

Benchmarking of 2D hydraulic modelling packages

RESULTS

This report summarises how the software package (described in the table below) performed in the benchmark tests developed during the Joint Defra / Environment Agency research programme. The report from the research project was published in June 2010 and is available from the Environment Agency ([summary](#) and [report](#)). To access the test specification and datasets email fcem.evidence@environment-agency.gov.uk.

Software name:	RiverFlow2D Plus	RiverFlow2D Plus GPU
Software version:	4.5	4.5
Software developer:	Hydronia  Web: www.hydronia.net	
Report completed by:	Cameron Jenkins and Reinaldo Garcia	
Report completed on:	31 March, 2015	
Report supersedes:	RiverFlow2D Plus: First Report RiverFlow2D Plus GPU: First Report	

Report contents

Contents	Section	Page
	Software and hardware details	2
	Tests completed	3
	Test results	4
	Test 1: Flooding a disconnected water body	4
	Test 2: Filling of floodplain depressions	6
	Test 3: Momentum conservation over a small obstruction	7
	Test 4: Speed of flood propagation over an extended floodplain	13
	Test 5: Valley flooding	14
	Test 6A and 6B: Dam break	28
	Test 7: River to floodplain linking	38
	Test 8A and 8B: Rainfall and sewer surcharge flood in urban areas	39
	Overall summary of performance	40

Software and hardware details

Name of software	RiverFlow2D Plus		RiverFlow2D Plus GPU
Version of software	4.5		4.5
Software developer	Hydronia		Hydronia
Numerical scheme of software	Finite volume schemes over a flexible mesh of triangular elements		Finite volume schemes over a flexible mesh of triangular elements
Shock capturing scheme	yes		yes
1D-2D linkages	Embedding of 1D stage discharge relationships to model structures available.		Embedding of 1D stage discharge relationships to model structures available.
Minimum recommended hardware specification	Make	Any Windows based or compatible PC.	
	Model	No restrictions	
	Type	No restrictions	
	Cores	No minimum requirement.	
	RAM	2 GB	
	Operating system	Any Windows OS, but only later ones recommended (Windows XP onwards).	
	CPU processing	32-bit or 64-bit	
	Graphics card	No restrictions for RiverFlow2D Plus. RiverFlow2D Plus GPU only functional for NVIDIA GPUs.	
Hardware specification used to carry out tests	Make	CyberPower PC	
	Model	Intel Core i7-4790 3.6Ghz	
	Type	Desktop	
	Cores	8	
	RAM	16 GB	
	Operating system	Windows 8.1 Pro	
	CPU processing	64-bit	
	Graphics card	NVIDIA GTX 760	

Tests completed

Test	Description	Test complete / reason for not completing		Justification
		RiverFlow2D Plus	RiverFlow2D Plus GPU	
1	Flooding a disconnected water body	Yes	Yes	
2	Filling of floodplain depressions	Yes	Yes	
3	Momentum conservation over a small (0.25m) obstruction.	Yes	Yes	
4	Speed of flood propagation over an extended floodplain.	Yes	Yes	
5	Valley flooding	Yes	Yes	
6A	Dam break	Yes	Yes	
6B	Dam break	Yes	Yes	
7	River to floodplain linking	No	No	In development.
8A	Rainfall and sewer surcharge flood in urban areas	No	No	Hydrology test in development.
8B	Rainfall and sewer surcharge flood in urban areas	No	No	Test in development.

Test results

Test 1: Flooding a disconnected water body

Objective:

The objective of the test is to assess basic capabilities such as handling disconnected water bodies and wetting and drying of floodplains.

Description:

This test consists of a sloping topography with a depression as illustrated in Figure (a). The modelled domain is a perfect 700m x 100m rectangle. A varying water level, see Figure (b), is applied as a boundary condition along the entire length of the left-hand side of the rectangle, causing the water to rise to level 10.35m. This elevation is maintained for long enough for the water to fill the depression and become horizontal over the entire domain. It is then lowered back to its initial state, causing the water level in the pond to become horizontal at the same elevation as the sill, 10.25m.

Figure (a): Plan and profile of DEM used in Test1. The area modelled is a perfect rectangle extending from X=0 to X=700m and from Y=0 to Y=100m as shown.

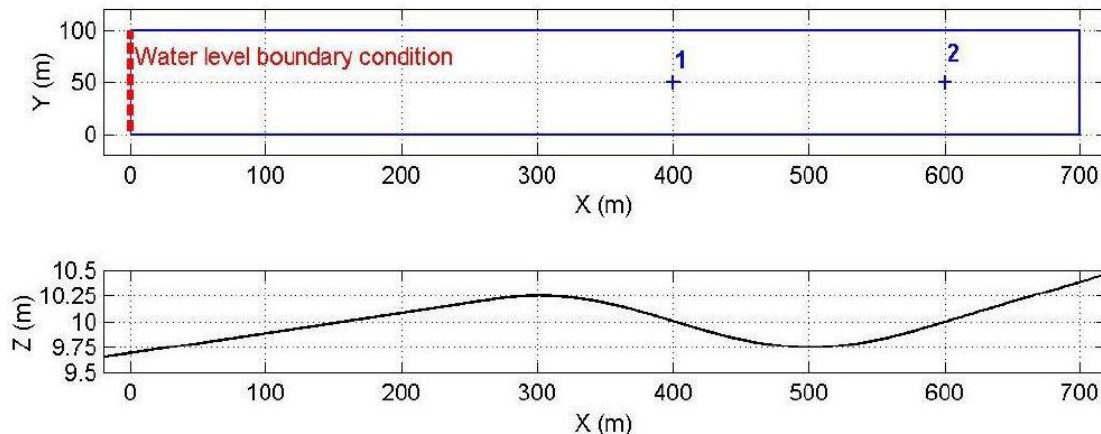
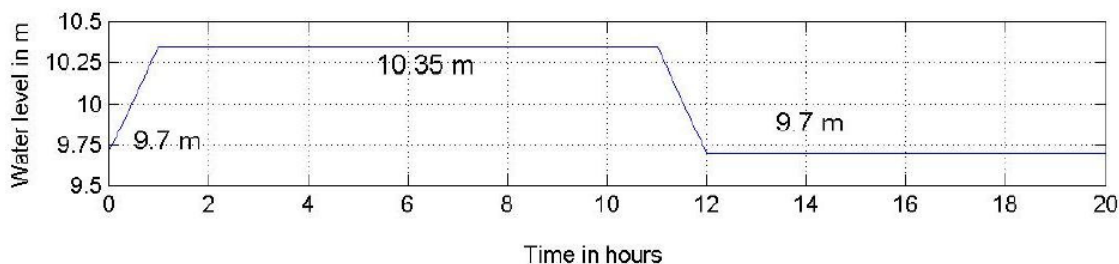


Figure (b): Water level hydrograph used as a boundary condition (table provided as part of the test input dataset)



Boundary and initial conditions:

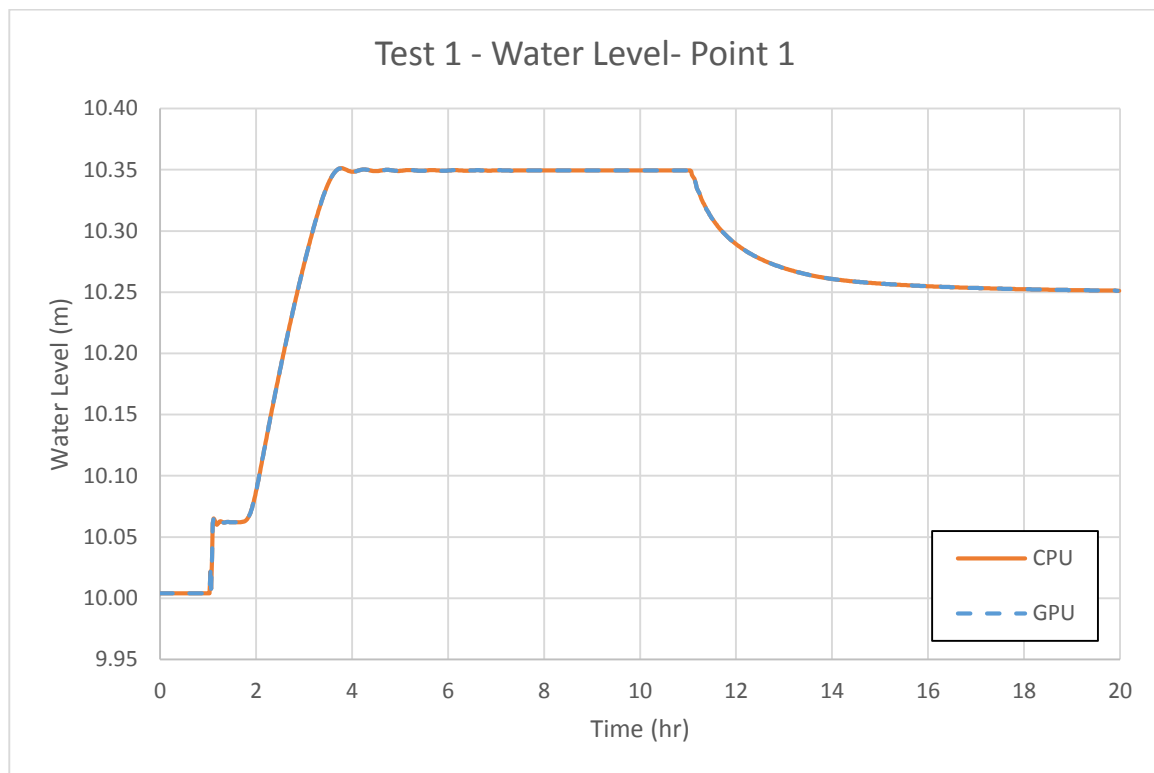
- Varying water level along dashed red line shown in figure (a). Figures provided as part of the test input dataset;
- All other boundaries closed;
- Initial condition: water elevation = 9.7m.

Parameter values:

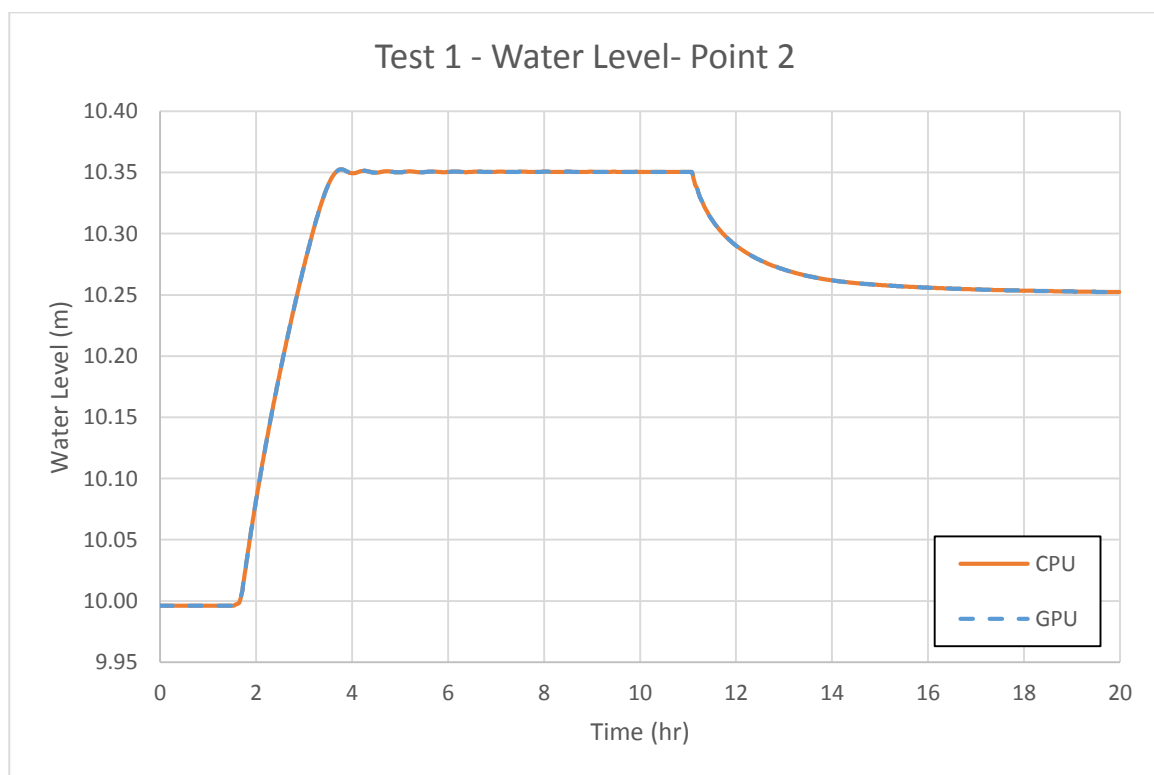
- Manning's n: 0.03 (uniform)
- Model grid resolution: 10m (or 700 nodes in modelled area)
- Time of end: model is to be run until time $t = 20$ hours

Results:

Test 1, point 1: Water level versus time (output frequency 60s)



Test 1, point 2: Water level versus time (output frequency 60s)



Summary of relevant technical information for the test:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.03	0.03
Grid	860 Elements	860 Elements
Time-stepping	Adaptive (0.5 to 2.4s)	Adaptive (0.6 to 2.4s)
Total simulation time (hrs)	0.002 (6s)	0.008 ¹ (27s)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give identical results.

Test 2: Filling of floodplain depressions

Objective:

The test has been designed to evaluate the capability of a package to determine inundation extent and final flood depth, in a case involving low momentum flow over a complex topography.

Description:

The area modelled, shown in Figure (a), is a perfect 2000 m x 2000 m square and consists of a 4 x 4 matrix of ~0.5 m deep depressions with smooth topographic transitions. The DEM was obtained by multiplying sinusoids in the North to South and West to East directions and the depressions are all identical in shape. An underlying average slope of 1: 1500 exists in the North to South direction, and of 1: 3000 in the West to East direction, with a ~2m drop in elevation along the North-West to South-East diagonal. The inflow boundary condition is applied along a 100m line running South from the North Western corner of the modelled domain, see Figure (a). A flood hydrograph with a peak flow of 20m³/s and time base of ~85mins is used (figure b)). The model is run for 2 days (48 hours) to allow the inundation to settle to its final state.

Figure (a): Map of the DEM showing the location of the upstream boundary condition (red line), ground elevation contour lines every 0.05 m, and output point locations (crosses).

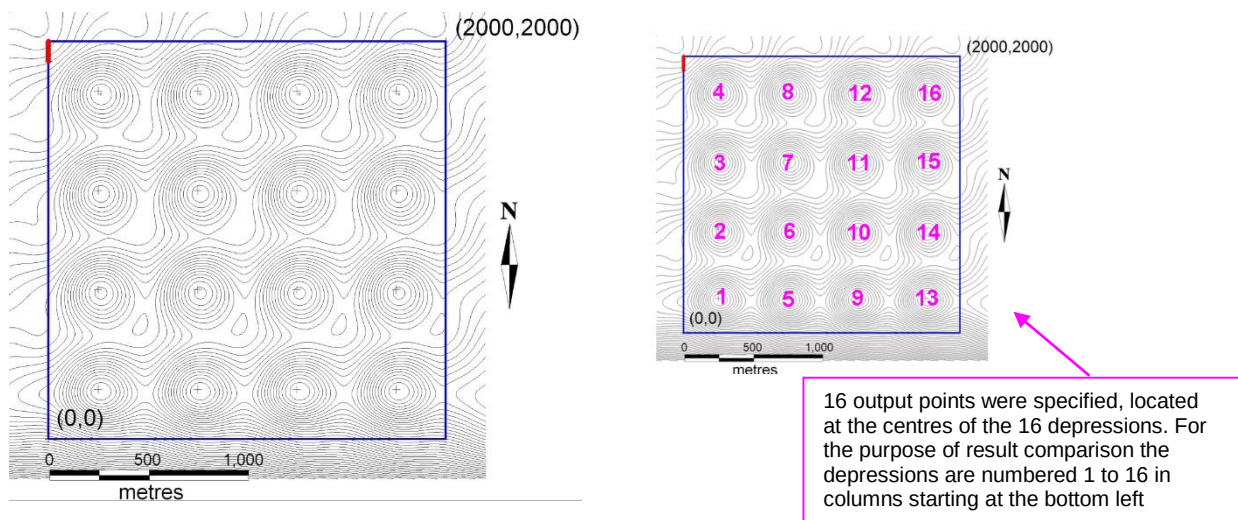
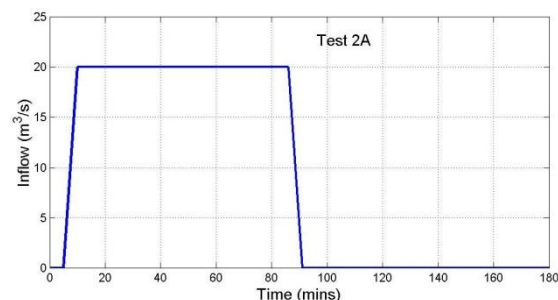


Figure (b): Inflow hydrograph used as upstream boundary condition.



Boundary and initial conditions:

- Inflow along the red line in Figure (a). Location and tables provided as part of dataset.
- All other boundaries are closed.
- Initial condition: Dry bed.

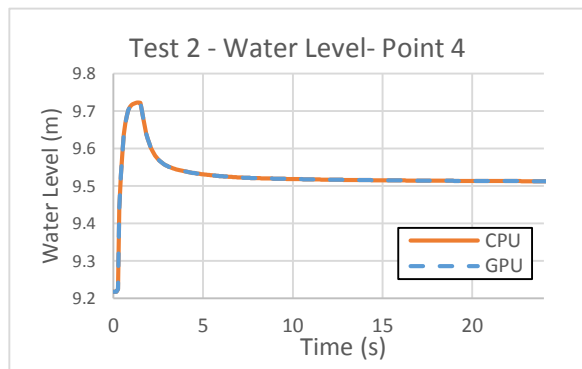
Parameter values:

- Manning's n: 0.03 (uniform)
- Model grid resolution: 20m (or ~10000 nodes in the area modelled)
- Time of end: model is to be run until time $t = 48$ hours

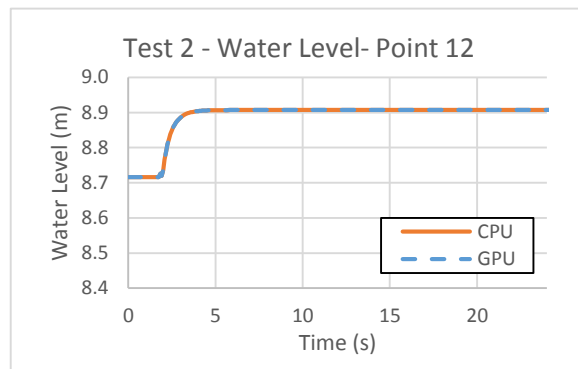
Results:

Water level versus time (output frequency 300s)

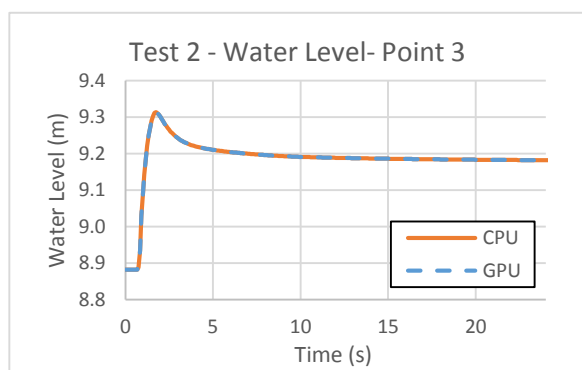
Test 2, point 4:



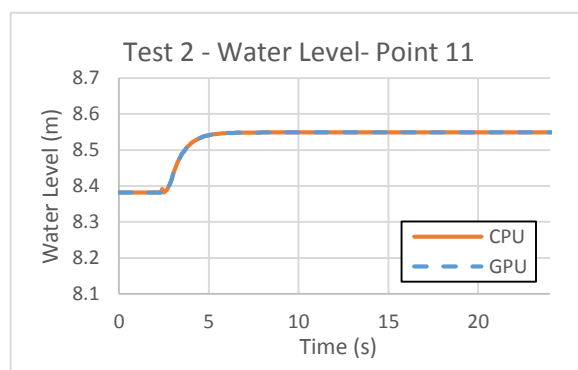
Test 2, point 12:



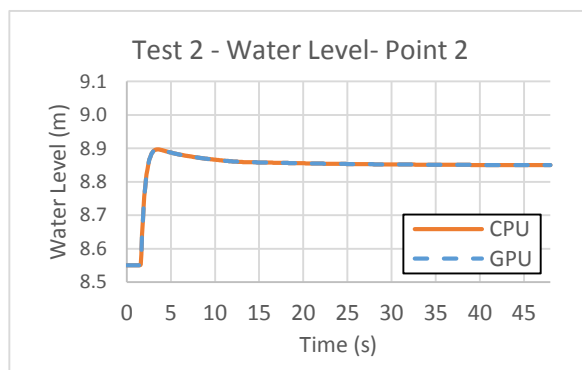
Test 2, point 3:



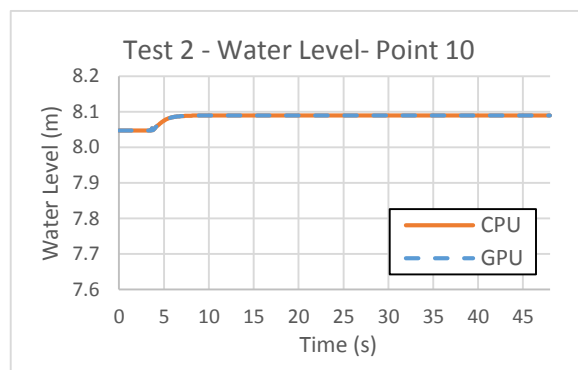
Test 2, point 11:



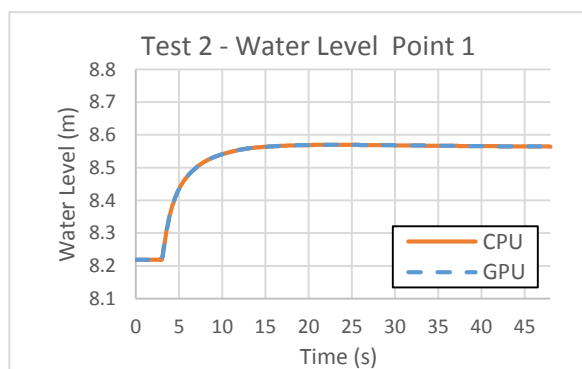
Test 2, point 2:



Test 2, point 10:

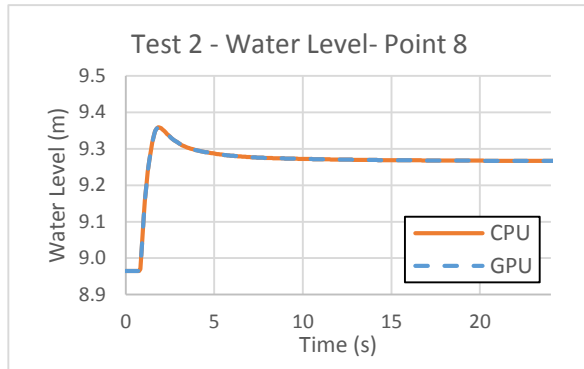


Test 2, point 1:

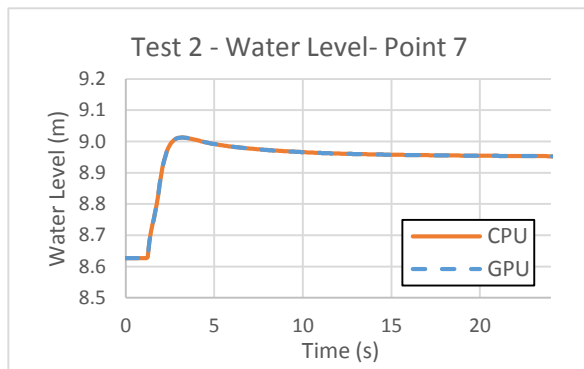


Test 2, point 9:

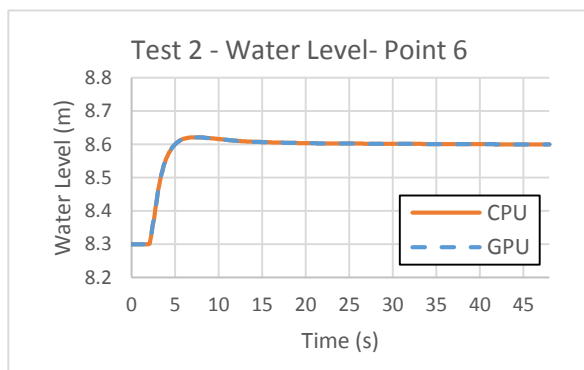
All models remain dry.

Test 2, point 8:**Test 2, point 16:**

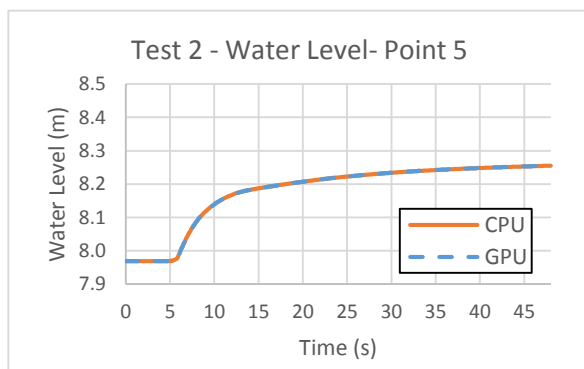
All models remain dry.

Test 2, point 7:**Test 2, point 15:**

All models remain dry.

Test 2, point 6:**Test 2, point 14:**

All models remain dry.

Test 2, point 5:**Test 2, point 13:**

All models remain dry.

Summary of relevant technical information for the test:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.03	0.03
Grid	10309 Elements	10309 Elements
Total volume of water left on the flood plain at the end of the simulation	97103 m ³	97103 m ³
Time-stepping	Adaptive (1.5 to 3.4s)	Adaptive (2 to 4.4s)
Total simulation time (hrs)	0.013 (48)	0.011 ¹ (41)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give identical results.

All locations that remained do not include a figure.

Test 3: Momentum conservation over a small obstruction

Objective:

The objective of this test is to assess the package's ability to conserve momentum over an obstruction in the topography. This capability is important when simulating sewer or pluvial flooding in urbanised floodplains. The barrier to the flow is designed to differentiate the performance of packages without inertia terms and 2D hydrodynamic packages with inertia terms. With inertia terms, some of the flood water will pass over the obstruction.

Description:

This test consists of a sloping topography with two depressions separated by an obstruction as illustrated in figure (a). The dimensions of the domain are 300m longitudinally (X) and 100m transversally (Y). A varying inflow (see figure (b)) is applied as an upstream boundary condition on the left-hand end, causing a flood wave to travel down the 1:200 slope. While the total inflow volume is just sufficient to fill the left-hand side depression at $x=150\text{m}$, some of the volume is expected to overtop the obstruction because of momentum conservation and settle in the depression on the right-hand side at $x=250\text{m}$. The model is run until time $T=900\text{s}$ (15mins) to allow the water to settle.

Figure (a): plan and profile of DEM used in test 3. The area modelled is a perfect rectangle extending from $X=0$ to $X=300\text{m}$ and from $Y=0$ to $Y=100\text{m}$.

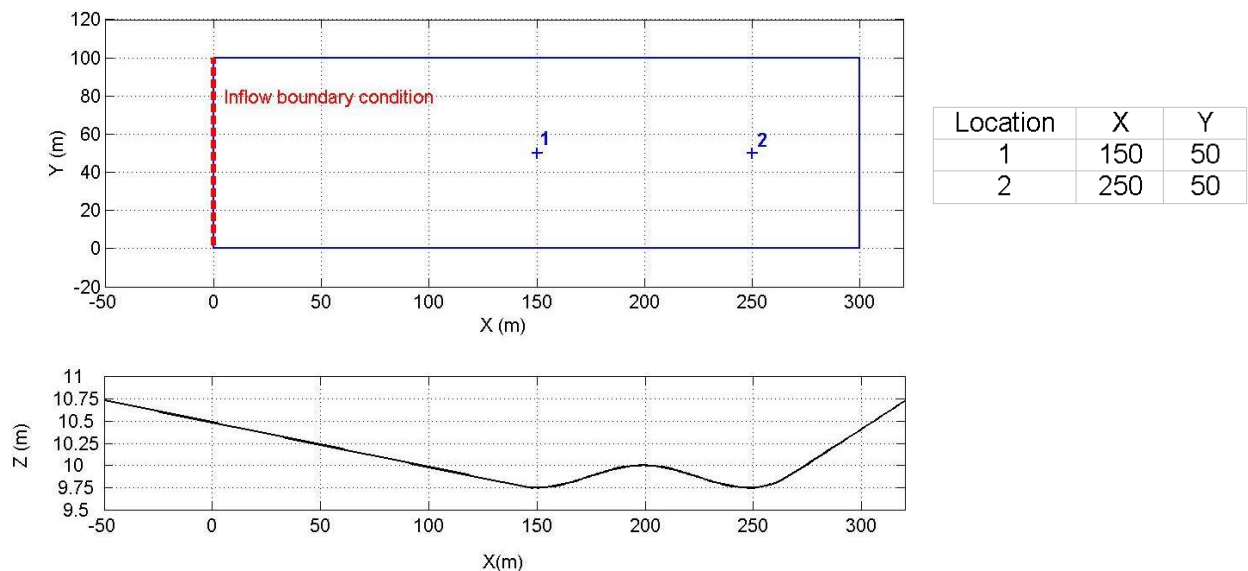
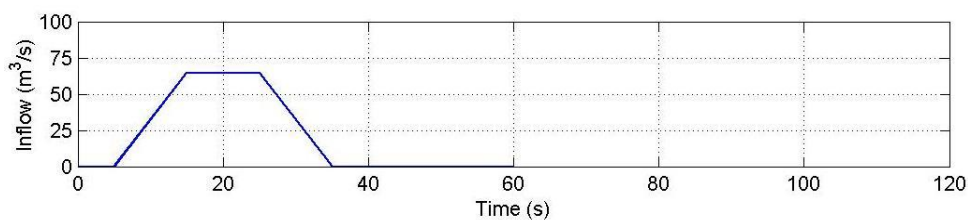


Figure (b): inflow hydrograph used as an upstream boundary condition.



Boundary and initial conditions:

- Inflow boundary condition along the dashed red line in figure (a). Table provided as part of the dataset;
- All other boundaries are closed;
- Initial condition: dry bed.

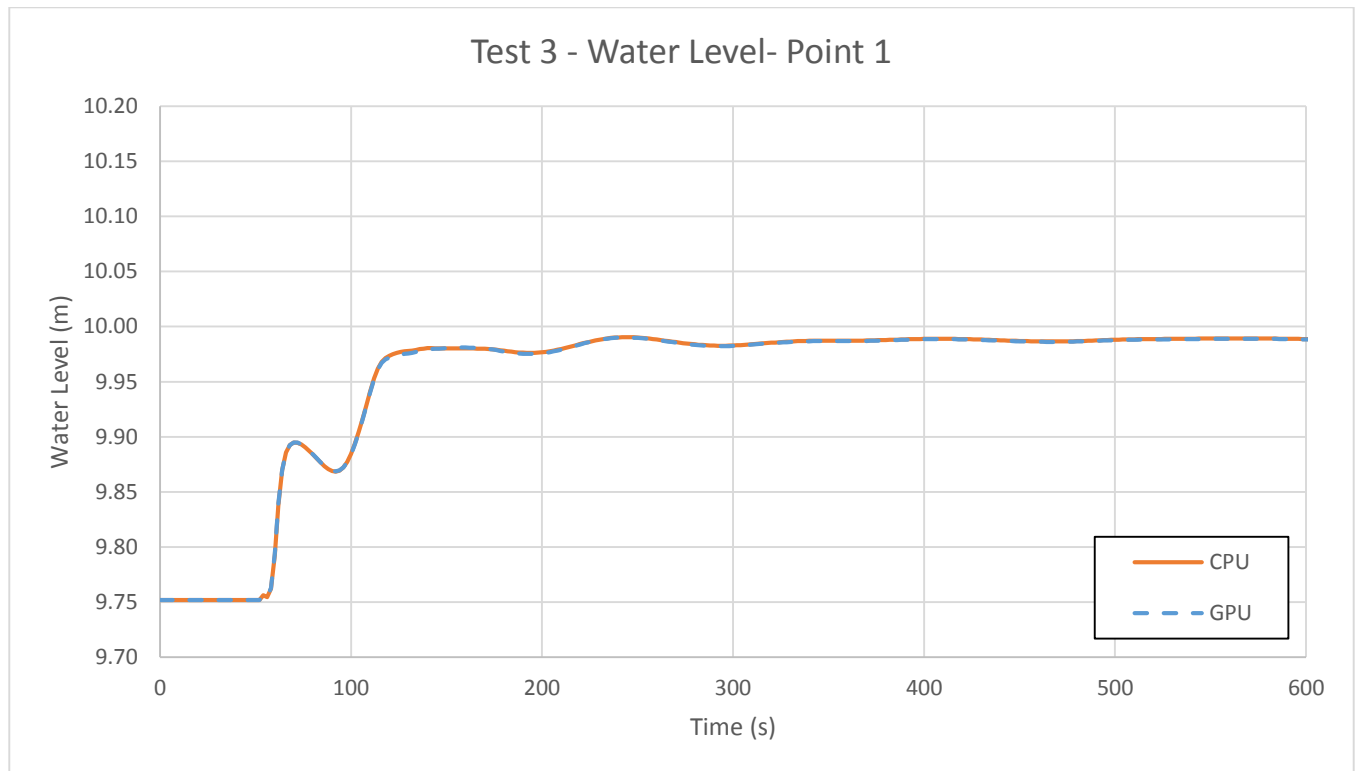
Parameter values:

- Manning's n : 0.01 (uniform);
- Model grid resolution: 5m (or ~1200 nodes in the area modelled);
- Time of end: the model to be run until $T=15\text{mins}$ (900s).
-

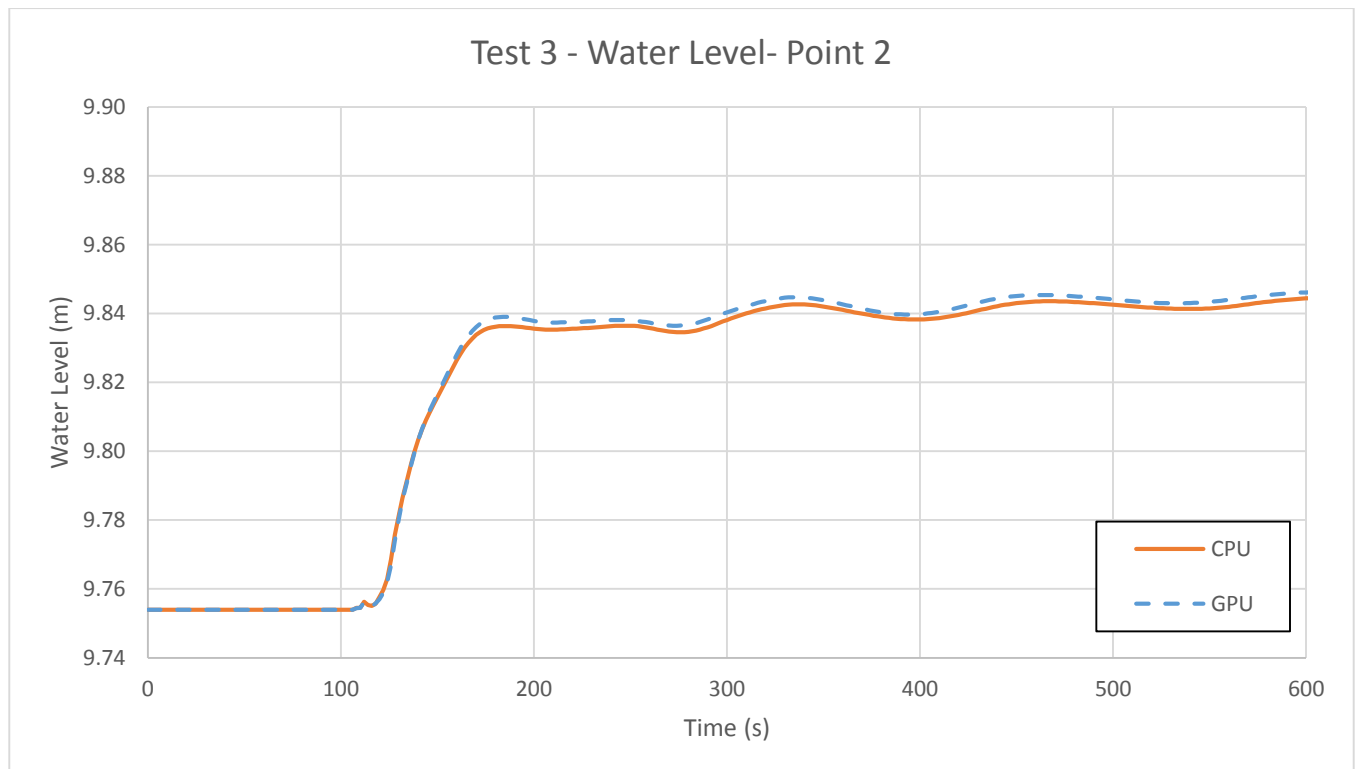
Results:

Water level time series:

Test 3, point 1: water level versus time (output frequency 2s)

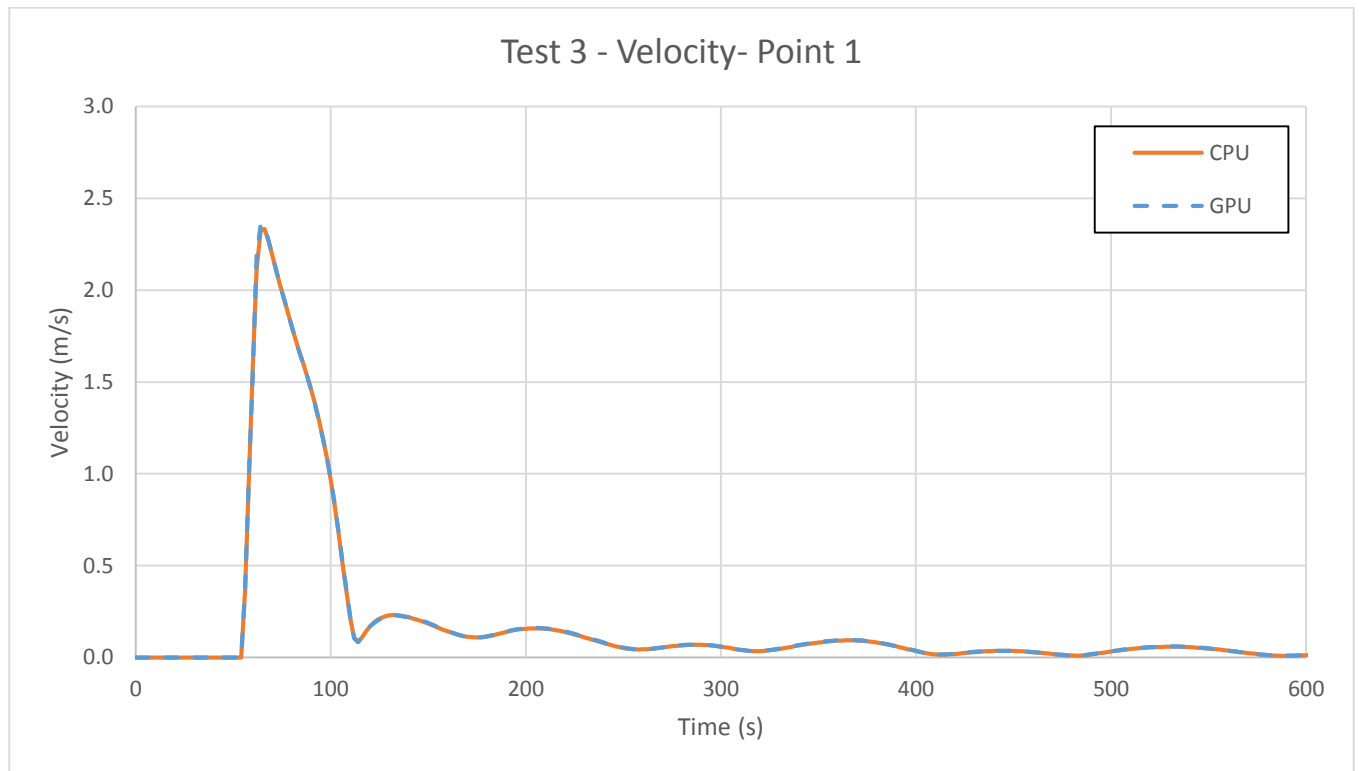


Test 3, point 2: water level versus time (output frequency 2s)



Velocity time series:

Test 3, point 1: velocity versus time (output frequency 2s)



Summary of relevant technical information for the test:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.01	0.01
Grid	1194 Elements	1194 Elements
Time-stepping	Adaptive (0.6 to 1.0s)	Adaptive (0.2 to 1.0s)
Total simulation time (hrs)	<1s	<1s ¹

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give nearly identical results.

Test 4: Speed of flood propagation over an extended floodplain

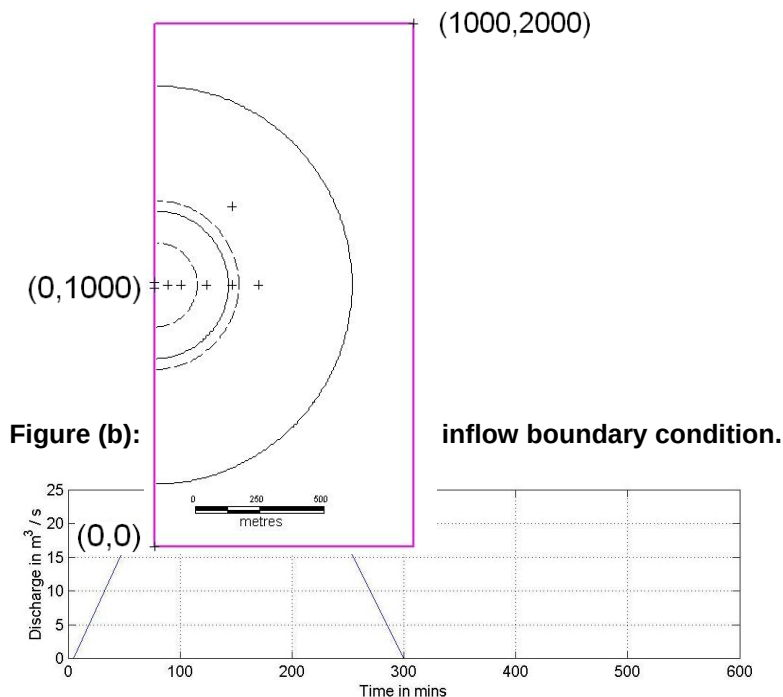
Objective:

The objective of this test is to assess the package's ability to simulate the celerity of propagation of a flood wave and predict transient velocities and depths at the leading edge of the advancing flood front. It is relevant to fluvial and coastal inundation resulting from breached embankments.

Description:

The test is designed to simulate the rate of flood wave propagation over a 1000m x 2000m floodplain following a defence failure (figure (a)). The floodplain surface is horizontal, at elevation 0m. One inflow boundary condition is used in the test, simulating the failure of an embankment by breaching or overtopping, with a peak flow of 20m³/s and time base of ~6hours. The boundary condition is applied along a 20m line in the middle of the western side of the floodplain.

Figure (a): modelled domain, showing the location of the 20m inflow, 6 output points, and possible 10cm and 20cm contour lines at time 1hr (dashed) and 3hr (solid).



Boundary and initial conditions:

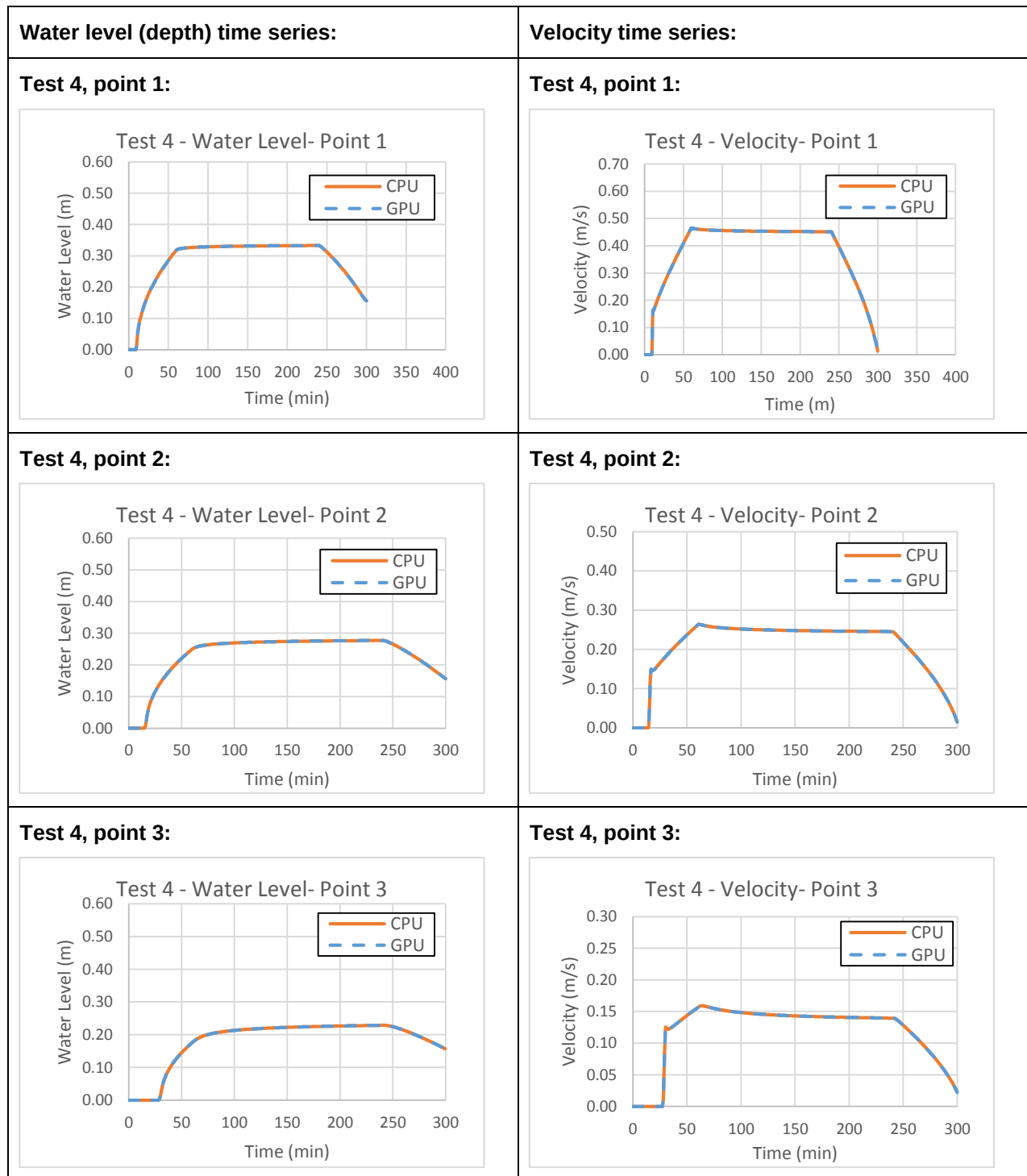
- Initial boundary condition as shown in figure (b). Table provided as part of the test dataset.
- All other boundaries are closed.
- Initial conditions: dry bed.

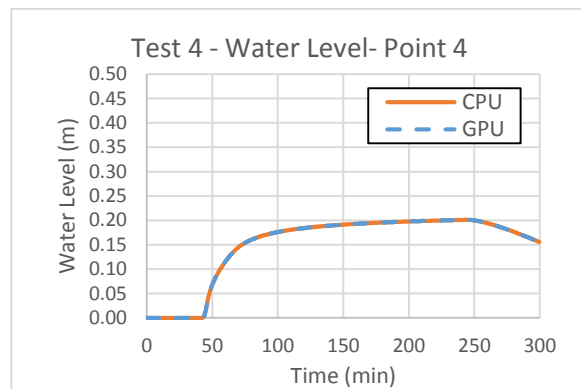
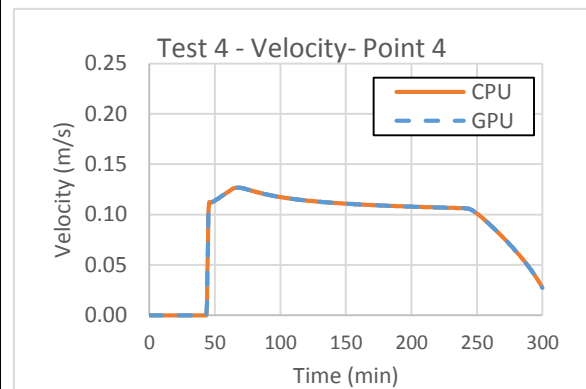
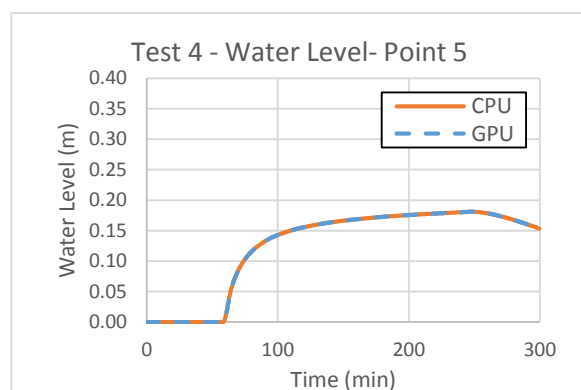
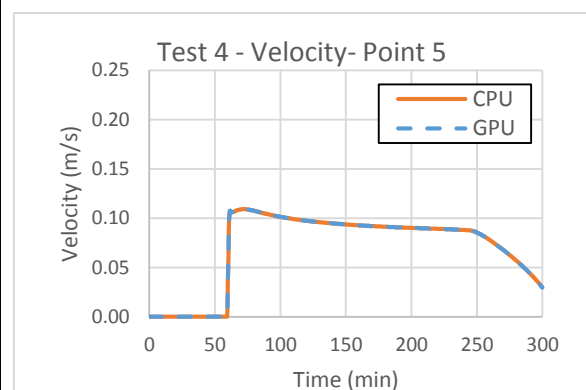
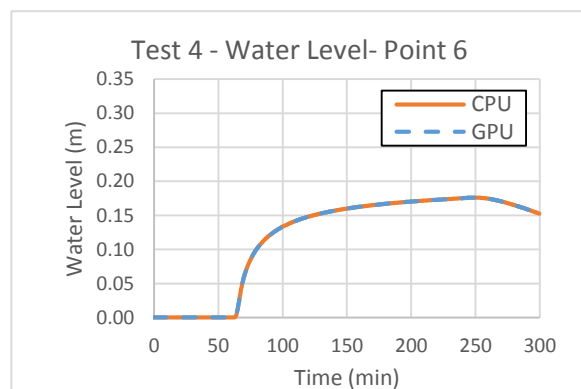
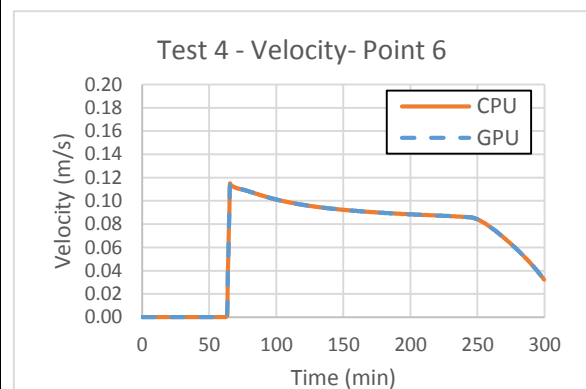
Parameter values:

- Manning's n: 0.05 (uniform).
- Model grid resolution: 5m (or ~80000nodes in the area modelled).
- Time of end: the model is to be run until time t=5hrs (if an alternative end time is used, run times must be reported for t=5hrs).

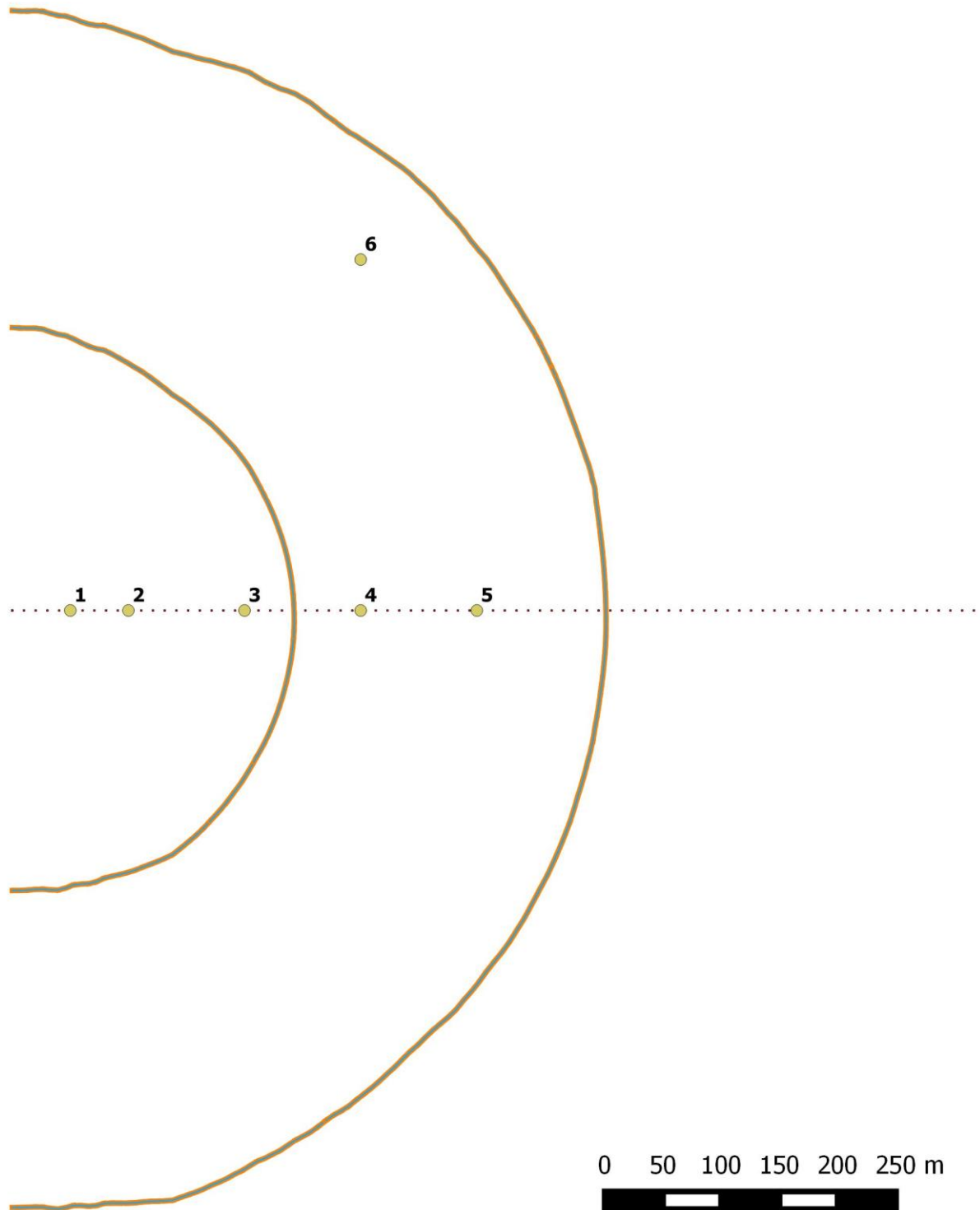
Results:

Water level (depth) and velocity time series:



Test 4, point 4:**Test 4, point 4:****Test 4, point 5:****Test 4, point 5:****Test 4, point 6:****Test 4, point 6:**

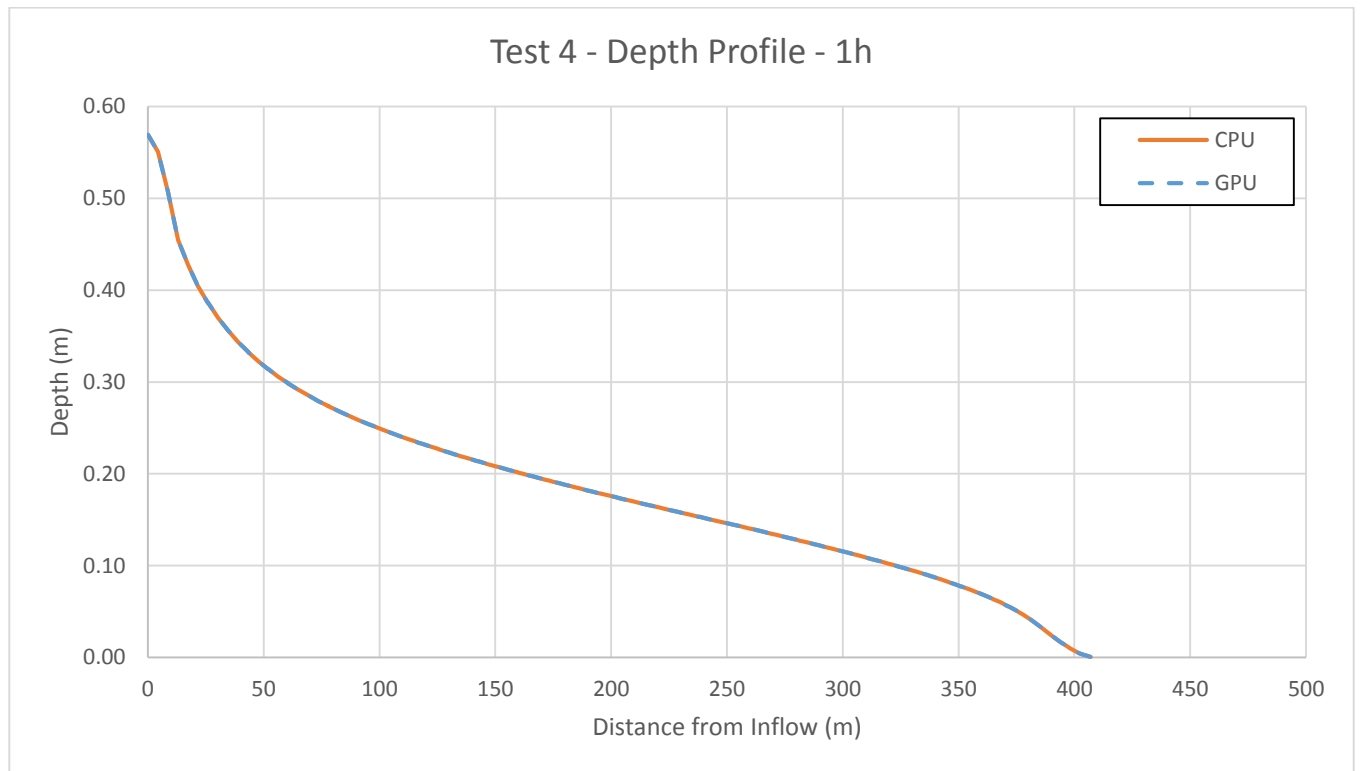
Output in raster format:



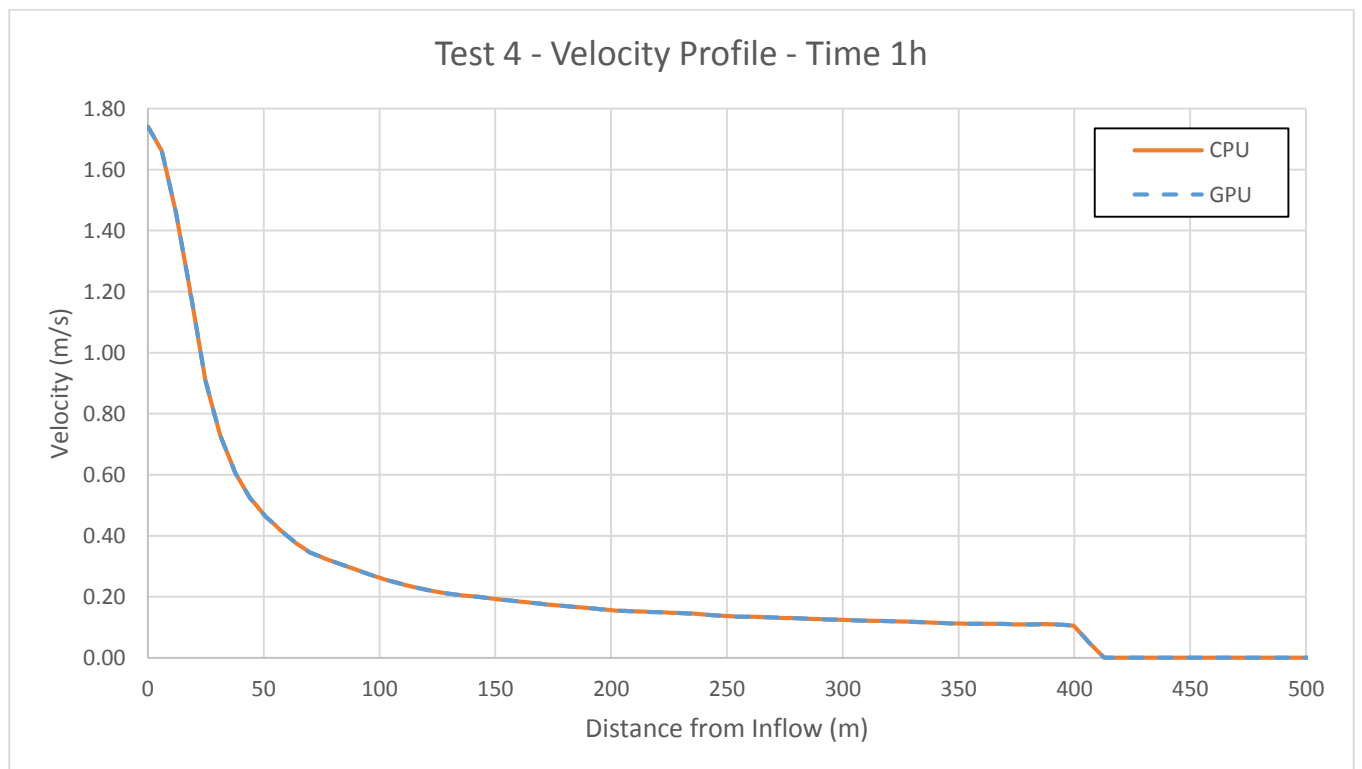
Notes:

0.15m depth contours at times 1hr (left) and 3hr (right). The colour coding is consistent with the one used in the rest of this report. Cross-sections shown in the two following figures were taken along the black dashed line, which starts at the left boundary and runs through output points 1 to 5.

Cross-section of depths along dotted line in previous figure, at t=1hr:



Cross-section of velocities along dotted line in previous figure, at t=1hr:



Summary of relevant technical information for the test:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.05	0.05
Grid	79890 Elements	79890 Elements
Time-stepping	Adaptive (0.6 to 1.4s)	Adaptive (0.3 to 1.6s)
Total simulation time (hrs)	0.103 (370s)	0.013 ¹ (47s)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give identical results.

Test 5: Valley flooding

Objective:

This tests a package's capability to simulate major flood inundation and predict flood hazard arising from dam failure (peak levels, velocities, and travel times).

Description:

This test is designed to simulate flood wave propagation down a river valley following the failure of a dam. The valley DEM (figure (a)) is ~0.8km by ~17km and the valley slopes downstream on a slope of ~0.01 in its upper region, easing to ~0.001 in its lower region. The inflow hydrograph (figure (b)) applied as a boundary condition along a ~260m long line at the upstream end is designed to account for a typical failure of a small embankment dam and to ensure that both super-critical and sub-critical flows will occur in different parts of the flow field.

Figure (a): DEM used, with cross-section along the centre line, and location of the output points. The red line indicates the location of the boundary condition and the blue polygon is the modelled area.

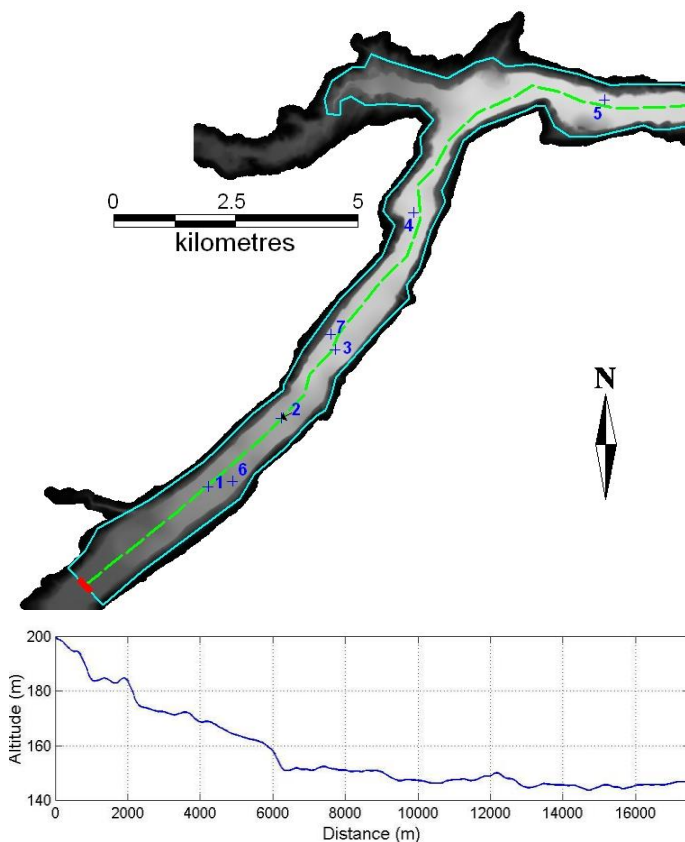
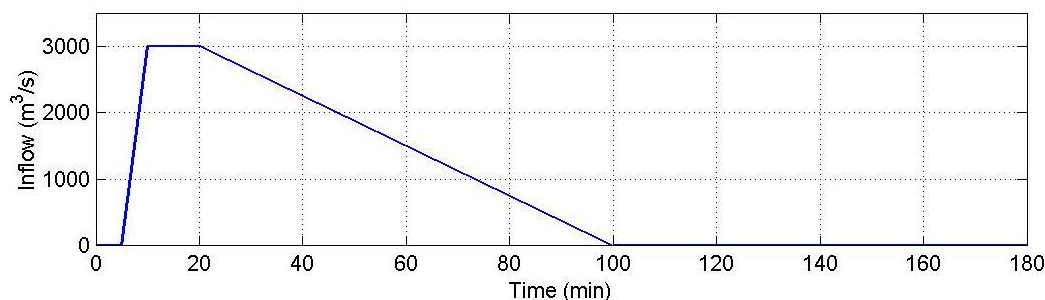


Figure (b): inflow hydrograph applied



Boundary and initial conditions:

- Initial boundary condition along the dashed red line in figure (a). Table provided as part of the dataset.
- All other boundaries are closed.

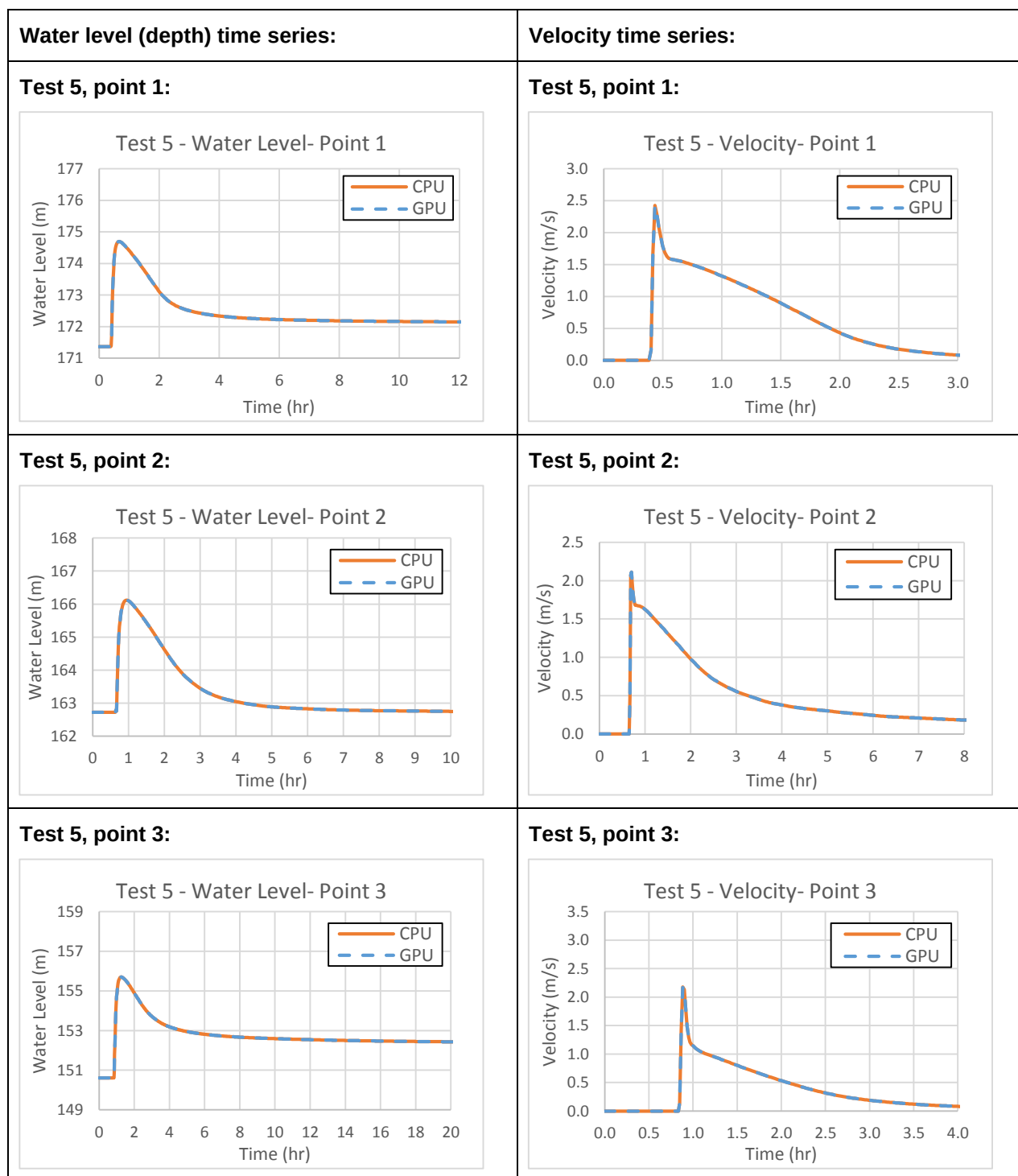
- Initial condition: dry bed.

Parameter values:

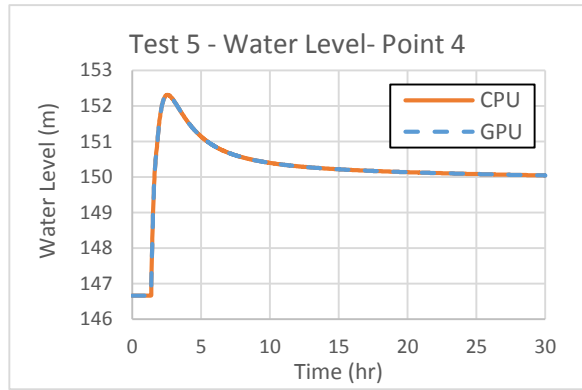
- Manning's n: 0.04 (uniform)
- Model grid resolution: 50m (or ~7600nodes in the 19.02km² area modelled)
- Time of end: the model is to be run until T=30hrs (if an alternative is used run times must be reported for T=30hrs)

Results:

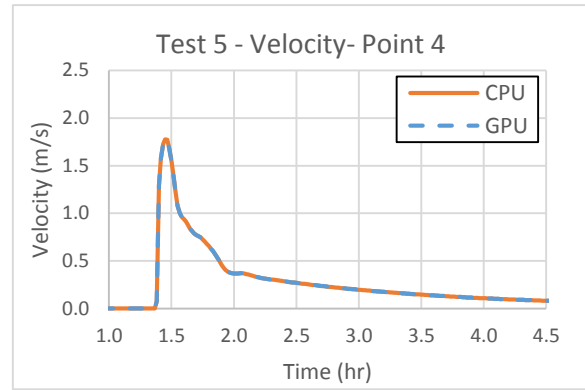
Water level (depth) and velocity time series:



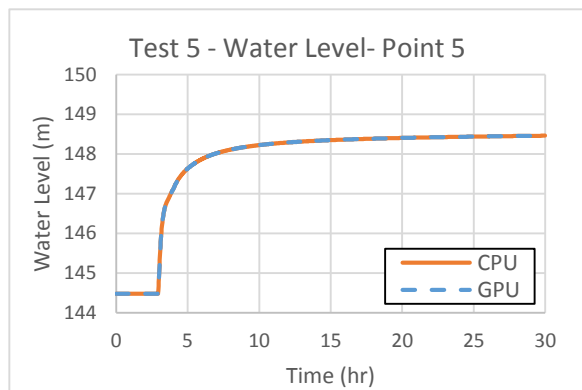
Test 5, point 4:



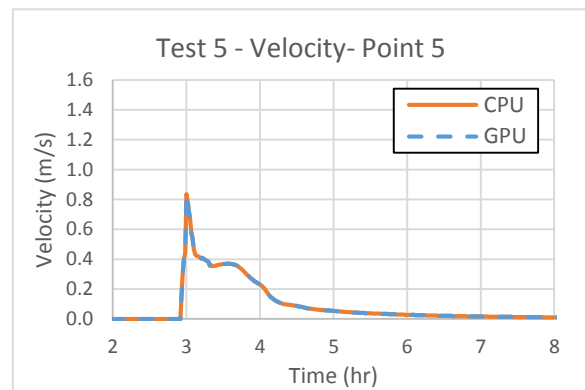
Test 5, point 4:



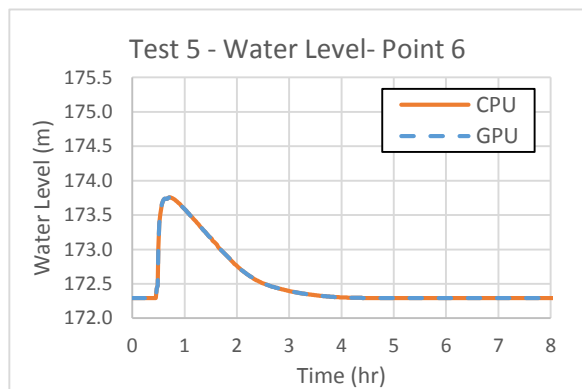
Test 5, point 5:



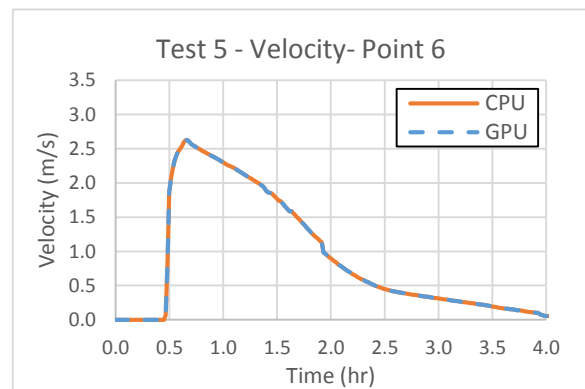
Test 5, point 5:



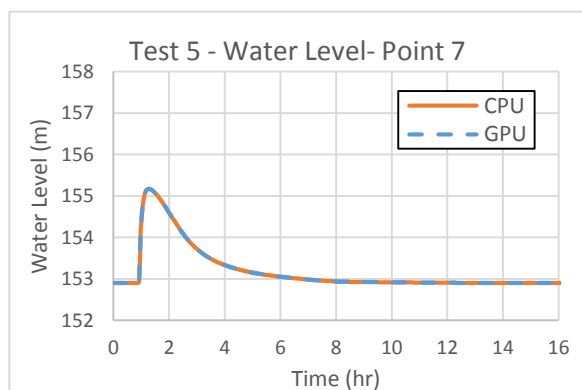
Test 5, point 6:



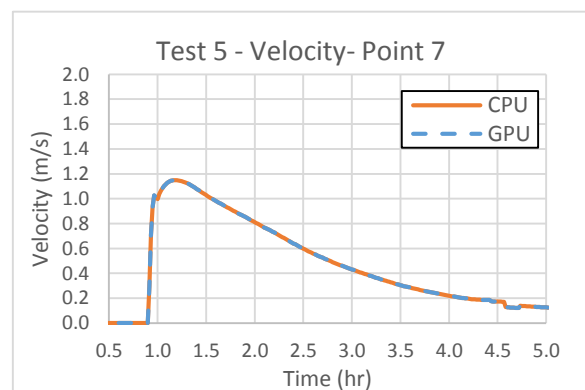
Test 5, point 6:



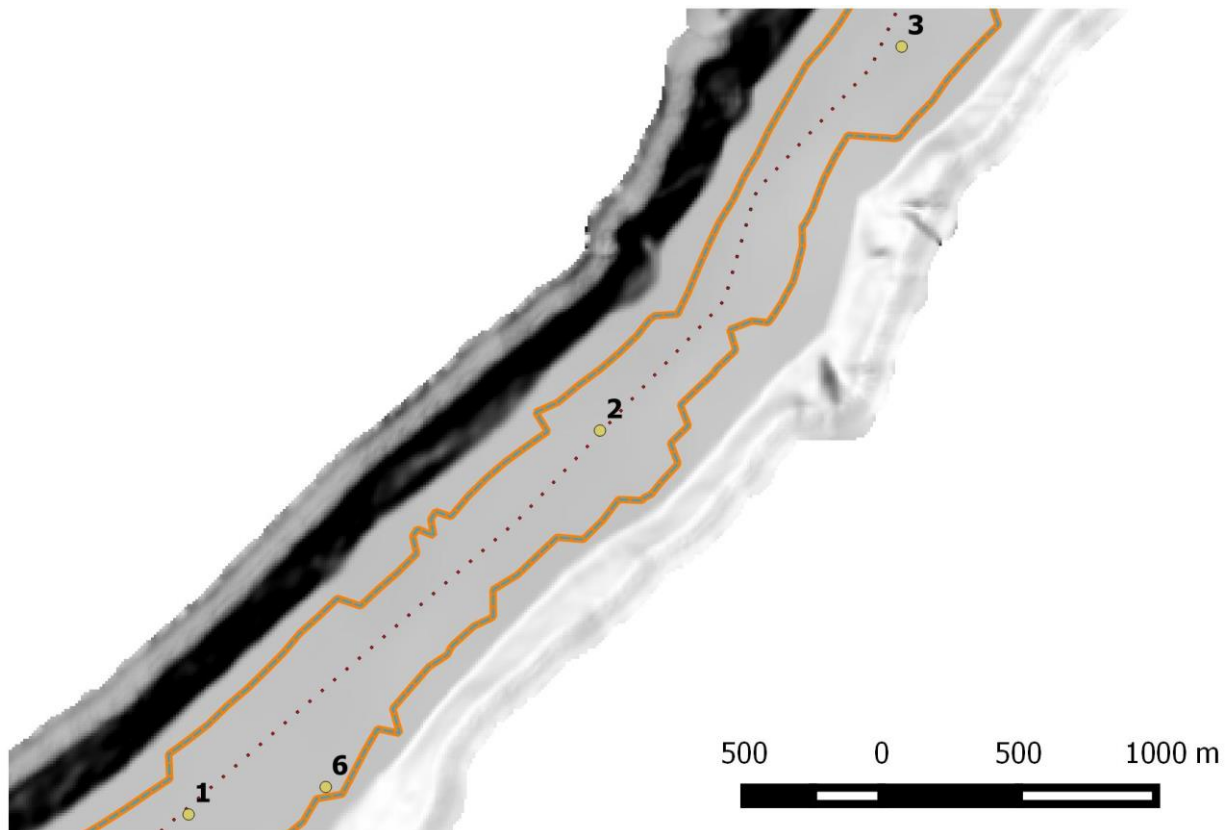
Test 5, point 7:



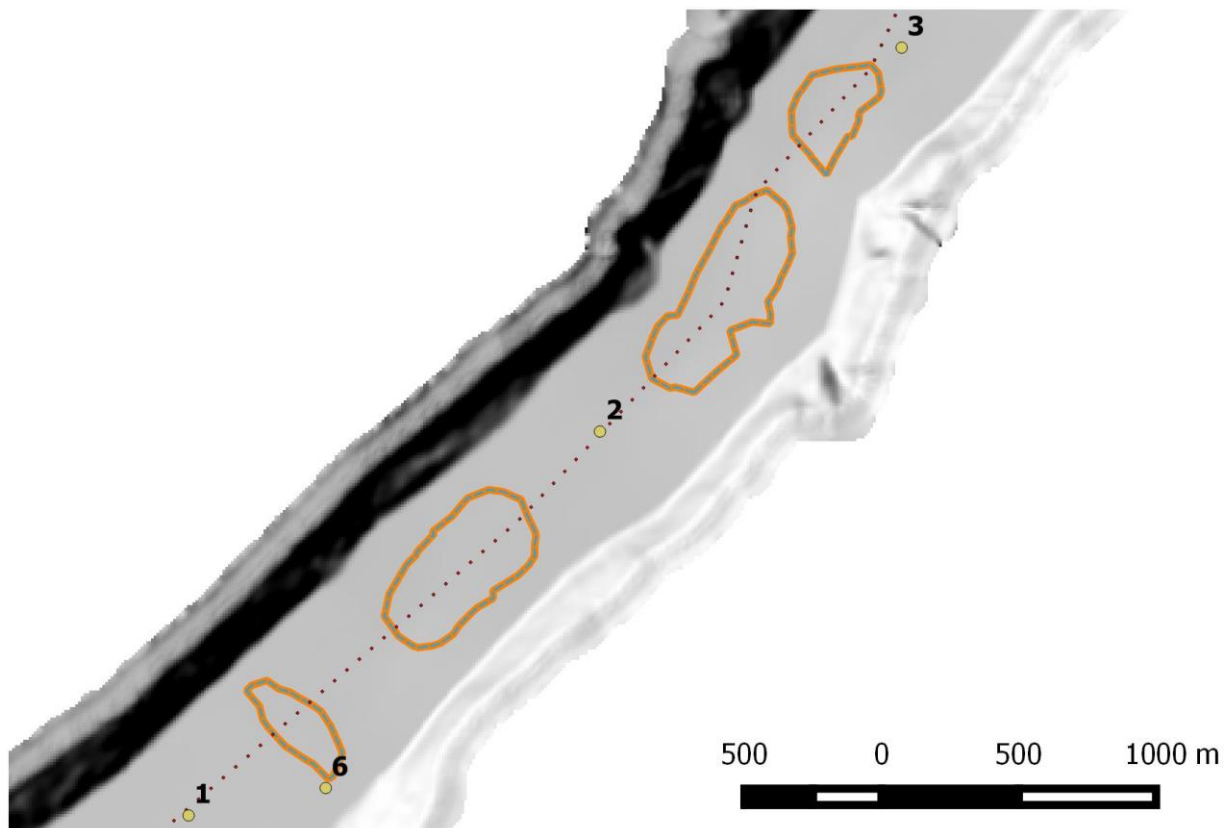
Test 5, point 7:



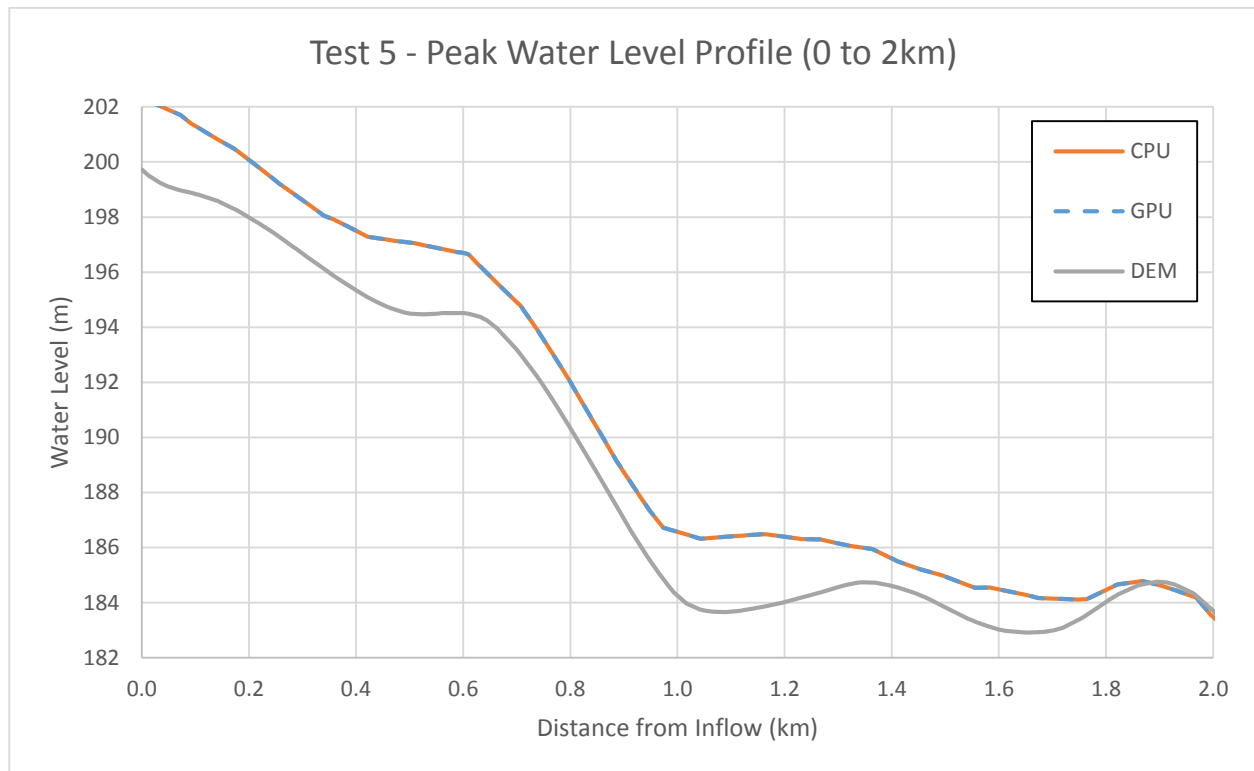
0.5m contour lines of peak depths for a section of floodplain around points 1, 2 and 6:



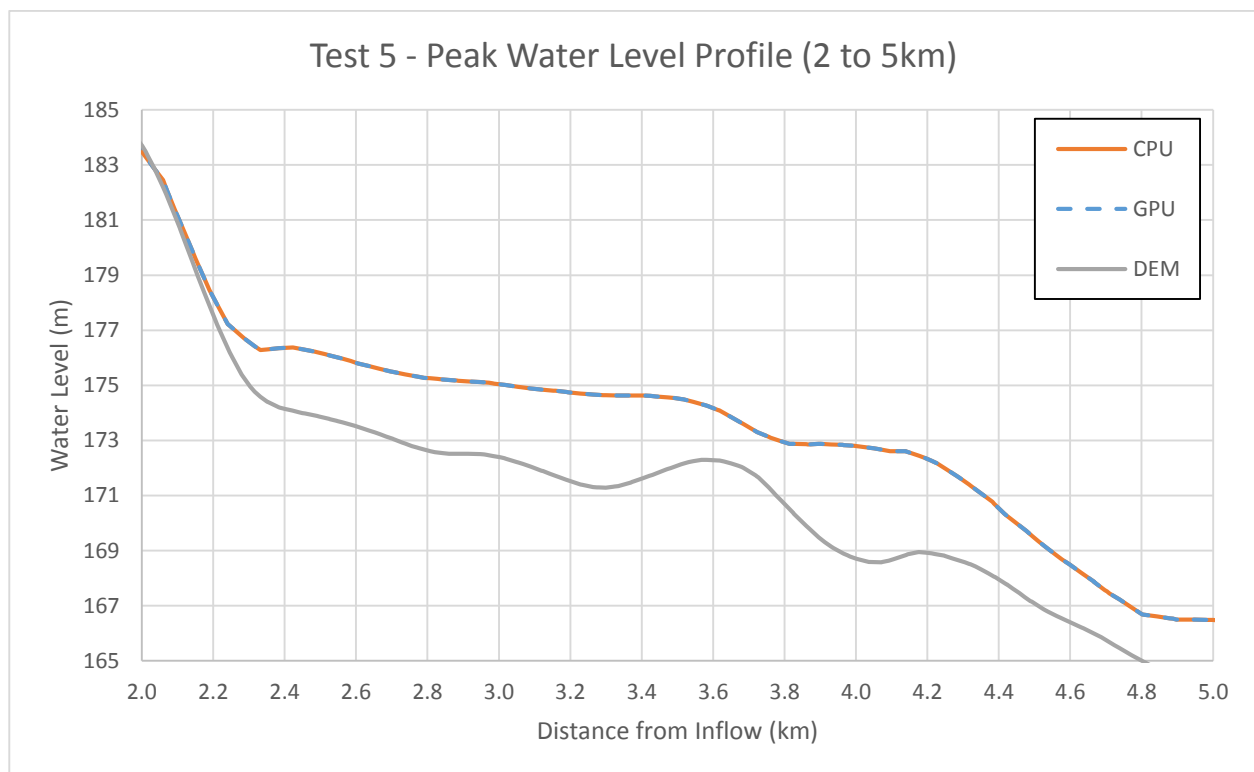
3m/s contour lines of peak velocities for a section of floodplain around points 1, 2 and 6:



Cross section of predicted peak levels (0 to 2km) along valley centre line:



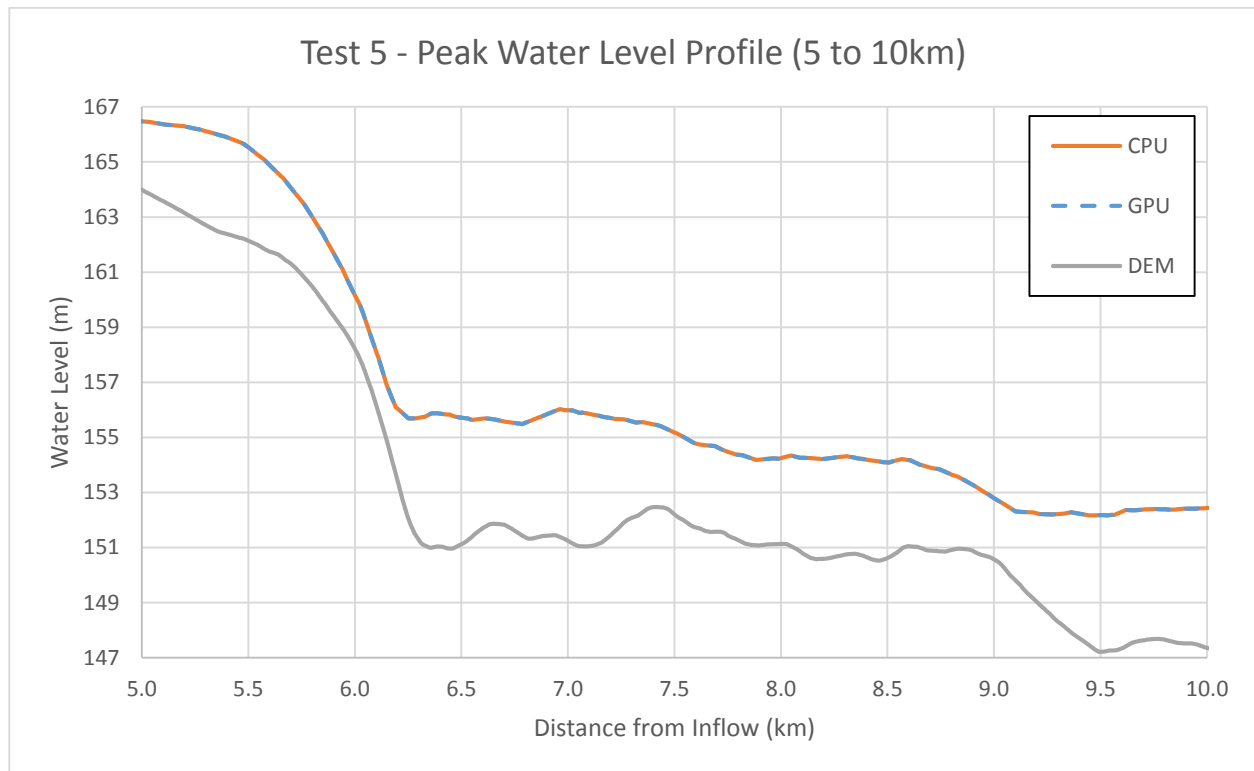
Cross section of predicted peak levels (2 to 5km) along valley centre line:



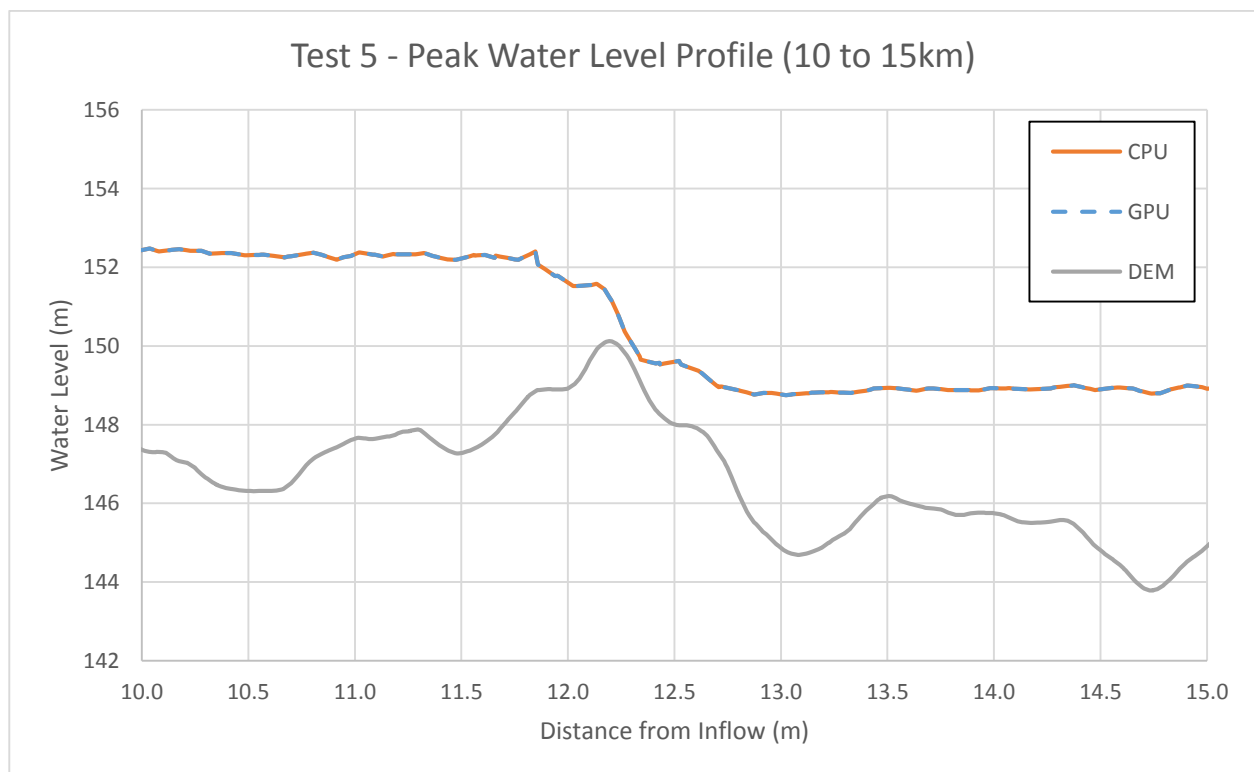
Approximate locations of time series output points along valley centerline:

- Point 1 (3.24km)
- Point 6 (3.67km)
- Point 2 (5.29km)
- Point 3 (7.08km)
- Point 7 (7.33km)
- Point 4 (10.46km)

Cross section of predicted peak levels (5 to 10km) along valley centre line:



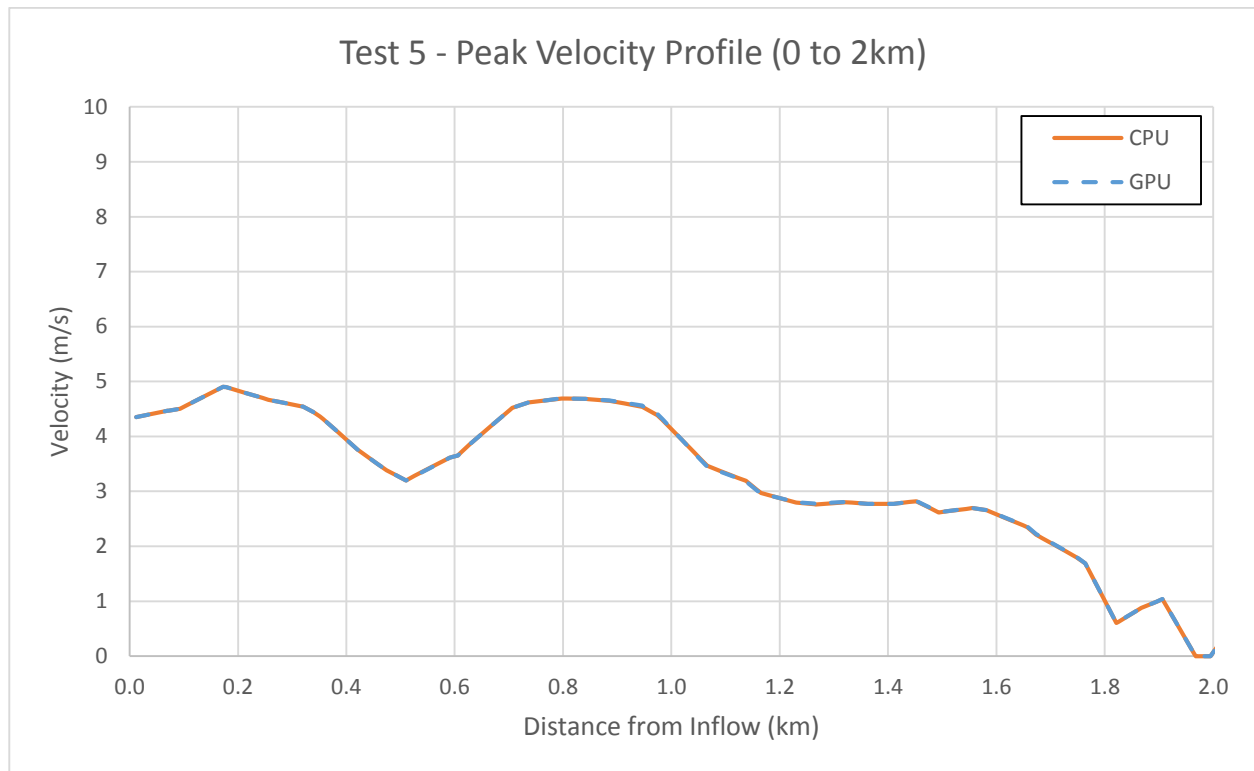
Cross section of predicted peak levels (10 to 15km) along valley centre line:



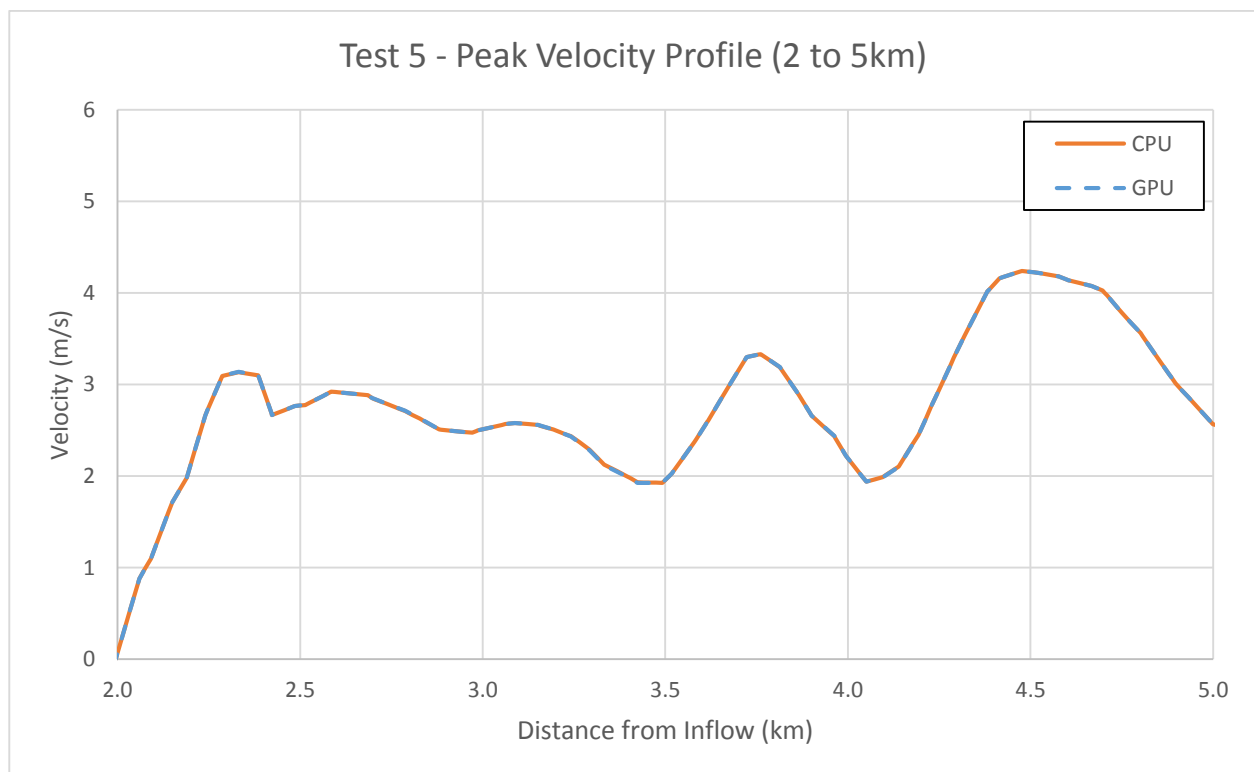
Approximate locations of time series output points along valley centerline:

- Point 1 (3.24km)
- Point 6 (3.67km)
- Point 2 (5.29km)
- Point 3 (7.08km)
- Point 7 (7.33km)
- Point 4 (10.46km)

Cross section of predicted peak velocities (0 to 2km) along valley centre line:



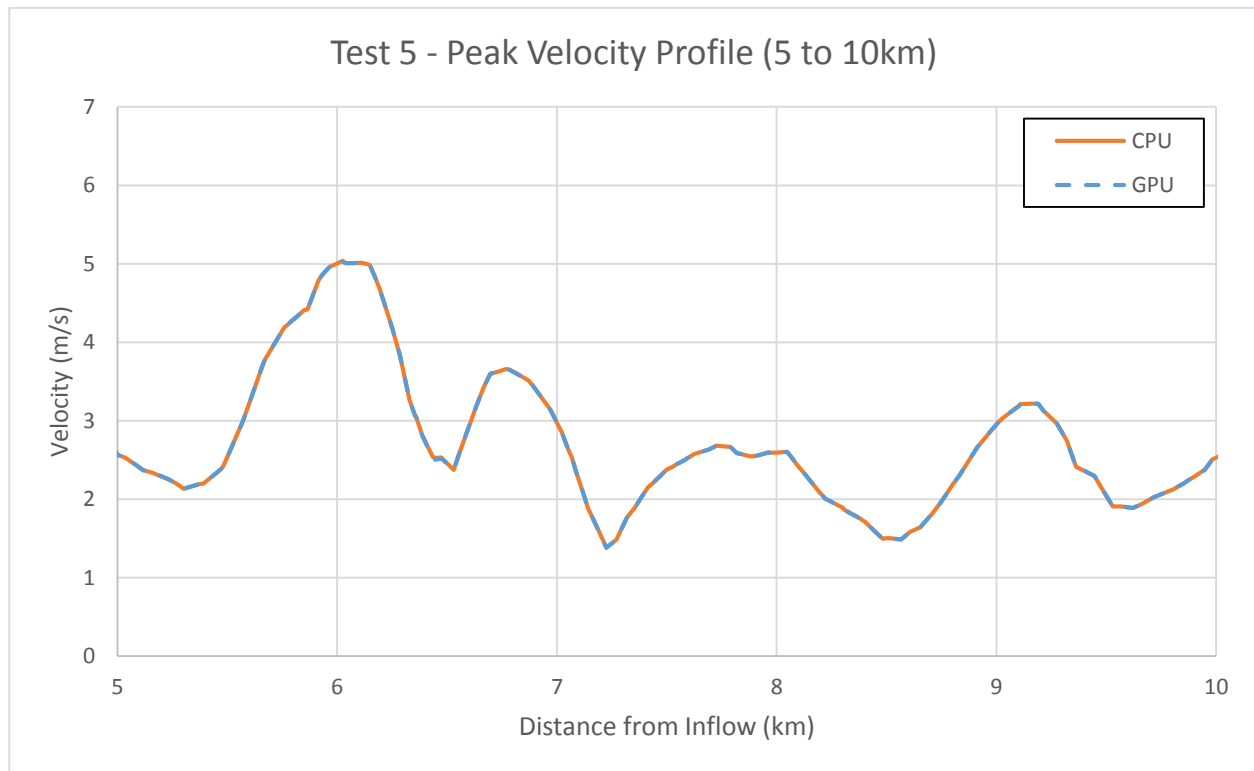
Cross section of predicted peak velocities (2 to 5km) along valley centre line:



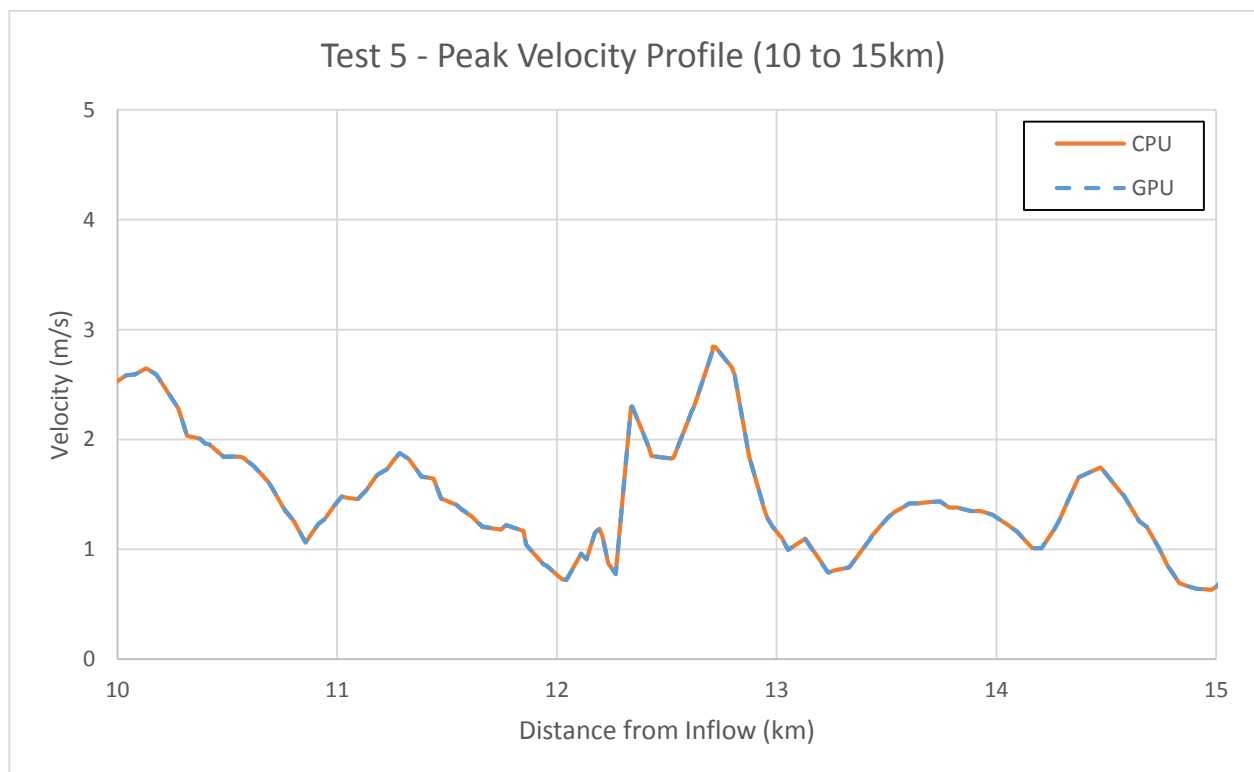
Approximate locations of time series output points along valley centerline:

- Point 1 (3.24km)
- Point 6 (3.67km)
- Point 2 (5.29km)
- Point 3 (7.08km)
- Point 7 (7.33km)
- Point 4 (10.46km)

Cross section of predicted peak velocities (5 to 10km) along valley centre line:



Cross section of predicted peak velocities (10 to 15km) along valley centre line:



Approximate locations of time series output points along valley centerline:

- Point 1 (3.24km)
- Point 6 (3.67km)
- Point 2 (5.29km)
- Point 3 (7.08km)
- Point 7 (7.33km)
- Point 4 (10.46km)

Summary of relevant technical information for the test:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.04	0.04
Grid	7490 Elements	7490 Elements
Final Volume on Floodplain	9,444,924 (-0.05% ME)	9,444,934 (-0.05% ME)
Time-stepping	Adaptive (1.0 to 1.9s)	Adaptive (0.8 to 1.9s)
Total simulation time (hrs)	0.009 (33s)	0.009 ¹ (34s)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give identical results.

Test 6A and 6B: Dam break

Objective:

This tests the capability of each package to correctly simulate hydraulic jumps and wake zones behind buildings using high-resolution modelling.

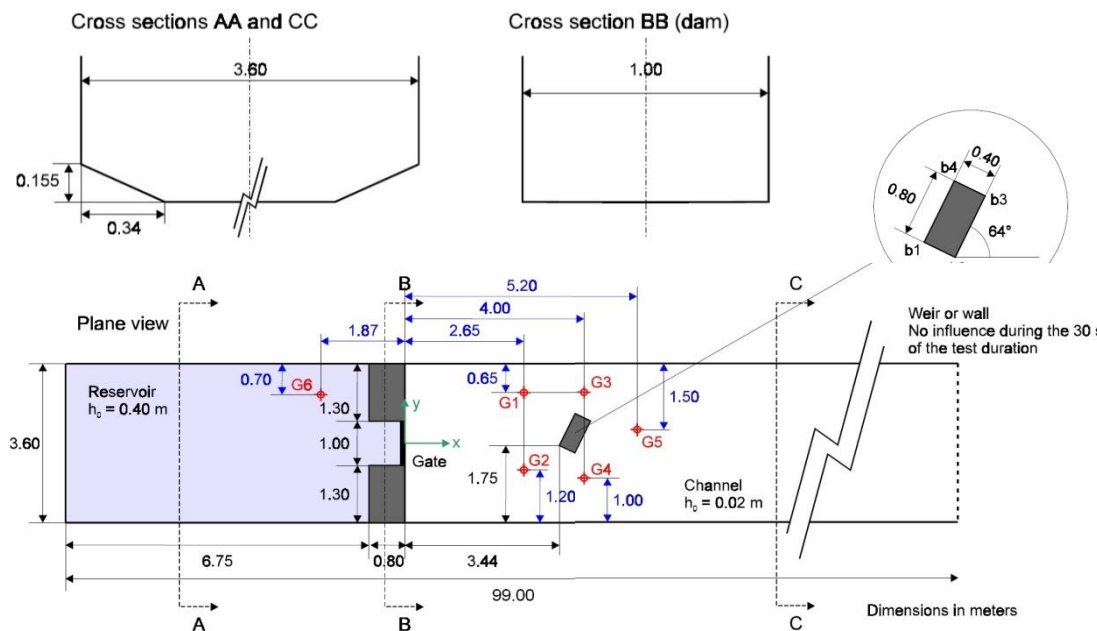
Description:

This dam-break test case has been adapted from an original benchmark test available from the IMPACT project (IMPACT, 2004; Soares-Frazao and Zech, 2002), for which measurements from a physical model at the Civil Engineering Laboratory of the Université Catholique de Louvain (UCL) are available.

Test 6A is the original test is the original test proposed in Soares-Frazao and Zech 2002, where the physical dimensions are those of the laboratory model. The test involves a simple topography, a dam with a 1m wide opening, and an idealised representation of a single building downstream of the dam, see Figure (a). An initial condition is applied, consisting in a uniform depth of 0.4m upstream from the dam, and 0.02m downstream from the dam. The flow is contained by vertical walls at all boundaries of the DEM.

Test 6B is identical to Test 6A although all physical dimensions have been multiplied by 20 to reflect realistic dimensions encountered in practical flood inundation modelling applications.

Figure (a): Set-up for Test 6A (adapted from Soares-Frazao and Zech, 2002).



Boundary and initial conditions:

- No boundary condition specified as the flow is contained by vertical walls.
- Initial condition: in test 6A:
 - depth = 0.4m upstream from the dam (i.e. for $X < 0$);
 - depth = 0.02m downstream from the dam (i.e. for $X > 0$);
- Initial condition: in test 6B:
 - depth = 8m upstream from the dam (i.e. for $X < 0$);
 - depth = 0.4m downstream from the same (i.e. for $X > 0$);

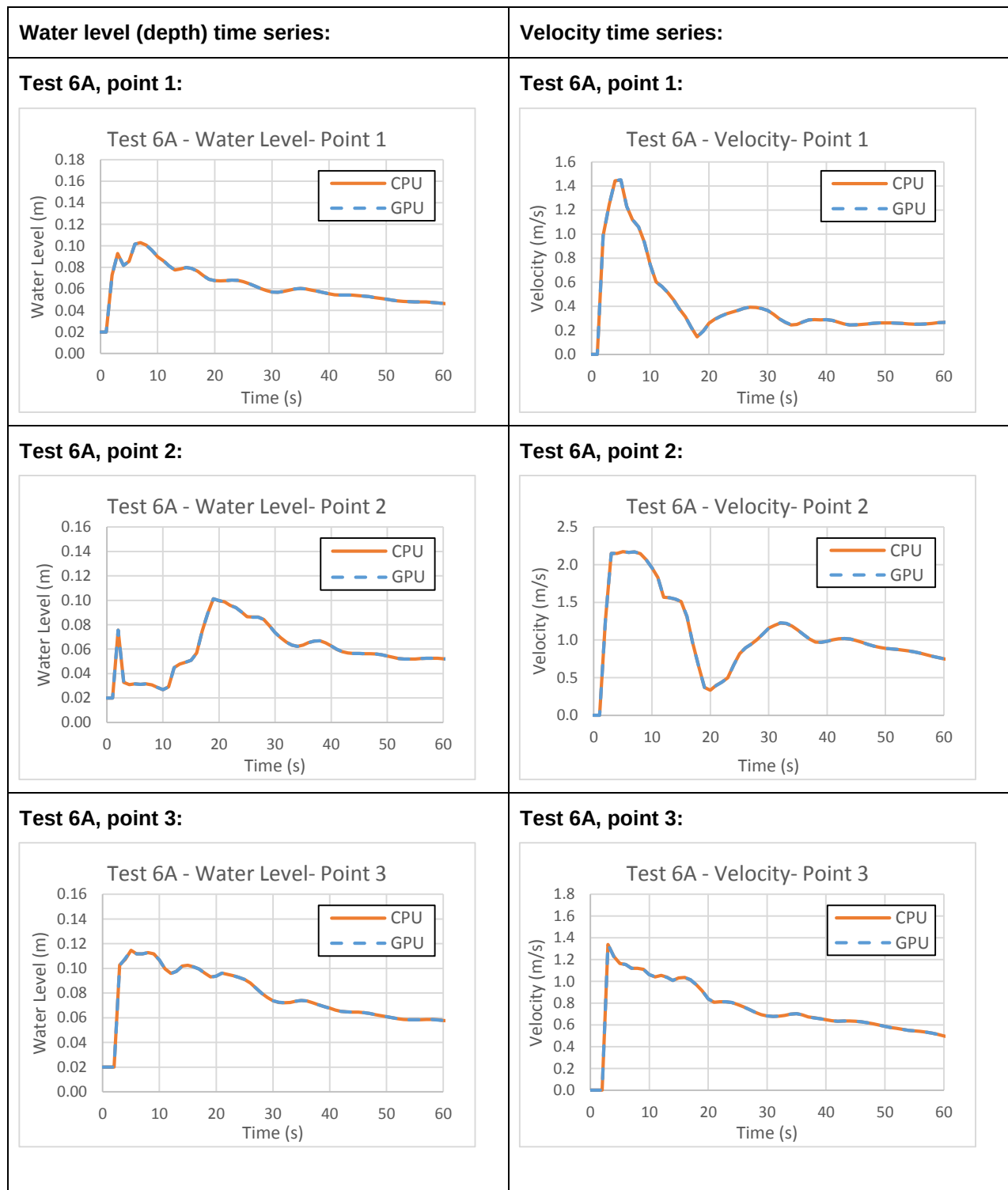
Parameter values:

- No preferred value of eddy viscosity is specified;
- In test 6A:
 - Manning's n : 0.01 (uniform);
 - Model grid resolution: 0.1m or ~36000 nodes in area bounded by vertical scale;
 - Time of end: the model is to be run until $t = 2$ mins (if an alternative end time is used, run times must be reported for $t=2$ mins)
- In test 6B:
 - Manning's n : 0.05 (uniform);
 - Model grid resolution: 2m or ~36000 nodes in area bounded by vertical scale;

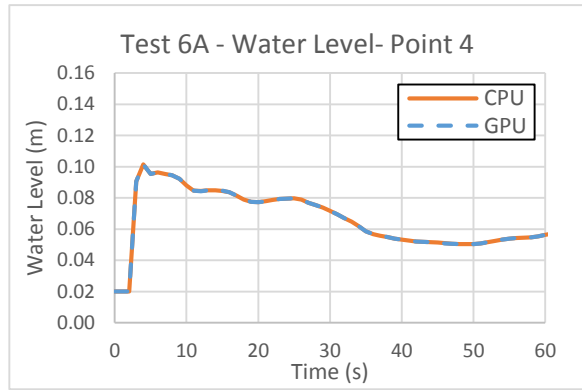
- Time of end: the model is to be run until time $t=30\text{mins}$ (if an alternative end time is used, run times must be reported for $t=30\text{mins}$)

Results:

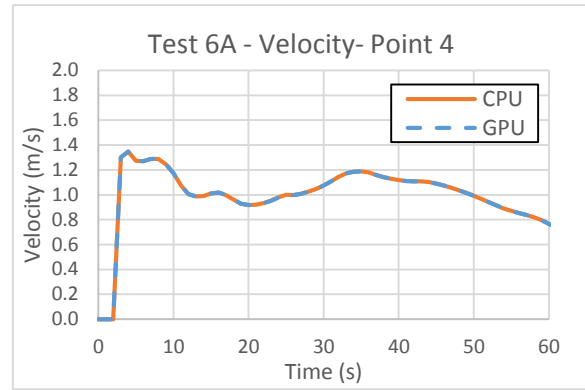
Test 6A: Water level (depth) and velocity time series:



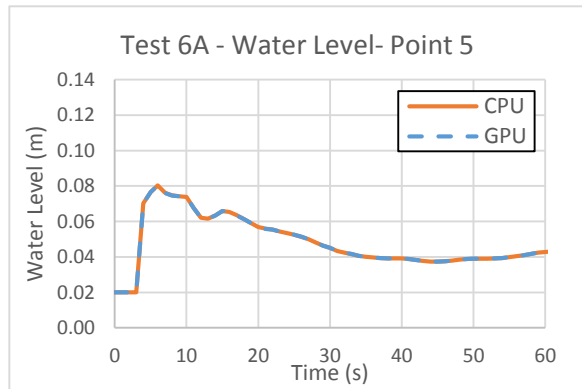
Test 6A, point 4:



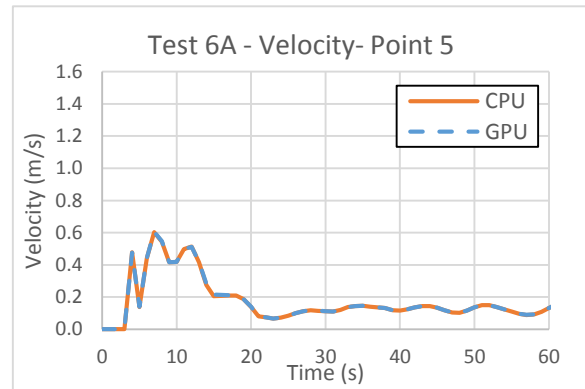
Test 6A, point 4:



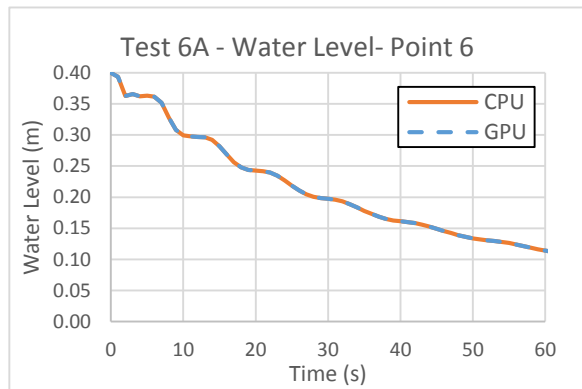
Test 6A, point 5:



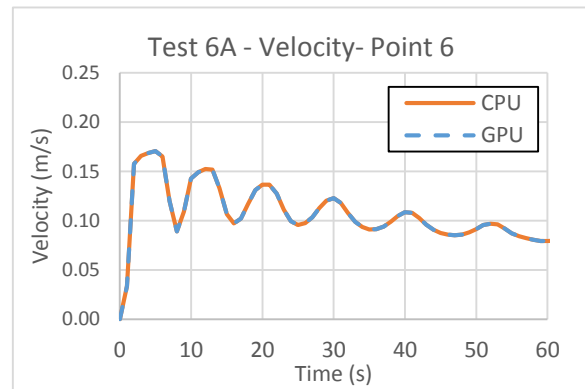
Test 6A, point 5:



Test 6A, point 6:



Test 6A, point 6:

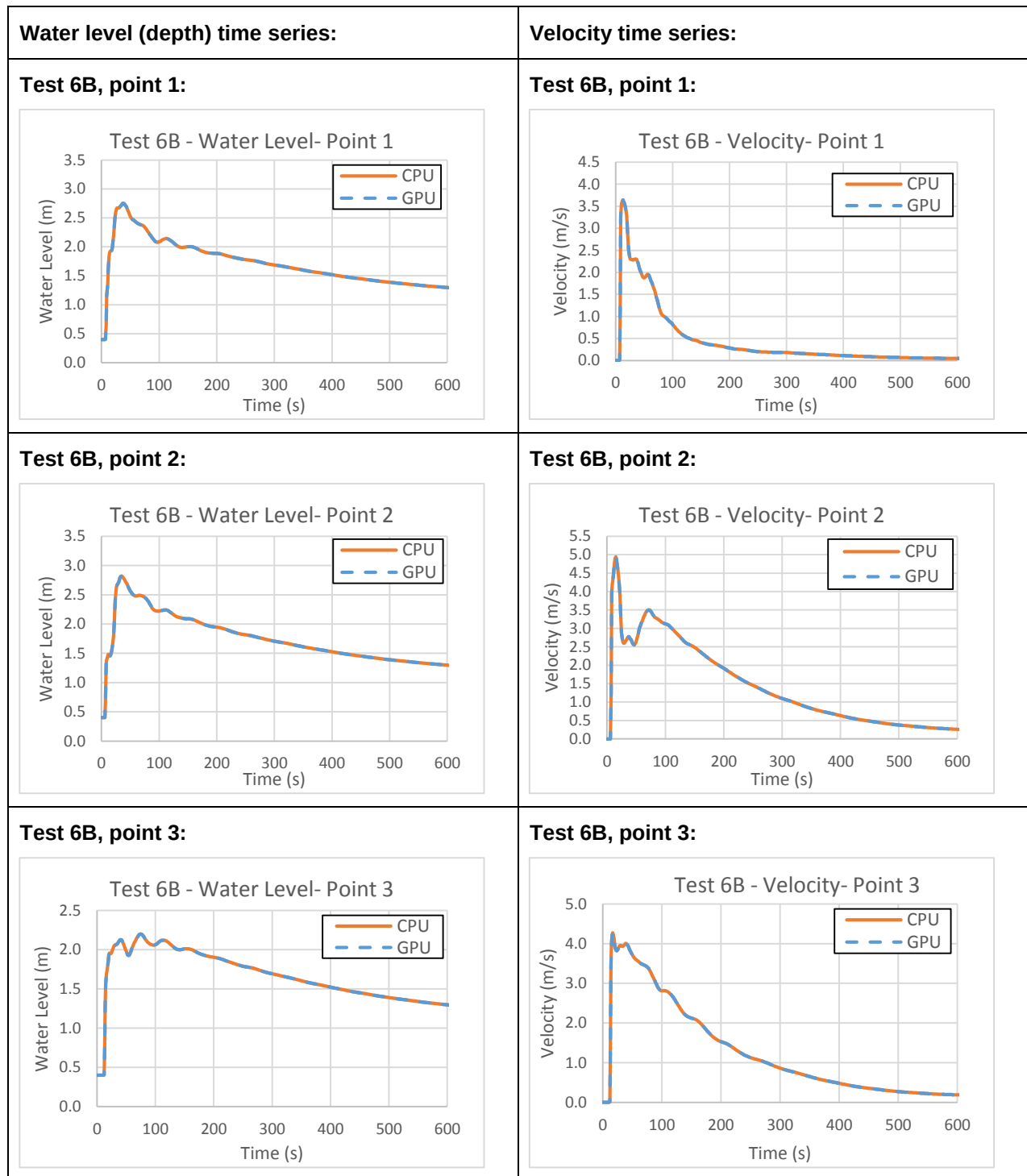


Summary of relevant technical information for the test 6A:

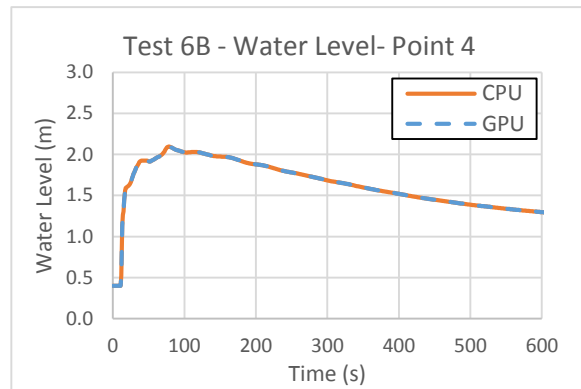
Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.01	0.01
Eddy viscosity coefficient used	N/A	N/A
Grid	35898 Elements	35898 Elements
Time-stepping	Adaptive (~0.01)	Adaptive (0.01 to 0.025)
Total simulation time (hrs)	0.025 (90s)	0.005 ¹ (17s)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

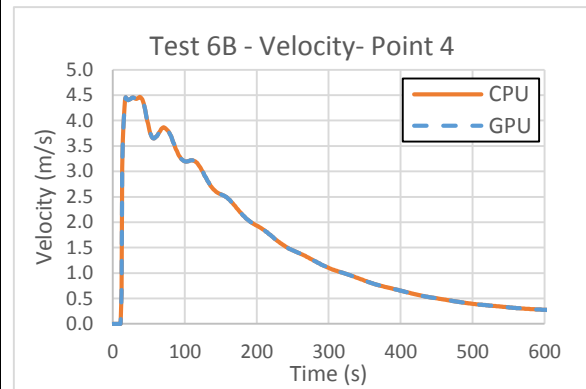
Test 6B: Water level (depth) and velocity time series:



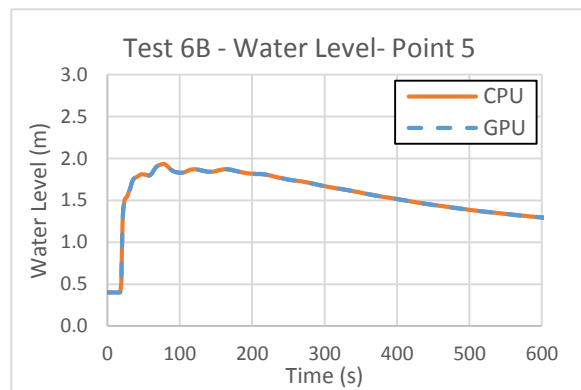
Test 6B, point 4:



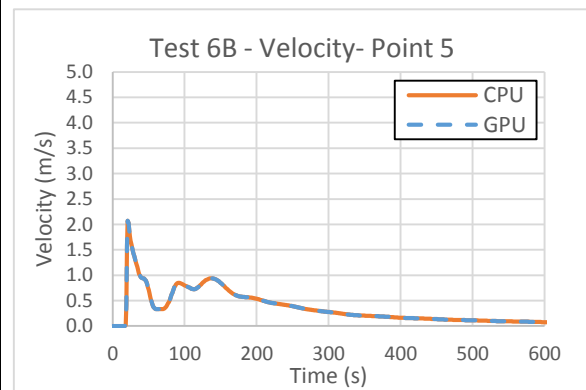
Test 6B, point 4:



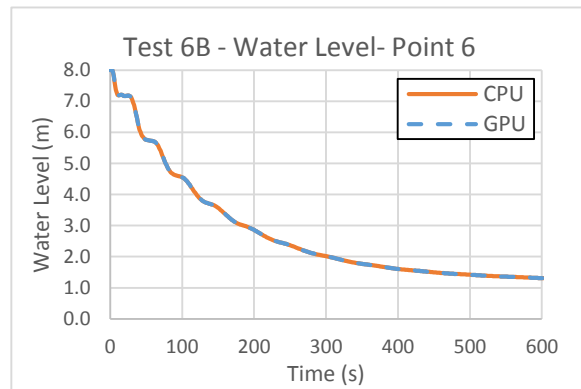
Test 6B, point 5:



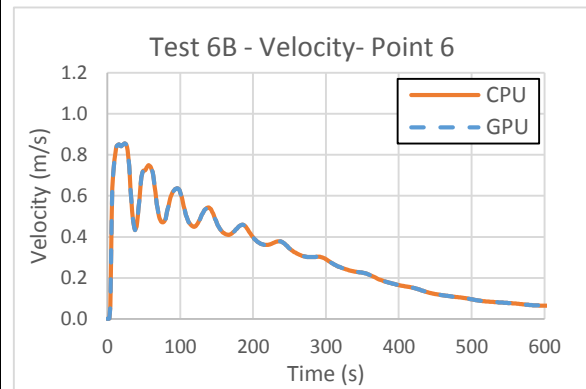
Test 6B, point 5:



Test 6B, point 6:

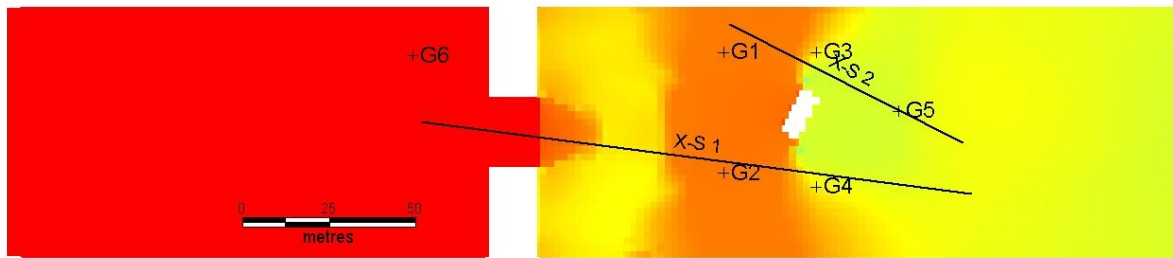


Test 6B, point 6:

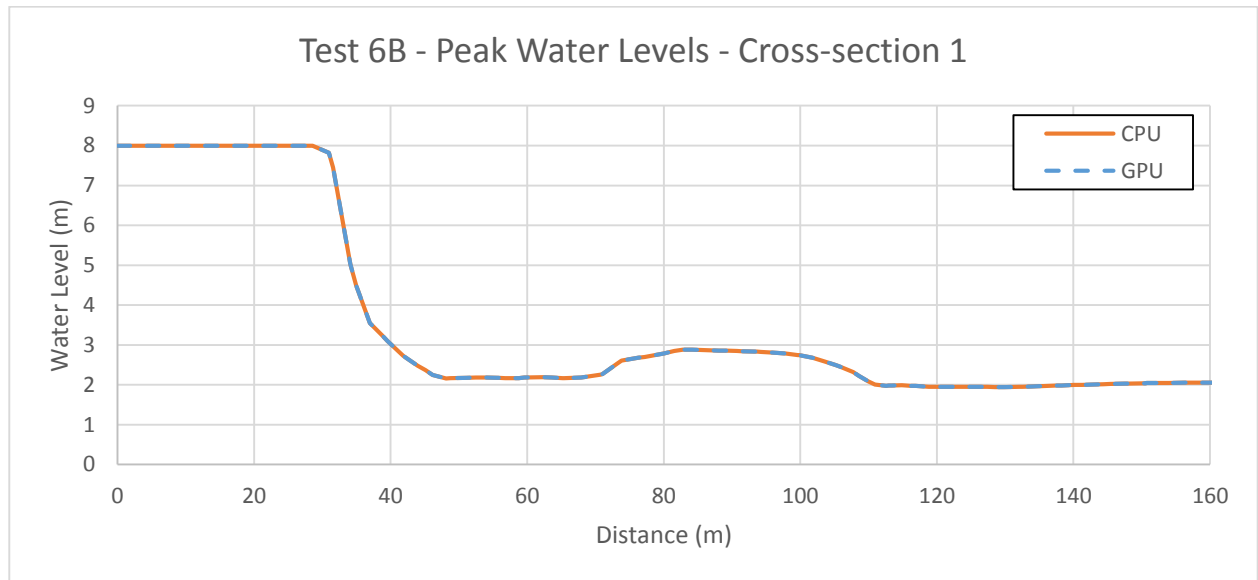


Test 6B: peak levels and velocities for cross sections 1 and 2 (shown in figure (b)):

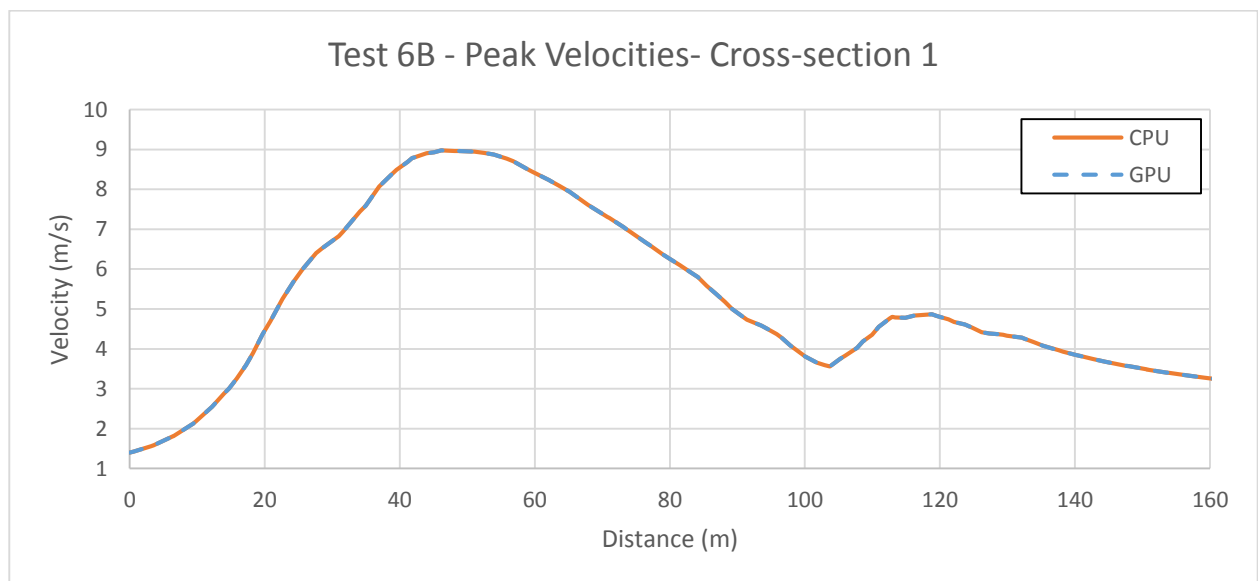
Figure (b): plan view showing the hydraulic jump and locations of the cross sections (from a peak level water grid)



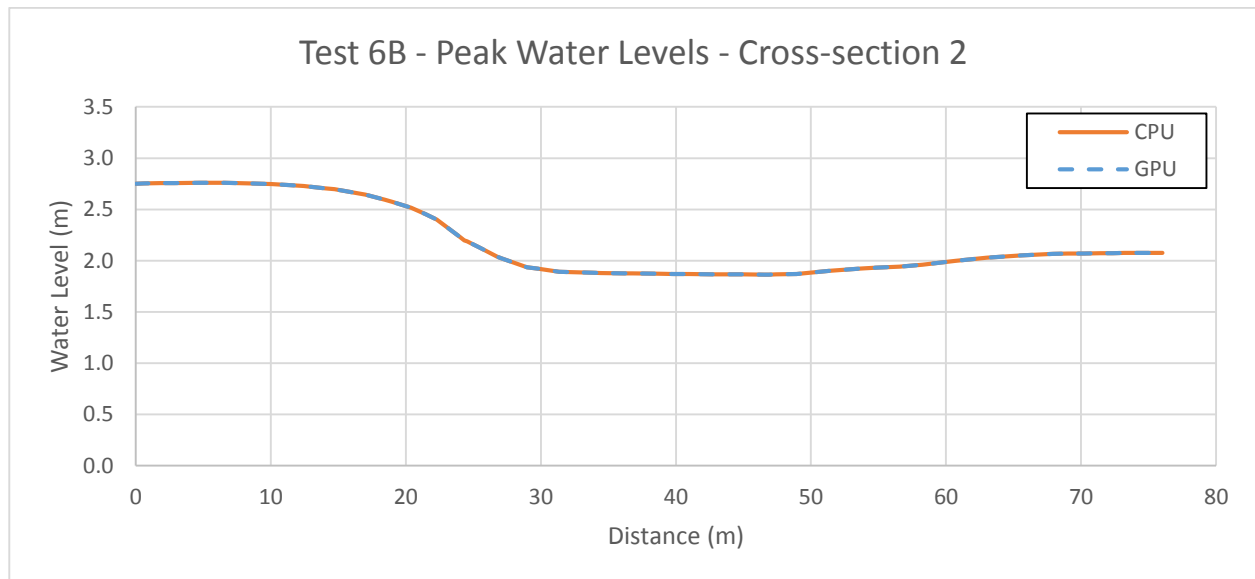
Peak water level elevations along cross-section 1



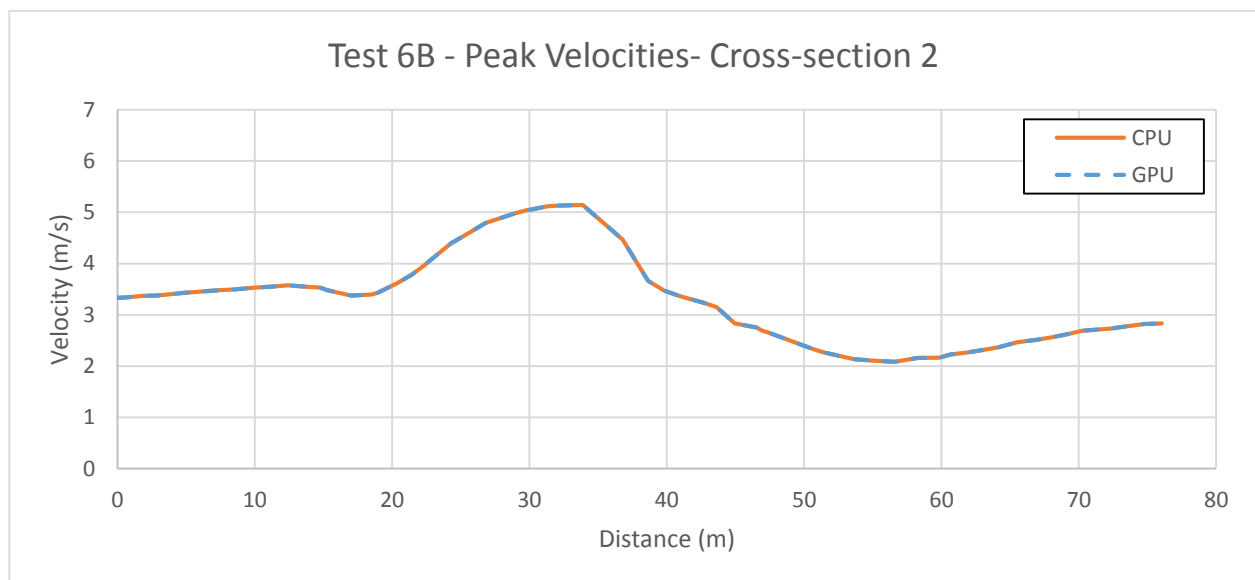
Peak velocities along cross section 1



Peak water level elevations along cross section 2



Peak velocities along cross section 2



Summary of relevant technical information for the test 6B:

Version number (and numeric scheme)	Refer to table at start of report.	
Hardware used to undertake the simulation	Refer to table at start of report.	
Minimum recommended hardware specification for a simulation of this type	Refer to table at start of report.	
	RiverFlow2D Plus	RiverFlow2D Plus GPU
Multi-processing	Yes	Yes
Manning's n used	0.05	0.05
Eddy viscosity coefficient used	N/A	N/A
Grid	35898 Elements	35898 Elements
Time-stepping	Adaptive (0.03 to 0.75s)	Adaptive (0.03 to 0.75s)
Total simulation time (hrs)	0.058 (210s)	0.009 ¹ (33s)

1. Refer to note on RiverFlow2D Plus GPU run times at end of report in Overall Summary of Performance section.

Software developer comments:

The CPU and GPU versions give identical results.

The results for Test 6A are based on output at every 1 second and not 0.1 second. This is due to a limitation with the model where you cannot specify output less than 1 second.

Overall summary of performance

	Predictions	Suitable?	Software developer comments
Situations the software package is suitable for use	inundation extent	Yes	RiverFlow2D Plus and RiverFlow2D Plus GPU are suitable for all of these categories. The programs have demonstrated nearly identical results for all tests and consistent results with the other fully dynamic schemes presented. The software is also suitable for many other situations such as sediment transport, mud and debris flows, oil spills, and pollutant transport
	maximum depth	Yes	
	maximum velocity	Yes	
	temporal variation in inundation extent	Yes	
	temporal variation in depth	Yes	
	temporal variation in velocity	Yes	
Other comments on performance of software	1. As with other GPU enabled models, simulation times for RiverFlow2D Plus GPU are not indicative of the significant speed gains by larger models (>1,000,000 elements). RiverFlow2D Plus GPU can be up to 100 times faster than RiverFlow2D Plus depending on the GPU specifications and model 2. The tests required to have output at very small time increments which has an impact on run times. Changing the output time increments to larger values could decrease model run times by more than 5 times.		

The table below shows common Environment Agency applications and the predictions required to produce these applications. It shows which benchmark tests can be used to prove the predictions required can be achieved. It should be used with the table above to decide whether the software package reported can achieve the outcomes required by the modelling project being undertaken.

Application	Predictions required	Relevant benchmark test
Large Scale Flood Risk Mapping	inundation extent	1 & 2
Catchment Flood Management Plan	inundation extent maximum depth	1, 2 & 7
Flood Risk Assessment and detailed flood mapping	inundation extent maximum depth	1, 2, 3 and 7
Strategic Flood Risk Assessment	inundation extent maximum depth maximum velocity	1, 2, 3, 4 7, and 8.
Flood Hazard Mapping	inundation extent maximum depth maximum velocity	1, 2 3, 4, 7 and 8
Contingency Planning for Real Time Flood Risk Management	temporal variation in inundation extent temporal variation in depth temporal variation in velocity	1, 2 3, 4, 5, 7 and 8
Reservoir Inundation Mapping	temporal variation in inundation extent temporal variation in depth temporal variation in velocity	1, 2, 3, 4, 5, and 6.