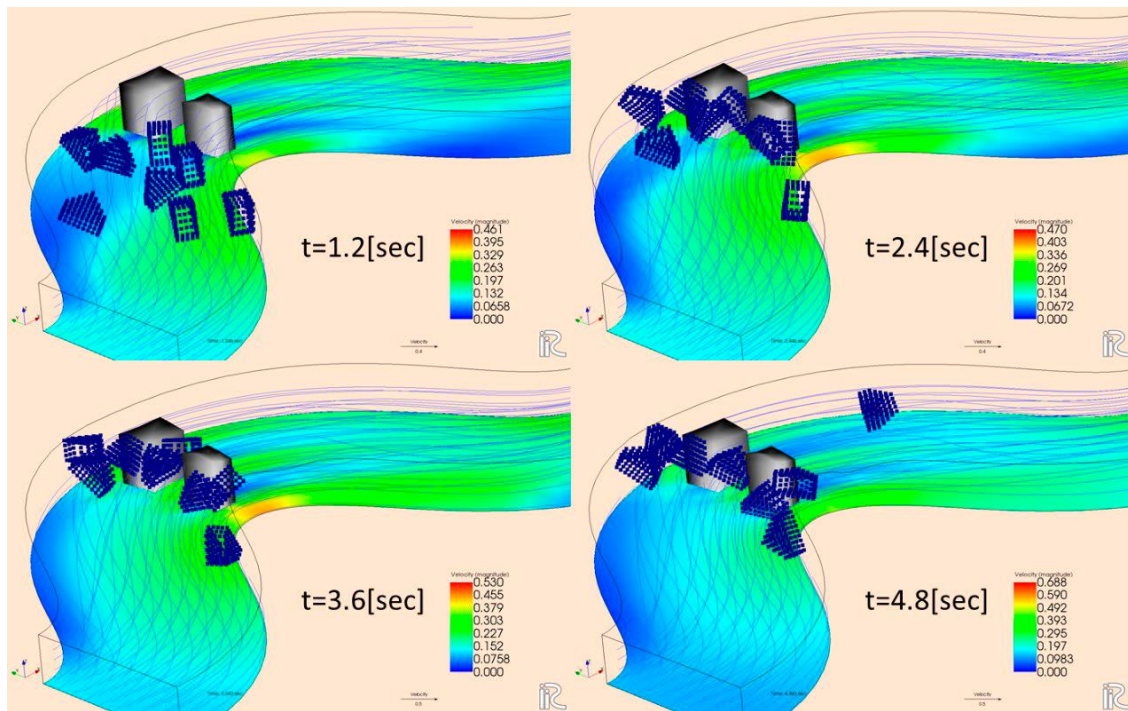
# RAZLIKE NIVOVA I BRZINA VODE U KARAKTERISTIČNIM TAČKAMA IZAZVANE POJAVOM DRVENIH KOMADA U KANALU

<b>Lokacija</b>	<i>Promena nivoa vode sa pojavom drvenih komada [mm]</i>		<i>Promena brzine sa pojavom drvenih komada [cm/s]</i>	
	<i>t=30s</i>	<i>t=39s</i>	<i>t=30s</i>	<i>t=39s</i>
0	-0.02	-0.02	0.1	0.1
1a	0.04	0.05	-0.1	-0.1
1b	0.01	0.02	0.0	0.0
1c	0.05	0.06	0.0	0.0
2a	0.50	0.53	-0.2	-0.3
2b	0.50	0.53	-0.3	-0.4
2c	0.36	0.39	0.1	0.1
3a	0.85	0.88	-0.6	-0.6
3b	0.94	0.97	-0.6	-0.6
3c	1.06	1.09	0.0	0.0



# Zaključna razmatranja

- Različita prostorna raspodela drvenih komada prilikom sprovedenih simulacija
- Najveće zagušenje drvenih komada između stubova ostvareno je u Scenariju 2
- Nivoi i brzine u karakterističnim tačkama kroz posmatrane vremenske preseke u sve tri simulacije su isti. Nisu izazvane promene vrednosti, menjanjem parametara proračuna.
- U posmatranim tačkama kroz različite vremenske preseke opaža se povećanje nivoa i smanjenje brzina sa pojavom drvenih komada u toku prizmatičnog kanala



Ispitati osetljivost rezultata modela u odnosu na broj sfera od kojih se formira DriftWood



Ispitati osetljivost rezultata modela u odnosu na vučnu silu



Uporediti rezultate numeričkog modela sa fizičkim modelom



Umesto DriftWood-ova simulirati advekciju krutih objekata (krovova)